Methanol Dynamics

Fuel Cell

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Fuel Cell Market

- 11 Billion dollar global market by by 2029
- Uses: electricity production, vehicles, energy storage
- Methanol in particular- less developed

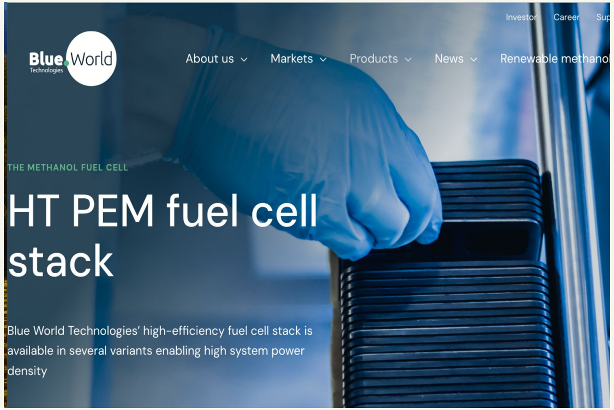
SWOT Analysis

Strength	Weakness	Opportunity	Threat
Energy Density	**Toxicity and Flamability**	**Ease of Operation**	**Competition from Hydrogen**
Methanol has a higher volumetric energy density than other fuel cell materials like hydrogen. When considering conversion efficiency it is competitive with gasoline.	Methanol is toxic and can cause vomiting, blindness, and liver damage if accidentally consumed. In addition it has a high vapor pressure and is flammable.	Methanol fuel cells can be fed with a dilute liquid feed. This makes fuel storage easy and operation relatively risk-free when compared with other fuels and materials.	Hydrogen fuel cell technology is much more well-known and has received more research and attention, leading to less focus on methanol.

Competitor Analysis

- DMFCs used today in 1. *portable power applications* and 2. *Defense*
- Popular for portable power applications due to their modularity and high power density
- Popular with defense due to low noise and minimal thermal signatures, i.e. applicable to covert military operations
- Portable power applications spotlight: **Blue World Technologies ApS** (Danish)
- Defense spotlight: **SFC Energy** (German)

HT PEM fuel cell stack (Blue World)
vapor feed
operates at -30°C to +50 °C
39 kg / 57 kg
9 kW/ 18 kW
43 V / 77 V output voltage
$4,500 / $ 9,000



EMILY3000 (SFC Energy)
liquid feed
10L fuel cartridge
operates at -25°C to +50 °C
12 kg
88 hours at 3000 Wh/day (full cartridge)
12-24 V output voltage
$20,000-$30,000 range

Marketing Strategy and Opportunity

- **Target Recreational & Off-Grid Consumers** – Target campers, RV users, and outdoor enthusiasts seeking reliable, clean portable power
- **Target Military & Defense** – Focus on tactical applications requiring low-noise, low-thermal signature power for covert operations
- **Geographic Focus – Developed Markets** – Prioritize North America, where competitors dominate the European market
- **Geographic Focus – Emerging Markets** – Expand into Southeast Asia and Latin America, where grid instability drives demand for off-grid solutions
- **Leverage Green Energy Incentives** – Capitalize on tax benefits and government/corporate subsidies, though opportunities in North America may be limited (Trump administration)
- **Strategic Partnerships in Renewable Energy** – Collaborate with battery and renewable energy companies to develop hybrid systems

Progress & Timeline

- GANTT chart main tool for timeline setup and task distribution
- Log updated consistently to track progress in accordance with the GANTT chart
- Please consult GitHub page to access GANTT chart and log

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Break

Project Start Date: 2/24/2025 (Monday) — Display Week: 1

Project Lead:

