ECE 445 Team 59

Automatic Titration Machine

Electrical & Computer Engineering

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Project Overview

Problem Statement and Proposed Solution

Titration is used in many areas of industry, research, and for home projects. Although the market is very limited on the types of titration devices, on one end we have manual titration, and the other is a several thousand-dollar automatic machine. The goal of our project is to bring a product to market to bridge this gap with something on the low end of the hundreds of dollars range and a device that has more accuracy, precision, and is quicker than manual titration techniques.

Definitions/Terminology

- Titration: A technique where a solution of known concentration is used to determine the concentration of an unknown solution
- Analyte (Titrand): Known volume, unknown molarity
- Reagent (Titrant): Known molarity, variable volume
- Color Indicators
  - Endpoint vs equivalency point

High-Level Requirements

- 1st Requirement (Precision): Repeat titration with only +/-0.5% deviation between measured titration equivalence points
- 2nd Requirement (Speed): Perform a titration as fast or faster than five minutes
- 3rd Requirement (Accuracy): Measure pH with the pH probe within +/-0.056 (+/-0.02 V of the correlated voltage; 0 V +/-0.02 V for 0 pH, and 5 V +/-0.02 V for 14 pH)

Original Design

Visual Aids

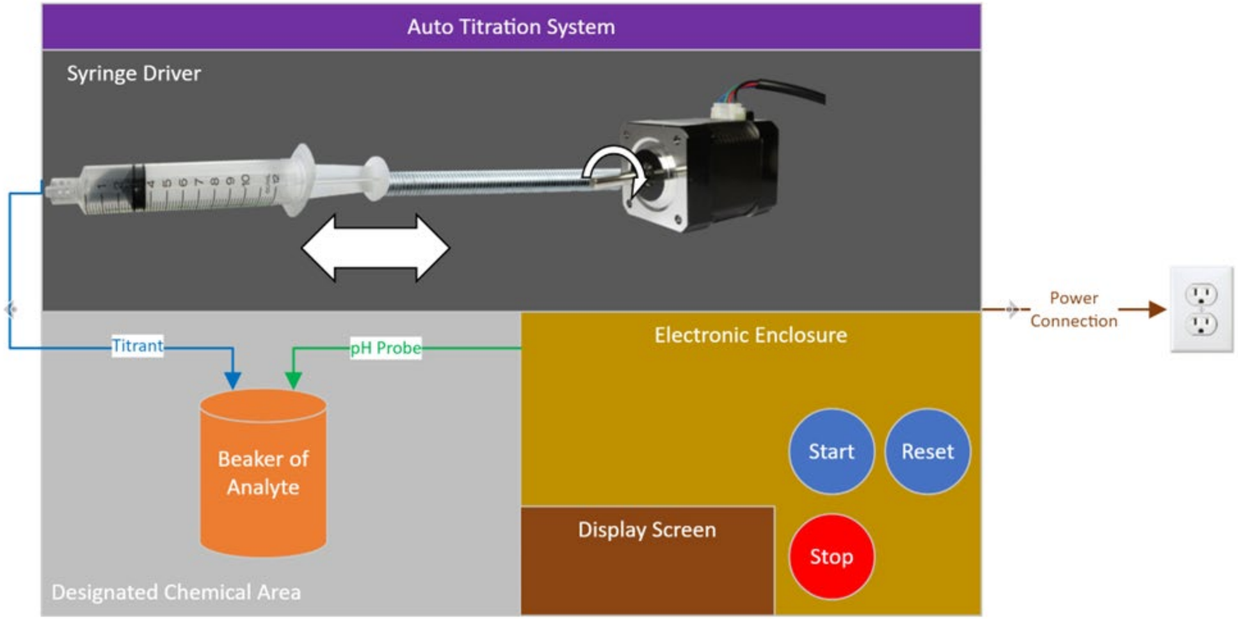


Figure 1: High Level Visual Overview of Titration System, highlighting chemical locations and User I/O

