SMART GARDEN CONTROLLER

Group 12:

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Project Description

- The Smart Garden Controller brings twenty first century technology to gardening. It allows the gardener to automate the watering system of a garden and collects metrics via sensors.

Motivation

- The Number of households participating in food gardening continues to grow. According to the National Gardening Association, from 2008 to 2013 alone, 6 million households had a personal garden and the average amount spent on the back yard or balcony nationwide in 2015 was $401 per household.
- There are other products available in the market with similar features, however, current products with automated features can be expensive and not geared toward gardening. Home watering products are usually geared towards watering the lawn and provide no feedback on the soil.
- A profit could be turned by creating a product which could provide some of the high-end features at a lower price point.

Goals & Objectives

The Goal of this project is to design and build a smart garden controller which will help home gardeners ensure that their plants thrive with the right amount of irrigation provided, a system which provides important data to the user which will be helpful in tuning the watering of the garden, and a web application which will allow the user to control the device remotely. The controller should be affordable when compared to the competition while providing similar features.

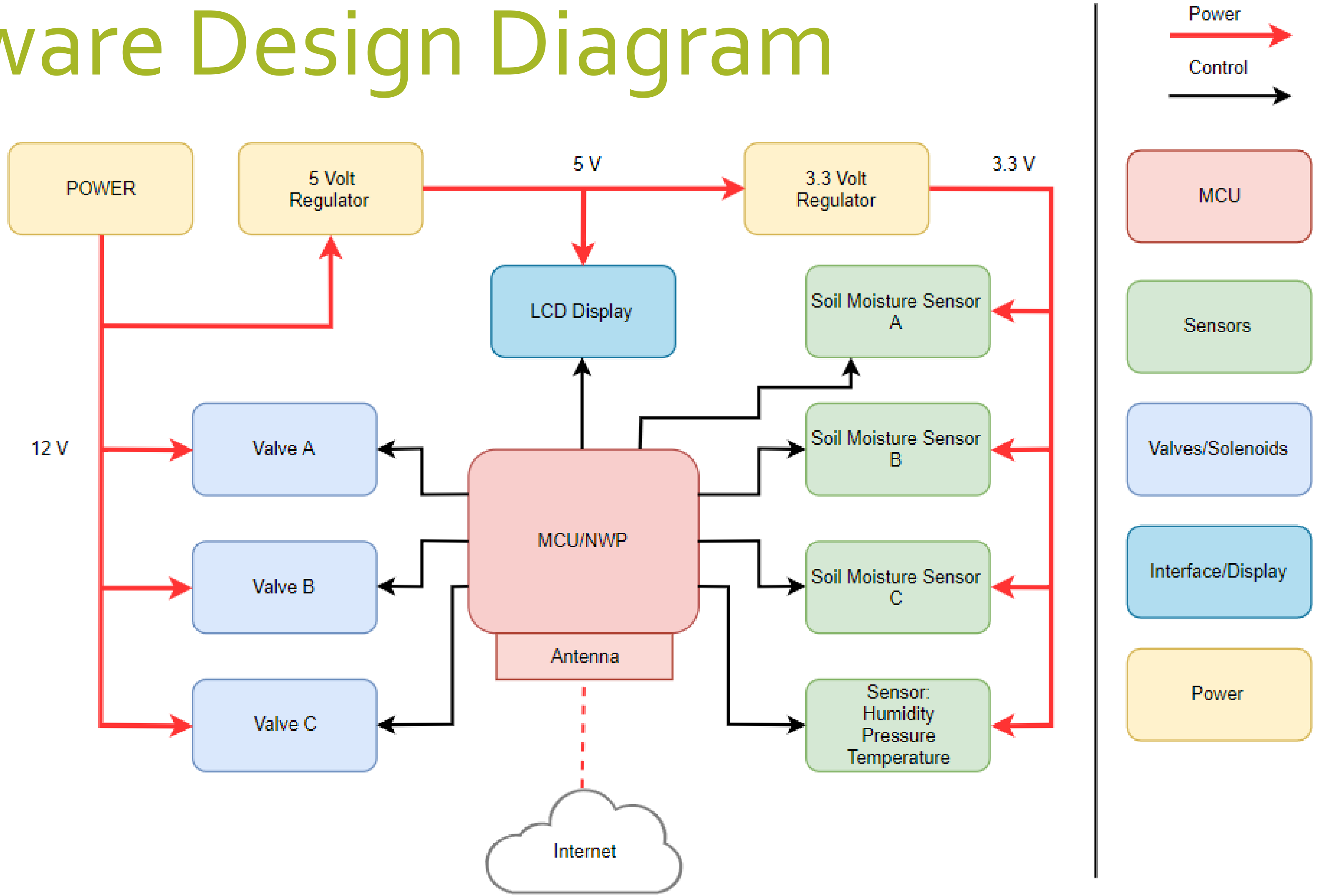
As the main features include:

- Automated watering.
- Environmental Data Collection via sensors.
- Remote control of system.
- Review of data collected via a web application.

Specifications

Requirement	Value
User Interface and Communication	
Communication from controller to Web Server	WiFi (802.11)
Local control of device	True
Remote control of device	True
Data Collected	
Humidity	%
Pressure	HectoPascals (hPa)
Temperature	Degrees Centigrade
Light	Lux
Moisture	pF
Hardware	
Number of zones Available	3
Number of zones watered at once (schedule/demand)	1
Input Voltage	24V DC
Temperature Range	0°C - 45°C
Dimensions	Less than 10’x10’x10’

Hardware Design Diagram

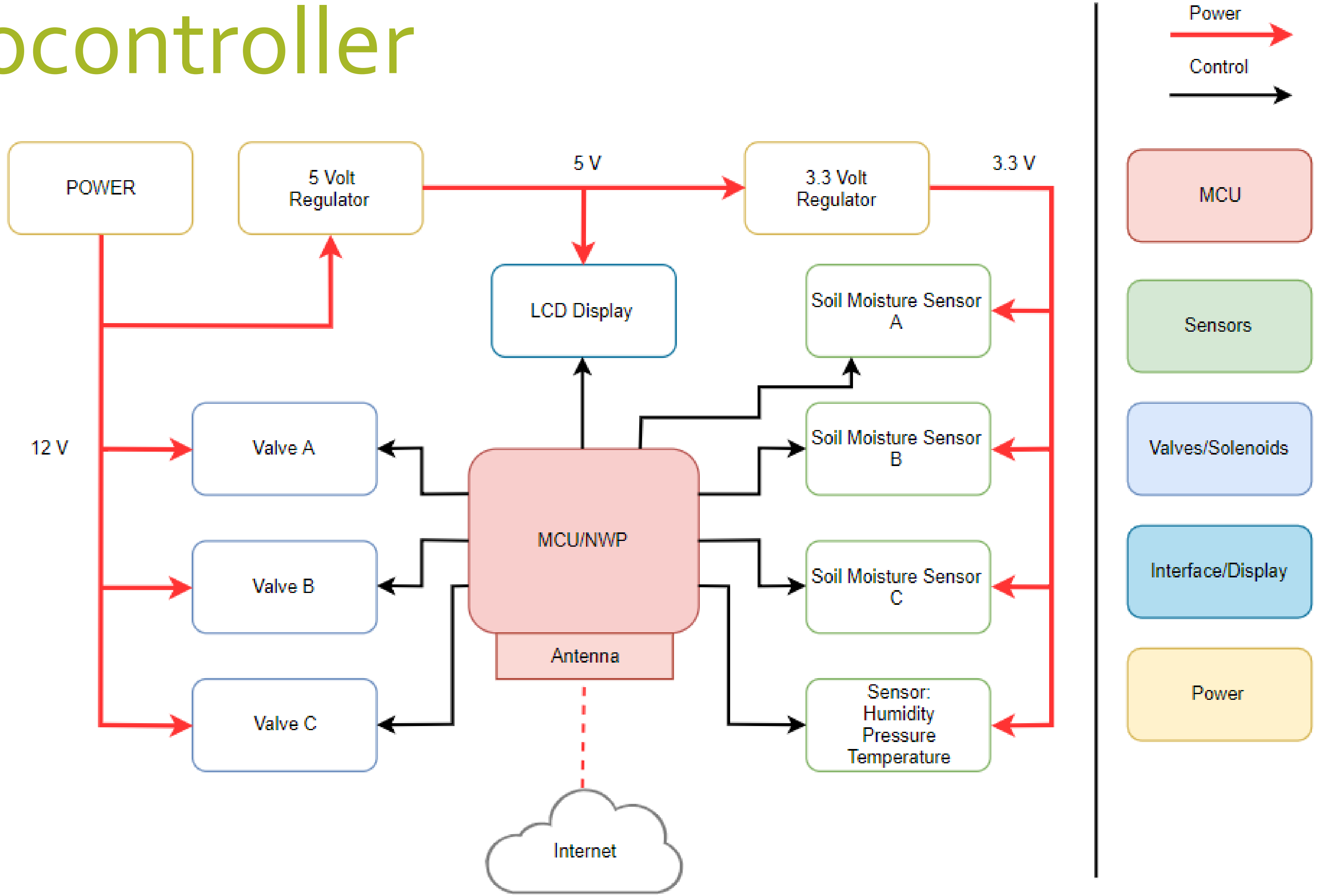


Design & Component Decisions

The following sections will discuss the design decisions our team made to ensure the required features of the system are provided. These design choices include...

- The microcontroller chosen to save & process data, manipulate the sub-systems, and communicate with the software components.
- The sensors that will be used to collect environmental data.
- The valve components that will control the flow of water to each plot in the garden.
- The software to maintain a database of user and garden information, a web application for users to control the system and view garden data, and logic for the system to water autonomously.

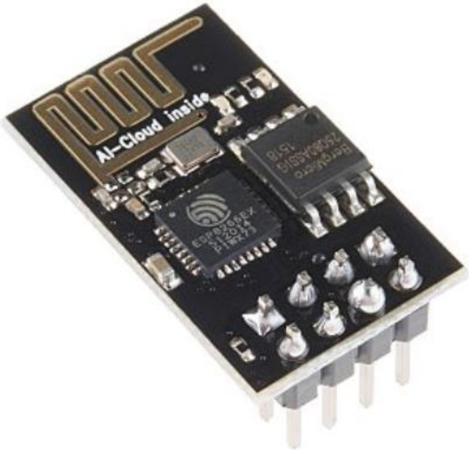
Microcontroller



Microcontroller

Purpose:
- Communicate with sensors.
- Control LCD.
- Commutate to web server and upload data.