Week 1 — 24 Feb 2025 | Week 2 — 3 Mar 2025 | Week 3 — 10 Mar 2025

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
1	**Fuel cell stack setup and initial testing**			-			-
.1	Parts ordering	Max	Wed 2/26/25	Wed 2/26/25	1	100%	1
.1	Set up air/MeOH feed systems	Max	Fri 3/07/25	Fri 3/07/25	1	100%	1
.1	ensure proper sealing and leak test	Max	Fri 3/07/25	Fri 3/07/25	1	100%	1
.1							
.1	**Baseline voltage measurement**		Fri 3/07/25	Fri 3/07/25	1	100%	1
.1	Measure and log open-circuit voltage	Jack	Fri 3/07/25	Fri 3/07/25	1	100%	1
.1	Measure under load conditions	Jack	Fri 3/07/25	Fri 3/07/25	1	100%	1
.1	Verify proper operation and troubleshoot	Jack	Fri 3/07/25	Fri 3/07/25	1	100%	1
.1							
1	**Control System Design**			-			-
.1	**Fluid handling system**						
.1	Verify operation of peristaltic pumps	Karam	Fri 3/07/25	Fri 3/07/25	1	100%	1
.1	Calibration test to ensure accurate flow rate	Karam	Wed 2/14/18	Fri 2/16/18	3	100%	3
.1	Design tubing connections and safety valves	Karam	Sat 2/17/18	Thu 2/22/18	6	100%	4
	Sensor Integration and Data Collection						
	Write code for real-time voltage monitoring	Jack	Mon 3/03/25	Thu 3/06/25	4	100%	4
	implement flow rate control automation	Jack	Mon 3/03/25	Thu 3/06/25	4	100%	4
	Code data-logging for Voltage vs Flow rate	Jack	Mon 3/03/25	Thu 3/06/25	4	100%	4
	View results in python	Jack	Fri 3/07/25	Fri 3/07/25	1	100%	1
	Design Arduino circuit	Max	Mon 3/03/25	Wed 3/05/25	3	100%	3
	Solder and assemble Arduino circuit	Max	Wed 3/05/25	Fri 3/07/25	3	100%	3

Snapshot of the GANTT chart

A	B	C	D
Circuit	☐	Find and learn to use MOSFET	Jack
	☐	Solder new circuit	Jack
	☐	Solder battery attachments	Jack
	☐	Close box	All
Code	☐	Code the feedback loop	Max
	☐	Code user friendly interface	Max
Others	☐	Final Report	Karam
	☐	Slide deck	Karam
	☐	Website	All
	☐	Run cell with water	All