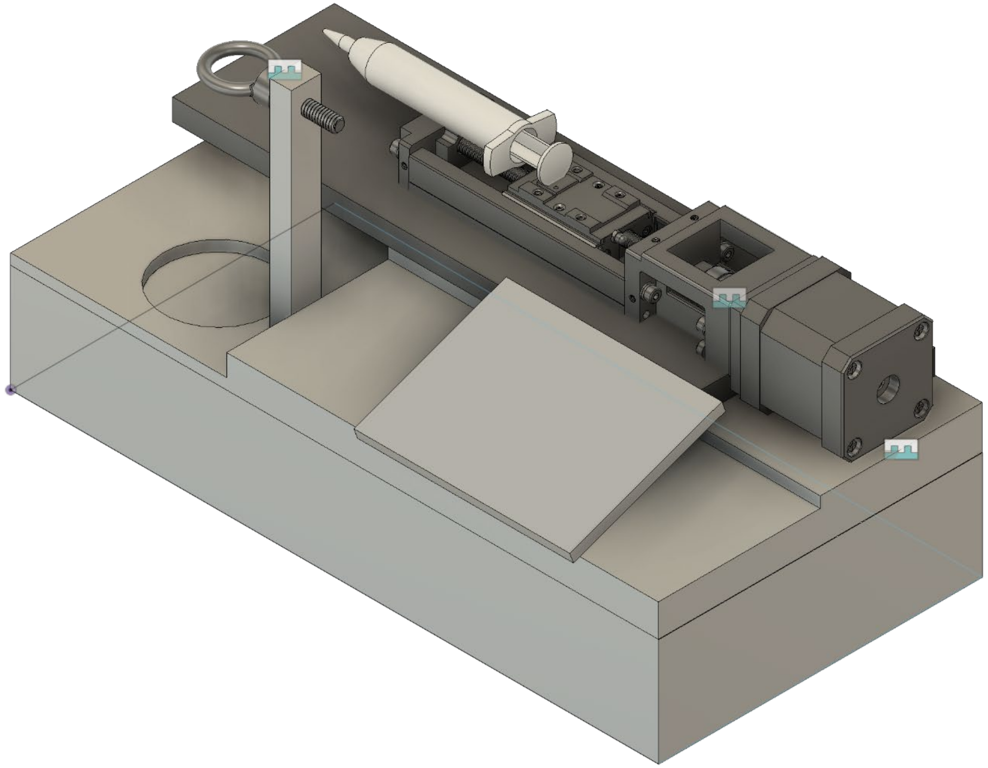


Figure 2: 3D/CAD Initial Design Concept

Block Diagram

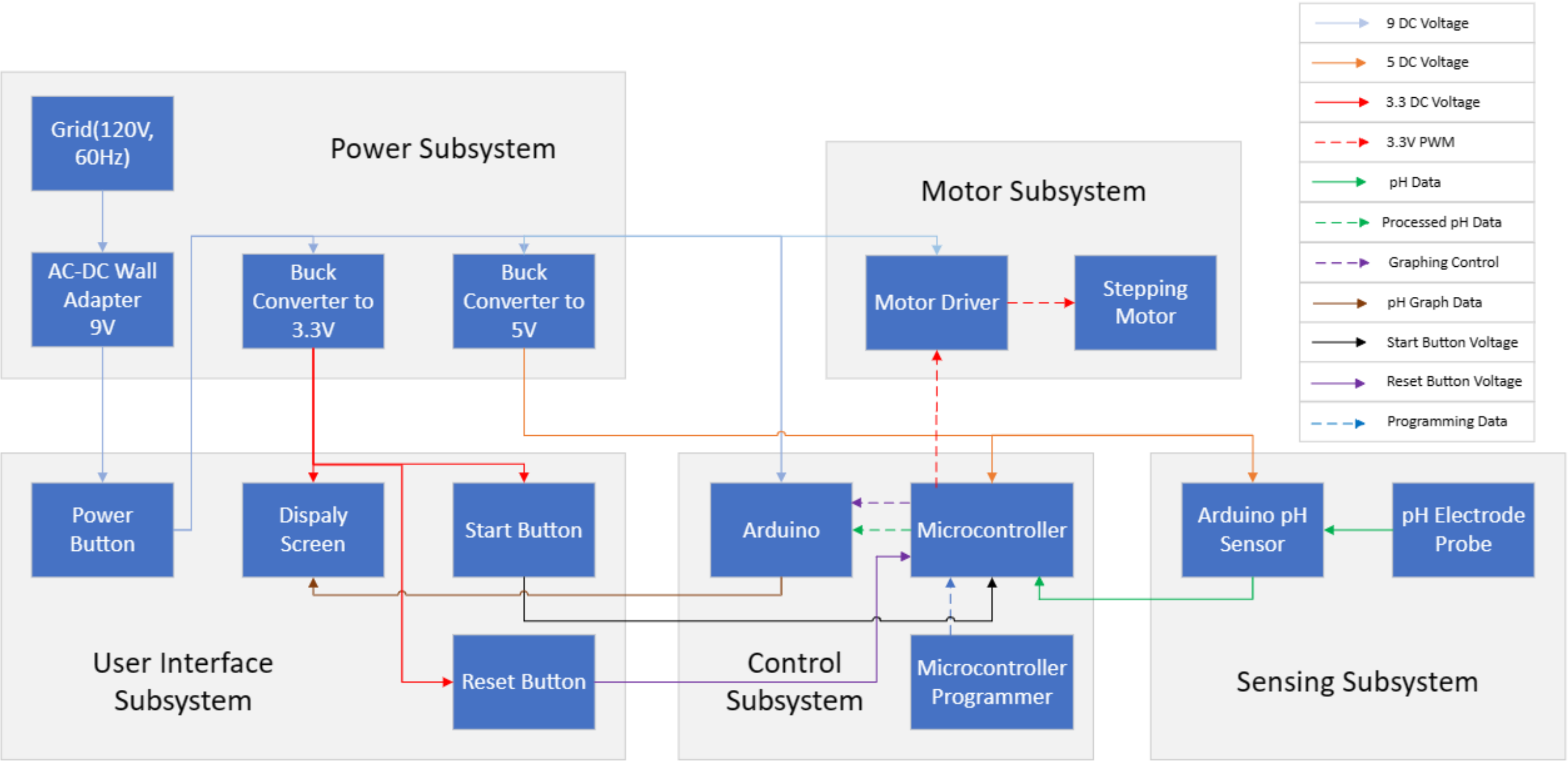


Figure 3: Diagram of Titration System Consisting of The Five Subsystems: Power, Motor, Sensing, Control and User Interface

Design Changes

PCB Version 1

Base design

- Microcontroller was programable, connected to subsystems, and reacted to external buttons
- Stepper motor used external driver

Weaknesses

- Op-amp could not handle negative voltages of pH probe (Unknown at the time)
- Some layouts incorrect
- The linear regulator required capacitor for full capacity