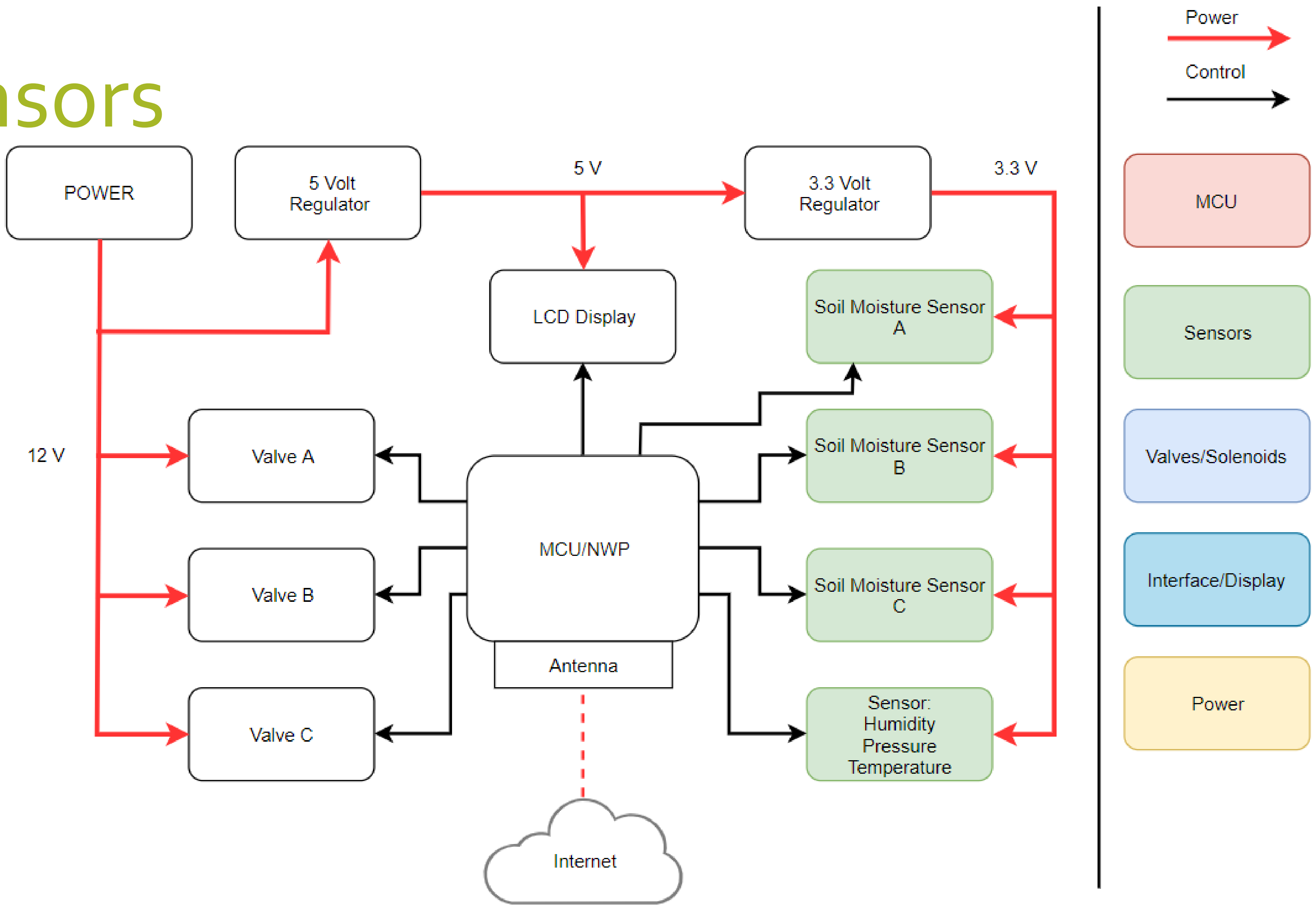
Selection Criteria:
- Memory
- Storage
- Large number of I/O lines
- Integrated NWP



Microcontroller

Microcontroller Trade Analysis			
Selected	No	No	Yes
Module	ATWINC1500	ESP 8266	CC3220MODASF
Price	$8.08	$5.00	$11.64
Voltage Range	2.7V-3.6V	2.7V-3.6V	2.3V-3.6V
Processor	Cortus APS3	Tensilica L106	Cortex–M4
Bits	32 - bit	32 - bit	32 – bit
RAM	128kB	50kB	256kB
Flash	4MB	n/a	1MB
Data Rate	72.2Mbps	72.2Mbps	54Mbps

Sensors



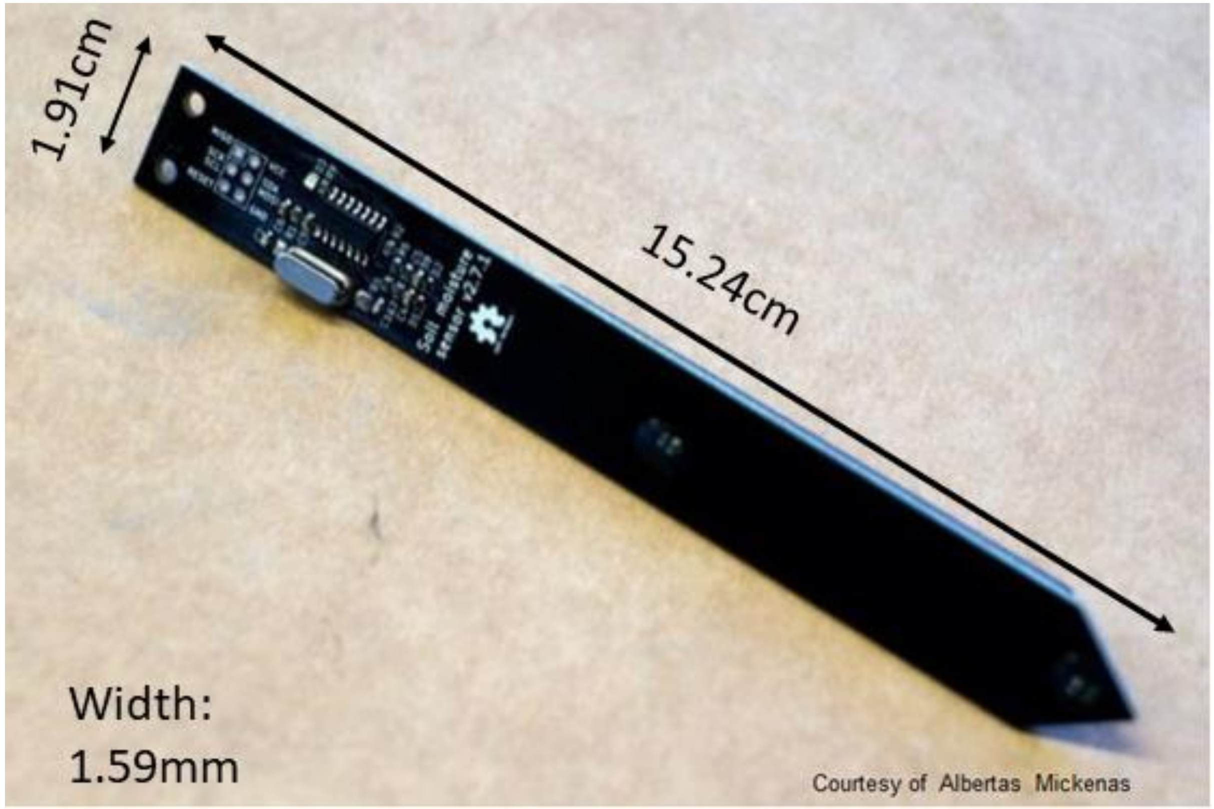
POWER
5 Volt Regulator
5 V
3.3 Volt Regulator
3.3 V
LCD Display
Soil Moisture Sensor A
12 V
Valve A
Soil Moisture Sensor B
MCU/NWP
Valve B
Soil Moisture Sensor C
Antenna
Valve C
Sensor: Humidity Pressure Temperature
Internet
Power
Control
MCU
Sensors
Valves/Solenoids
Interface/Display
Power

Sensors

- The collection of environmental data is a key objective of the automated Smart Garden.
- To provide users an advanced and informed connection to their garden, the system employs sensor modules to collect environmental data.
- The system measures five major environmental metrics: temperature, relative humidity, atmospheric pressure, soil moisture, and ambient light.
- The following sections will provide insight and information regarding the sensors used in the design of our system.

Moisture, Temperature, & Ambient Light

This I2C Soil Moisture Sensor uses a capacitive circuit to measure a relative moisture level in soil, while also returning a relative ambient light measurement, and temperature within a range of 0°C to 85°C (32°F to 185°F). Purchased at $12.49 ea. from Catnip Electronics via Tindie.



Moisture, Temperature, & Ambient Light (con't)

Description	Catnip Electronics Sensor	DF Robot SEN0114
Version	2.7.5	1.0
Supply Voltage	3.3V - 5V	3.3V or 5V
Current Consumption (idle)	0.7mA - 1.1mA	N/A
Current Consumption (measure)	7.8mA - 14mA	N/A
Current Consumption (constant)	2.8mA - 4.5mA	3.5mA
Operating Temperature	0°C - 85°C	0°C - 45°C
Crystal Speed	16MHz	ADC output
Default I2C Address	0x20	Analog

Humidity & Pressure

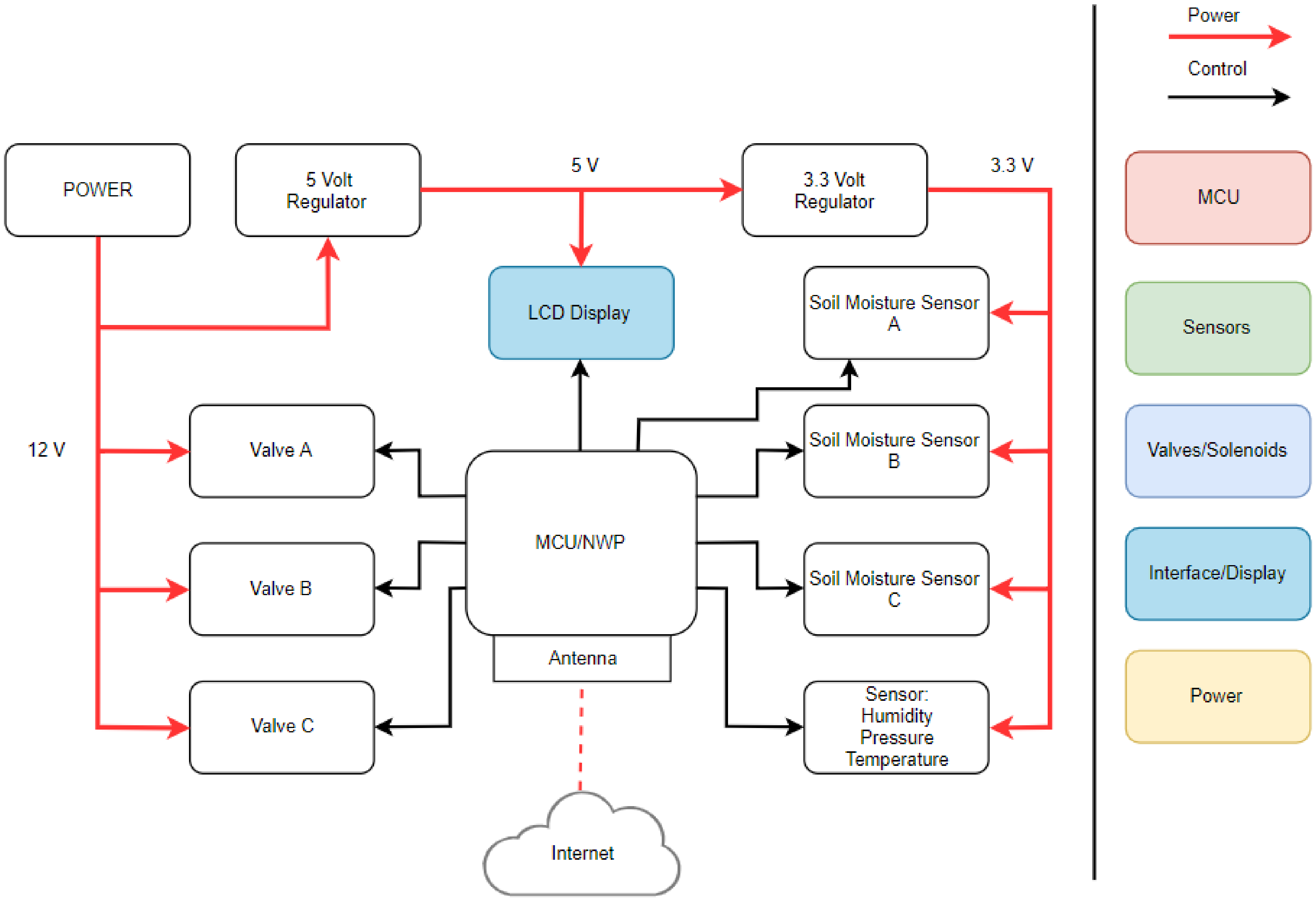
The Bosch BME280 Humidity and pressure sensor measures relative humidity in the standard range of 0% - 100% and atmospheric pressure within the range of 300 - 1100 hectopascals (hPa). This sensor uses I2C or SPI protocol and was purchased at $16.09 from Digi-key Electronics.

