Rain Energy Harvester Final Presentation

Senior Design Project: Group 18

Meet the Team

Evan Mayne

Electrical Engineer

Carlos Molina

Electrical Engineer

Alexander Weatherford

Electrical Engineer

Rayan Baig

Electrical Engineer

Concept

- Our project will effectively take the rainwater flowing through a pipe or gutter and generate electric power using a hydroelectric turbine.
- This project will repurpose the rainwater coming from a gutter into a renewable source of energy

Motivations

- Develop an innovative and sustainable solution for energy generation.
- Use a natural source of energy that is currently not explored or utilized.
- Provide a clean energy source that contributes to the preservation of the environment.

Goals

- ❑ The device will be capable of generating energy through rainfall.
- ❑ The energy generated will then be used to power an external device.
- ❑ Information about energy generated will be shown to the user.

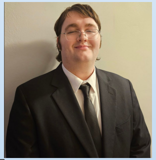
Objectives

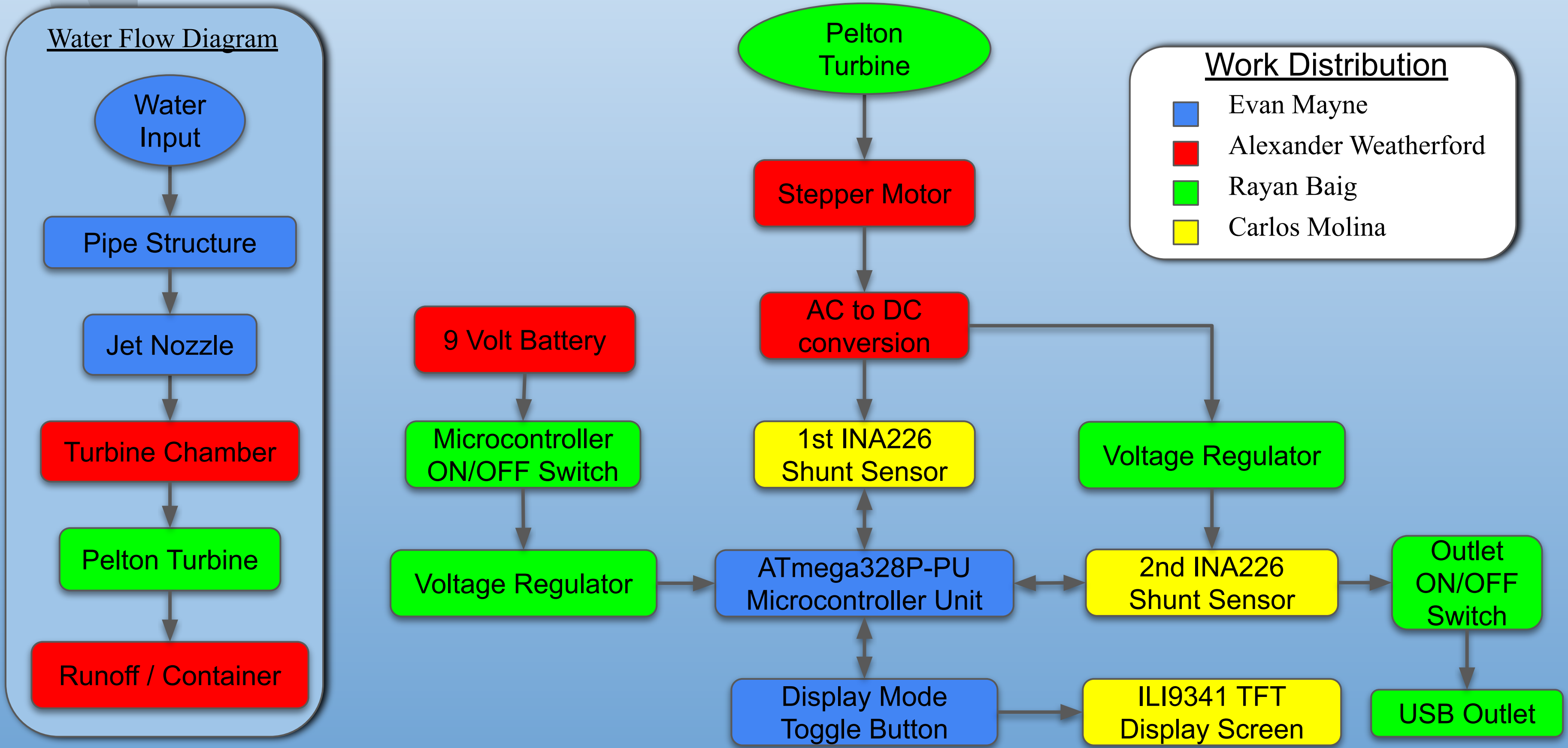
- ❑ Convert mechanical energy to electrical energy using a Pelton turbine and a Stepper motor.
- ❑ Use the energy generated to provide power to low-energy consuming devices, such as LEDs.
- ❑ Use wood material with a water-resistant sealant and plexiglass material for the turbine and electrical casings to prevent water damage and provide visibility.
- ❑ Sensors will be used to measure the signal generated and pass this data to the MCU, which will be displayed on the LCD screen.

Engineering Specifications

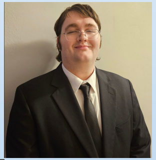
Specifications Table	
Engineering Requirement	**Specification**
Turbine Speed:	Min: **120 RPM** Max: **350 RPM**
Power Generated:	Min: **0.25 W** Max: **5 W**
Output Power:	Min: **0.1 W** Max: **4 W**
Regulation Efficiency:	**>=50%** power efficiency
Turbine Efficiency:	**>= 45%** turbine efficiency
Temperature:	Min: **5℃** Max: **35℃**
Water Capacity:	Min: **2 gallons per minute** Max: **6 gallons per minute**
Dimensions:	**1.5 m x 1.5 m x 2.75 m** (Length x Width x Height)

Hardware Diagram



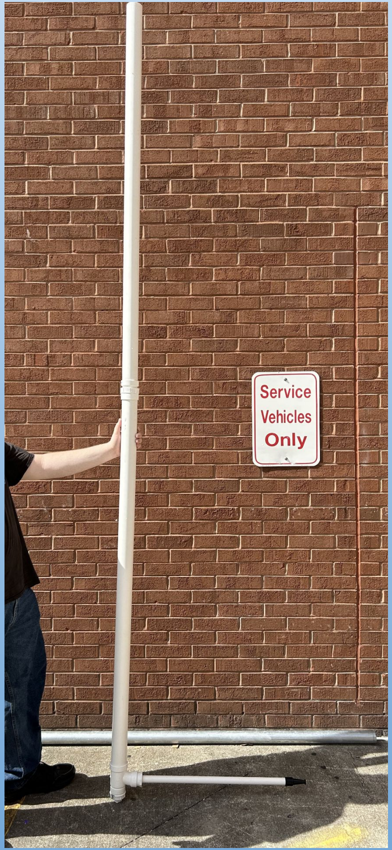


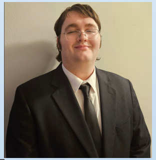
Piping Segments



White PVC piping and a hose are used to simulate the water that would flow through a gutter. This water is focused into the turbine.