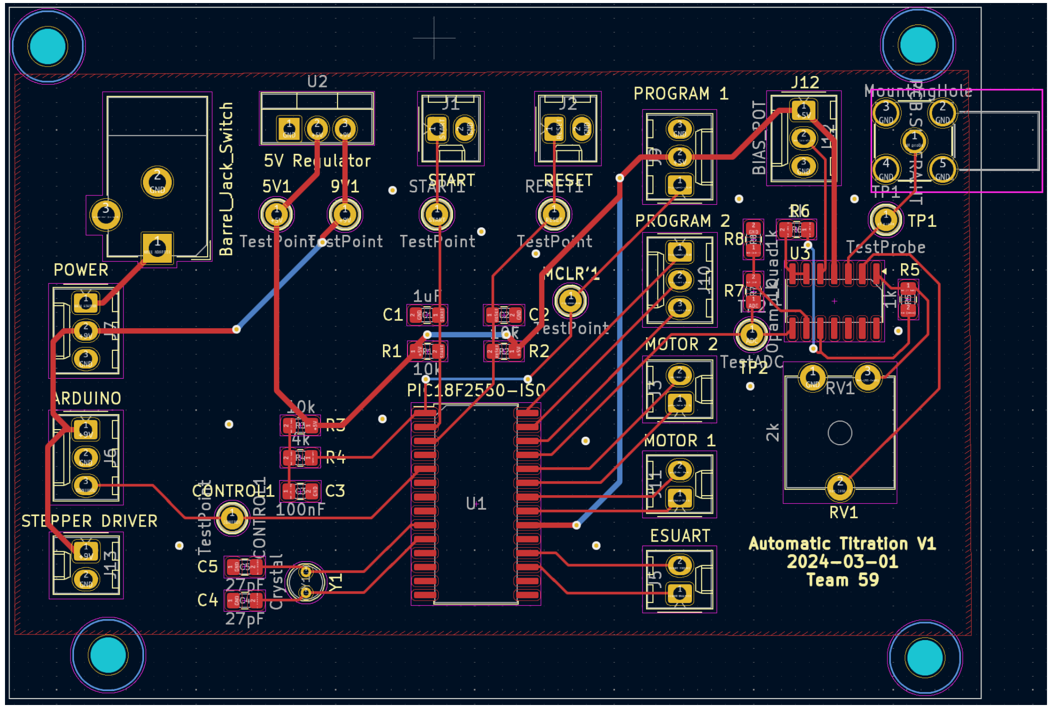


Figure 4: PCB v1 Schematic

PCB Version 2 (Never Populated)

Improvements

- Added a third push button for user control
- Updated layouts for the Wall Adapter, Linear Regulator, and potentiometer RV1

Weaknesses

- Same as version 1
  - pH circuit negative voltage
  - Missing capacitors

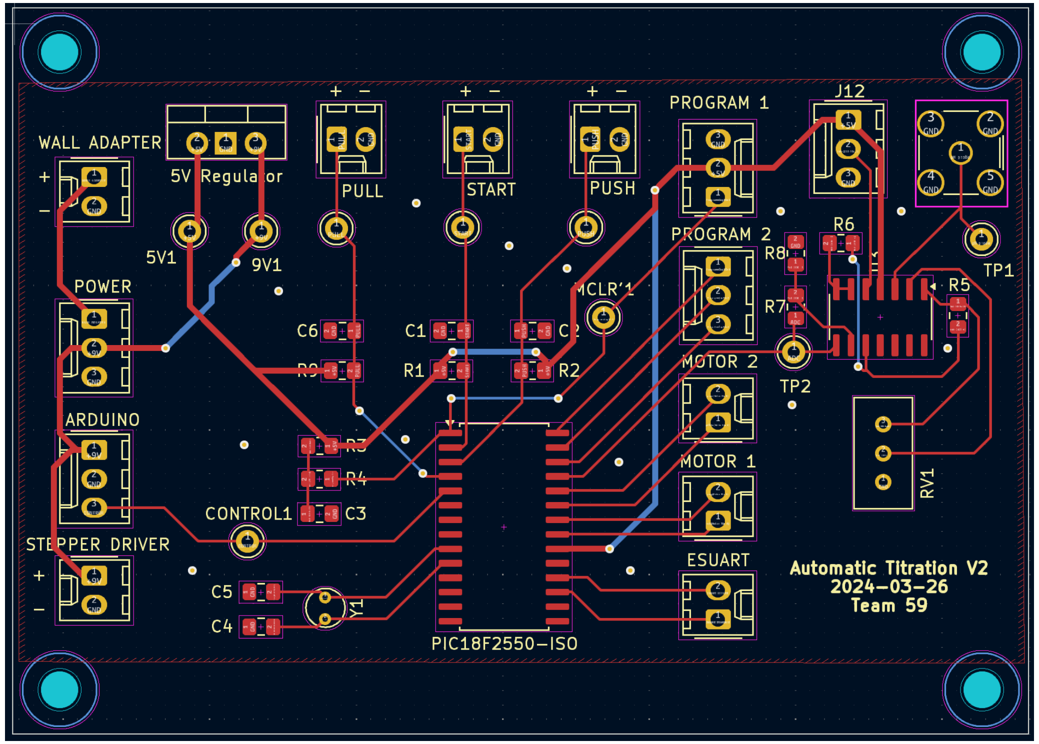


Figure 5: PCB v2 Schematic

PCB Version 3

Improvements

- Added stepper driver circuitry
- Added multiple capacitors to reduce ripple and to keep the linear regulator at 5v
- Reworked pH electrode voltage reference

