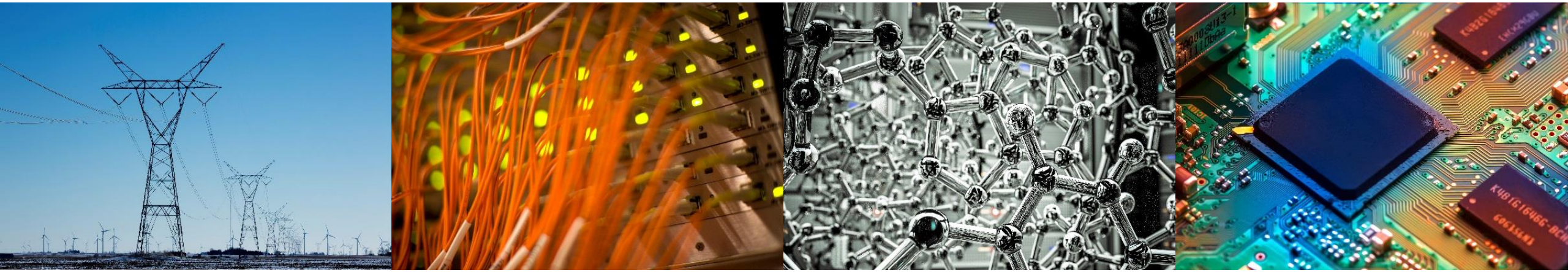
PhytoHome – Regulated Aeroponic System

Team 4: Pablo Catalan, Umme Kulsoom, Joseph Rapp

ECE 445 Final Presentation

December 9th 2019



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Overview

- Background
- Problem and Objective
- Solution
- System Overview
  - Microcontroller
  - Software
  - Subsystem Specifics
- Conclusion

Background

- By 2100, world population projected to reach 10.9 billion [1]
  - Represents 42% increase over 80 years
- Traditional farming may be incapable of matching required food production
  - Limitations due to inclement weather, land, insects, etc.
- Vertical farming is one method to combat limitations in traditional farming
  - Uses controlled environment agriculture and techniques like aeroponics
- Vertical farming has helped inspire commercial home systems

Problem and Objective

- Problem: Current home systems:
  - Have limited crop density
  - Lack of controlled environment
  - Experience lighting Power Inefficiencies

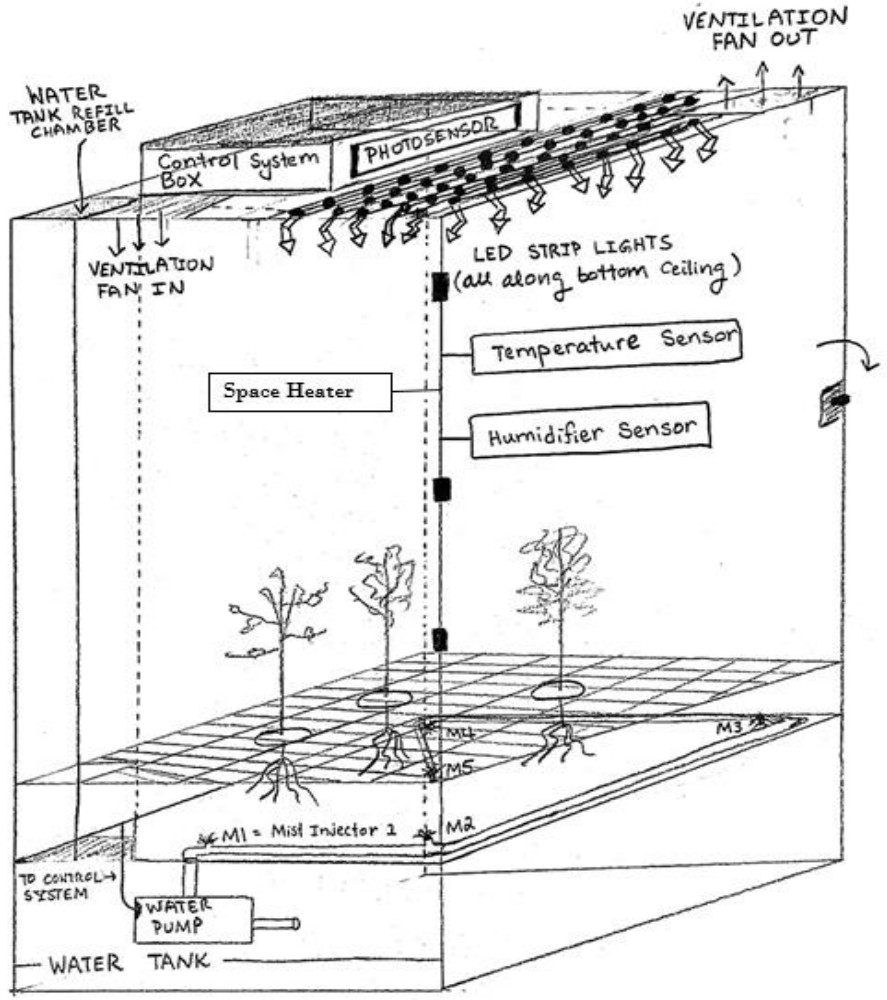
- Objective: Design an indoor farming system that solves these problems