Description	**BME 280 (selected)**
Supply Voltage	1.71V - 3.6V
Temperature range	-40°C - 85°C
Interface	I2C, SPI
Package size (Metal lid LGA)	2.5x2.5x0.93mm^3
Current consumption @ 1Hz	3.6µA
Operating supply voltage	1.8V
Operating supply current	0.5µA

Humidity & Pressure (con't)

Description	**<u>BME 280 (selected)</u>**	BME 680	BMP 280
Supply Voltage	1.71V - 3.6V	3.3V – 5.0V	3.0V – 5.0V
Temperature range	-40°C - 85°C	-40°C - 85°C	-40°C - 85°C
Interface	I2C, SPI	I2C, SPI	I2C, SPI
Package size (Metal lid LGA)	2.5x2.5x0.93mm^3	16x11x2.8mm^3	2.0x2.5x0.95mm^3
Measurments	Humidity, Pressure, Temperature	Humidity, Pressure, Temperature, VOC concentration	Pressure, Altitude

LCD



POWER
5 Volt Regulator
5 V
3.3 Volt Regulator
3.3 V
LCD Display
Soil Moisture Sensor A
12 V
Valve A
Soil Moisture Sensor B
MCU/NWP
Valve B
Soil Moisture Sensor C
Antenna
Valve C
Sensor: Humidity Pressure Temperature
Internet
Power
Control
MCU
Sensors
Valves/Solenoids
Interface/Display
Power

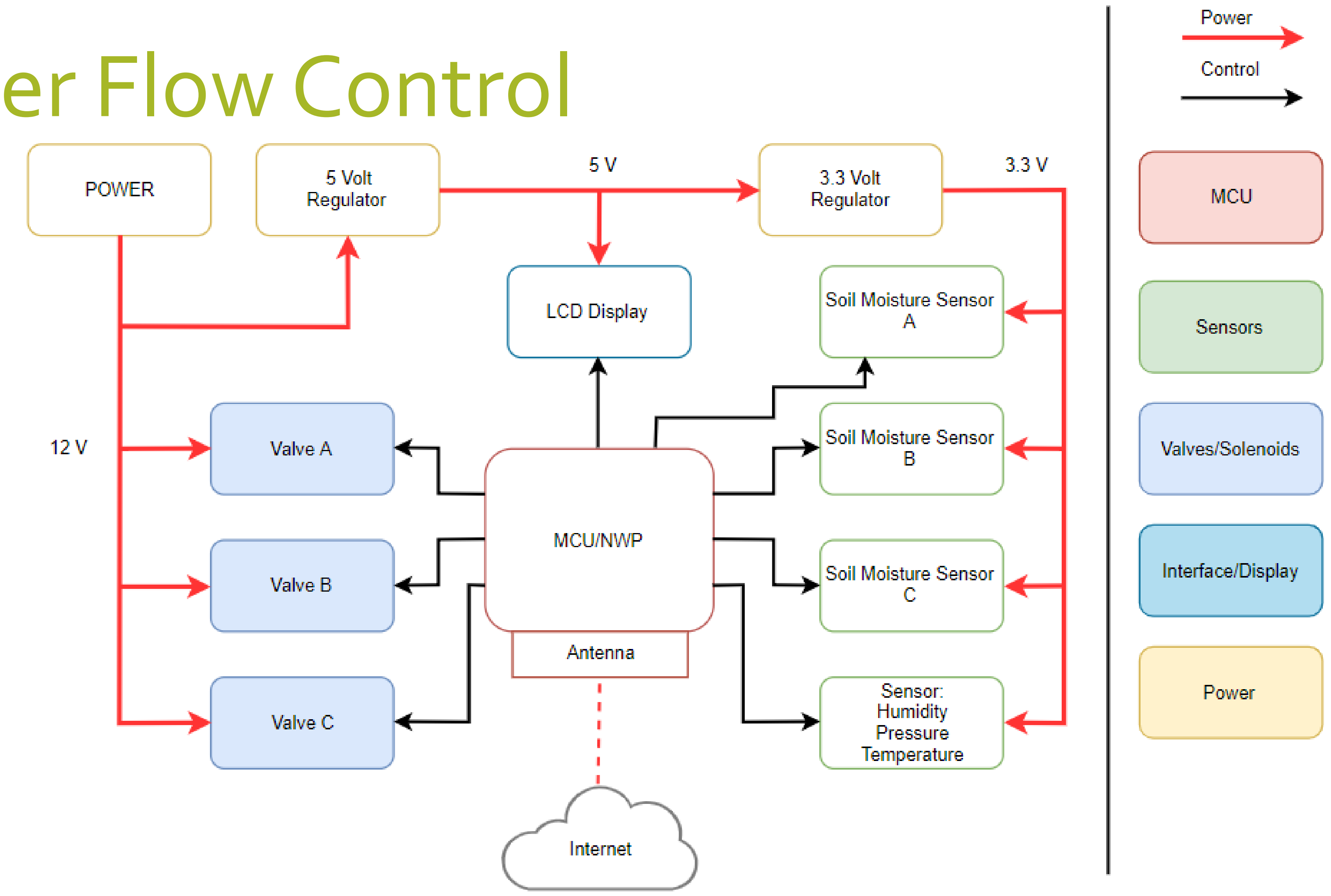
LCD

Purpose:

- View sensor data directly on device.
- Together with buttons, provide a user interface to configure device.
- Configure Username and password.
- Configure wireless network SSID and password.
- Run on-demand watering sessions.

Description	Superdroid Robot LCD	Geekcreit Ili9341 TFT
Interface	I2C	Digital I/O pins
Default Address	0x27	N/A
Pins	Gnd, Vcc, SDA, SCL	GPIO custom
Text dimensions	4 lines x 20 column	240x320 resolution
Backlight color	Blue	Black
Text color	White	White
Supply Voltage	5.0V	3.3V

Water Flow Control



Water Flow Control components

Description	**<u>Plastic Valve #997(selected)</u>**	Brass Valve #996
Supply Voltage	12V	12V
Temperature range	-40°C - 85°C	-5°C - 80°C
Minimum Pressure	3 PSI	0
Weight	4.3 oz	1.7 lbs
Response Time	<0.15 seconds	<0.3 seconds

Water Flow Control (con't)

- The solenoid valve that were selected for use in this project were selected for their cost effectiveness as well as their availability and user reviews.

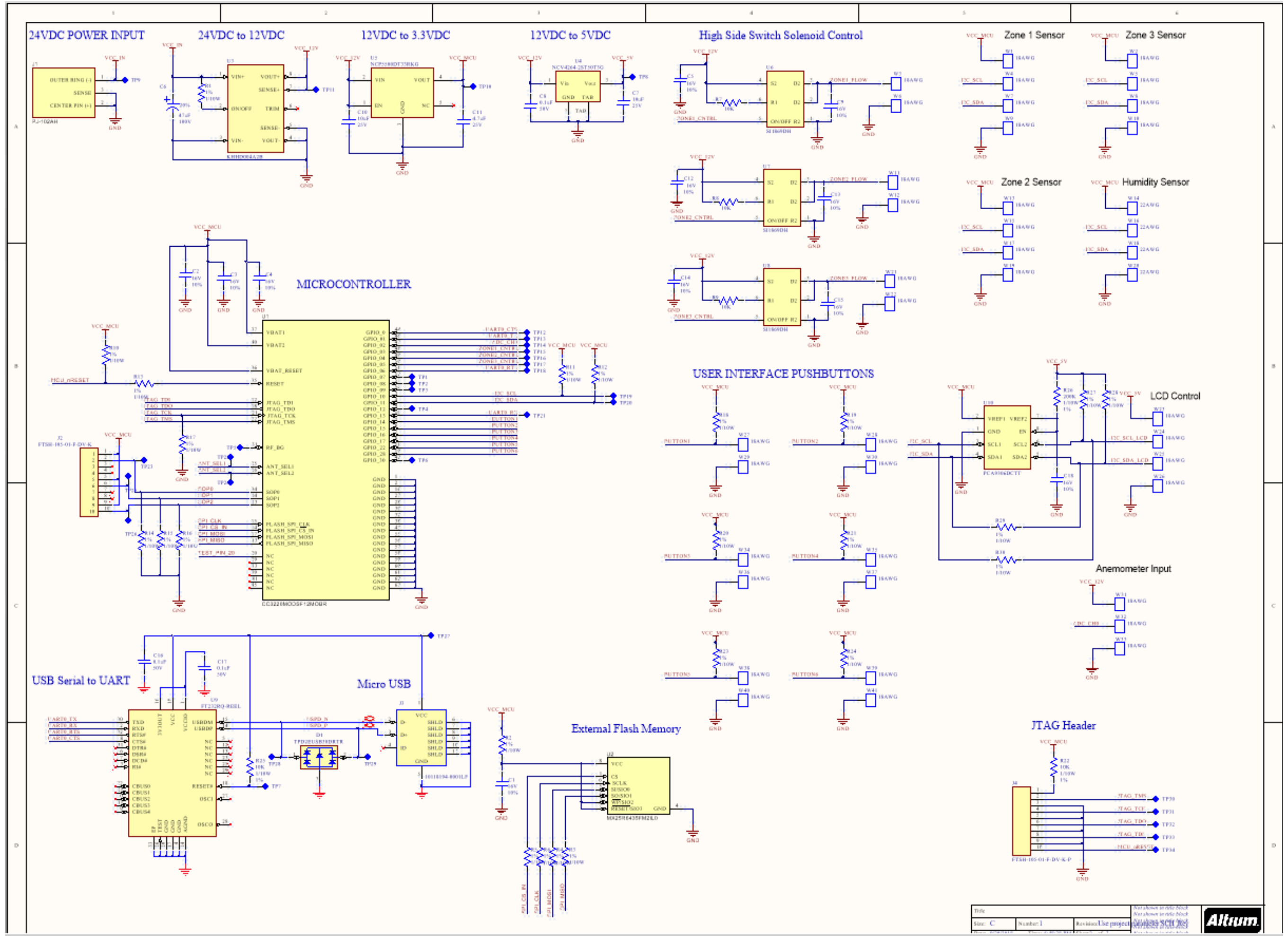
- The solenoid valves that were chosen for this project design are 12-volt devices. 12V applied= OPEN / Lower than 12V=Closed if there is sufficient current from the source. (Solenoid valve has a typical current draw of 2.4A).

- High voltage and current draw meant for the implementation of a high side switch, due to microcontroller operating at 3.3-volts and only consuming an average of 180mA itself, so there is no way it would be able to supply the power to open the solenoid valve itself.

Custom Enclosure

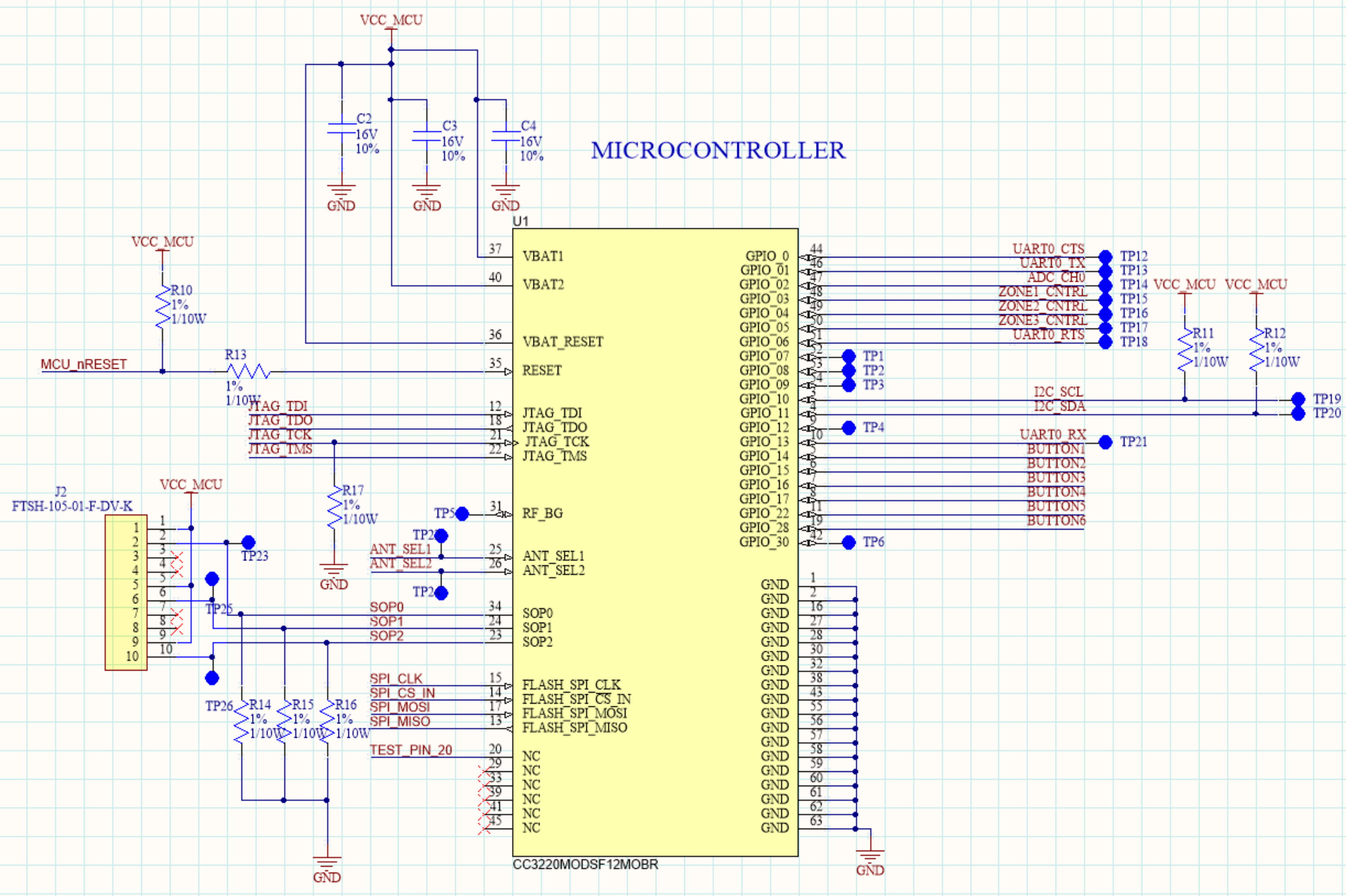
- Enclosure will be 3D printed to allow for secure and optimizable design, as well as to provide more practice for our team in 3D printing.
- To function properly in the operational environment and to protect the microcontroller and other electrical components.
- Make sure there is enough room for the sensors and ports so that the device is protected from repeated outside use and that the information recorded is accurate and reliable.
- The chassis must also allow the user to access the housed components if necessary.