Weaknesses

- Needed sensing resistor for the L298N
- Electrode wasn't operating as expected when connected to circuitry
- Op-amp kept getting damaged

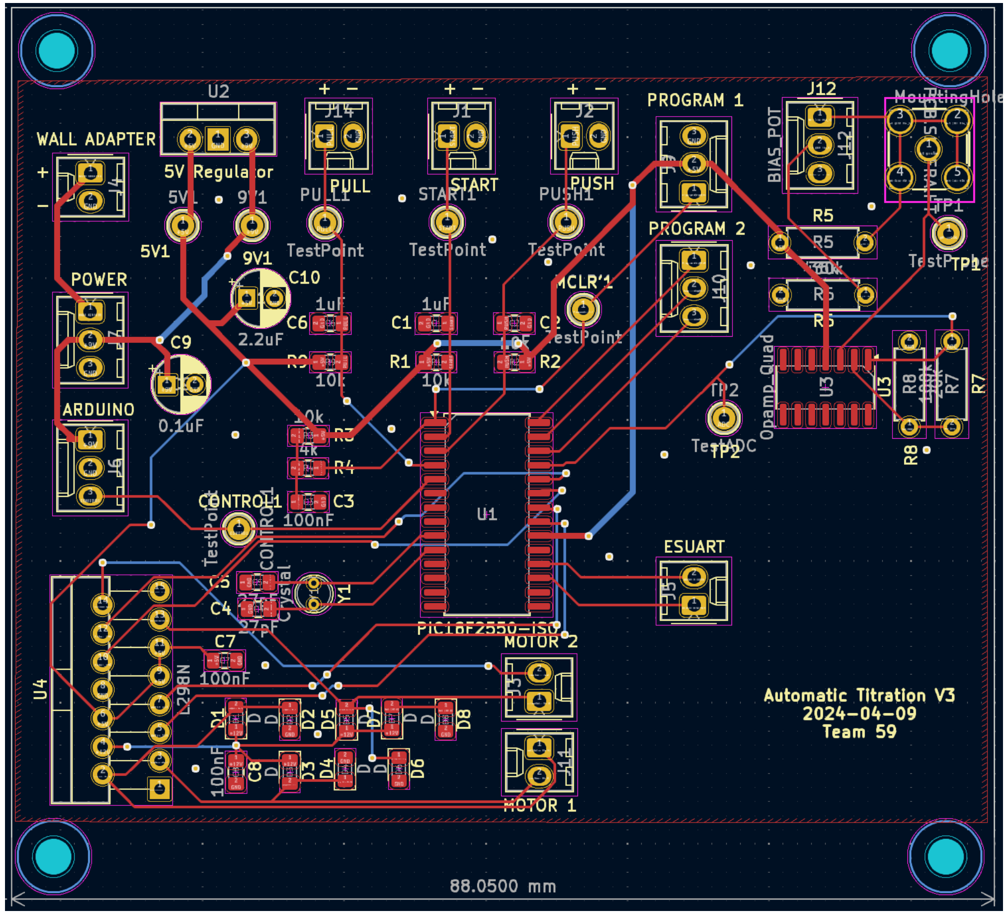


Figure 6: PCB v3 Schematic

Final Project Build