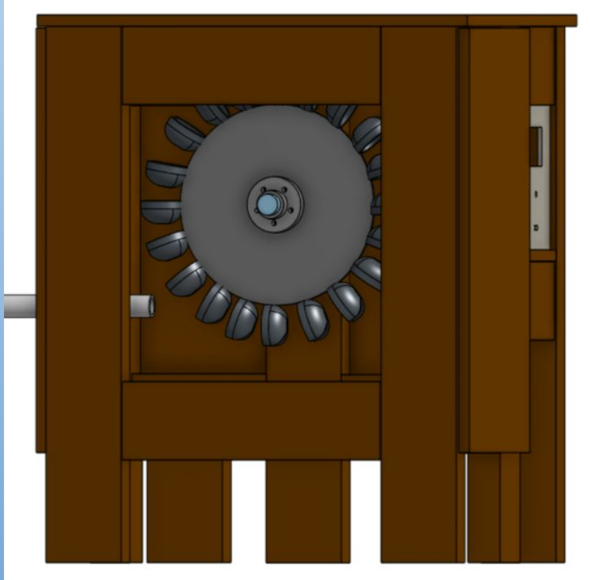
- 10 ft tall
- ¼ inch jet nozzle
- Can easily be assembled
- Cleanout trap at the bottom
- Support structure for pipe





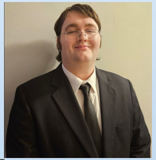
Casing Structure

The Turbine Chamber and Electronics Casing will keep the water interacting with the turbine separated from all of the electronic components. This casing will be made from pressure treated wood and will be coated using a sealant paint / clear coat.



3D model of Turbine Chamber (left) and Electronics Casing (right)

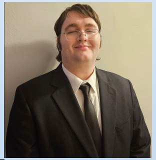
Hydro Turbine Selection



The Pelton Turbine type was chosen since it meets the water head level and expected flow rate for the scale of this project. Turgo Turbines were considered, but they are typically less efficient without higher flow rates. The primary deciding factors were cost, the runner diameter, and the number of paddles. A higher runner diameter and a higher paddle count leaves room for adjustment if the testing results using the stock paddles and runner diameter are not acceptable.

Criteria	Model 1 B0C4G29ZY9	Model 2 392349988306	Model 3 202303198415	Model 4 266448765936	Model 5 175953369509
Cost	$53.96	$63.48	$39.99	$80.04	$41.68
Runner Diameter	9.00 inches	6.05 inches	8.03 inches	7.8 inches	3.8 inches
Materials	Aluminum Runner, HDPE Paddles	Sheet Metal Runner, Plastic Paddles	Die Cast Aluminum Runner and Paddles	Plastic Runner and Paddles	Plastic Runner and Paddles
Maximum Number of Paddles	32 Paddles	20 Paddles	12 Paddles	15 Paddles	14 Paddles

MCU Selection



The MCU will be used for performing basic calculations and communicating with the shunt sensors and the LCD screen. Factors that were used during selection were the cost, operating voltage, and power consumption.The MCU and its peripherals will be powered by a battery, so the operating voltage, power consumption, and low power mode options were also considered. The Atmega328p on the Arduino Uno was selected due to group members already owning it and being familiar with it.

Criteria	Arduino Uno R3	Arduino Mega 2560 R3	Raspberry Pi Pico RP2040	MSP430FR6989
Cost	$26.33	$48.40	$4.00	$10.77
Operating Voltage	5 (V)	5 (V)	1.1 (V)	Min: 1.8 (V), Max: 3.6 (V)
Power Consumption Range	Min: at 6 (V), 20 (mA) Max: at 20 (V), 50 (mA)	Min: at 6 (V), 20 (mA) Max: at 20 (V), 50 (mA)	Min: 5 (mA), Avg: 24 (mA) Max: 90 (mA)	Active mode: (100µA/MHz) LPM3 with VLO: 0.4µA LPM3.5: 0.35µA LPM4.5: 0.02µA
RAM	32 KB Flash, 2 KB SRAM, 1 KB EEPROM	256 KB Flash, 8 KB SRAM, 4 KB EEPROM	16 MB Flash, 264 KB SRAM	128 KB FRAM 2 KB SRAM

Motor Type Selection

The motor will be used as a generator to convert mechanical energy to electrical energy when the turbine spins. The generated electrical energy will be used to power small scale devices.

Criteria	Brushed DC	BLDC	AC	Alternator	Stepper	Servo DC/AC
Cost	$5 - $30	$20 - $150	$5 - $15	+$80	$10 - $15	$5 - $15
Shaft Smoothness	Good	Fair	Poor	Good	Good	Fair/Good
Complication	none	Some	Some	Many	Few	Some
Efficiency	Fair	Good	Good	Great	Good	Good

Motor Selection and Comparisons

The Nema17 - 17ME15 was chosen because it may generate the most power by its high step count and high maximum voltage.

Criteria	Nema 17 - 17HS19-2004S1	Nema23 - 23HS30-2804	Nema 23 - 57HS56	Nema 17 - 17ME15-1504S
Cost	$13.99	$28.00	$22.00	$16.99
Steps	200	200	200	400
Rated Current	2 Amps	2.8 Amps	3 Amps	1.5 Amps
Max Voltage	55 Volts	74 Volts	54 Volts	73 Volts
Dimensions	1.65 x 1.65 x 1.80 inches	5.25 x 3.25 x 3.25 inches	2.2 x 2.24 x 2.24 inches	1.65 x 1.65 x 1.49 inches

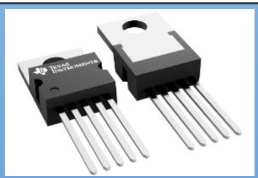
Voltage Regulator Type

Two voltage regulators will be used for the project. One for stepping down the voltage of the battery to the microcontroller, and the other to step down the voltage from the motor output.

	Switching Regulator	**Linear Regulator**
Advantages	• Step Up, Step Down, or combination of the two. • Efficient • More resilient to heat.	• Simple Configuration • Less Expensive
Disadvantages	• Higher Cost • Complex Design	• Only able to Step Down. • Lower Efficiency • Less Heat Resistant

Voltage Regulator comparison

Criteria	LV2862	LM2576	LMR51606
Cost	$0.93	$2.70	$0.79
Efficiency	87.6%	83.4%	88.1%
Vin	4V - 60V	4V - 40V	4V - 65V
Vout	Adj (0.765 - 58V)	Adj (3.3V - 37V)	Adj (0.8V - 28V)
Iout max	0.6A	3A	0.6A
Size	2.9 mm x 2.8 mm	10.16 mm x 15.24 mm	2.9 mm x 2.8 mm



The LM2576 was chosen because it was efficient, testable, and the range of voltage output and inputs allowed for stepping down both the voltage of the battery and the voltage output of the motor.

Battery Type Selection

9V Batteries	AA Batteries	Lithium Coin Batteries
• 9 Volts • Capacity 1200 mAH	• 1.5 Volts • Capacity 1700 mAH - 2500 mAH	• 3 Volts • Capacity 30 mAH - 620 mAH

Alkaline	Lithium	Carbon Zinc	NiCd
• High Capacity • Long Shelf Life • Commonly Sold	• Highest Capacity • Long Shelf Life • Commonly Sold • Higher Cost	• Low Capacity • Low Cost	• Rechargable • Higher Cost • Requires Independent Charger

The 9V alkaline batteries were chosen because only one cell was needed to reach recommended levels of the microcontroller and the capacity was large enough for the purpose of turing on the LCD briefly.

Battery Comparison

Criteria	MN1604	6LF22XWA	6LR61
Cost	$3.75	$2.34	$1.62
Capacity	~600mAH	~600mAH	~600mAH
Duration	~10-60 hrs	~24 hrs	~ 25 hrs

The alkaline 9 volt batteries that were compared had similar specifications. The MN1604 was chosen because they were available in store, avoiding any shipping fees.