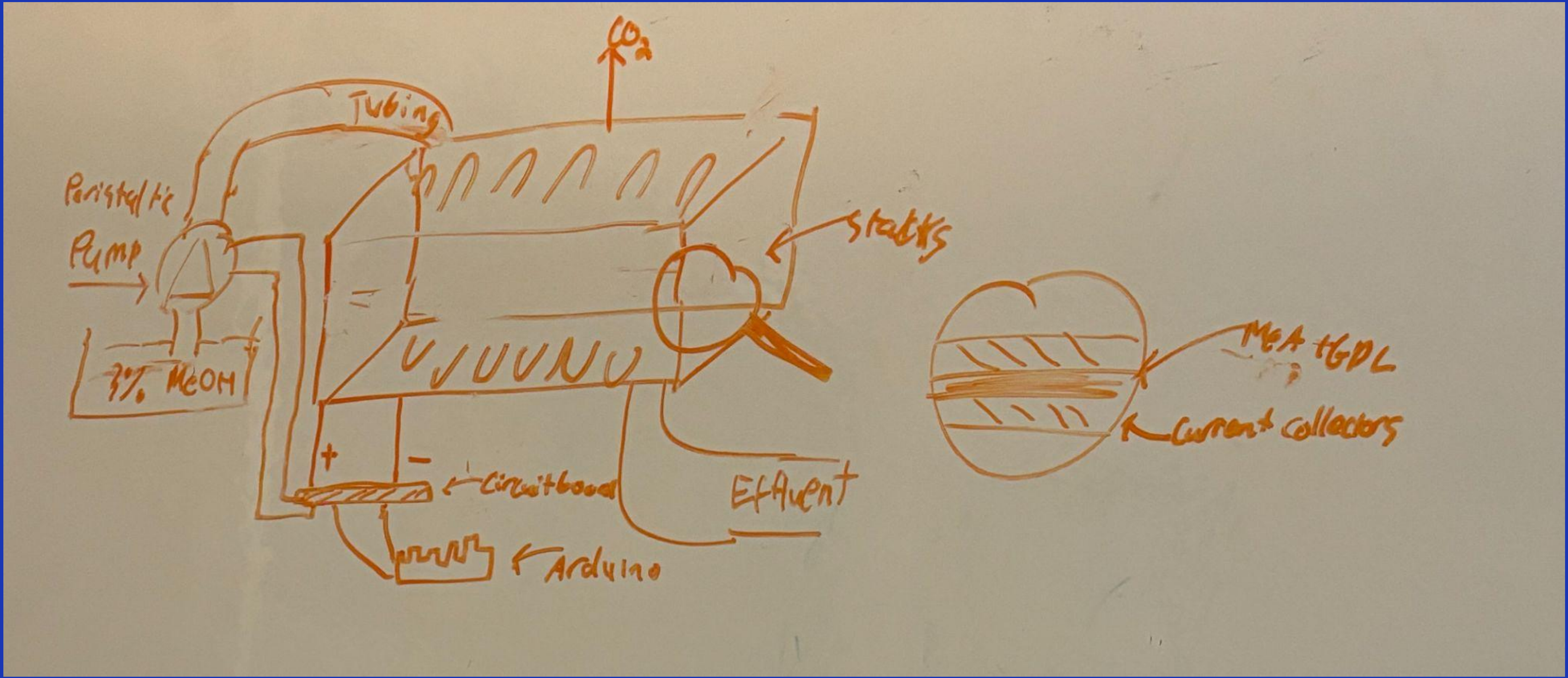
Final stretches to complete... (updated on GANTT chart)