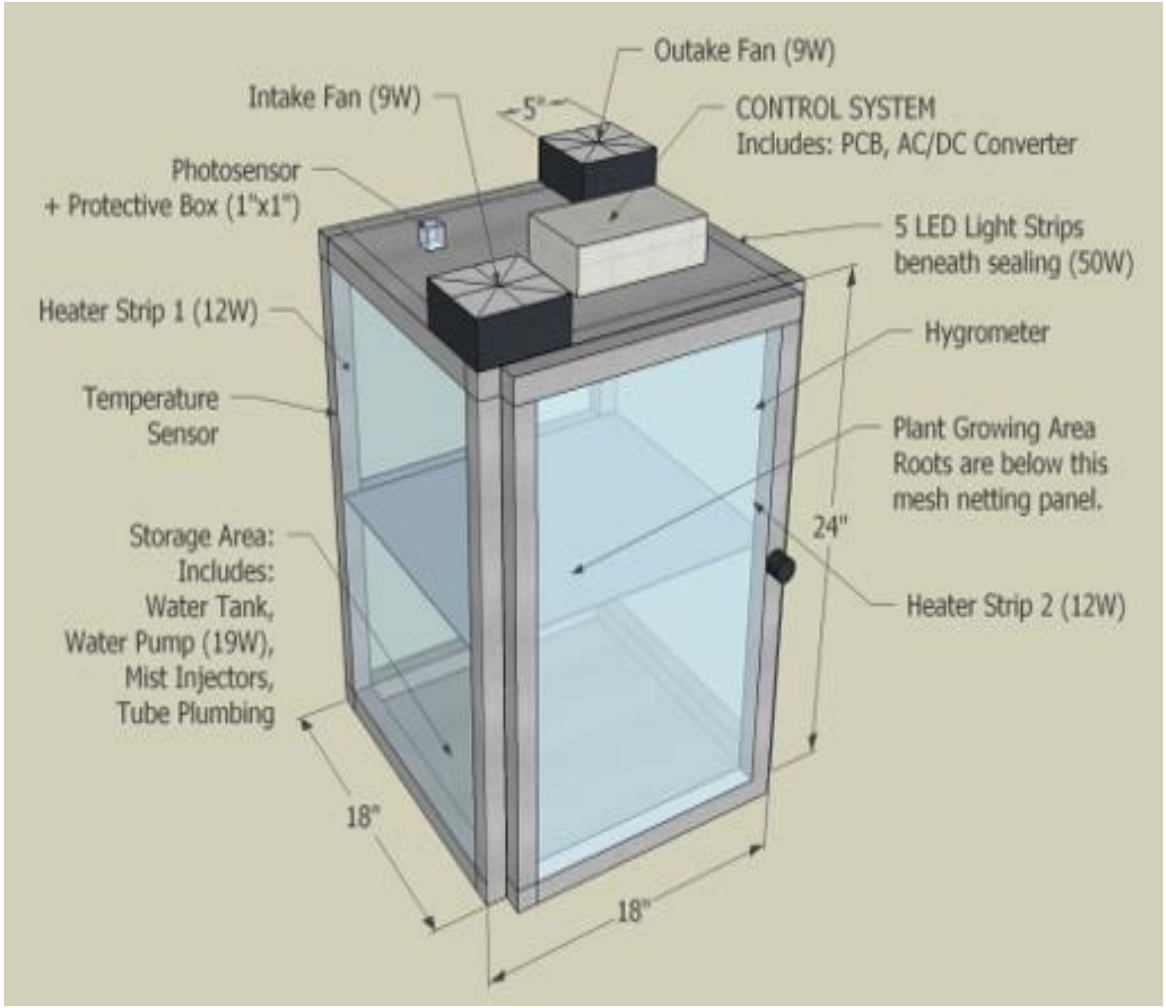
Solution

- PhytoHome: A Regulated Aeroponic System (RAS)

- PhytoHome meets the objective by providing the following features:
  - Aeroponic technology to increase crop density
  - An enclosed, regulated environment
  - Energy savings through improved LED emission and plant absorption matching.