Power Sub-System

User Interface-Switches

Sensing Subsystem

Motor Driver Subsystem

Microcontroller-Programming

Microcontroller-PIC

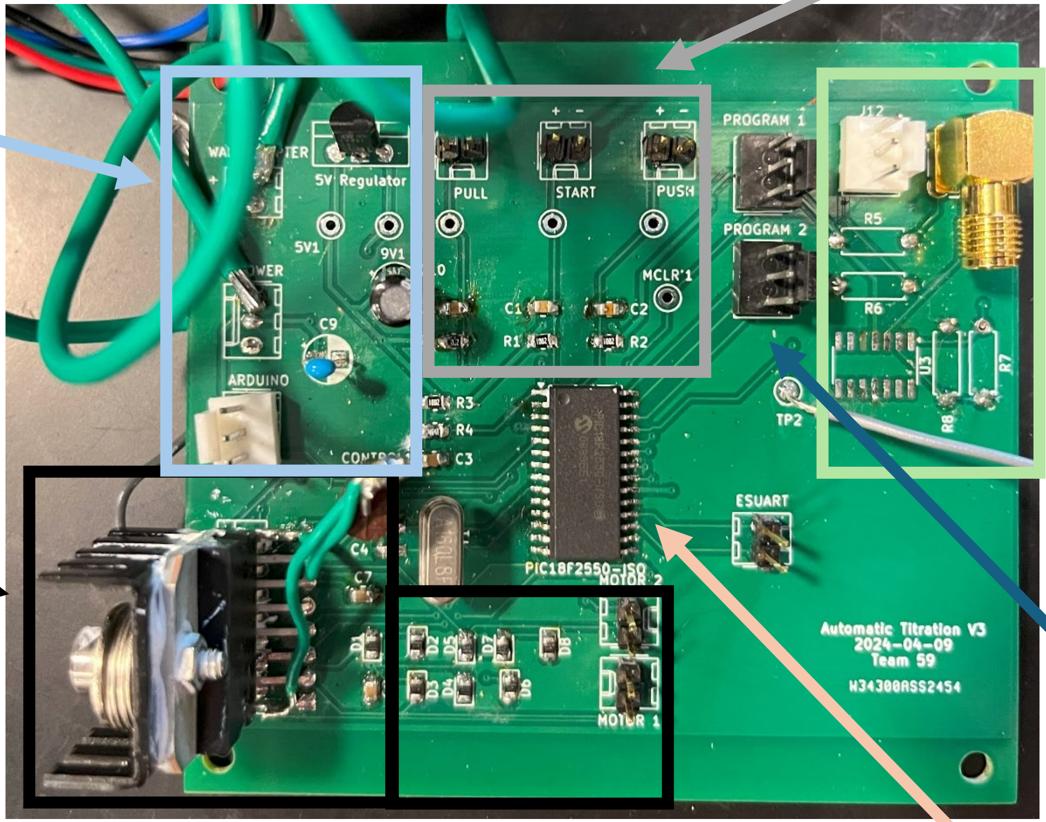
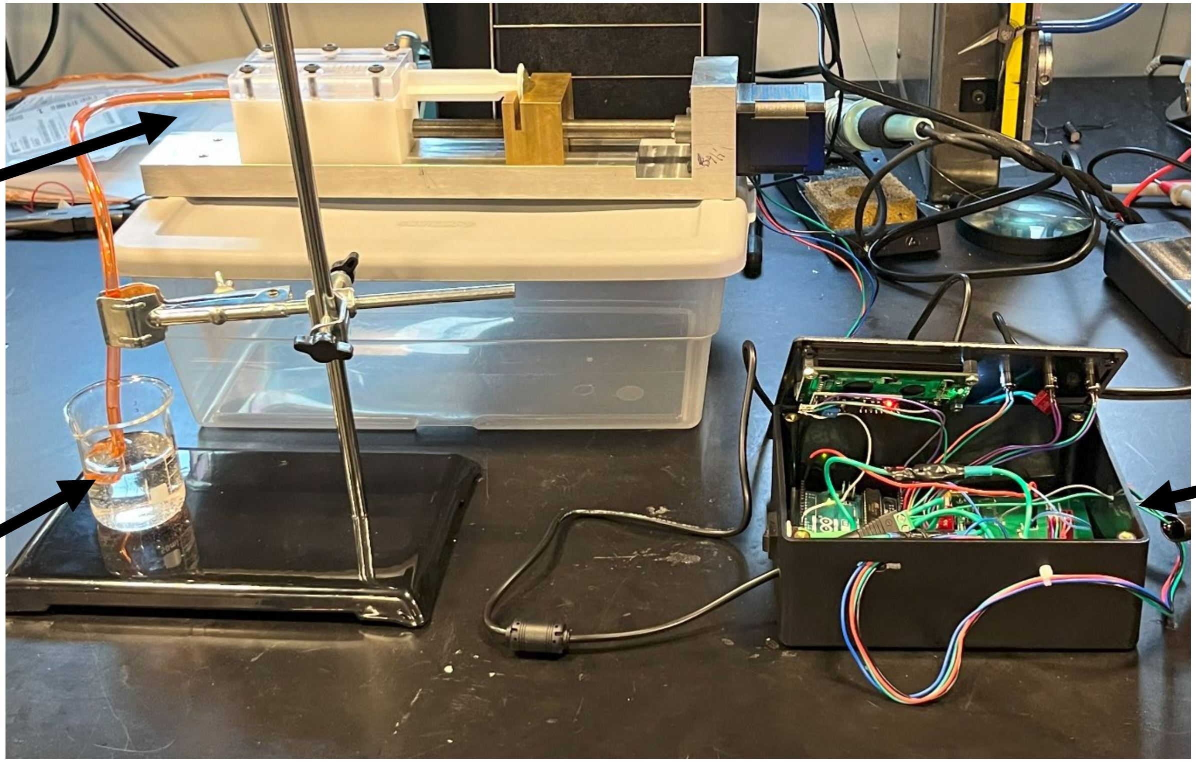
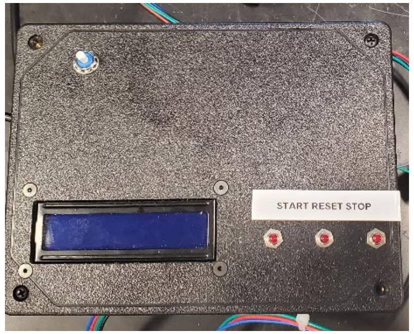