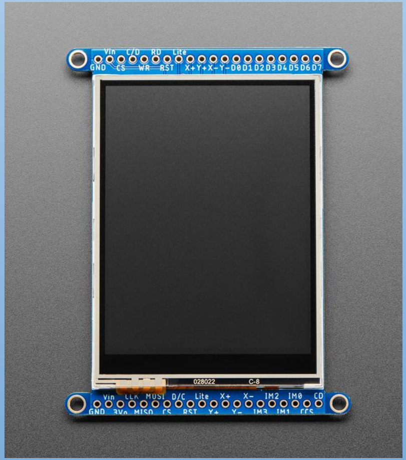
LCD Type Selection

- OLED Displays were a great alternative that also met our display requirements. However, TFT display were better suited for our specific application while providing great resolution.
- Several models of the other display types did not meet all of our display criteria, while most TFT screens met these requirements and also came with additional fixtures.

Criteria	TN Displays	IPS Displays	VA Panels	TFT Displays	OLED Displays
Image Quality	Poor	Great	Best	Great	Great
Viewing Angles	Poor	Best	Great	Good	Great
Response Times	Best	Fair	Poor	Good	Good
Power Consumption Range	Low	High	Medium	Medium	High
Cost Range	Low	High	Low to Medium	Low to Medium	Medium to High

LCD Selection and Comparisons

- The ILI9341 TFT Display met all of our requirements for display performance. This display comes with pre-existing libraries from the Adafruit Github which makes the programming of the display simple and easier to modify to meet our specifications.



Criteria	Teyleten OLED Display	Walfront OLED Display	Hitletgo TFT Display - Touch Panel	Adafruit TFT Display ILI9341	Adafruit TFT Display HXD8357D
Dimensions	L:2.244 in W: 1.161 in 2.42 in of Diagonal Display	L: 1.158in W: 0.579 in 1.3 in of Diagonal Display	L: 2.248 in W: 1.710 in 2.8 in of Diagonal Display	L: 2.268 in W: 1.701 in 2.8 in of Diagonal Display	L:2.891 in W: 1.928 in 3.5 in of Diagonal Display
Resolution	128 x 64 Pixels	128 x 64 Pixels	320 x 240 Pixels	320 x 240 Pixels	480 x 320 Pixels
Interface Compatibility	SPI or I2C	SPI or I2C	8-bit SPI	SPI or 8-bit Parallel	SPI or 8-bit Parallel
Cost	$14.99	$8.42	$15.99	$29.95	$39.99

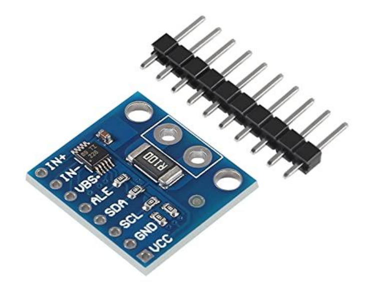
Voltage and Current Sensor Type Selection

- Most sensors using these 3 main measurement methods could have worked for our application, however, the shunt-based ones were less complex to implement while providing high accuracy and consistency.

Method	Hall Effect (Non-Invasive)	Shunt-Based (Invasive)	Induction (Non-Invasive)
Advantages	- Consistent measurements with high accuracy - Non-Contact measurement	- Consistent measurements with high accuracy - Temperature Stability and cost effective	- Non-Contact measurement with long life spans for these type of sensors - Fast response time in reading values that change at high speeds
Disadvantages	- Requires a relatively strong magnetic field to measure accurately - Can be affected by external magnetic fields	- Requires low-resistance resistors for accurate readings - Can disrupt the signal if not connected properly	- Requires an external component to get accurate measurements - Sensitive to environmental factors like changes in temperature or humidity

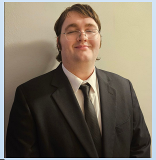
Voltage and Current Sensor Selection and Comparisons

- The INA226 Sensor can measure voltage from 0 to 36V and current from 0.5 mA to 50 A



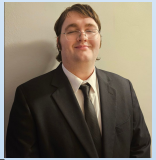
Criteria	Voltage Measuring Component	Current Measuring Components			Voltage & Current Measuring Components	
	25V DC Voltage Sensor + LM4040 Module	ACS712 Module - 5A	ADS 1115 Module	SCT0113 Current Sensor	Adafruit INA219 Sensor	DWEII INA226 Sensor
Accuracy Difference compared to Multimeter Reading	Less than 30 mV 10-bit Resolution	Less than 30 mA 10-bit Resolution	Less than 20 mA 16-bit Resolution	Less than 40 mA 10-bit Resolution	Less than 60 mA and less than 50 mV 12-bit Resolution	Less than 20 mA and less than 20 mV 16-bit Resolution
Input Signal	5V or 3.3V	5V	5V	5V	5V	5V
Required Pins	5 pins	3 pins	4 pins	2 pins	4 pins	4 pins
Interface Compatibility	5 Pin Interface	3 Pin Interface	I2C	2 Pin Interface	I2C	I2C
Cost	$19.94	$9.99	$14.99	$13	$9.95	$6.66

Hardware Design Details

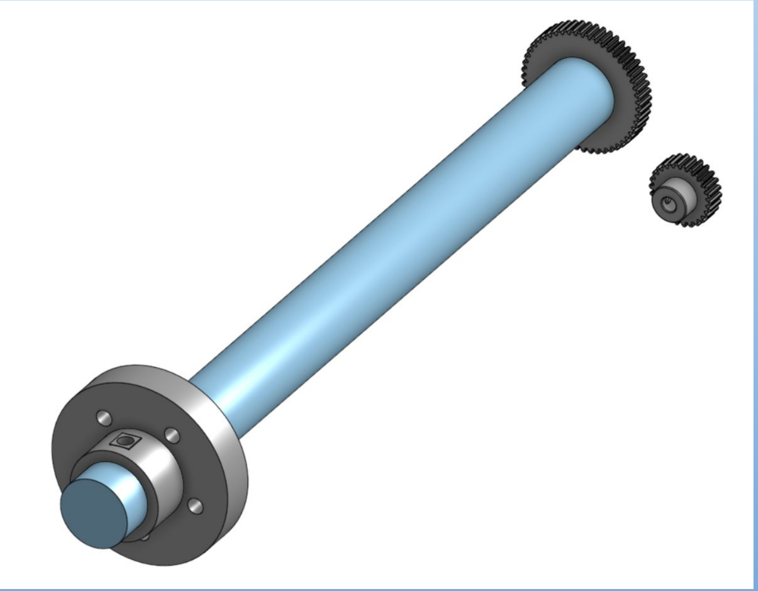


- I2C addressing on the INA226 sensors was handled connecting the address pins (A0 and A1) on each sensor to Vcc or GND to reflect the desired address.
- The 4-wire SPI option was chosen over the 8-bit parallel option for the Adafruit TFT Display.
- The the Atmega328P-PU model has dual in-line packaging, so a socket will be used.
- An FTDI adapter with a FT232RL chipset was used to program the MCU while connected to the PCB using UART communication protocols.