Fuel Cell Design

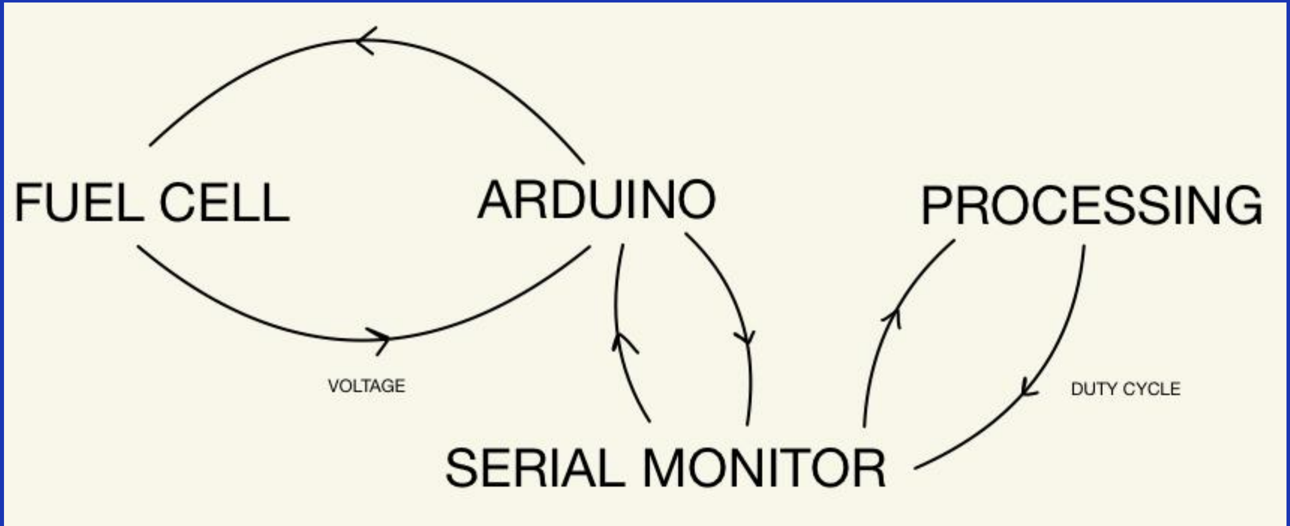
Circuitry
Feed
Pump and Casing

Confidential

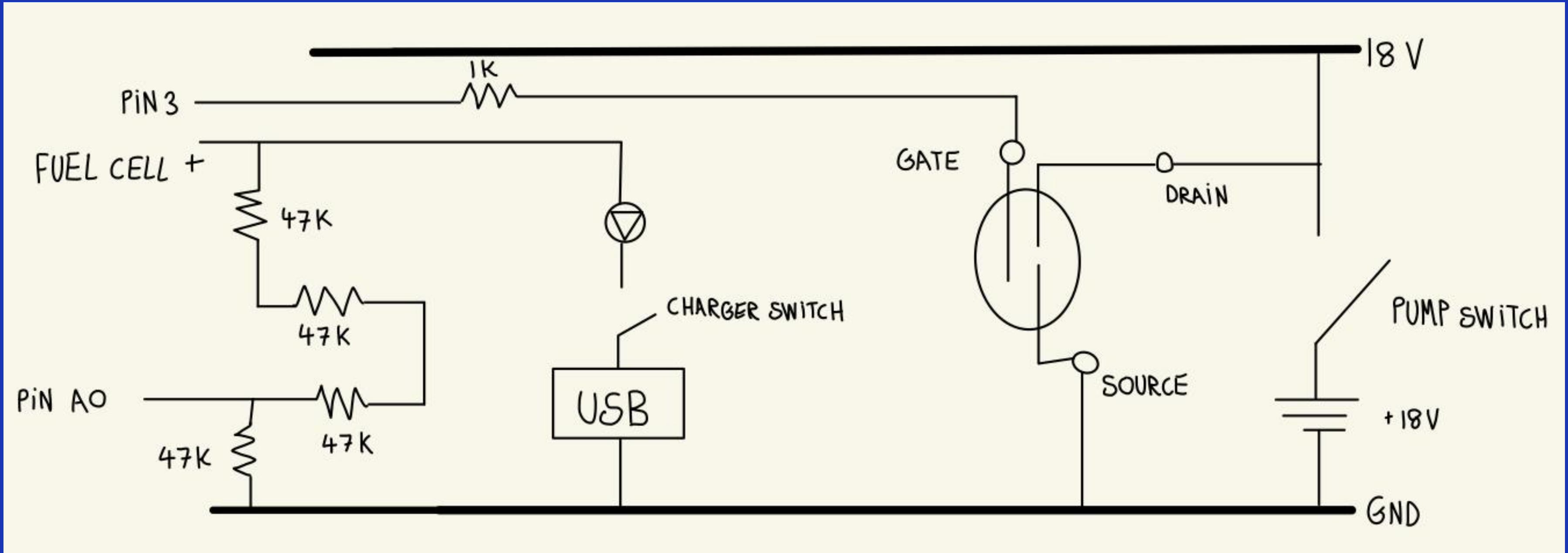
Initial Design Plan



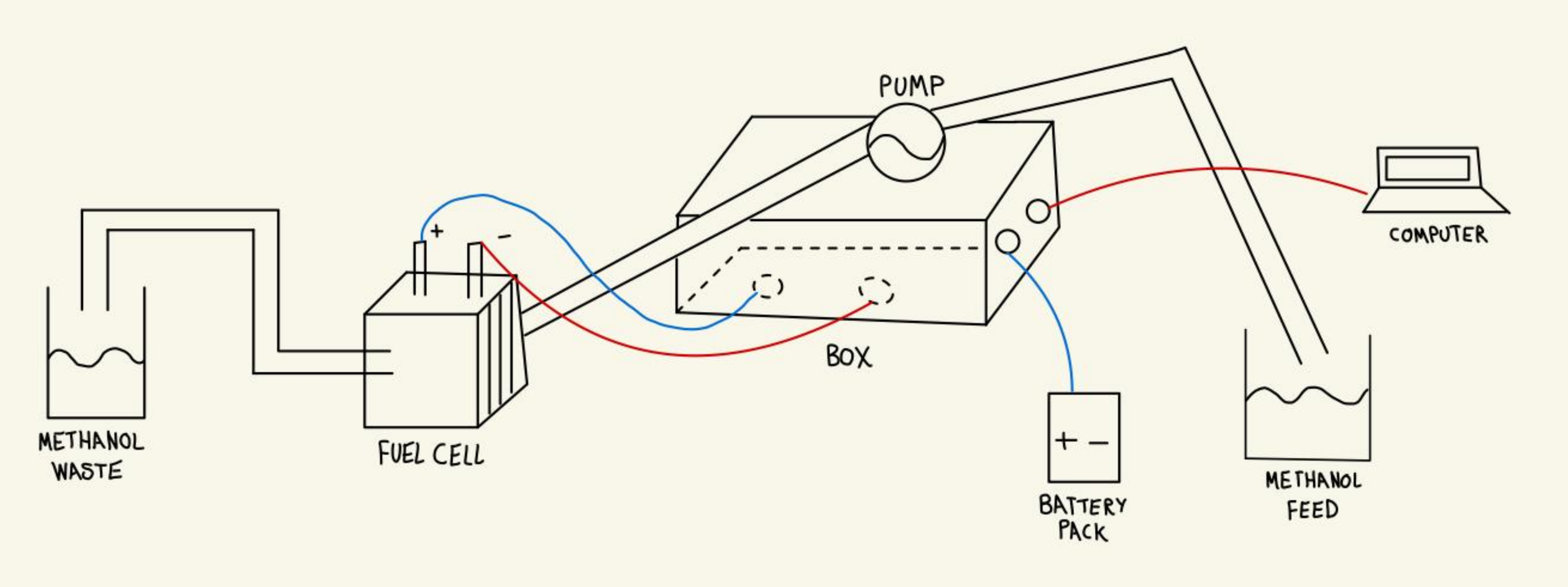
Final Design Plan: *Information Flow*



Final Design Plan: *Circuitry*



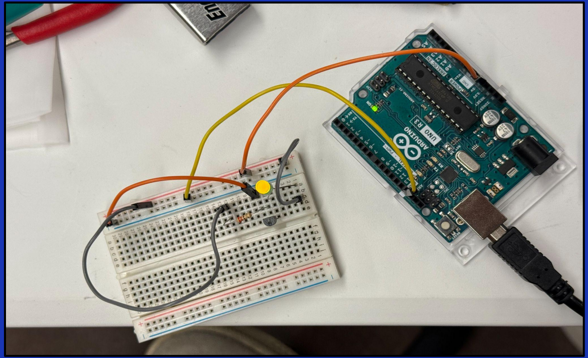
Final Design Plan: *Architecture*

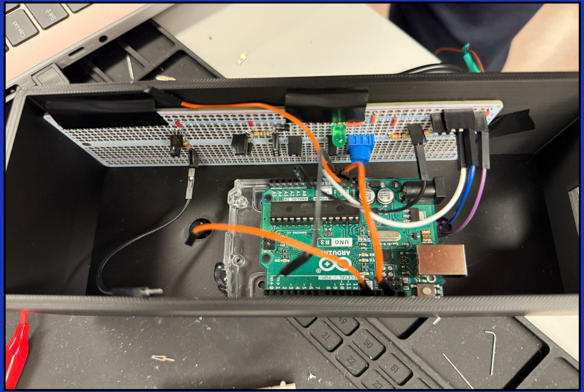


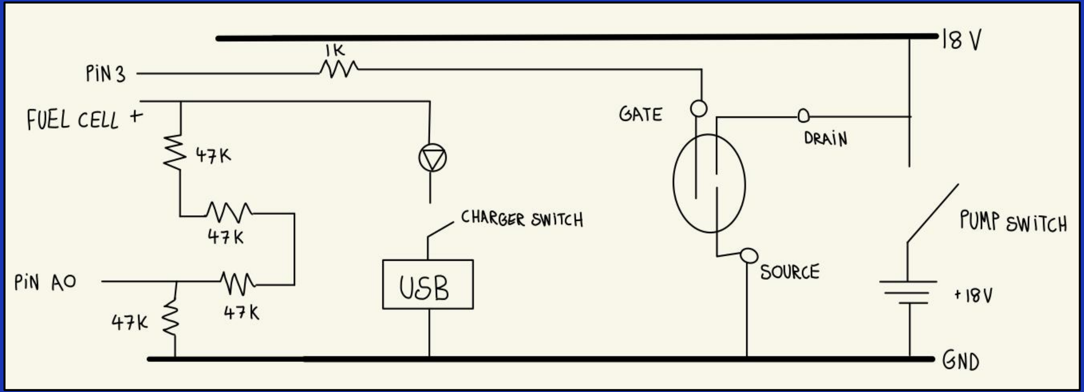
Circuitry: *Architecture*

- Goal: charge a 10,000 mAh power bank in < 24 hours

- The circuit consists of three main components:
  - A MOSFET transistor switch circuit controlling power to the pump,
  - A charger circuit with a manual USB switch for controlled charging,
  - A resistor voltage divider that safely steps down the fuel cell voltage for Arduino input







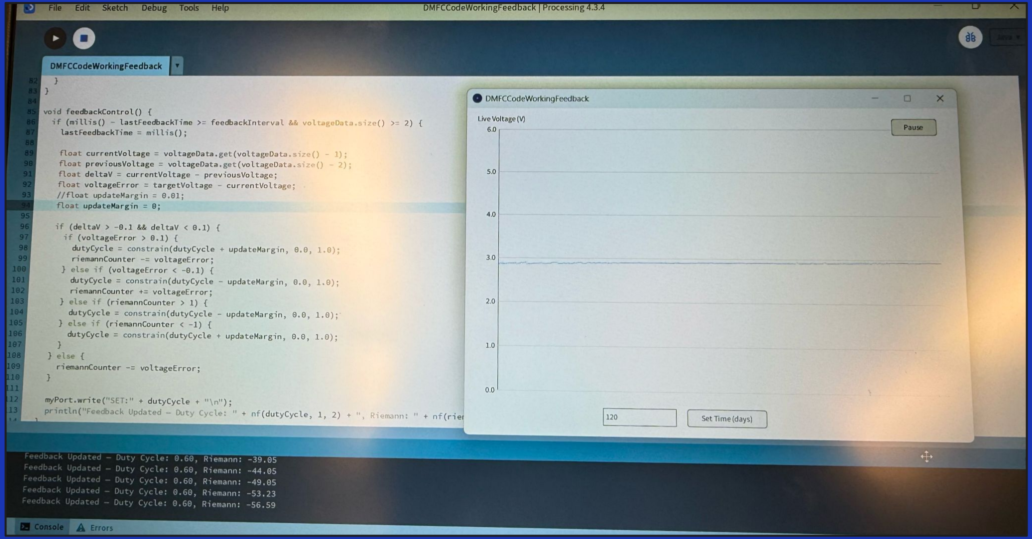
Code: *Calculation*

$$V_{pump} = \frac{5.4 + \frac{C^{*}R_{thev}}{t}}{K}$$

- K is the ratio of open cell voltage to pump voltage;
  - Unitless constant derived empirically from experimental data at various pump voltages,
  - Assumed to remain constant across runs
- C is the charger's capacity (in amp-hours), specified on the charging pack
- t is the desired charge time in hours (user input)
- R_{thev} is the Thevenin equivalent resistance of the fuel cell, determined from prior loading experiments
- The power pack charges at a constant voltage of 5.4 V. If the fuel cell's open-circuit voltage exceeds 5.4 V, the difference drives a current into the charging pack of I = ΔV / R
- Pump voltage, duty cycle, and flow rate are all directly proportional
- User inputs charge time; code delivers duty cycle