PhytoHome – Original Design



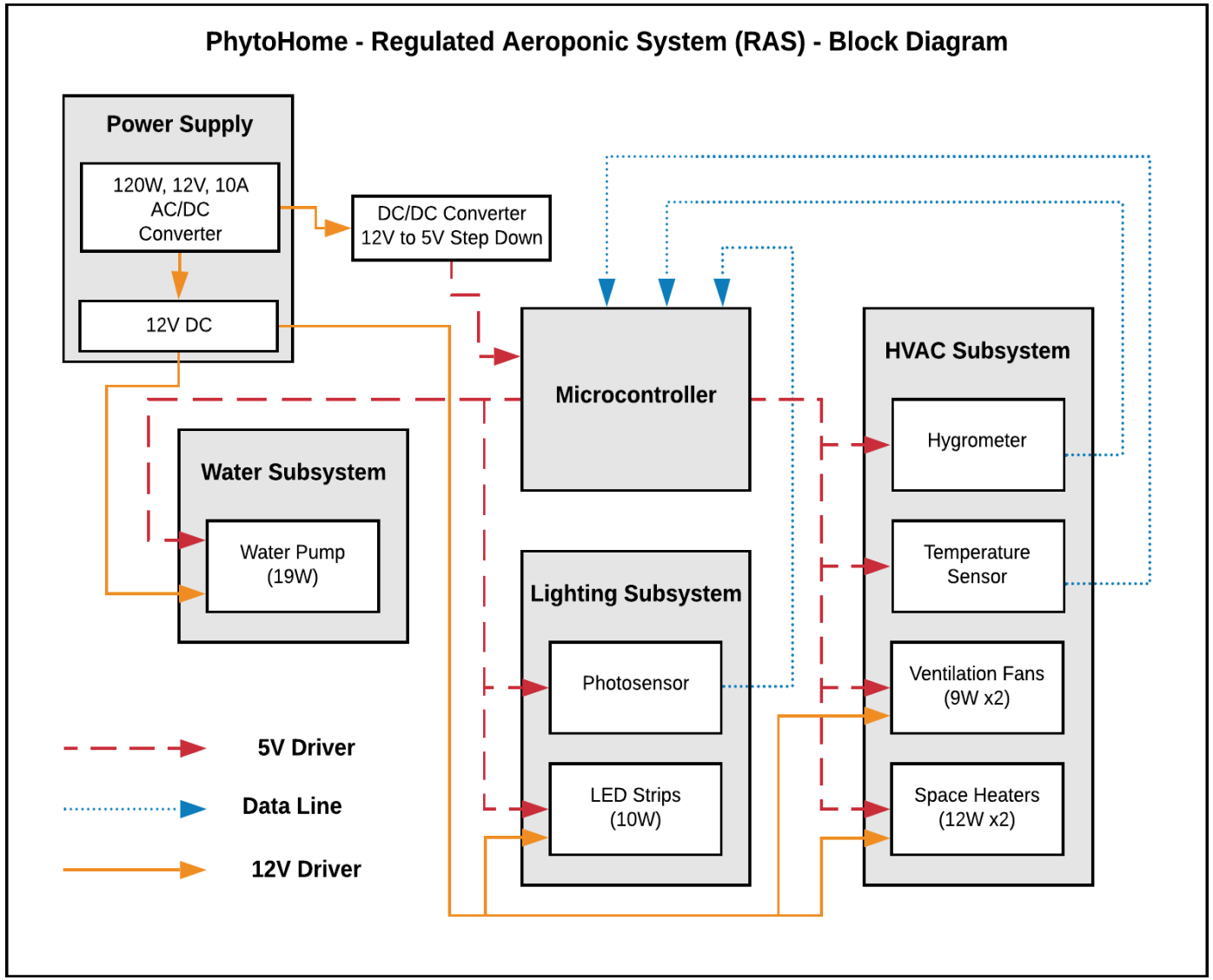


Features & Requirements

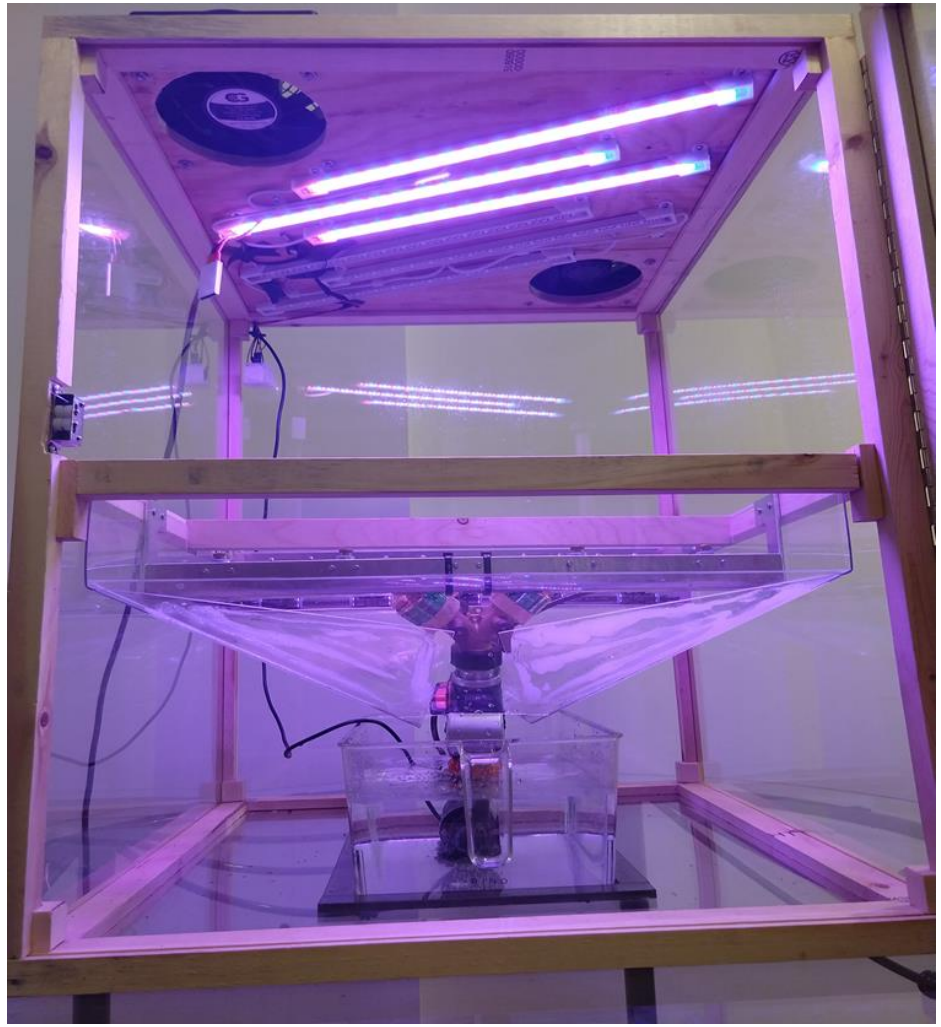
- Provide intermittent water misting to plant roots
- Provide approx. 25-30 W/SqFt to plants through LED lighting
  - Monitor ambient light to determine LED brightness
- Provide temperature & humidity controlled environment
  - heating through space heaters
  - cooling through ventilation fans

System Overview

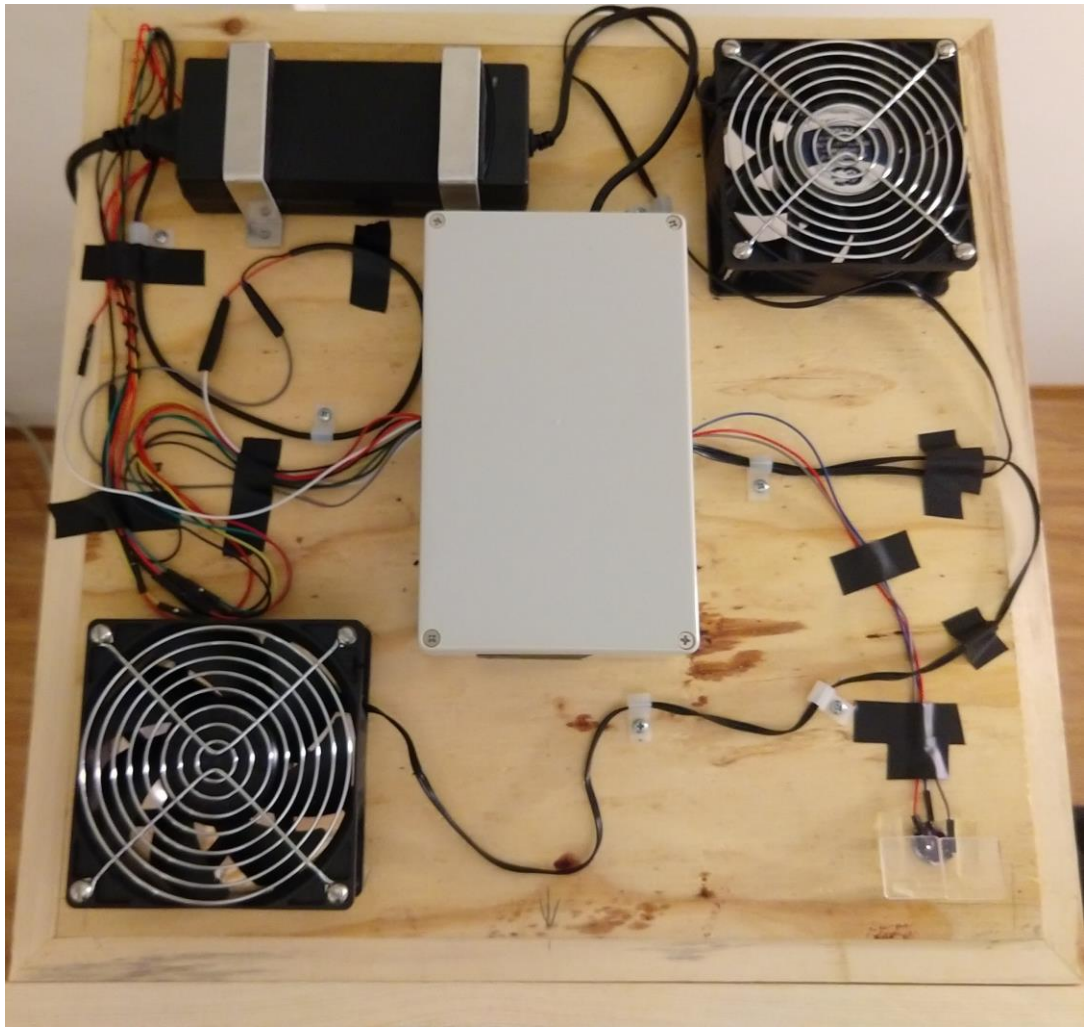
- Hardware
  - Power supply
  - Subsystems:
    - Water, Lighting, HVAC
- Software
  - Microcontroller interprets sensor data
  - Data is processed and decisions are made



Final Product

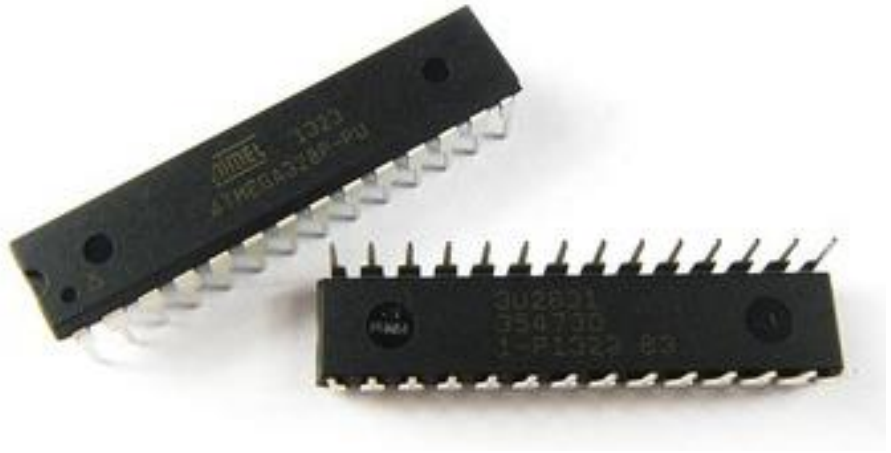


Final Product



Project Build - Microcontroller

- Serves 5V ± 5% to photo/temperature/humidity sensors
- Biases MOSFET-based driver circuits into saturation to serve as switching circuits