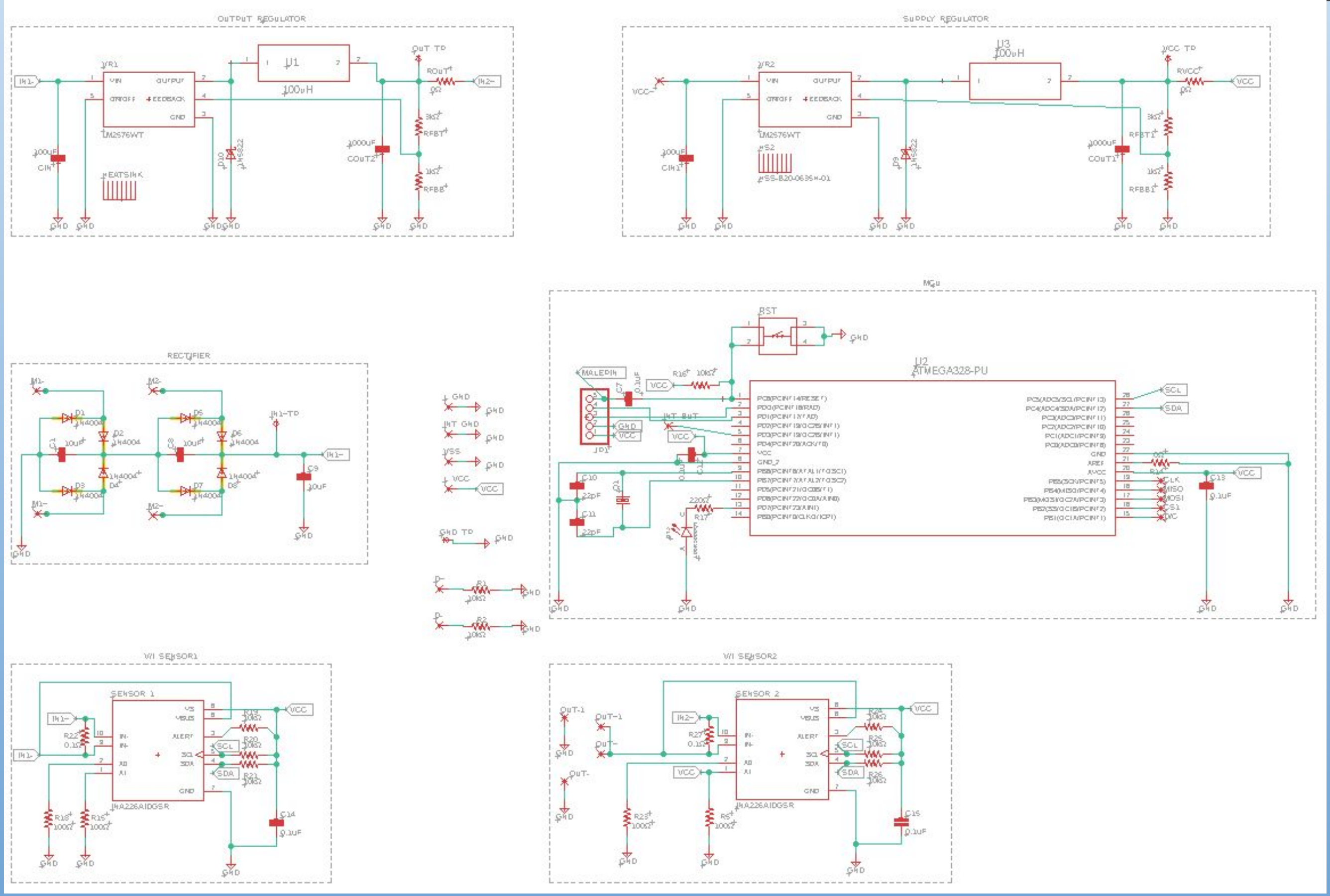
Major Mechanical Components

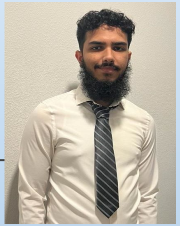


- ❑ Custom Turbine Shaft
- ❑ Gears (1:2 ratio)
- ❑ Flange Coupling
- ❑ 2 Wall Mounted Bearings