Figure 7: Final soldered PCB

Syringe Driver/Motor System

Beaker & Ring Stand





Electronics Storage- PCB, Arduino, LCD, Buttons, Power

Figure 8: Final demonstration setup

Block Diagram

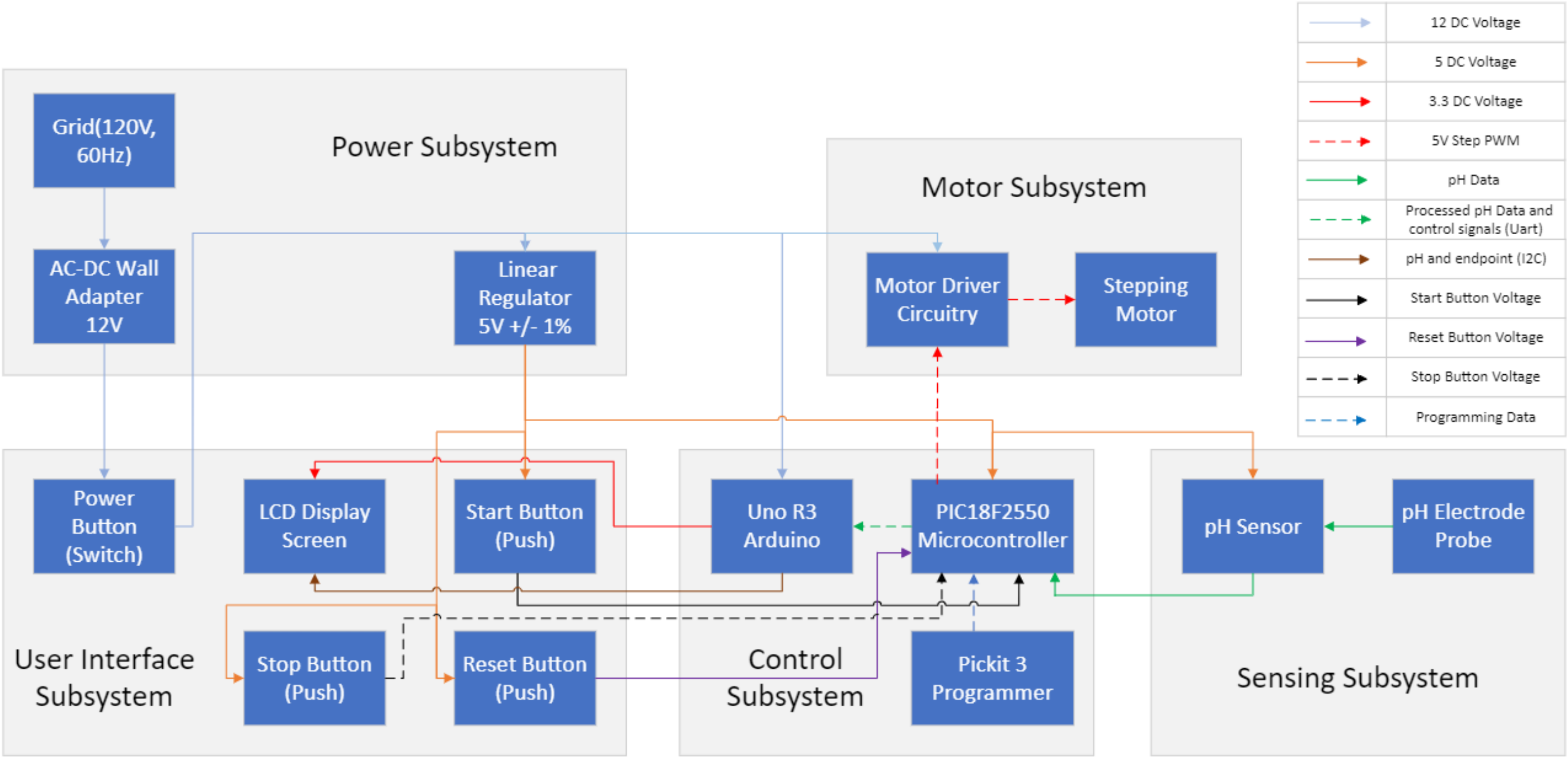


Figure 9: Final Diagram of Titration System Consisting of The Five Subsystems: Power, Motor, Sensing, Control and User Interface

Subsystem Requirements & Overview

Sensing Subsystem R&V Tables

Requirements	Verification	Results
pH sensor utilize 5 +/- 0.1V input	Probe Vdd and GND using Multimeter	5.04 V
pH output 0 to 5 +/-0.1V	Probe ADC and GND using Multimeter	0-0.8V amplified to 0-5V Saw: 0.05V to 4.9V