ATMega328P and Arduino Uno Pin Mapping [2]

Arduino function					Arduino function
reset	(PCINT14/RESET) PC6	1	28	PC5 (ADC5/SCL/PCINT13)	analog input 5
digital pin 0 (RX)	(PCINT16/RXD) PD0	2	27	PC4 (ADC4/SDA/PCINT12)	analog input 4
digital pin 1 (TX)	(PCINT17/TXD) PD1	3	26	PC3 (ADC3/PCINT11)	analog input 3
digital pin 2	(PCINT18/INT0) PD2	4	25	PC2 (ADC2/PCINT10)	analog input 2
digital pin 3 (PWM)	(PCINT19/OC2B/INT1) PD3	5	24	PC1 (ADC1/PCINT9)	analog input 1
digital pin 4	(PCINT20/XCK/T0) PD4	6	23	PC0 (ADC0/PCINT8)	analog input 0
VCC	VCC	7	22	GND	GND
GND	GND	8	21	AREF	analog reference
crystal	(PCINT6/XTAL1/TOSC1) PB6	9	20	AVCC	VCC
crystal	(PCINT7/XTAL2/TOSC2) PB7	10	19	PB5 (SCK/PCINT5)	digital pin 13
digital pin 5 (PWM)	(PCINT21/OC0B/T1) PD5	11	18	PB4 (MISO/PCINT4)	digital pin 12
digital pin 6 (PWM)	(PCINT22/OC0A/AIN0) PD6	12	17	PB3 (MOSI/OC2A/PCINT3)	digital pin 11(PWM)
digital pin 7	(PCINT23/AIN1) PD7	13	16	PB2 (SS/OC1B/PCINT2)	digital pin 10 (PWM)
digital pin 8	(PCINT0/CLKO/ICP1) PB0	14	15	PB1 (OC1A/PCINT1)	digital pin 9 (PWM)

Digital Pins 11,12 & 13 are used by the ICSP header for MOSI, MISO, SCK connections (Atmega168 pins 17,18 & 19). Avoid low-impedance loads on these pins when using the ICSP header.

Project Build – Power Supply

- One power supply:
  - AC/DC convertor steps down 120V AC to 12V DC to power all subsystems (~96 W)
  - DC/DC linear regulator steps down 12V DC to 5V DC to power microcontroller

Challenges & Corrective Action – Power Supply

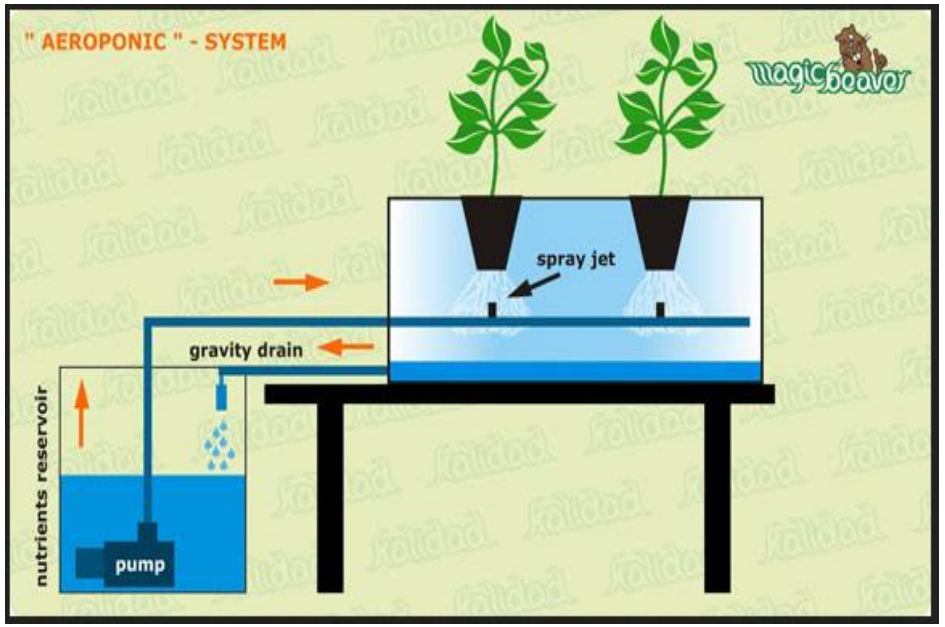
- Limitations of the AC/DC Converter may cause microcontroller browning so that system malfunctions when all entities are on
  - Could only use ½ total LEDs and fans

- Gauge of wires used too small in diameter
  - 12V DC bus wires smoking throughout testing
  - Added parallel 12V wires

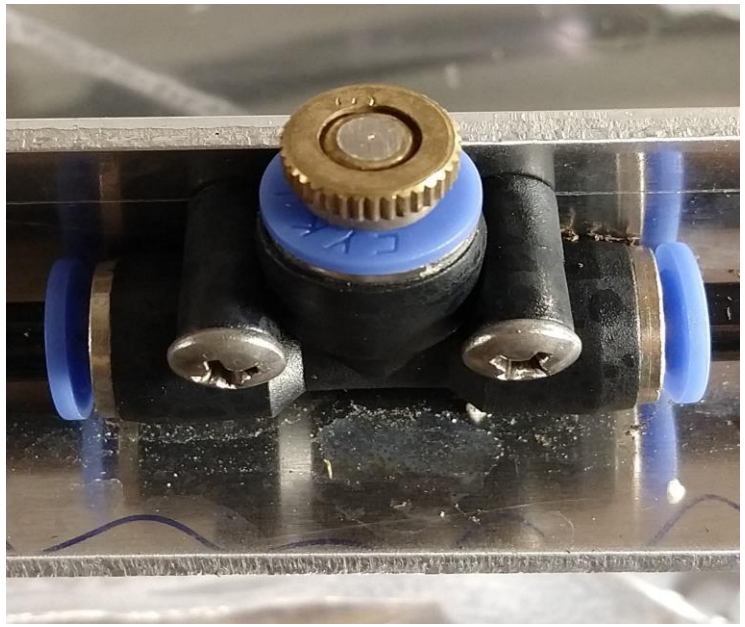
- Accidental shorts during debugging also melted many wires and blew out PCB traces
  - Had to replace wires, repair PCB traces, and use more insulation

Project Build – Water Subsystem

- Delivers nutrient-laden water to plant roots by pressurizing service tubes using a pump
- Ensures amount of water/nutrients for plant growth is controlled efficiently