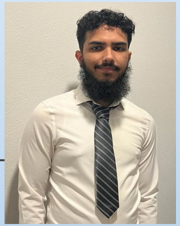


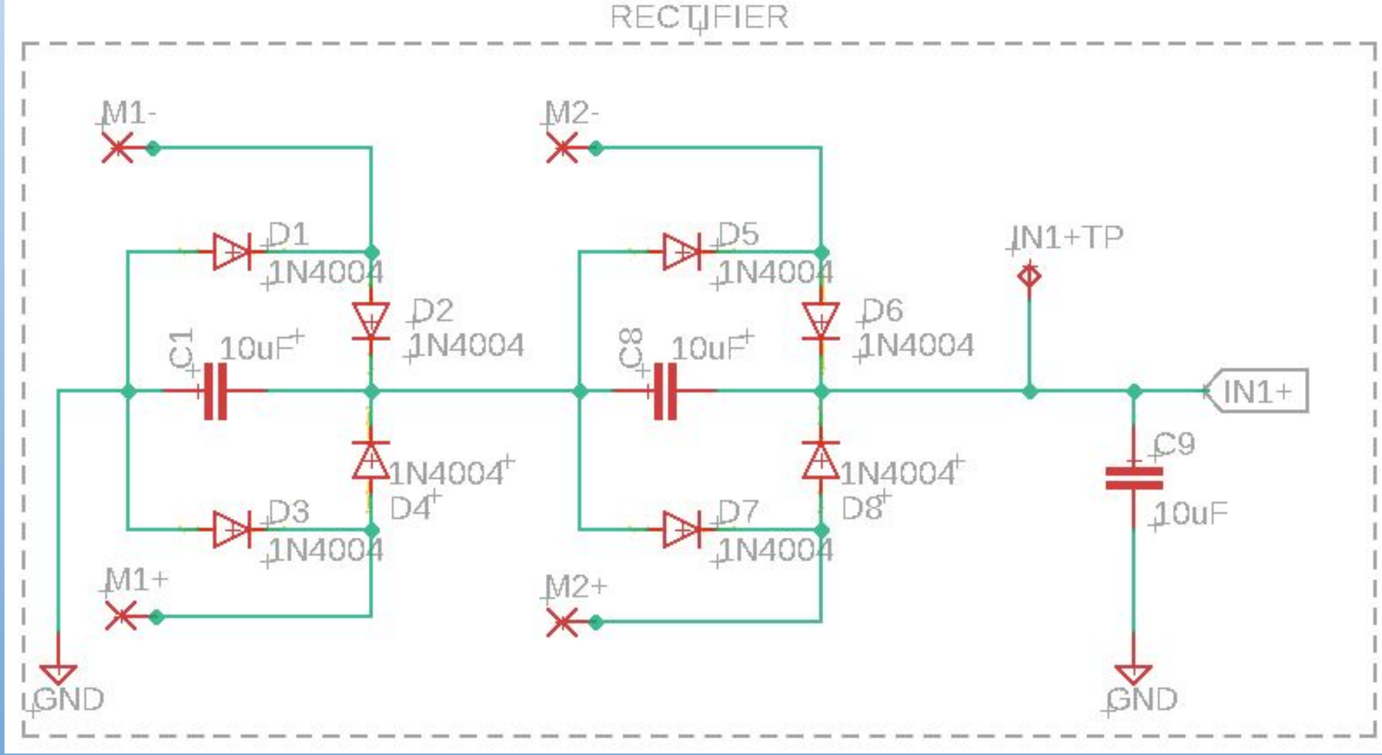
Overall PCB Schematic



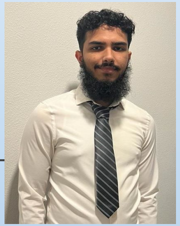


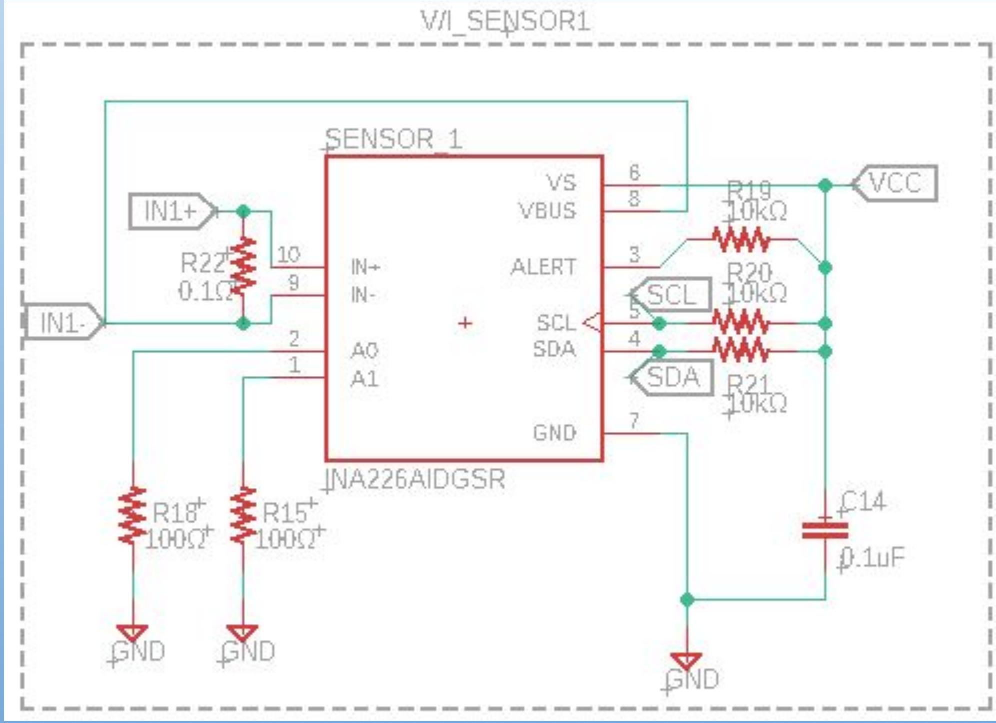
Full Bridge Rectifier PCB Schematic



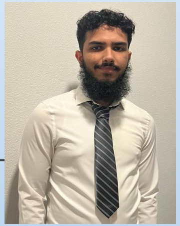


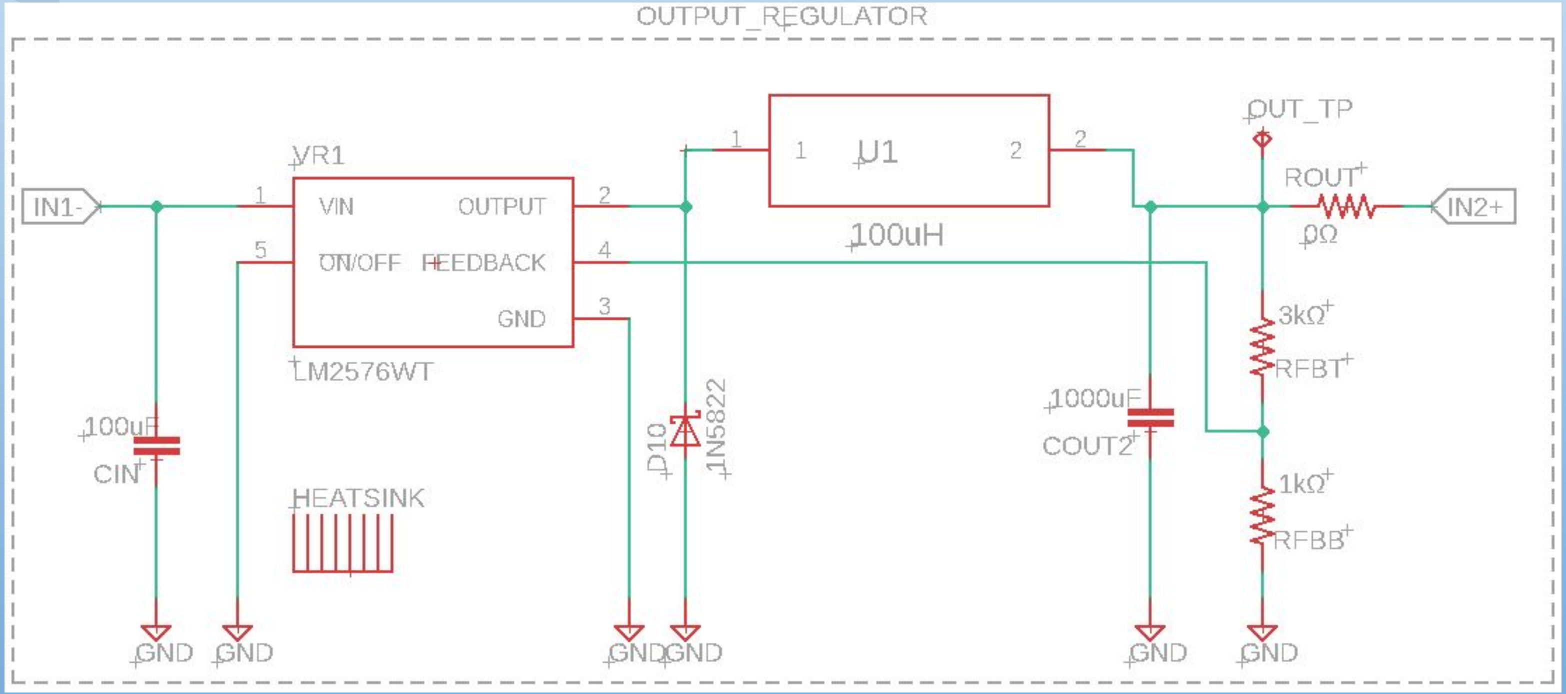
Voltage/Current Sensor 1 PCB Schematic



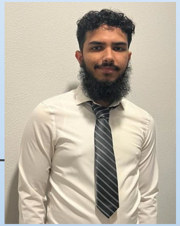


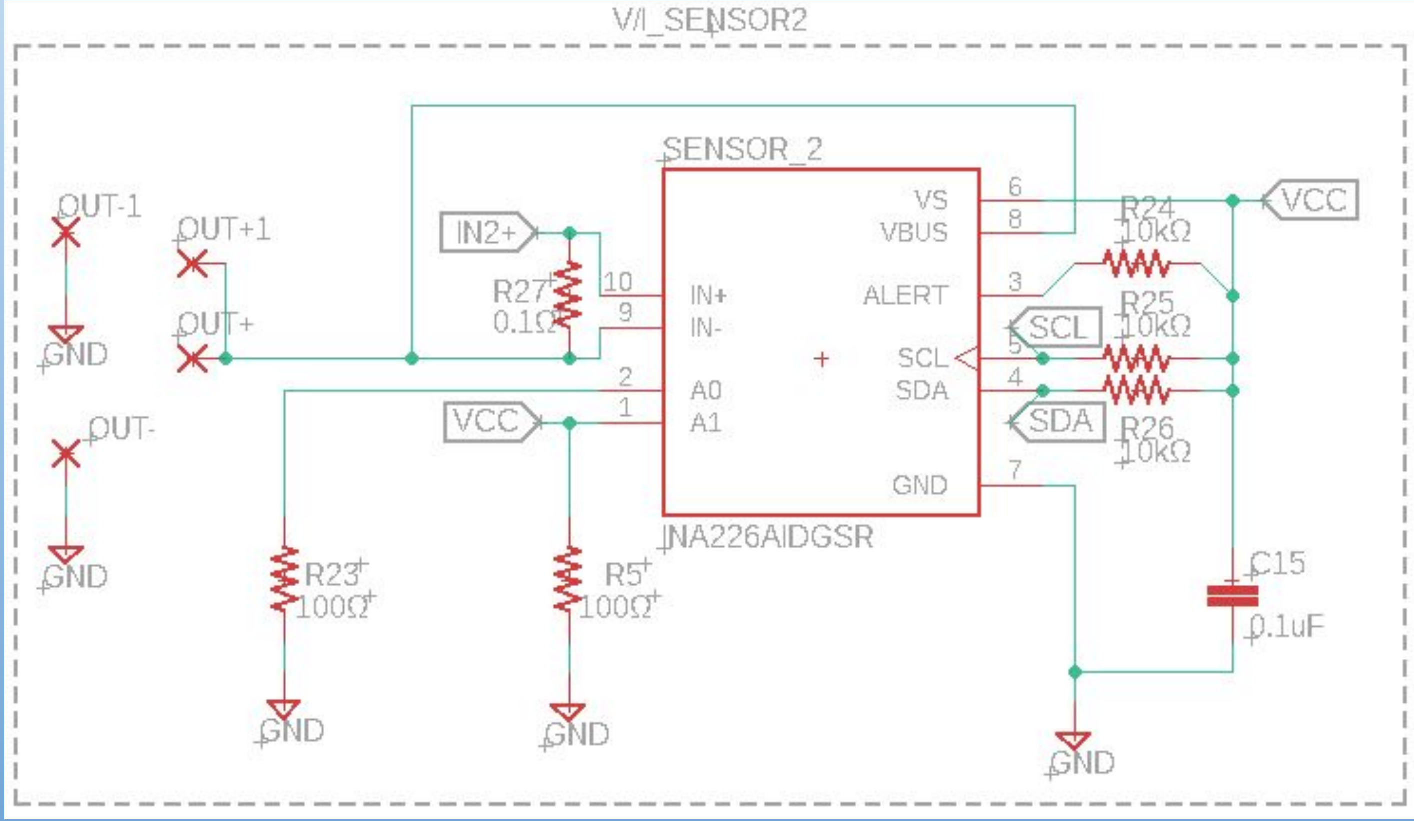
Output Voltage Regulator PCB Schematic



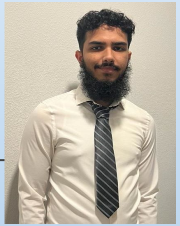


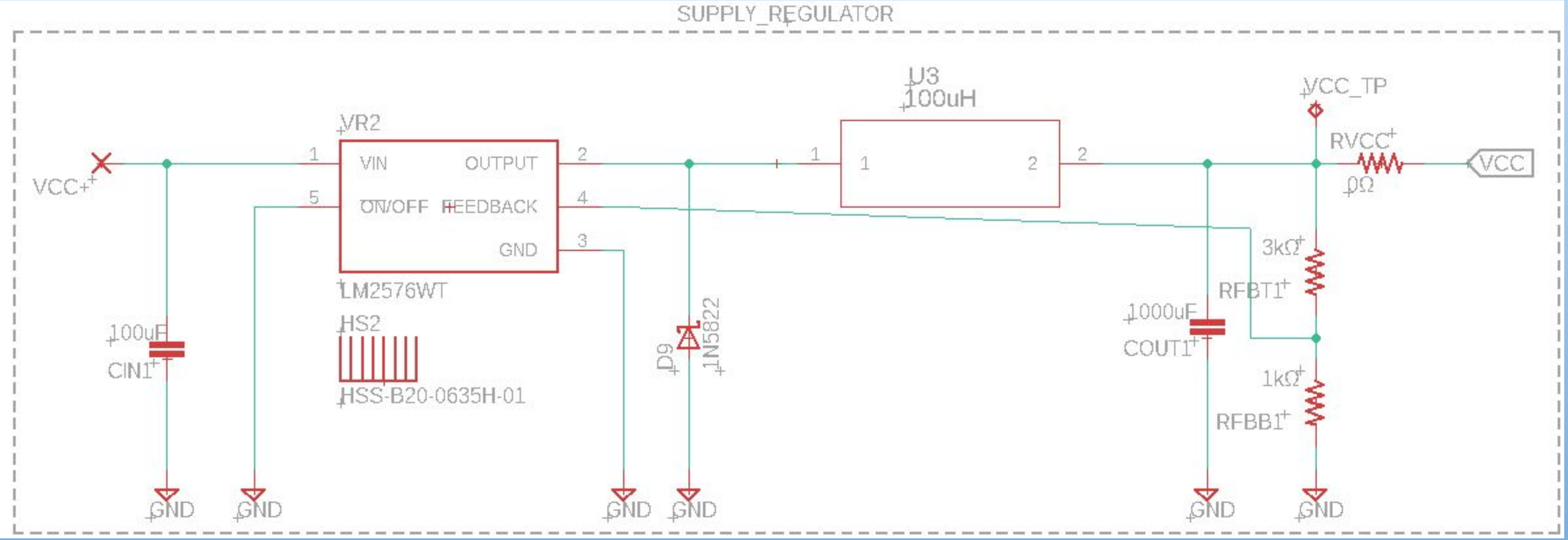
Voltage/Current Sensor 2 PCB Schematic



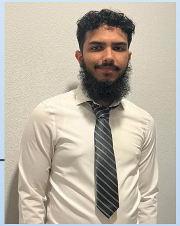


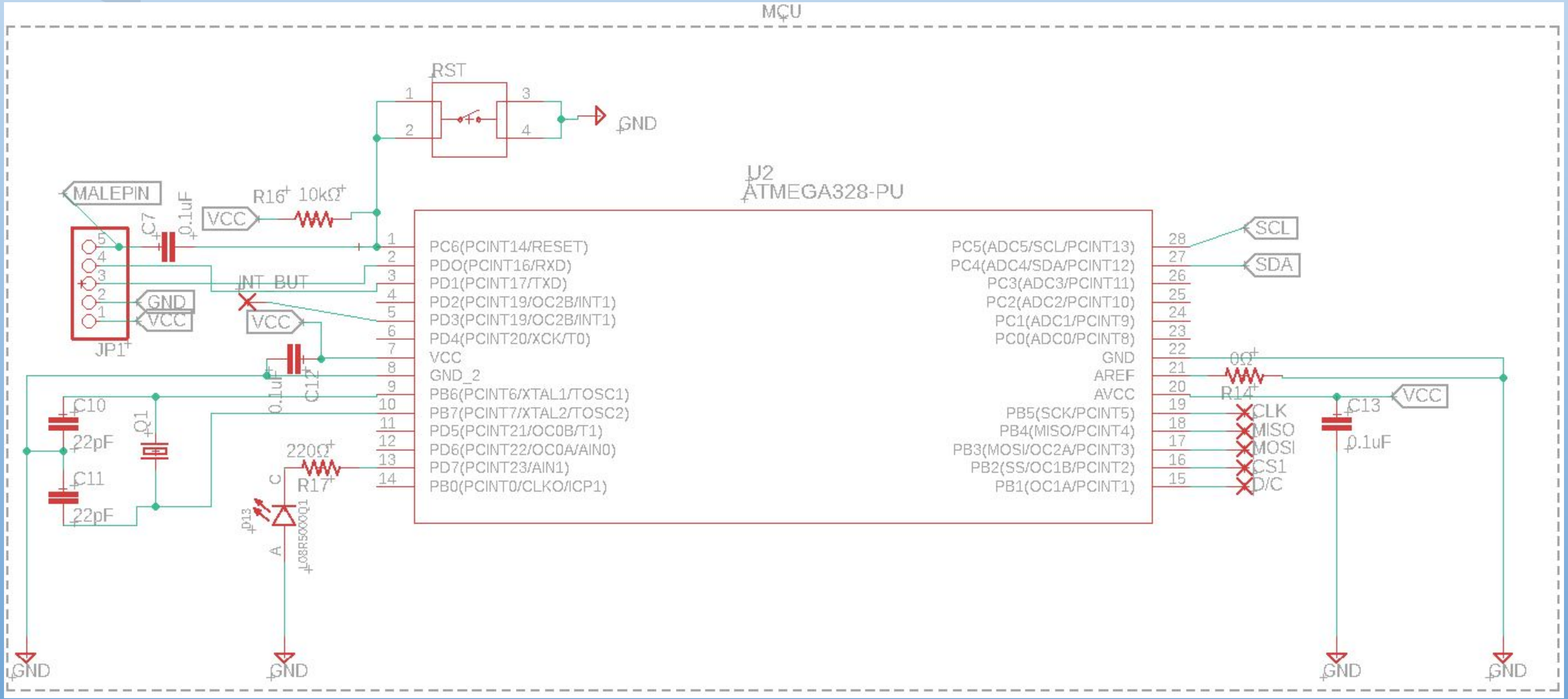
Supply Voltage PCB Schematic



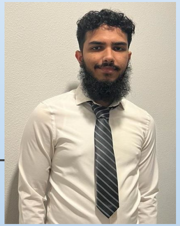


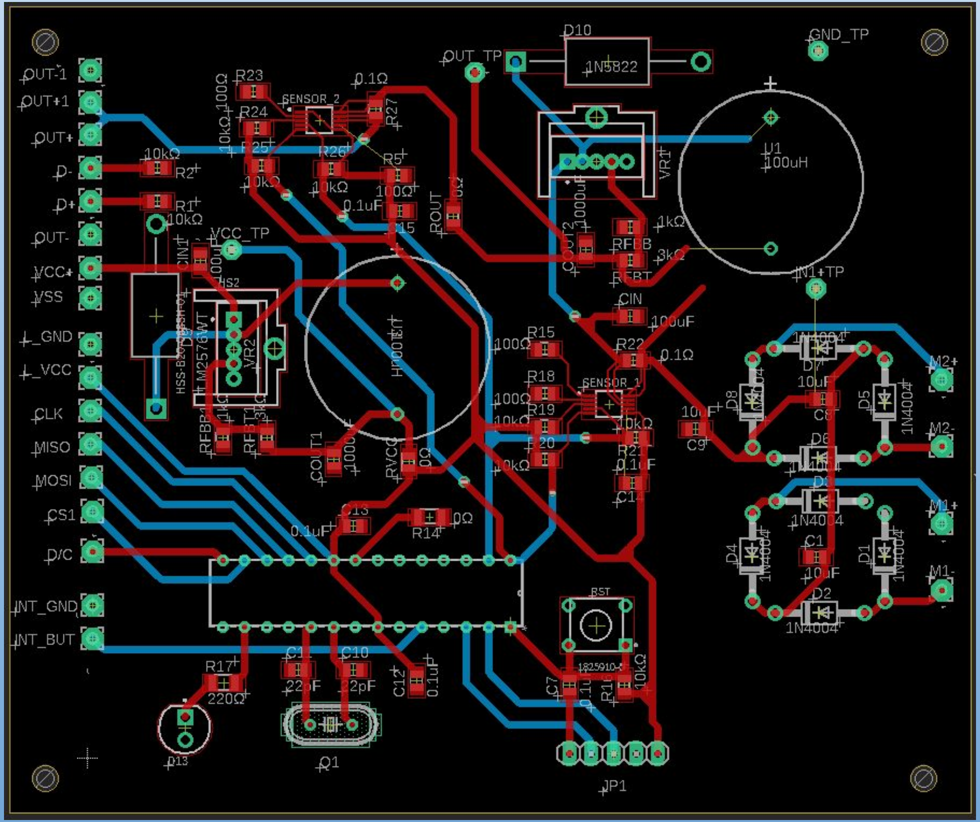
MCU PCB Schematic



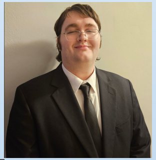


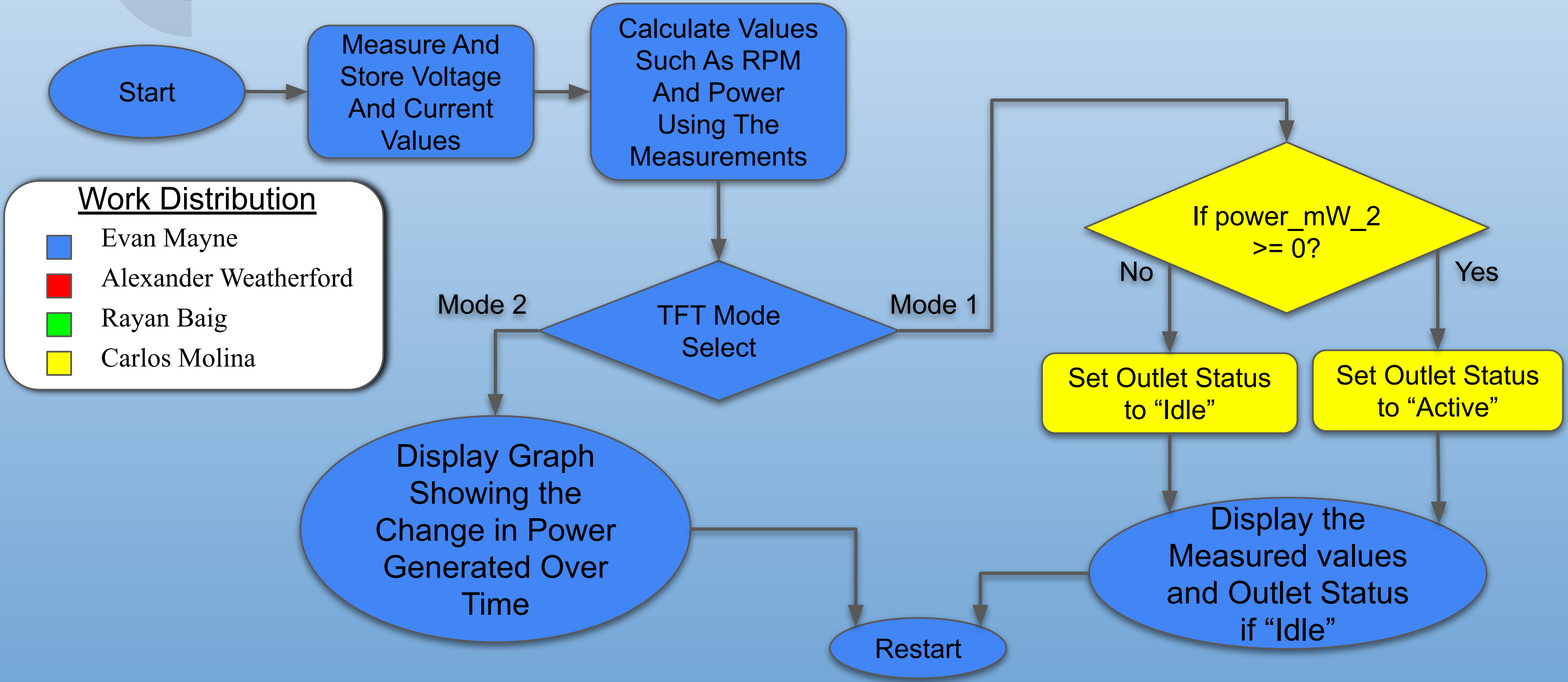
PCB Board Layout

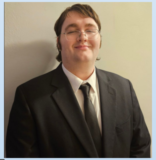




Software Diagram



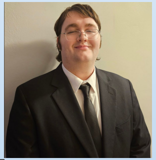