Smart Home Garden Schematics



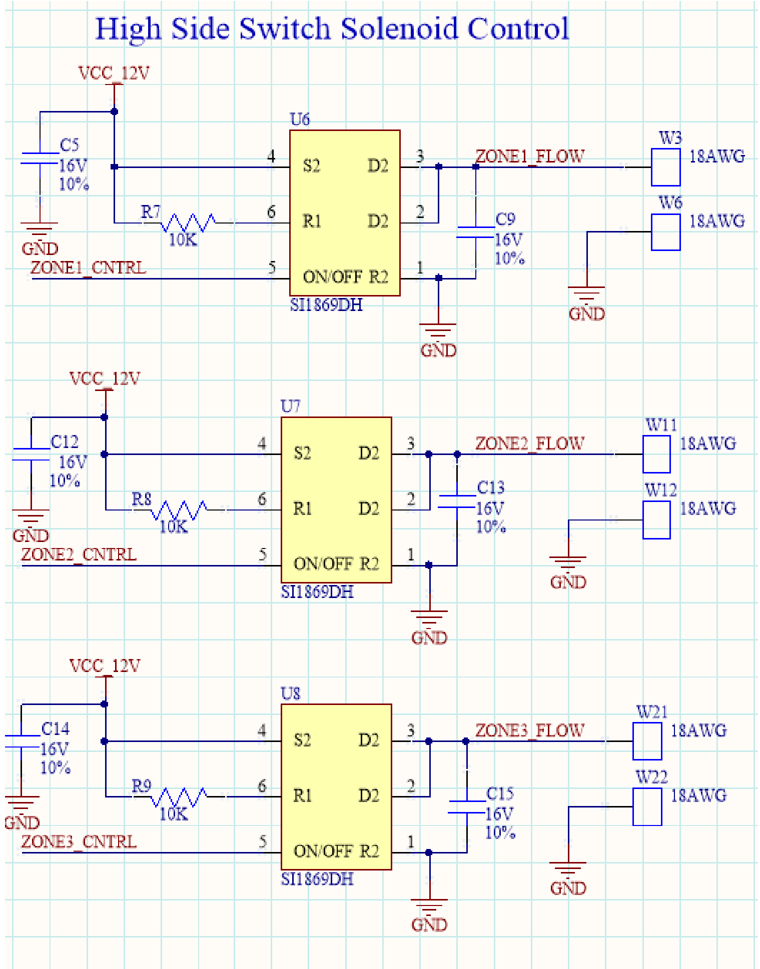
Schematics – Microcontroller/WiFi

- 3.3V Power supply
- Reset signal using pull-up resistor for proper JTAG initialization
- JTAG interface
- SOP signals to connector for bootstrapping options
- SPI signals for FLASH
- GPIO signals for sensors, buttons, LCD
- UART signals for Debug
- I2C signals for peripheral communication



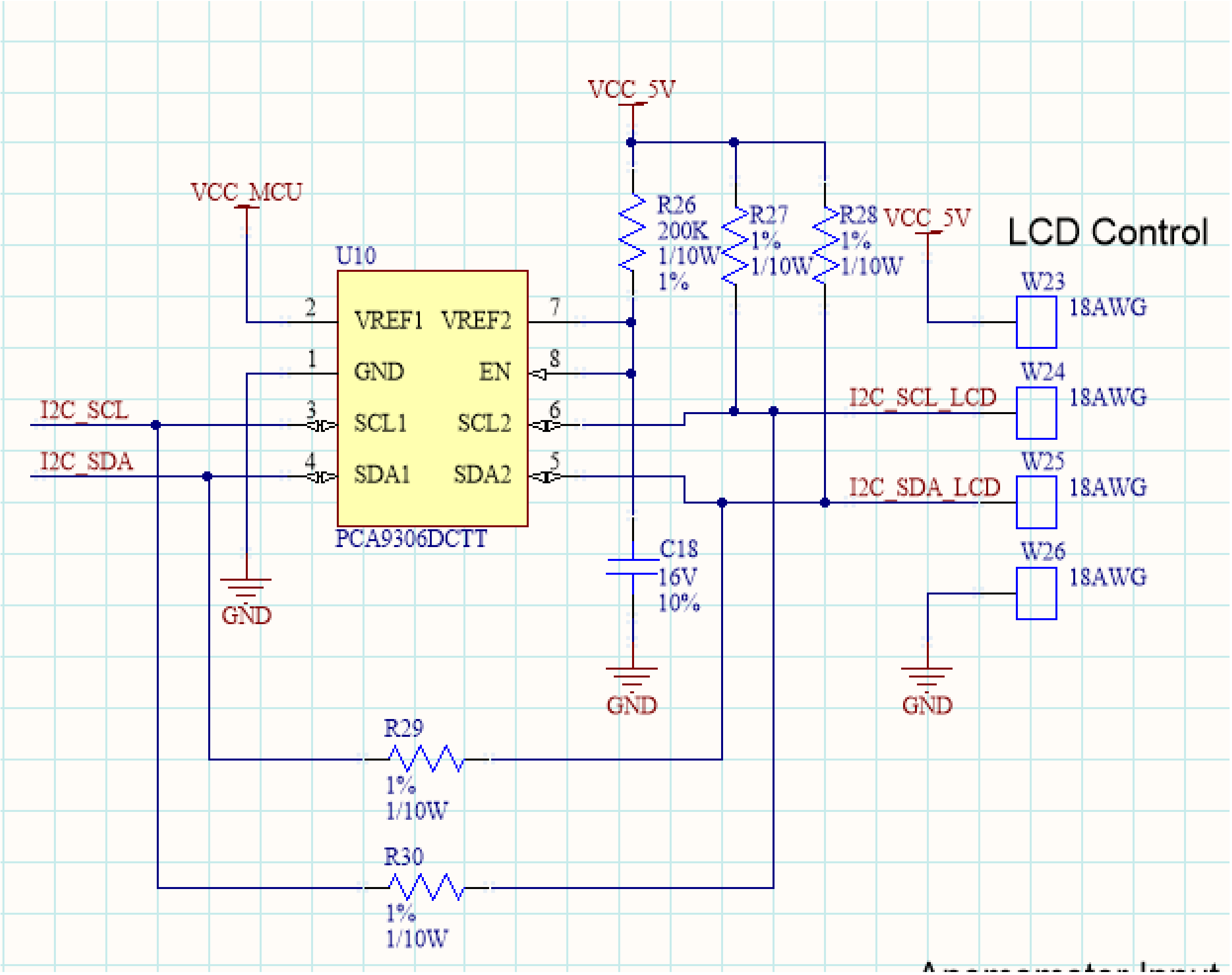
Schematics – High Side Switches

- Offers an electromechanical relay type functionality without any mechanical moving parts.
- 12V power supply.
- Input signal controls voltage/current path from S2 to D2.
- Effectively allows control of 12V signal using 3.3V logic.



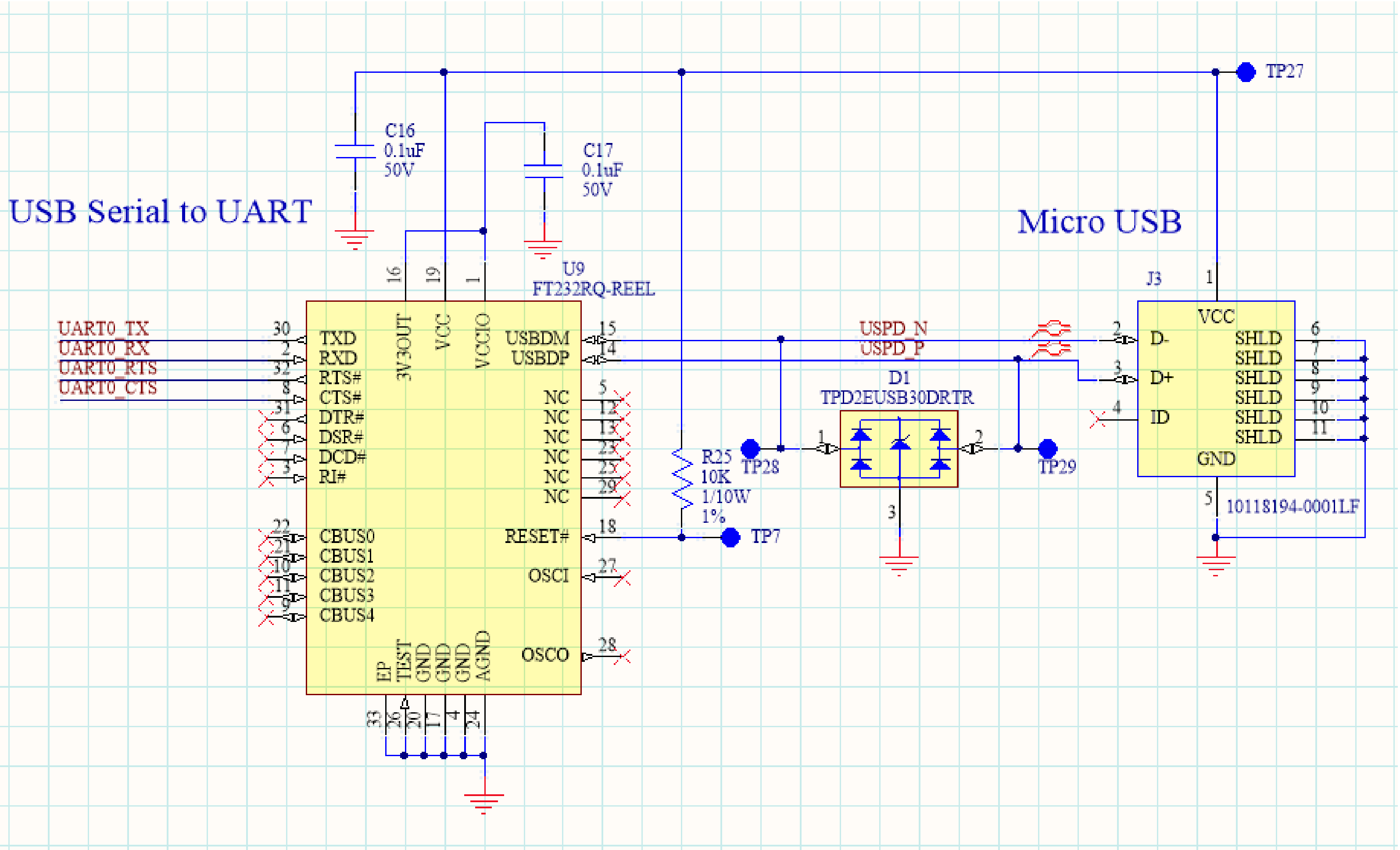
Schematics – I2C Voltage Level Translator

- 3.3V I2C signals in and 5V I2C signals out.
- Allows for control of parts operating at a different logic level than the microcontroller.
- Zero ohm resistors enable a quick change back to 3.3V logic level for LCD if 5V is not required.