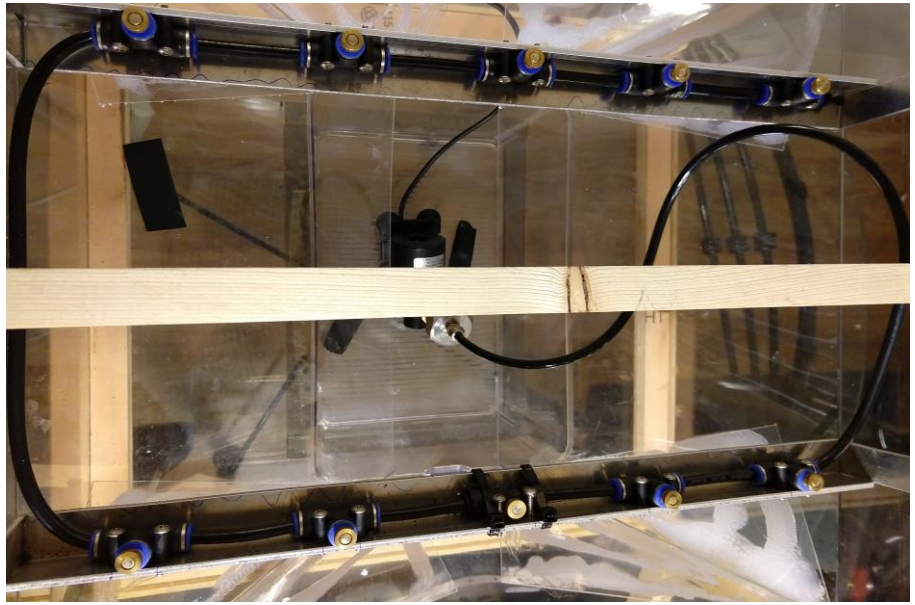


[3]



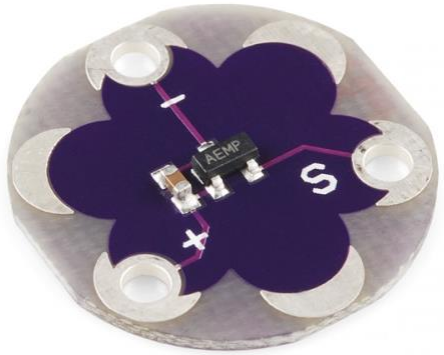
Challenges & Corrective Action – Water Subsystem

- Pressure provided by pump not enough
- Misters in original design give weak sprays of water
  - Had to buy additional screw-on injectors



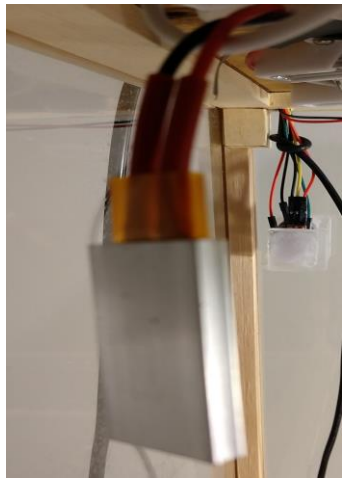
Project Build – HVAC Subsystem

- Maintain a humidity level between 20%-70% and temperature of 21°C-32°C for optimal plant growth [4]
- Use of temperature and humidity sensors, fans, and space heater to achieve desired environment



TEMPERATURE SENSOR

HUMIDITY SENSOR



SPACE HEATER

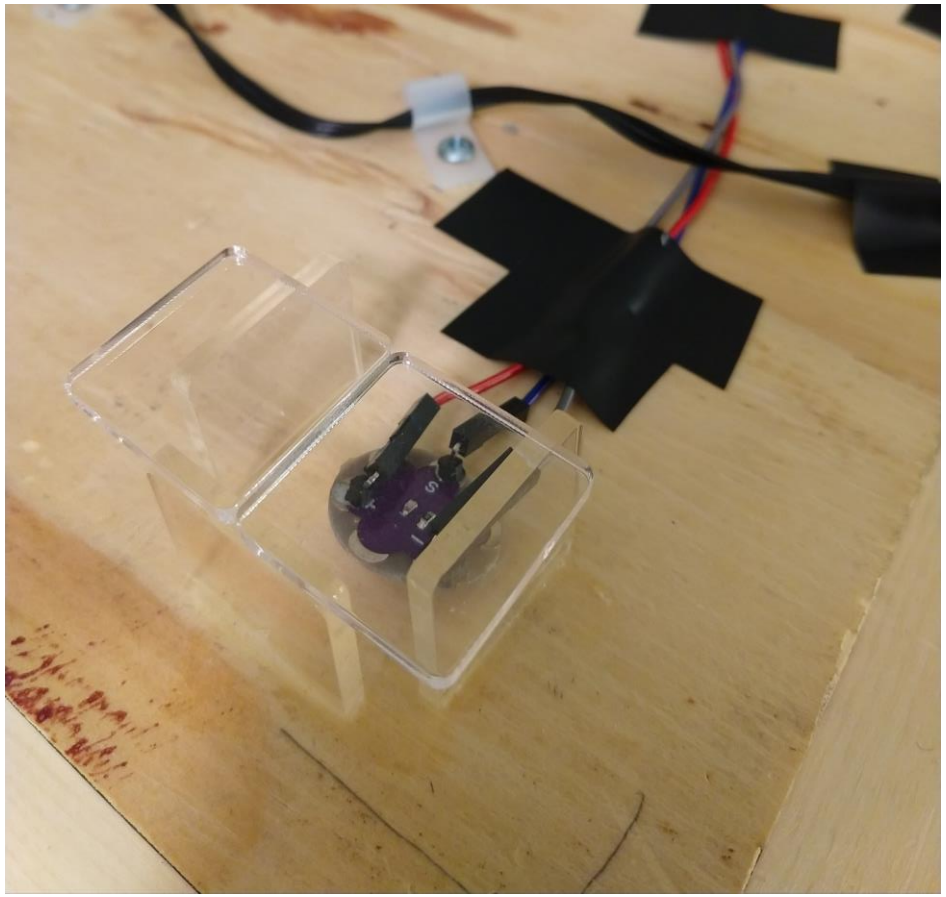
VENTILATION FANS

Challenges & Corrective Action – HVAC Subsystem

- Temperature sensor experienced occasional data anomalies
  - Code was written to discard outlier data

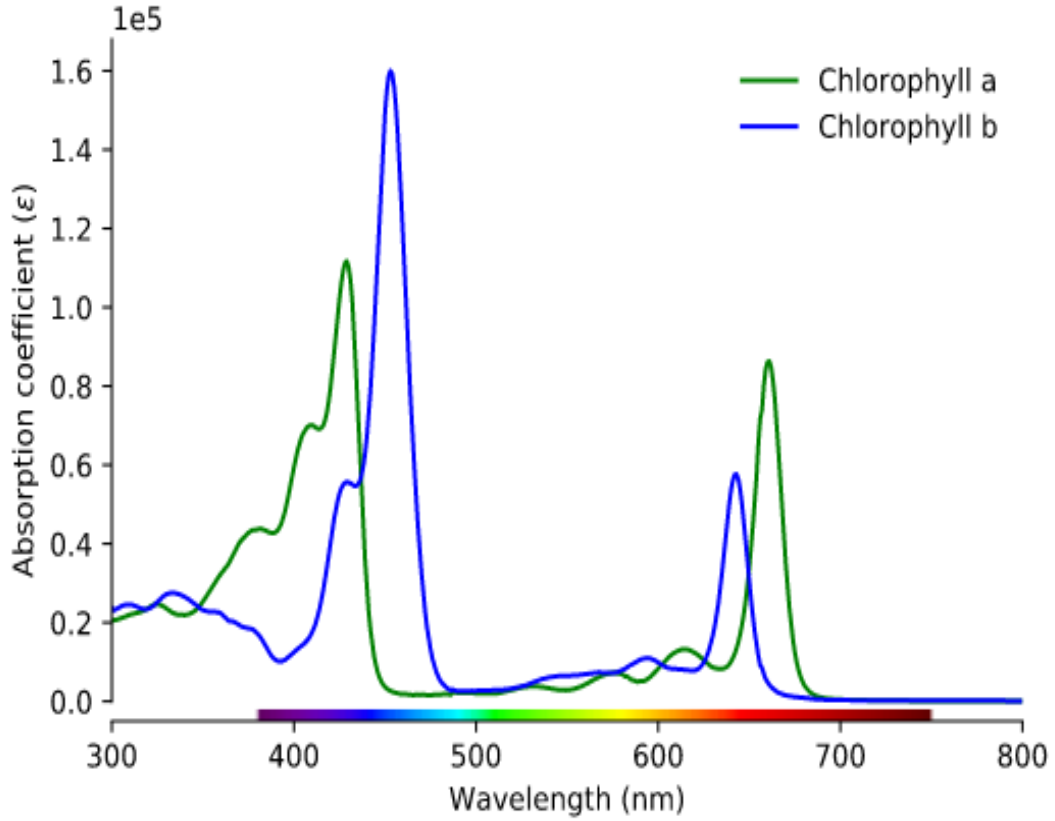
- Original space heaters melted due to high currents/power
  - Had to replace them with more durable ones