Software Design Details

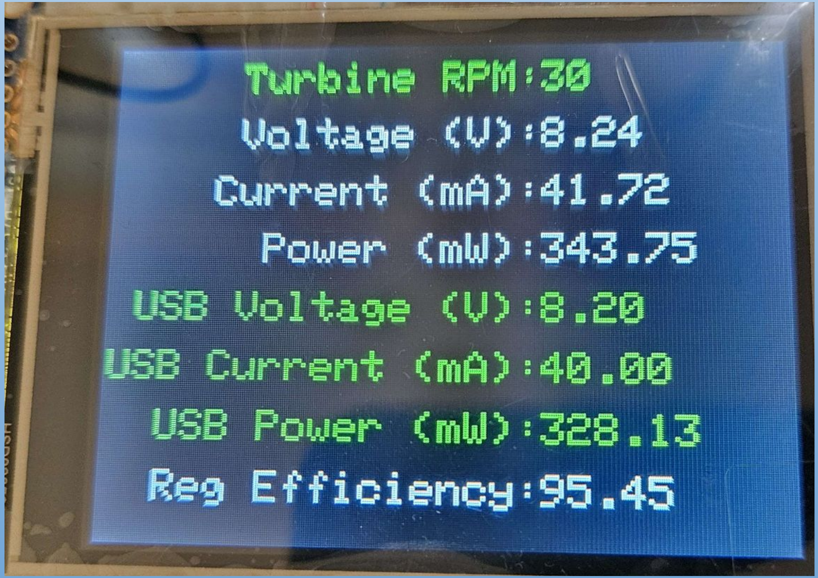
- ❑ Arduino IDE
- ❑ C++ language
- ❑ Github libraries
  - ❑ Tyeth (LCD libraries)
  - ❑ Rob Tillaart (Sensor libraries)
  - ❑ Kris Kasprzak (Graphing libraries)
- ❑ Button based interrupt
- ❑ Sleep Mode to reduce power consumption

User Interface

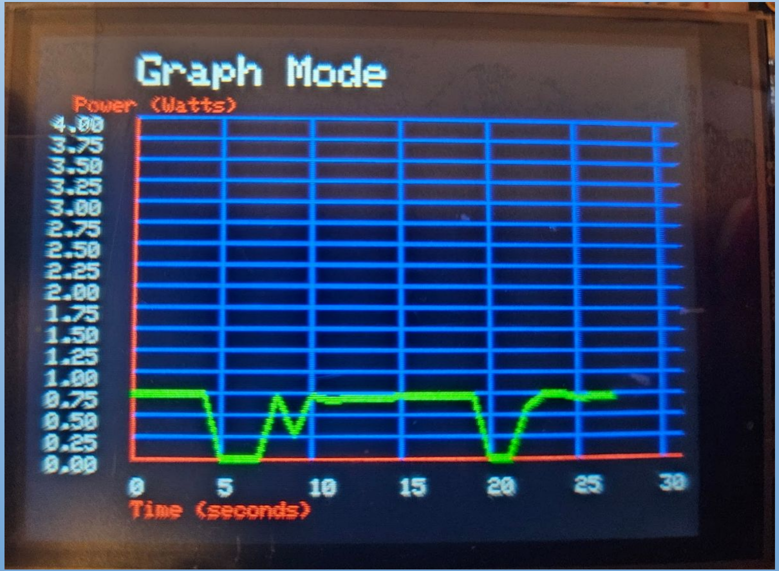


- ❑ LCD Toggle Button will be located to the right of the LCD.
- ❑ Switch for powering the monitoring components of the prototype.
- ❑ USB 2.0 outlet and switch connected to the outlet
- ❑ Door to the Electronics casing.

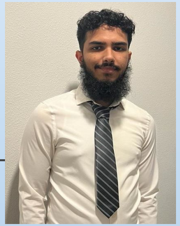
Text Display (Mode 1)



Graph Display (Mode 2)



Project Timeline



1/8
- PCB Design
- Programming Peripherals
- Research Ways of Connecting Turbine to Motor

2/5
- Order PCB
- Continue research to connect Turbine and Motor

2/12
- Order Mechanical parts
- Begin Turbine/Electronics Casing Construction

2/19
- Test Ordered PCB
- Connect Turbine and Motor Using Ordered Parts

3/11
- Fix Issues in PCB and Reorder