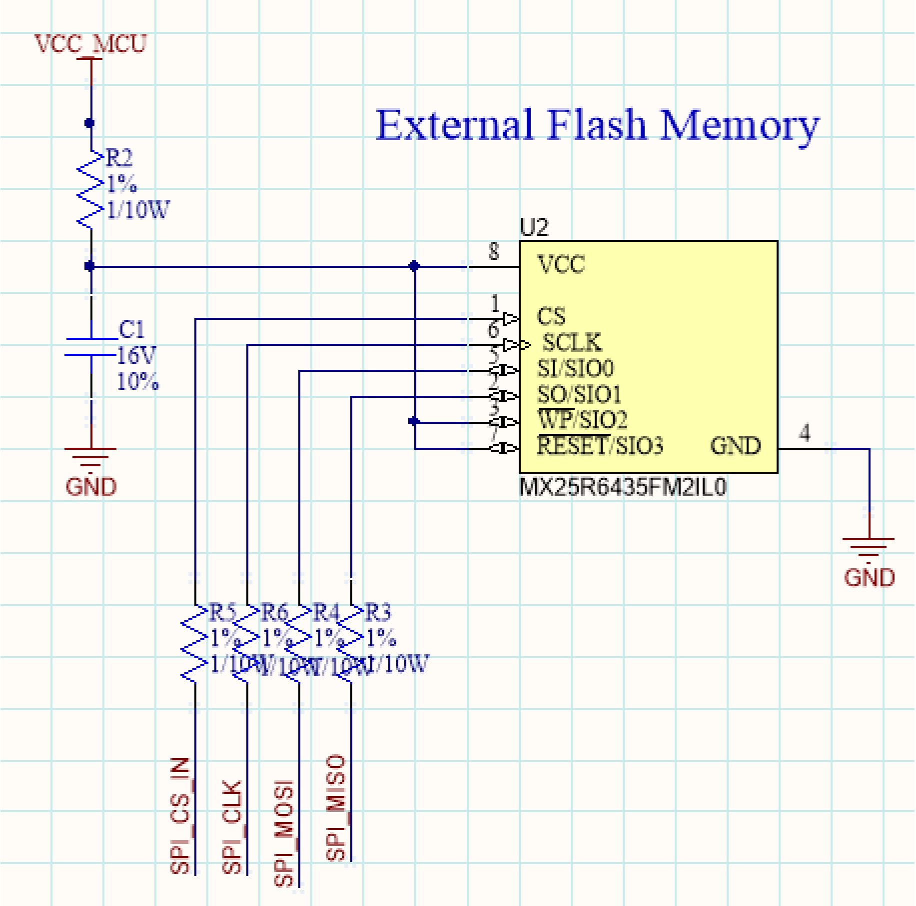
Schematics – USB Serial to UART

- USB to UART interface allows debugging using USB.
- FTDI part does all the work.
- USB port supplies power to the FTDI chip.
- D1 is transient voltage protection to protect against voltage spikes during plug in.

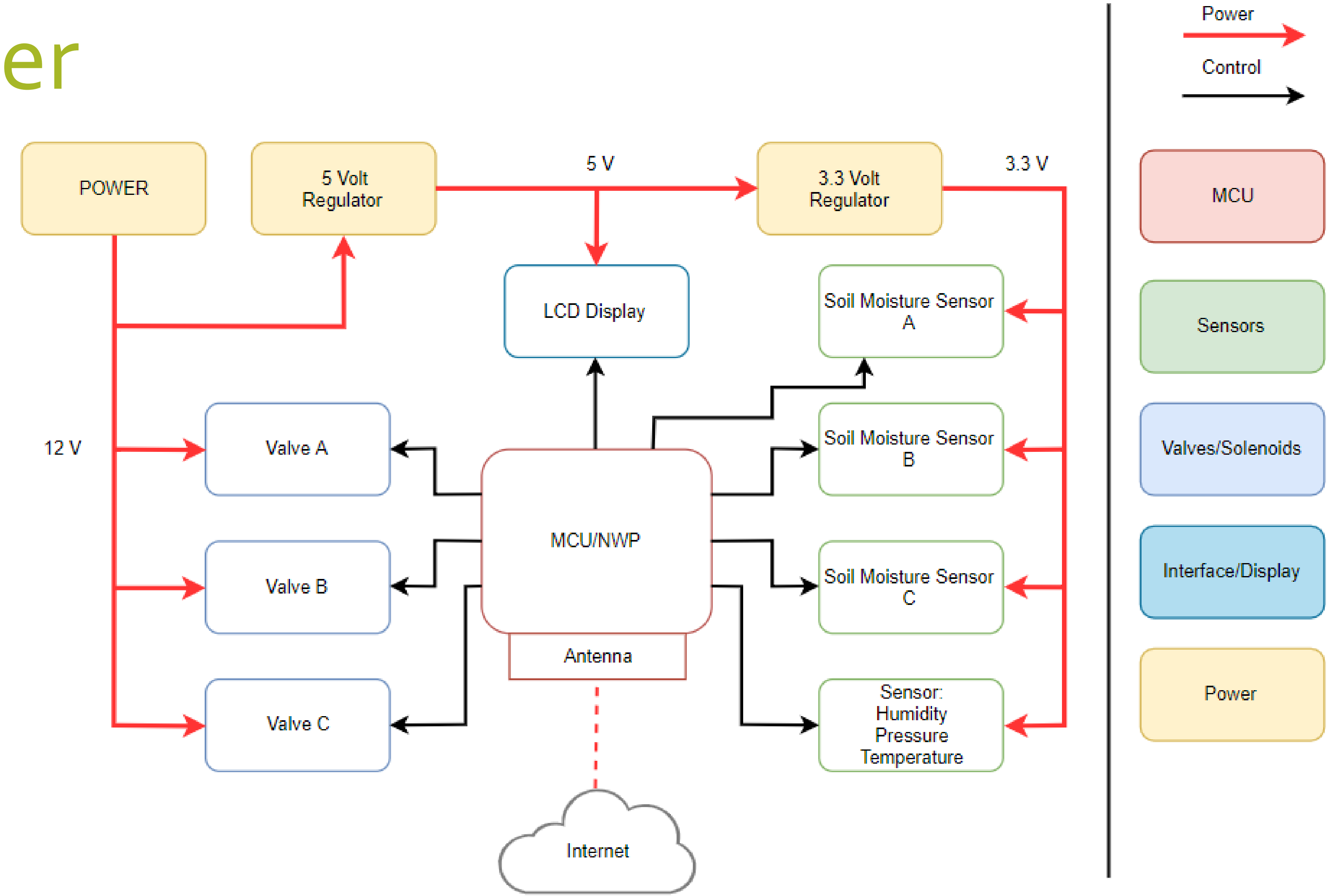


Schematics – External SPI FLASH

- CC3220 has a dedicated SPI FLASH interface.
- 64M-Bit Flash memory.
- For extra data storage.



Power


POWER
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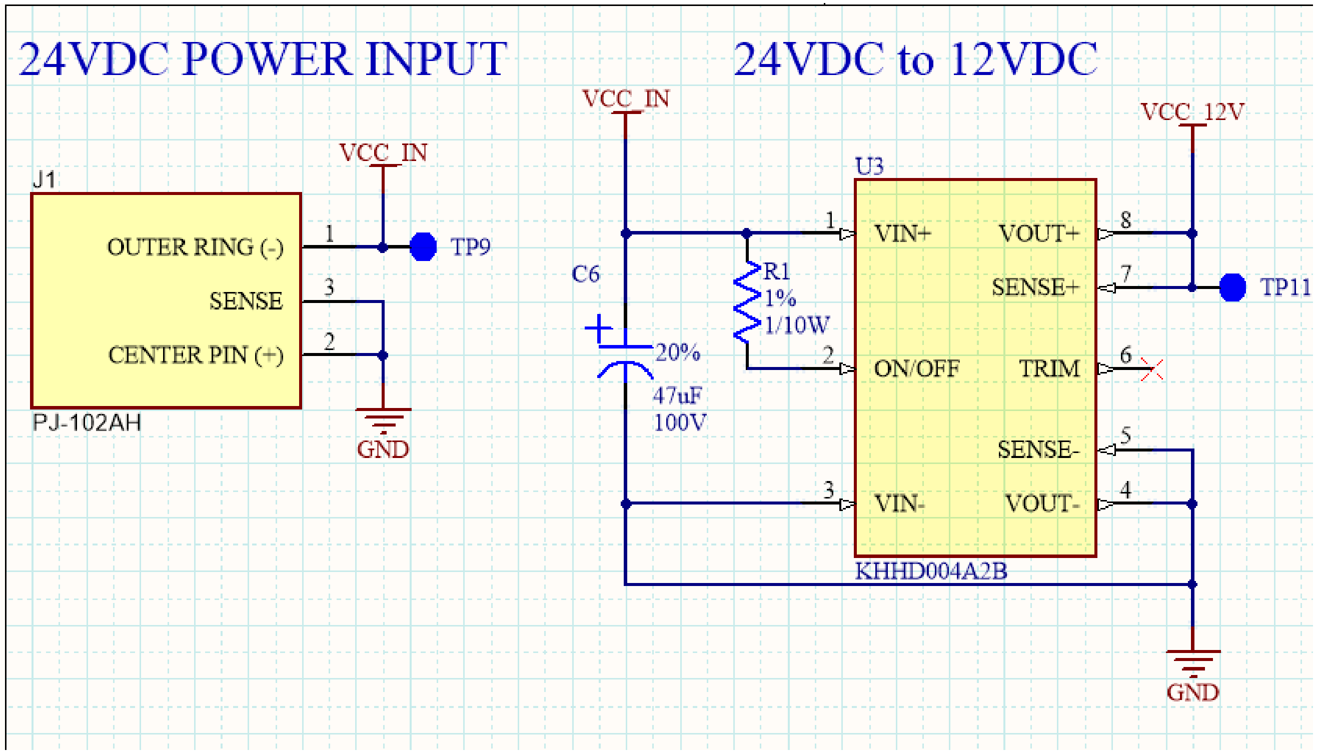
Antenna
Valve C
Sensor: Humidity Pressure Temperature
Internet
Power
Control
MCU
Sensors
Valves/Solenoids
Interface/Display
Power

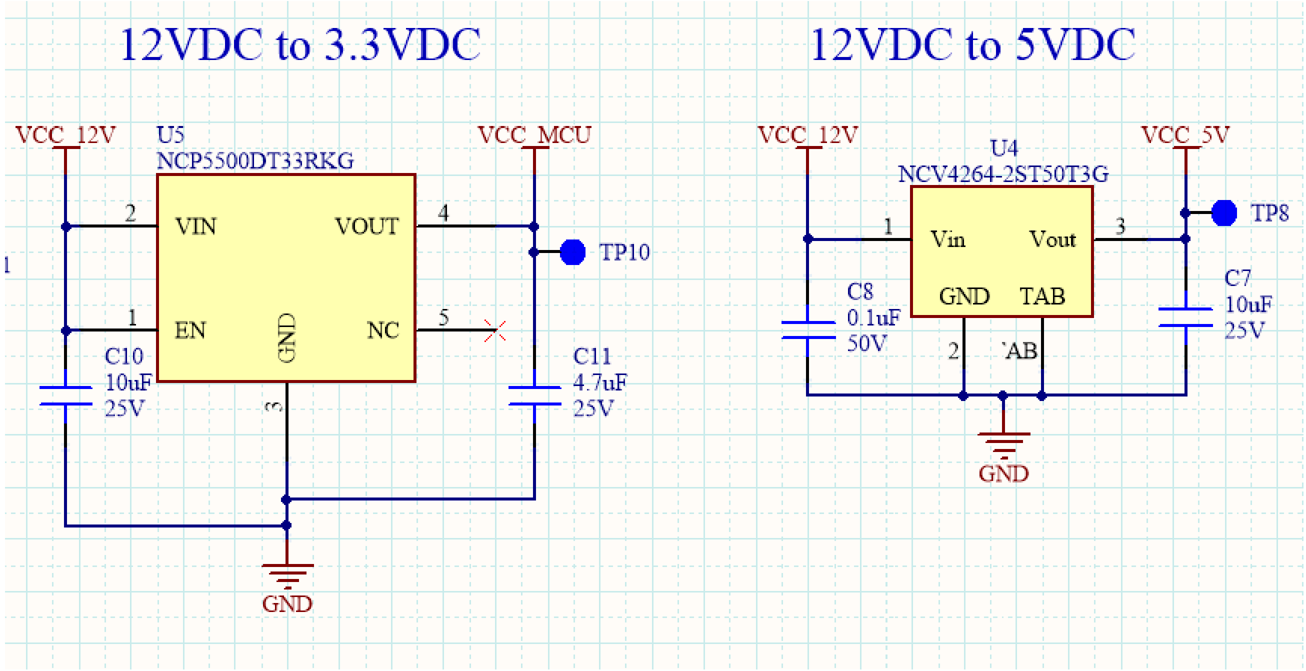
Schematics – Input Power

- 24 VDC power input jack.
- 24VDC supplied by external AC/DC converter.
- Hammerhead™ Series 50W DC to DC Isolated Converter Power Module.
- 90% efficient power switching at constant switching frequency.
- Up to 4.2 amp output.
- 12V rail runs anemometer, and solenoid valves.