Project Build – Lighting Subsystem



Project Build – Lighting Subsystem

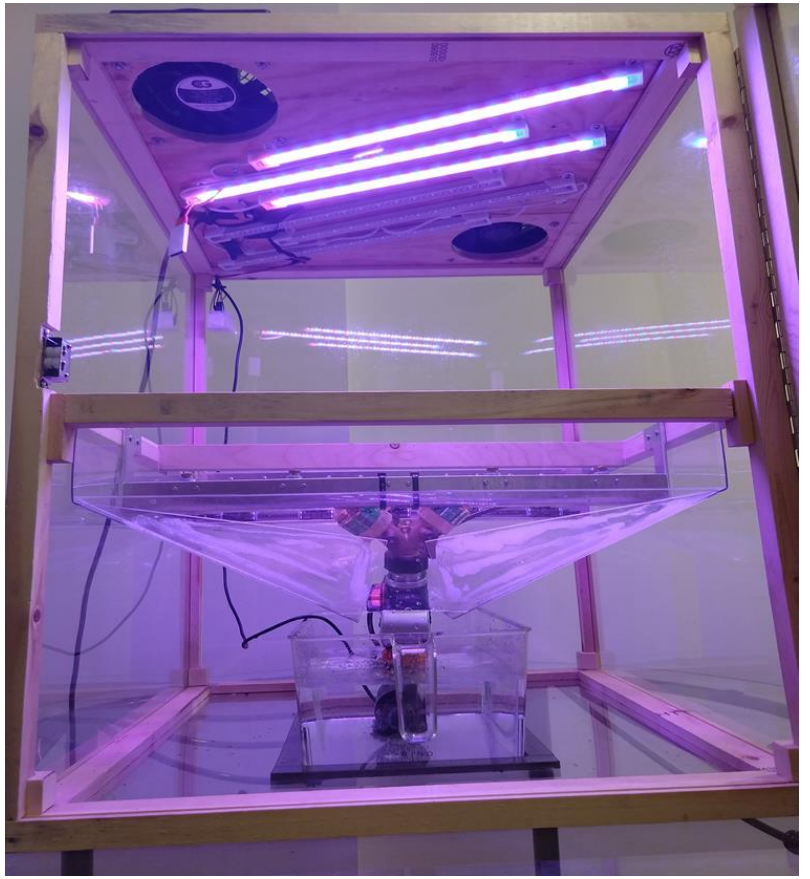
- Made up of 6 panels of blue/red LEDs & photosensor
  - Provide 420-520 nm & 610-720 nm wavelengths; overlap with peaks of absorption spectrum
- LED light intensity varies inversely with ambient light intensity detected by photosensor
  - Ensures plants always receive ~25-30 W/SqFt during daily cycle



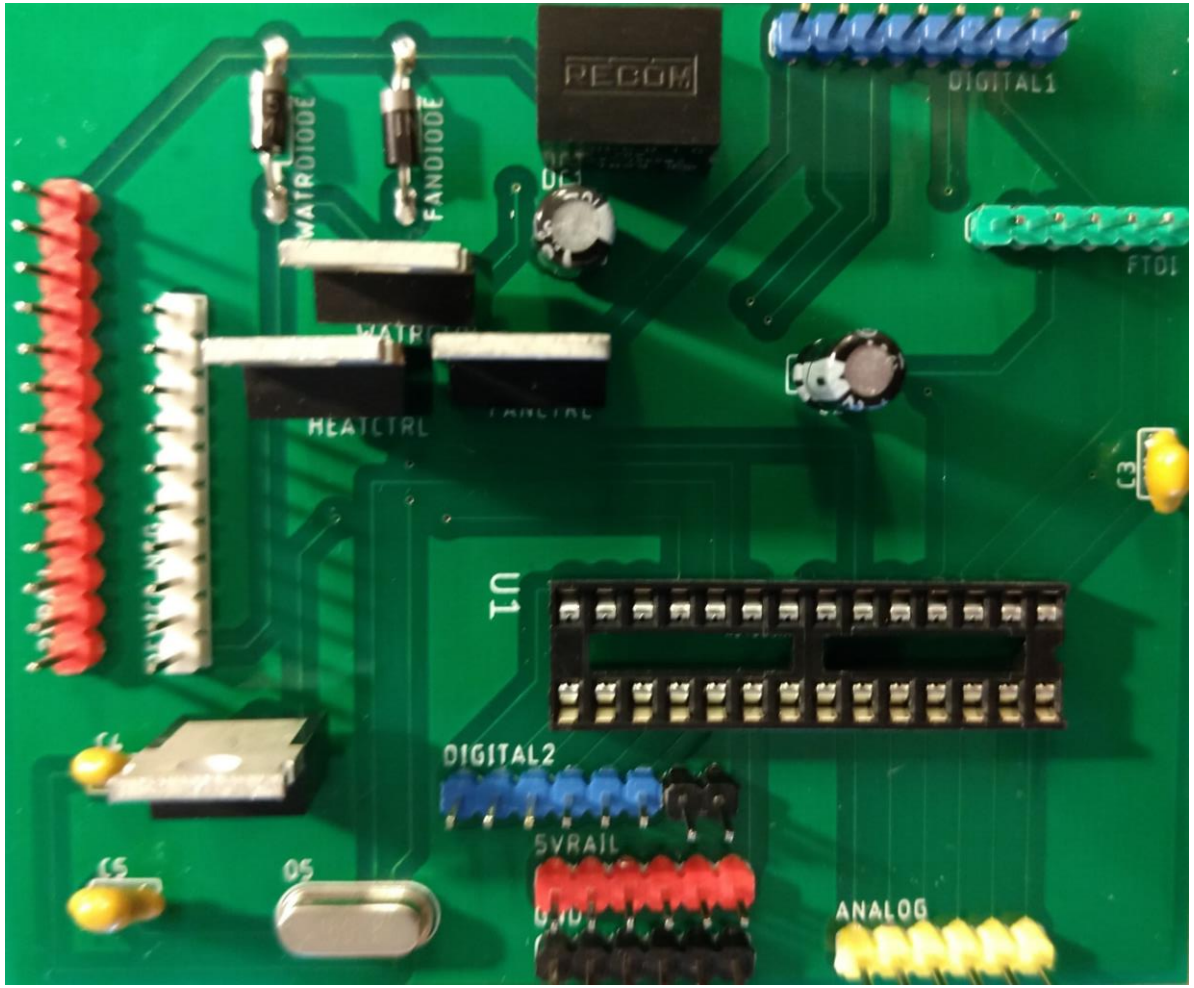
[5]