- Troubleshoot Mechanical Parts

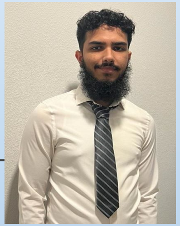
3/25
- Midterm Demo
- Continue Refining the Prototype

4/15
- Final Presentation Week

Work Distribution

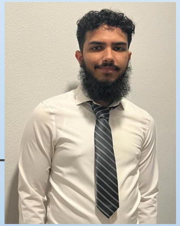
Team Members	Roles
Rayan Baig	PCB Design Voltage Regulator Design/Testing Turbine Assembly
Alexander Weatherford	Stepper Motor Testing Full Bridge Rectifier Design/Testing Voltage Regulator Testing
Evan Mayne	PVC Piping Design Voltage/Current Sensor Programming/Testing MCU Programming/Testing LCD Programming/Testing
Carlos Molina	LCD Display Testing Voltage/Current Sensor Testing I2C Programming/Testing Piping Support Structure Design

Bill of Materials



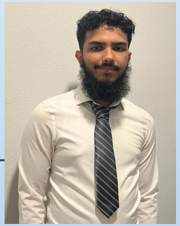
Part Description	Quantity	Total Cost
Pelton Turbine Model B0C4G29ZY9	1	$57.71
Mechanical Parts	1	~~$290~~ (Free)
ATMEGA328P-PU (Microchip of Arduino Uno Rev3)	1	$12.75
Nema 17 - 17ME15-1504S (Stepper Motor)	1	$18.18
Stepper Motor Mounting Bracket	1	$5.35
MN1604 (9V Battery)	1	$3.75
Adafruit TFT Display ILI9341	1	$35.03