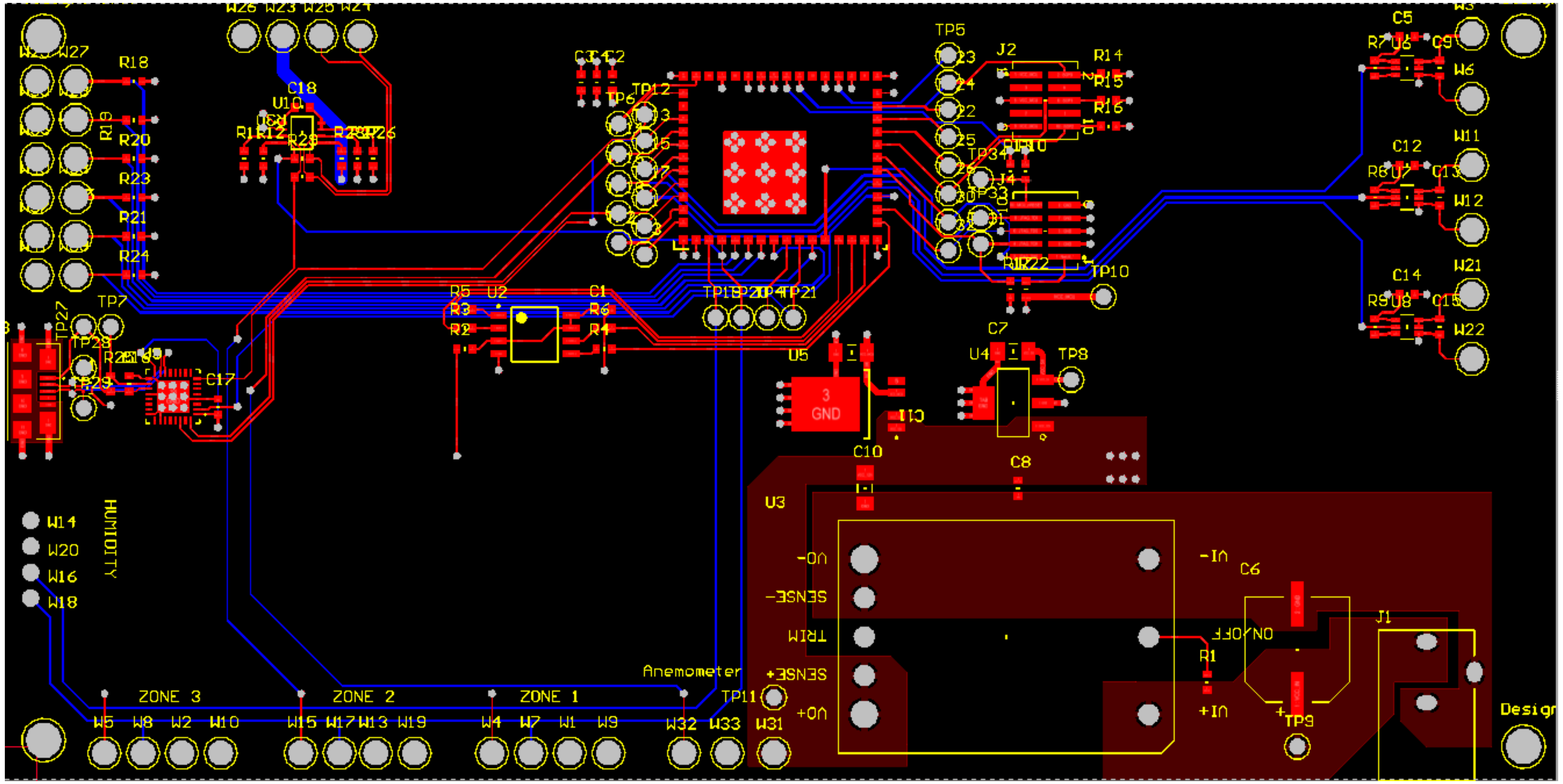
Schematics – Board Power

- Second stage of DC to DC conversion.
- Using simple LDOs for ease of design and to avoid any noise generated by power switching.
- 5V rail is used to supply the LCD screen.
- 3.3V rail is used to supply the microcontroller and all other low power parts.



PCB Board Layout

- Board Design was completed using Altium Designer 18.
- 4 Layer stack up
  - 2 external signal layers (top and bottom)
  - 1 internal ground plane
  - 1 internal power plane
- Dimensions: 6” X 2”.



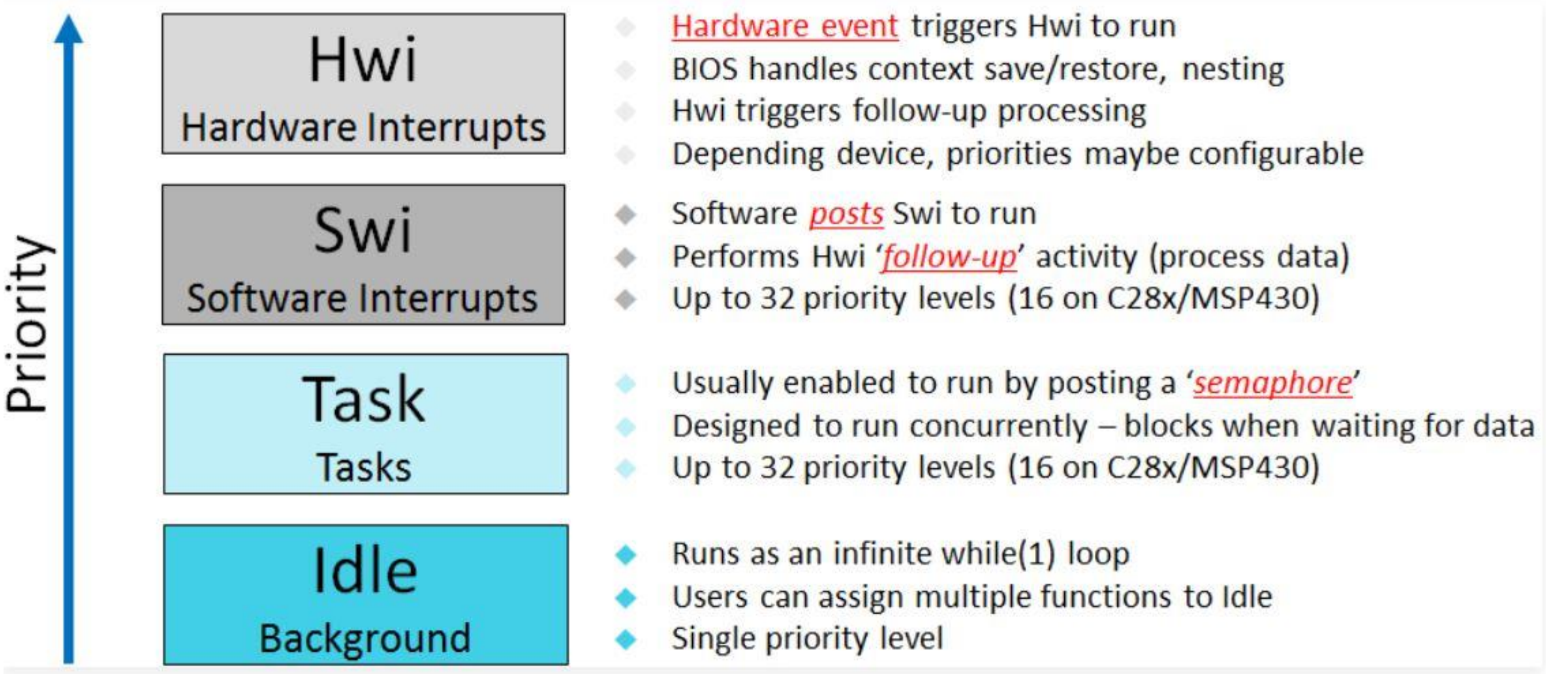
Software Components

Section	Software Chosen	Other options investigated
MCU	TI-RTOS	Bare-Metal
Database	MySQL	MSSQL, Oracle
Web Server	Tomcat	Glassfish, Microsoft IIS
DB and Web Server host OS	Linux	Windows
Web Application	Angular	ReactJS, Ember

MCU: TI-RTOS

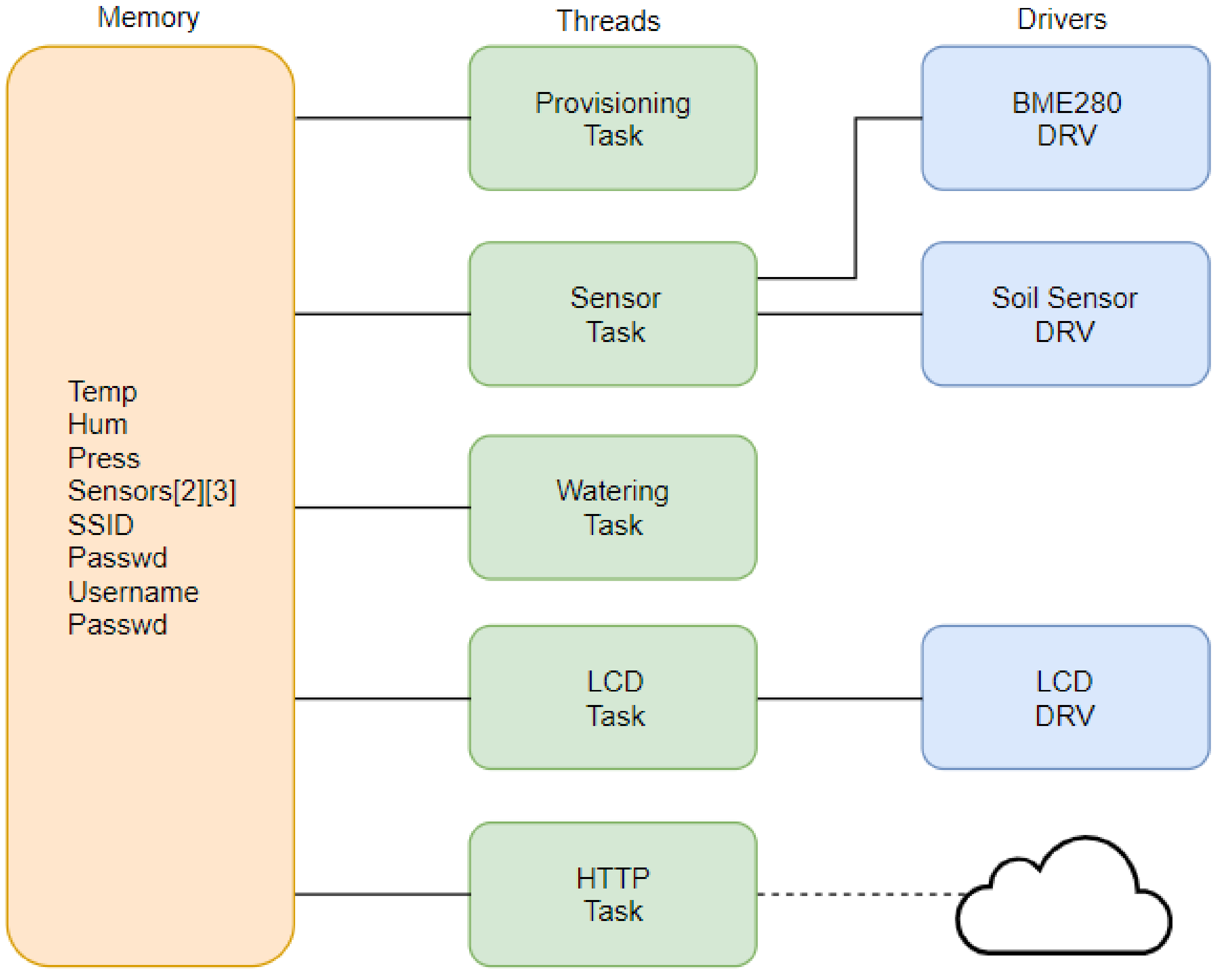
Bare metal:
- Bare metal can maximize resources. Likely to be critical only on slower MCUs.