Code: *Live Plotting and Feedback*

- Live plot of cell voltage generated in processing
- If voltage is lower, ups duty cycle and vise versa
- Uses counter to keep a memory of falling behind charge time and acting accordingly

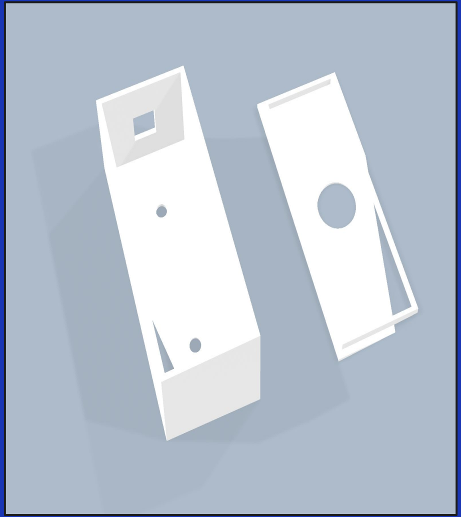


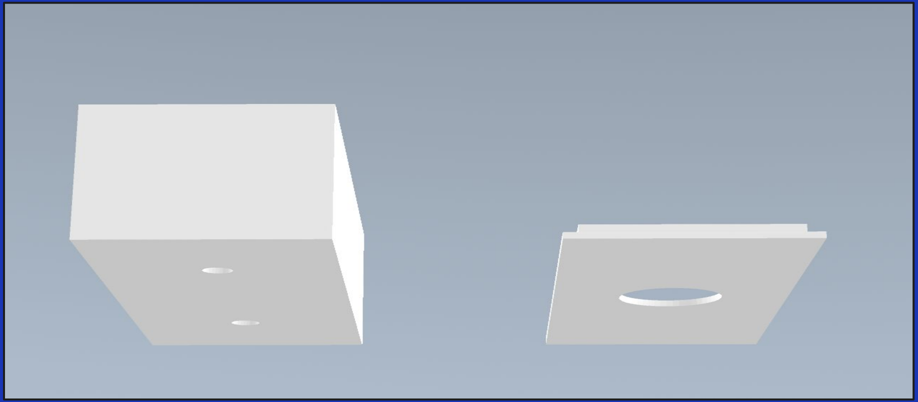
Feed

- 3% methanol (~1M) feed
- Room temperature
- Possible byproducts include CO, CO_2, hydroxymethyl-group compounds
- Airflow may limit performance; fan supplies air to fuel cell
- 4.32 L methanol required; 10 L stocked (3 mL/min * 1440 min/day = 4.32 L)
- Assume 24h feed

Pump and Casing

- 100-150 mA, voltage mediated peristaltic pump
- 3D-printed casing to house circuitry
- Larger hole in lid to accommodate for pump
- Two smaller holes on bottom of box to accommodate for leads to fuel cell (ground, voltage circuit, USB)
- Square hole on side of box to accommodate for USB connection to Arduino





ChemE Principles

- Applied mass and energy balances to design fuel and air feed systems
- Applied chemical process safety principles, particularly in handling methanol
- Gained hands-on skills in soldering and Arduino script programming
- Utilized electrochemical principles to predict fuel cell performance, including Nernst equation
- Chemical process control through feedback loop

Setbacks, growth, and next steps

- Unable to confirm if air was a limiting factor due to lack of control over airflow
- Lower-than-expected voltage efficiency (~33%), limiting effective power delivery
- Occasional transistor failures from voltage or thermal issues
- Low current delivery; implying low conversion of methanol

- Cleansing fuel cell led to improved operation but still not very efficient
- Replacing BJT with MOSFET led to more reliable circuit

- Running the fuel cell at elevated temperatures
- Experimenting with different methanol concentrations