DWEII INA226 Sensor (Voltage and Current Sensor)	2	$18.60 (9.30 ea.)
PVC Piping Segments and Jet Nozzle	N/A	$75.42
Plexiglass Casing (12-in x 36-in)	1	$23.62
Wood Casing (6-in x 1-ft x 1-in)	3	40.32 (13.44 ea.)
Wood Casing (1-ft x 1-ft x 1-in)	1	$26.88
LM2576 (Switching Regulator)	2	~~$1.80~~ (Free)
TO-220 Heatsink	2	$1.28 (0.64 ea.)

Bill of Materials Cont.



Part Description	Quantity	Total Cost
PCB + Stencil	1	$30.71
USB-A Breakout Board	1	$0.56
9V Battery Holder	1	$2.41
Push Button	1	$2.41
Switches	2	$8.55 (4.28 ea.)
Combined Total Cost		**$363.53**

Challenges We Faced



- Overall Casing Design
- Mechanical Design and Assembly
  - Gears, Shafts, Flanges, Couplings
- PCB Design/Testing
  - Multiple iterations needed for changing voltage regulators and shunt sensor design/calibration.
  - The final PCB design has inductors too close to the generated signal traces. This means that <1mA of current is unintentionally induced.
- Budget Concerns

THANK YOU FOR YOUR TIME!

Have a nice day!

Citations can be found in our official document.