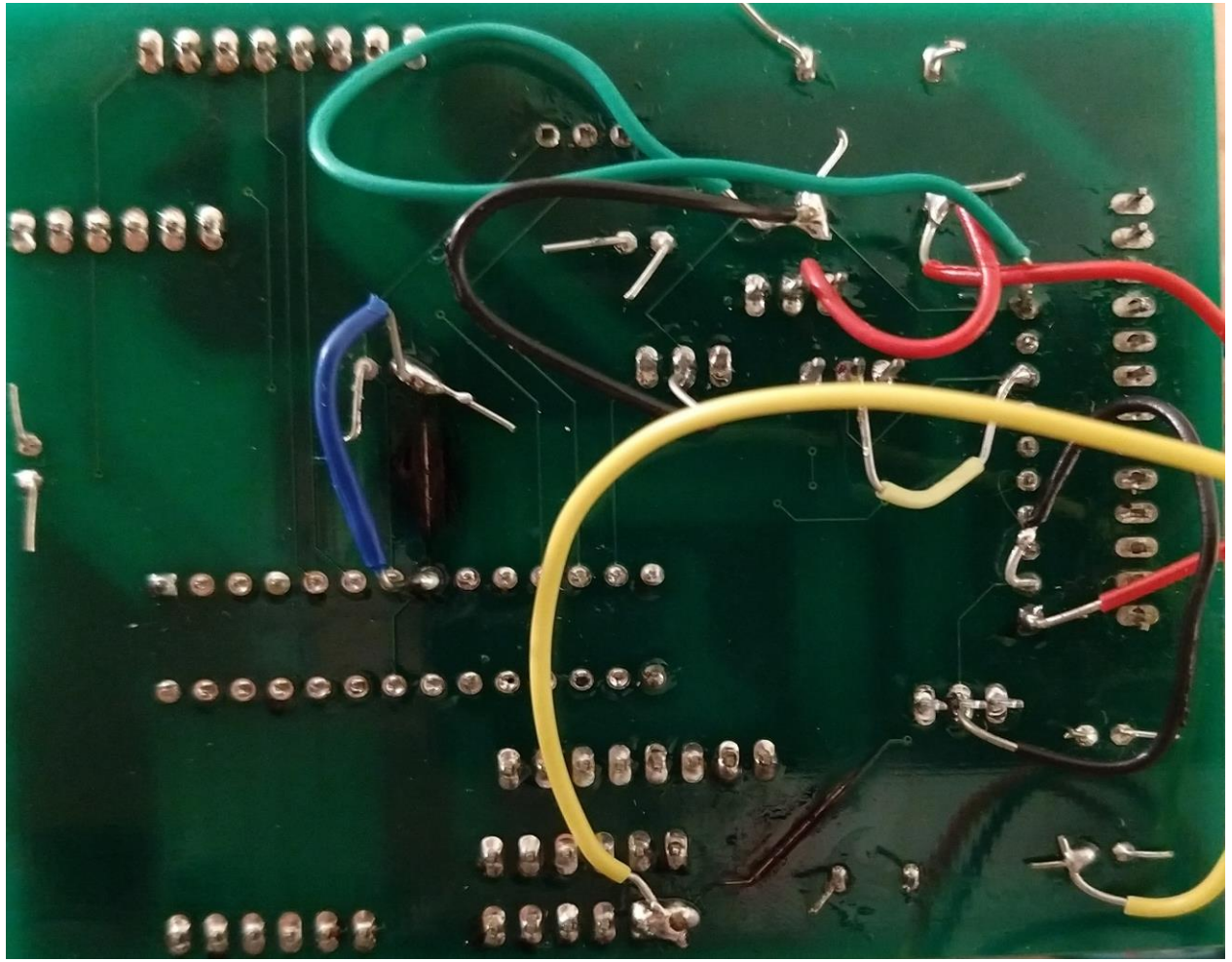
Challenges & Corrective Action – Lighting Subsystem

- All 6 LED strips are unable to remain on in conjunction with rest of subsystems
  - For demo, kept 3 LED strips on
  - Each strip consumes 2.5W and emits 5W incandescent equivalent
  - *PhytoHome* meets the 25-30W/SqFt light emittance for 6”x6” region of box



Project Build – PCB





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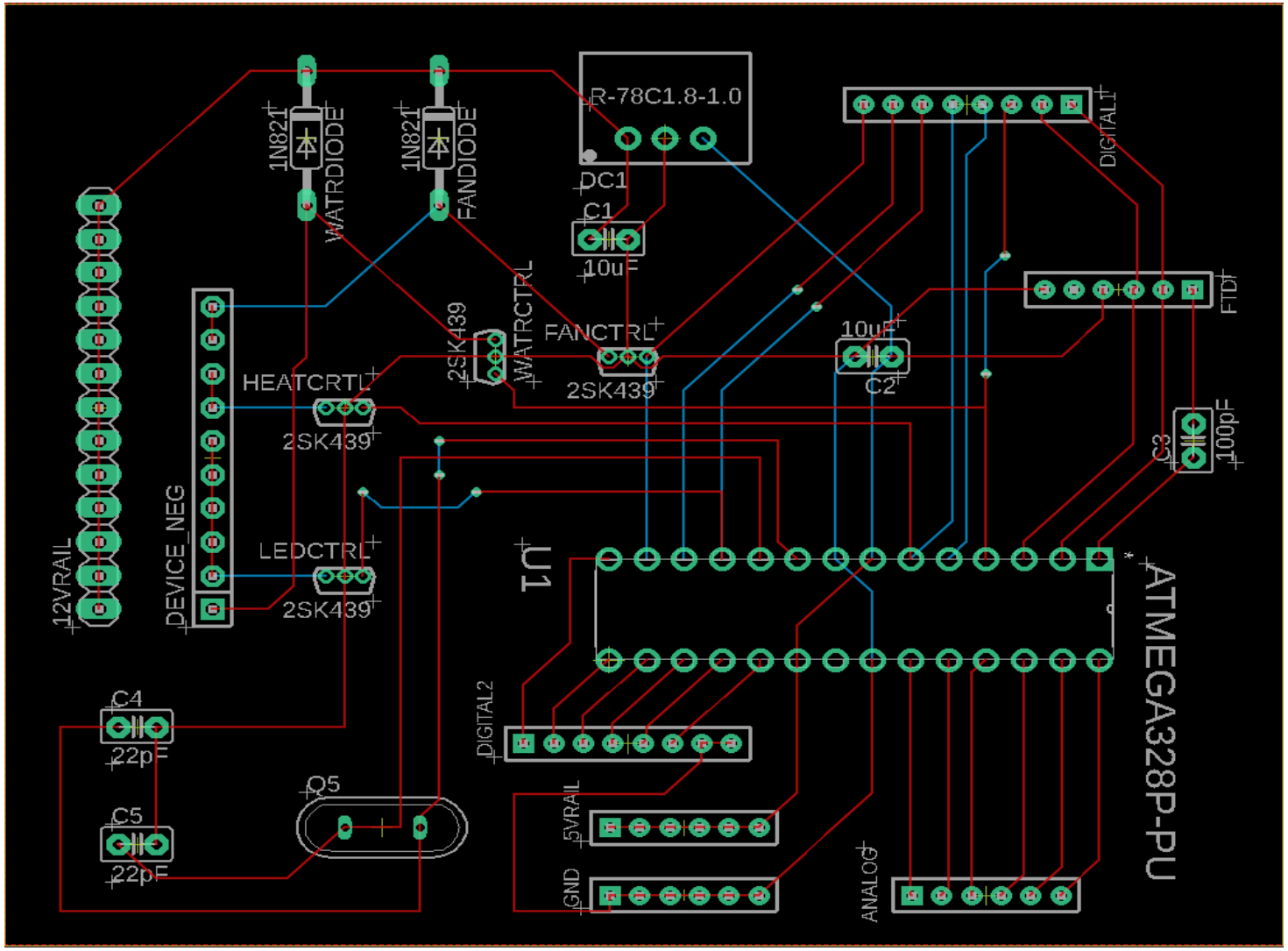