RTOS:
- When using an RTOS there is no need to manage interrupts. RTOS takes care of interrupts.
- RTOS use of drivers and code portability can increase programmer's performance.



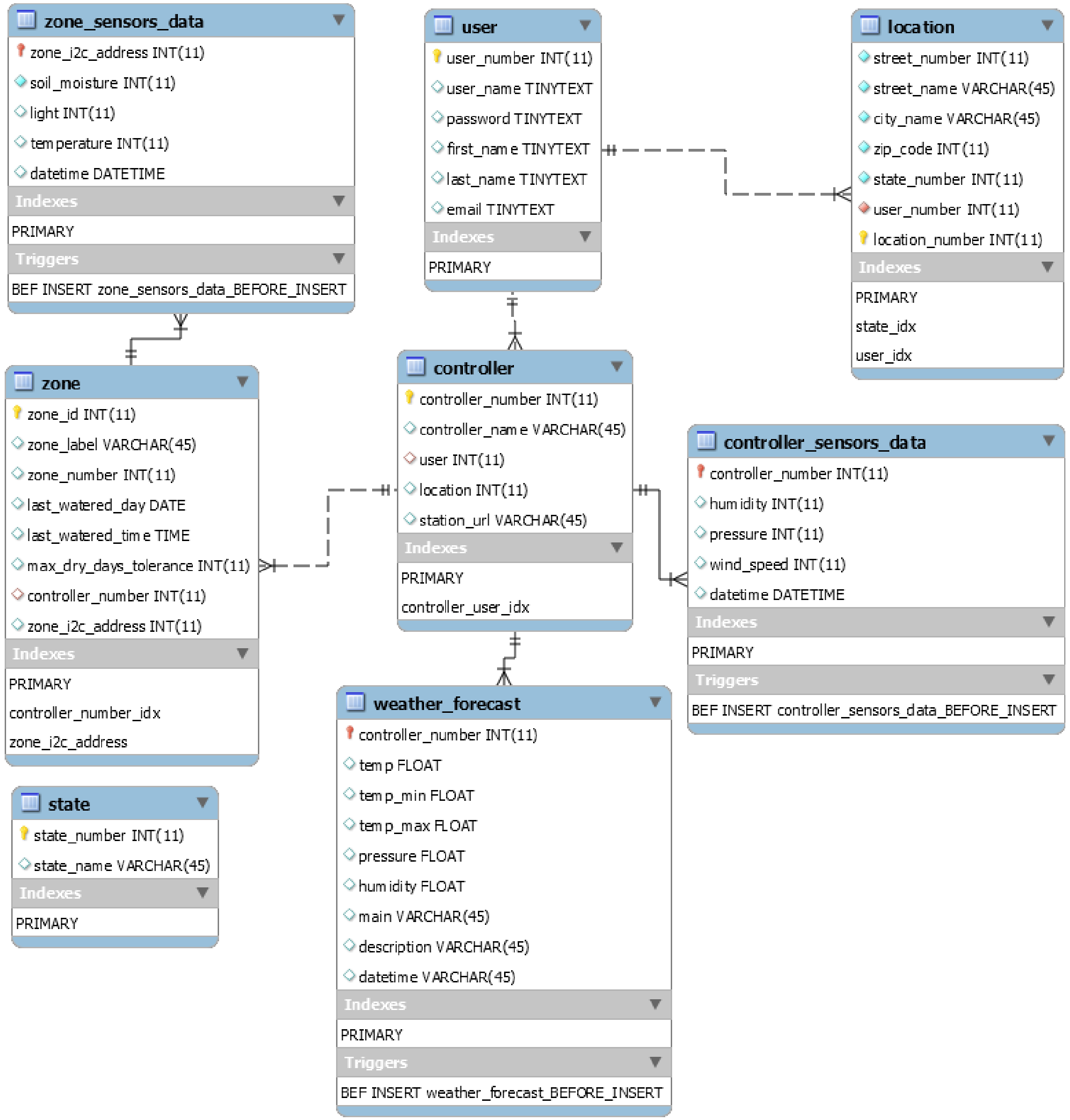
MCU Software: Overview

- Operations will be split amongst task.
- Each task will use the necessary drivers to interact with hardware.



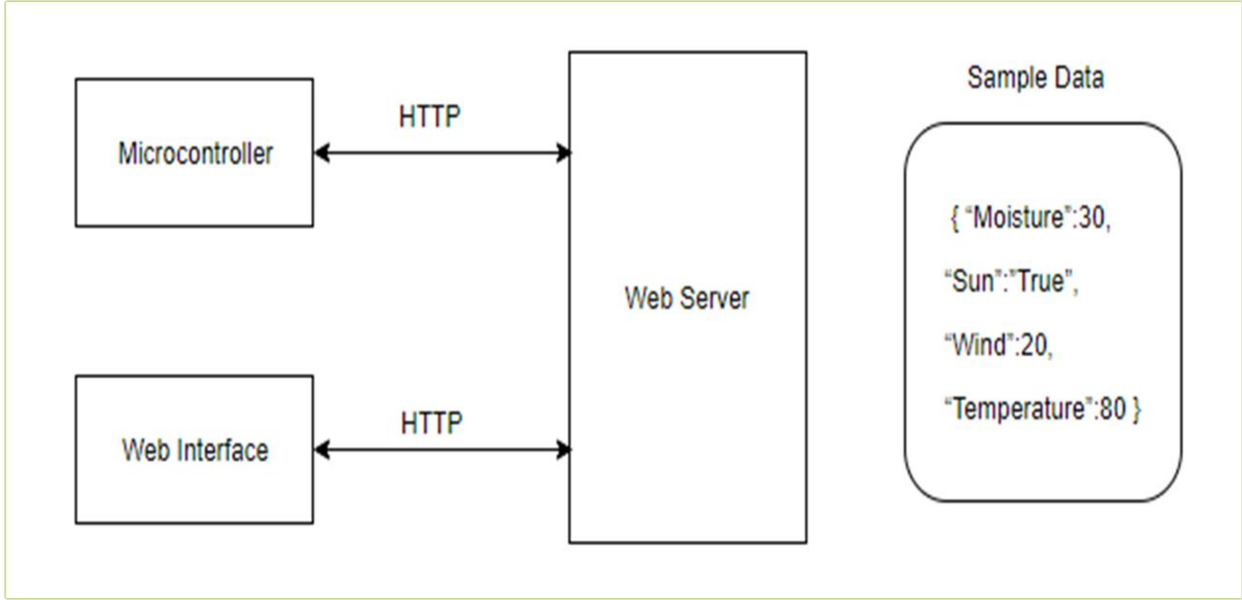
Database: MySQL

- The database server will keep all the sensor data collected by the smart garden controller.
- The database server will keep all user configuration.
- The database server will keep all scheduling information.
- MySQL software chosen because it has abundant resources available on how to configure and setup.
- MySQL software chosen because it had been used in previous projects as well.



Web Server: Tomcat

- Java Jersey framework was used to provide restful services.
- Works as a gateway between the MCU and Web Application to the database.
- Can provide web services to any future integration without having to update it.
- Data objects transferred in JSON format.




```java
@Path("user")
public class UserResource {

    public ResourcesDAO userRepo = new ResourcesDAO();

    @GET
    @Produces(MediaType.APPLICATION_JSON)
    public List<User> getUsers() {
       System.out.println("METHOD CALL: UserResource.getUsers()");

       List<User> users = userRepo.getUserList();
       //List<User> users = Arrays.asList(userA, userB);
       return users;
    }
```

Web Application: Angular

Some available front end frameworks:

- ReactJS
- Ember
- Angular

Why angular?

- Wealth of documentation available.
- Solid reputation.
- Known to be great to develop single page applications (SPA).

In the end, any framework would do it …

Web Application: Angular (con't)

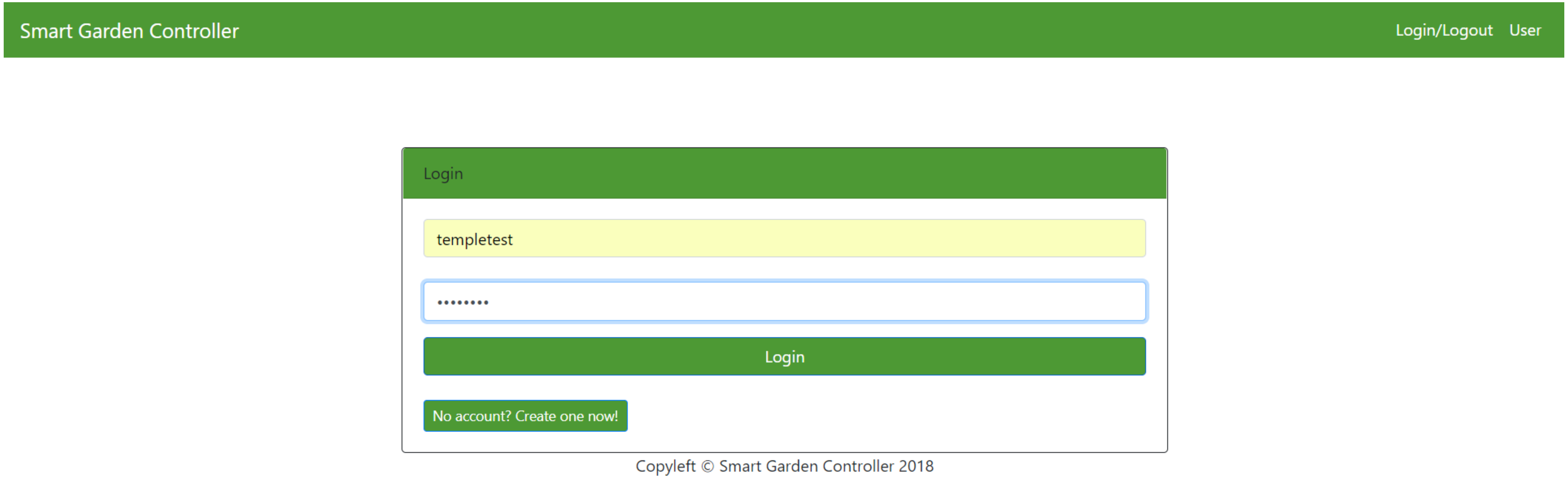
Main User Interface Pages:

- Data – User can view most recent data & data collected over a selected time period. Data is displayed with open-source chart software in line, bar, & pie graphs.
- Schedule – User can view a weekly calendar of all zones scheduled to be watered, set a weekly schedule for each zone, and delete any schedule.
- On-Demand – User can create and delete Demands to water any number of zones immediately.

Ancillary User pages:

- User info – User can change their name, email, username, and password.
- User Address – User can changer their address.
- Login/logout – User must log in to view full site, user can logout from here.