Software

- The purpose of the software is to control the mode of operation for all the subsystems drivers.

- The flow of the code is centered around a task-selecting scheduler

PhytoHome Strengths

- Achieved all intended requirements
- Improved upon existing indoor farming systems
- Ability to include vertical design to grow plants on multiple levels
- Current version portable so ease of transportation

PhytoHome Weaknesses

- Not enough trials performed to test if plants can actually survive from seed to maturity
  - Testing limited by duration of semester

- Need more diagnostics on AC/DC converter to safely incorporate all LEDs and fans

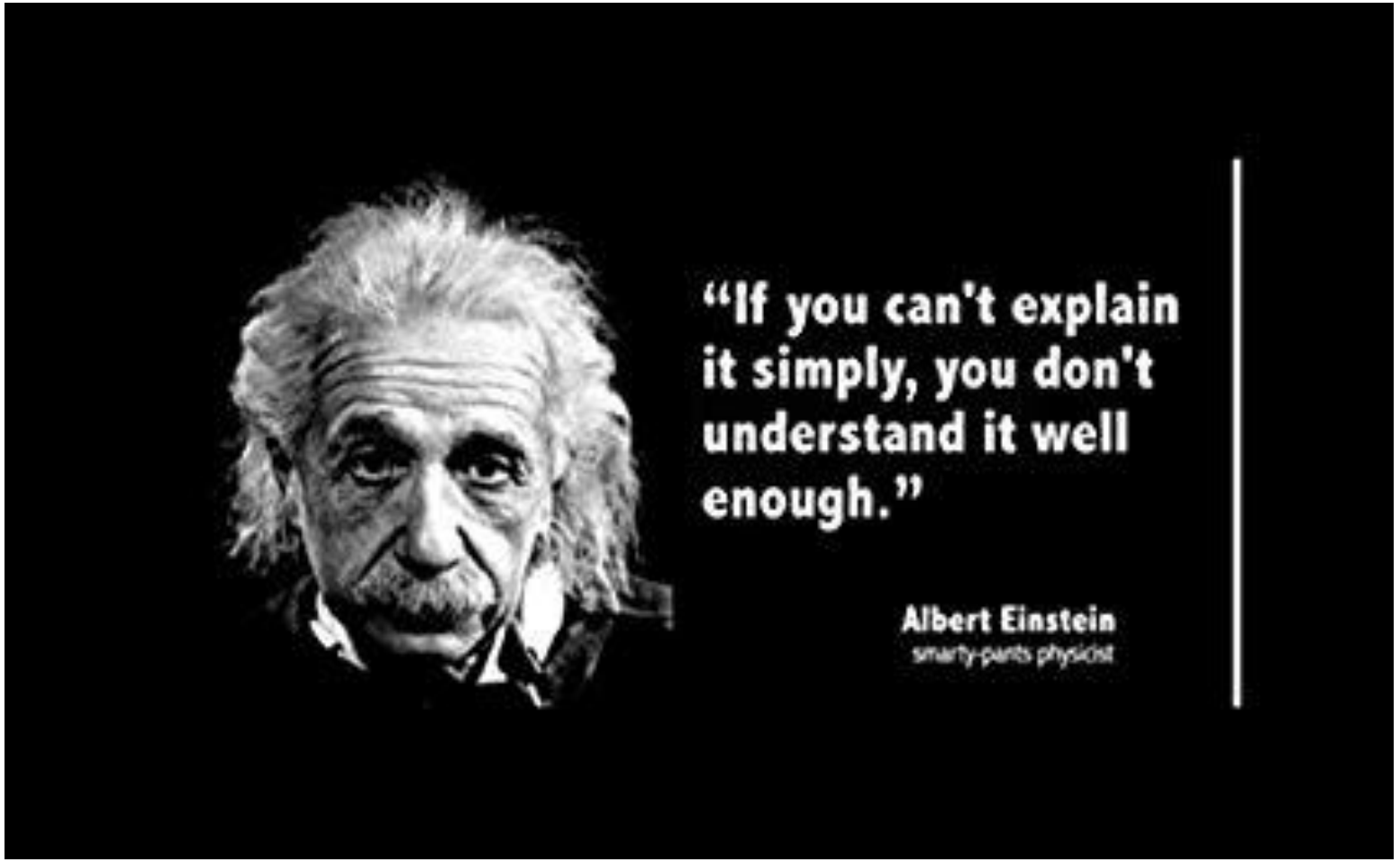
- Preferably remake *PhytoHome* without wood
  - Water subsystem will cause wood to rot eventually; not durable
  - Use aluminum or steel to make to system more durable

Future Work

- Demonstrate the vertical farming capabilities of the PhytoHome infrastructure in more detail

- Develop a more user-friendly interface
  - i.e. displaying temperature and humidity readings on serial monitor and/or alerting user when water levels are low

Questions?


"If you can't explain it simply, you don't understand it well enough."
Albert Einstein
smarty-pants physicist

References

[1] “Population of the World Today,” Our World in Data. [Online]. Available: https://ourworldindata.org/world-population-growth [Accessed: 09/17/2019]

[2] “ATMega328P Microcontroller,” Components 101. [Online]. Available: https://components101.com/microcontrollers/atmega328p-pinout-features-datasheet [Accessed: 09-29-2019]

[3] MagicBeaver. [Online] Available: https://commons.wikimedia.org/wiki/File:Systeme_AEROPONIC_573px.jpg [Accessed: 12/9/2019] No changes were made.

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[4] “TEMPERATURE AND HUMIDITY,” HealingCanna. [Online]. Available: https://www.thehealingcanna.com/growroom-temperature-humidity#targetText=Ideal%20humidity%20levels%20in%20a,to%2060%25%20for%20flowering%20plants [Accessed: 10/02/2019]

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Thank You