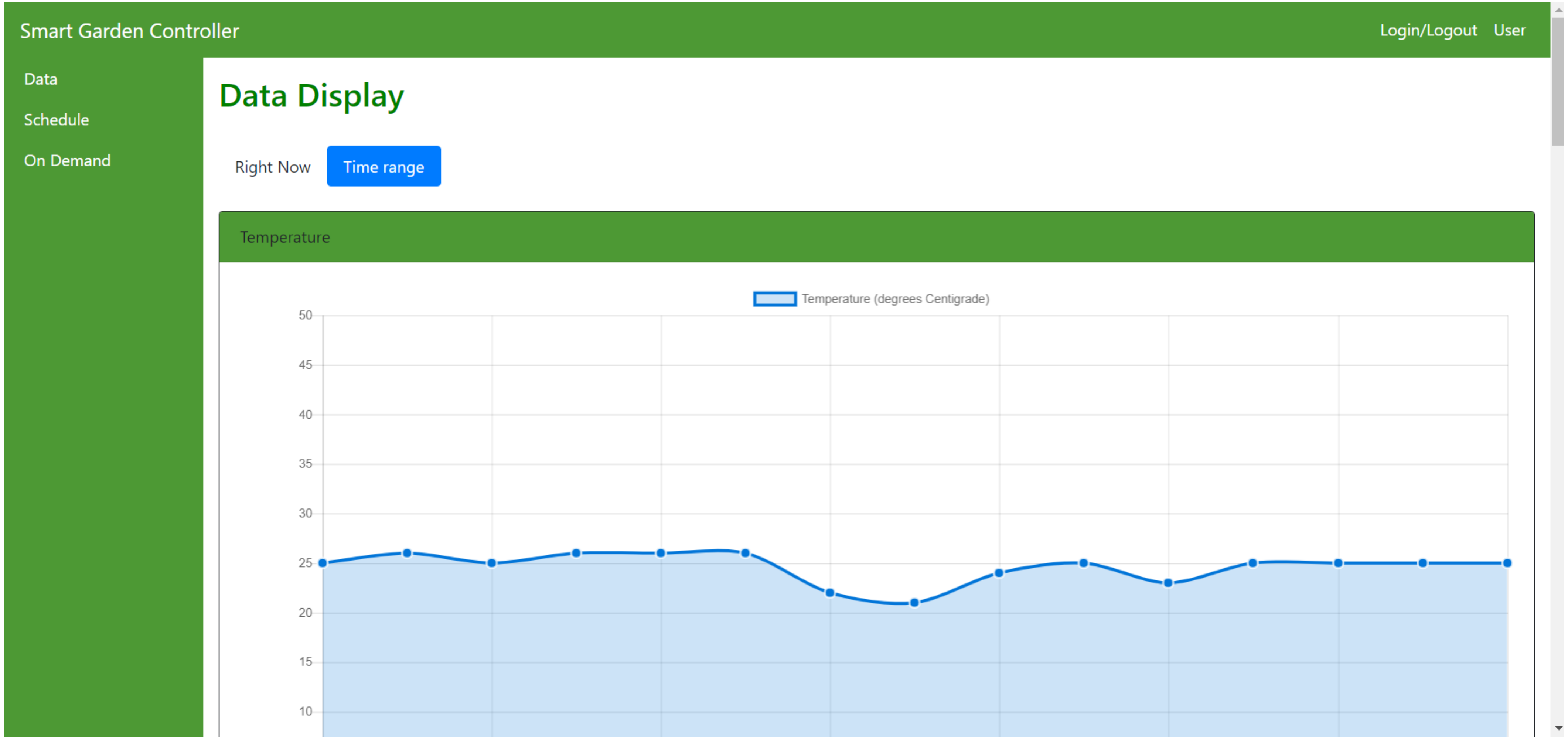
Login


Smart Garden Controller
Login/Logout
User
Login
templetest
Login
No account? Create one now!
Copyleft © Smart Garden Controller 2018

User Info Page

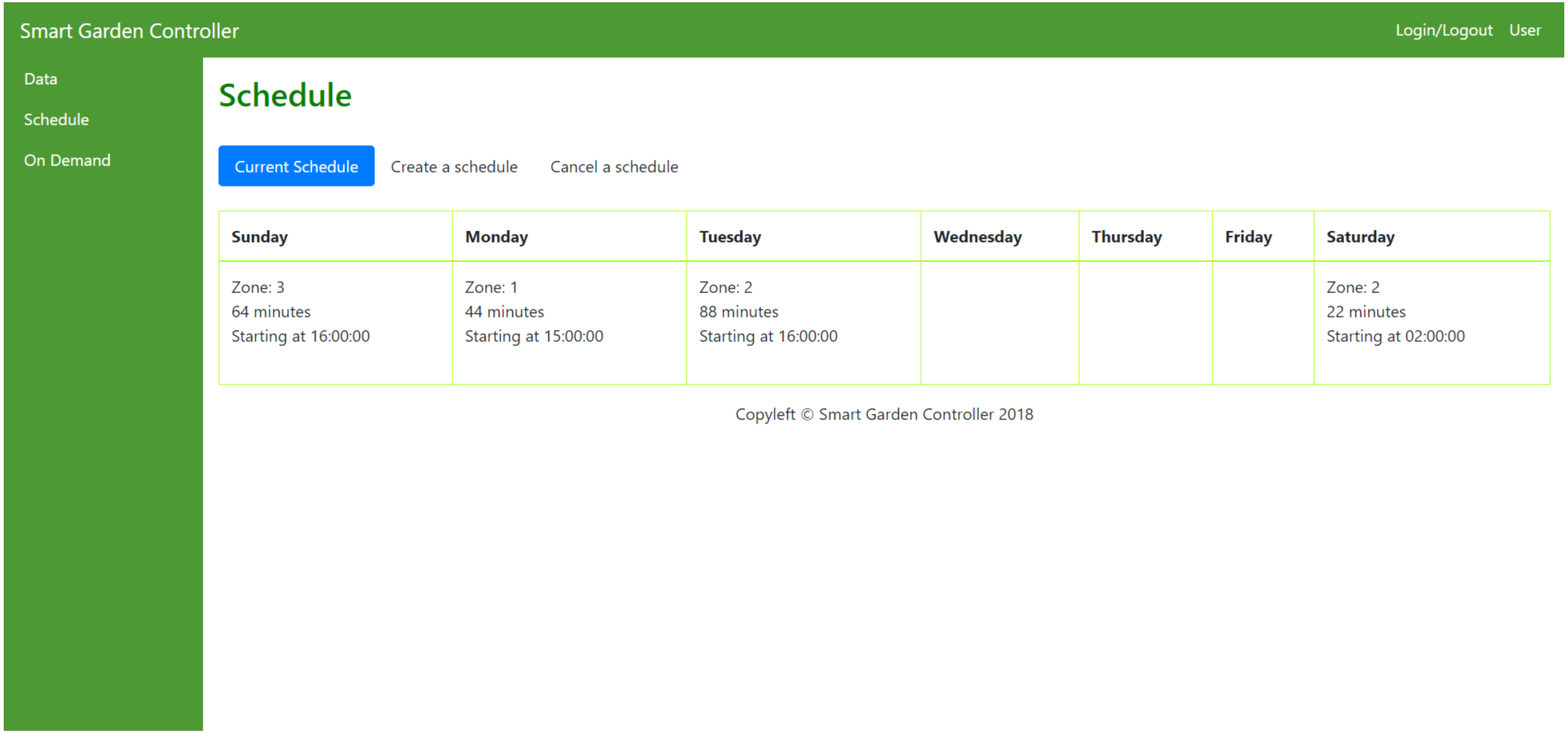
*Sample data shown

Data Page*



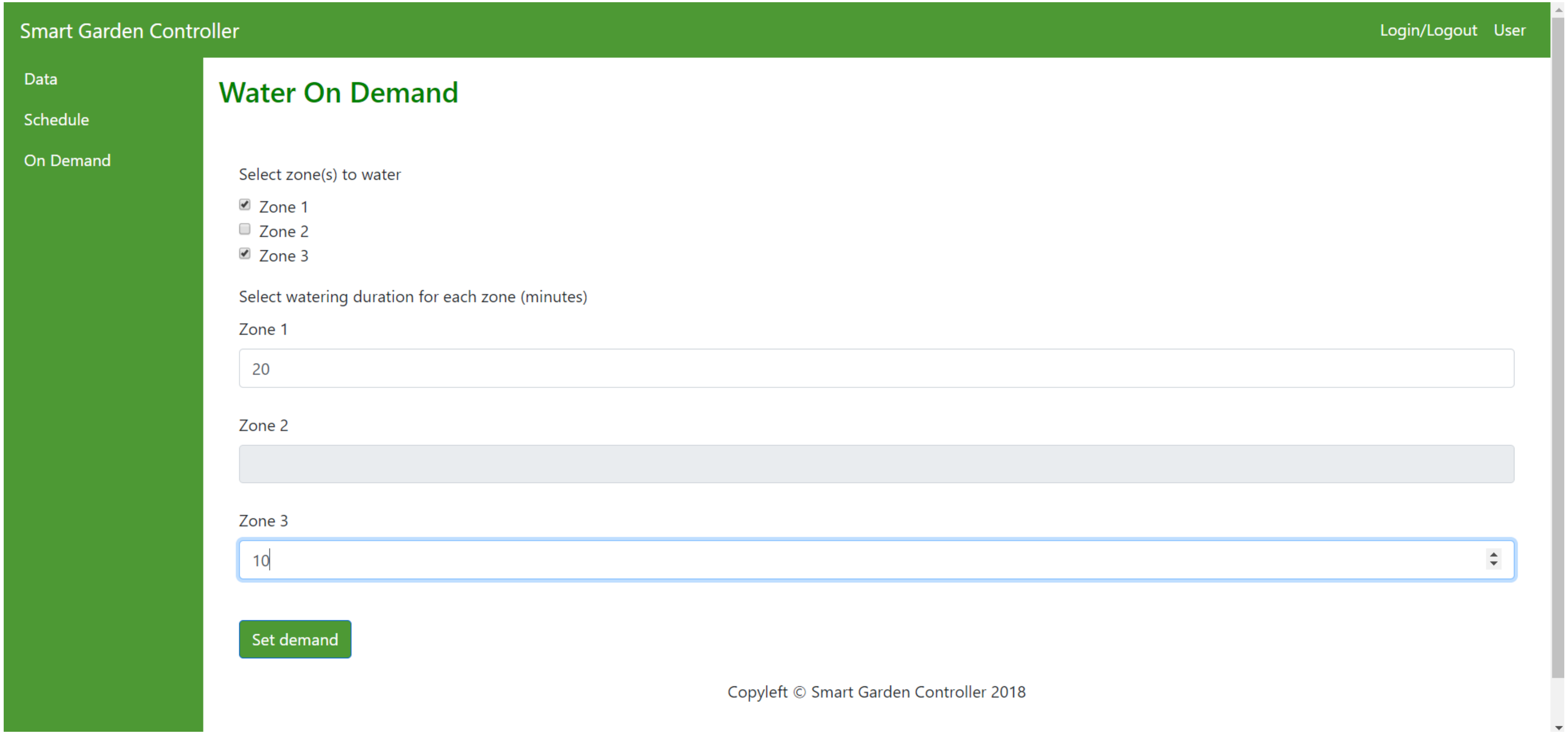
*Sample schedule shown

Schedule Page*



*Sample demand shown

On-Demand Page*



Challenges & successes

Issue 01: The hardware components chosen did not have libraries available for the CC3220SF.
Solution: We read the code for Arduino libraries for the same sensors/devices and re-wrote the code for the platform being used. The LCD driver alone had 2000 lines of code to be read, understood and re-coded.

Issue 02: The available documentation for CC3220SF is not beginner friendly. There are almost no tutorials available.
Solution: A lot of time was spent on researching how to use the features available. Also, a lot of time was spent reading documents and sample code.

Issue 03: Power consumption was high due to valves and therefore using a battery powered system would not be viable.
Solution: Review of problem showed us that running of the grid would be preferable and battery power would not be necessary.

Issue 04: The ordered soil sensors shipping took much longer then expected.
Solution: Worked on other parts of the project.

Budget & Financing

Description	Unit Cost	Project Parts Count	Project Cost Estimate	Final Product Parts Count	Final Product Cost
MCU/Wi-Fi Module	$10.00	3	$30.00	1	$10.00
Anemometer	$44.95	2	$89.90	1	$44.95
Humidity & Pressure sensor	$16.62	3	$49.86	1	$16.62
Moisture, Light, & Temperature sensor	$12.49	5	$62.45	3	$37.47
Water Valves Main	$24.95	3	$74.85	3	$74.85
Water Valves Backup	$6.95	3	$20.85	0	$0.00
PCB	~$30.00	3	~$90.00	1	~$30.00
LCD screen	$24.90	3	$74.70	1	$24.90
Chassis Enclosure	~$1.00	3	~$3.00	1	~$1.00
Power Source	~$10.00	2	~$20.00	1	~$10.00
Miscellaneous (hoses, sprinklers, garden content)	~$100.00	1	$100.00	0	$0.00
Total Cost			$665.61		$249.79

Work Distribution

Artifact	Alex	Renan	Temple	Geo
Hardware Design/Schematic				
PCB Layout				
Circuit Card Assembly				
Mechanical Design/Chassis				
MCU Software				
Database Server				
Web Server				
Weather API				
Web Application				
Testing/Documentation				

Q & A