Measure pH with probe within +/-0.056	Use pH4 and pH7 solutions in pair with the electrode adjusting the potentiometer to ensure pH4 correlates to 1.429V and pH7 to 2.5V (with a variation of +/-0.02V) (Clean with distilled water in between solutions)	Obtained and utilized solutions, cleaned with distilled water, measurement did not stabilize, got 17mV readout
Remove external electrical interference	Remove/relocate any machinery or electronics	Verified distance on PCB and proximity to high voltage components

Table 1: All requirements and verification needed for the Sensing Subsystem

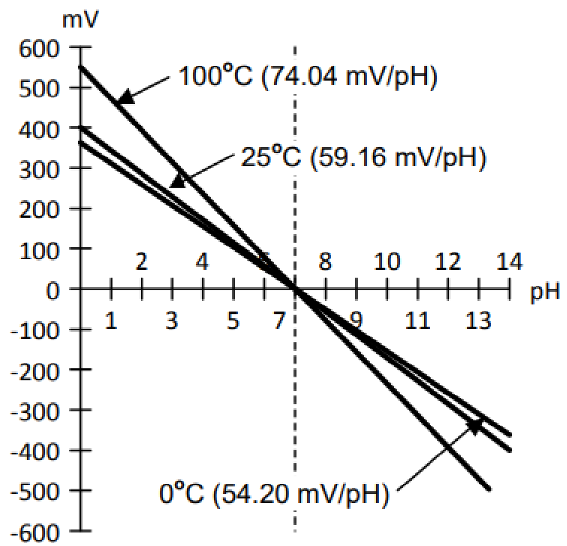


Figure 10: pH electrode output

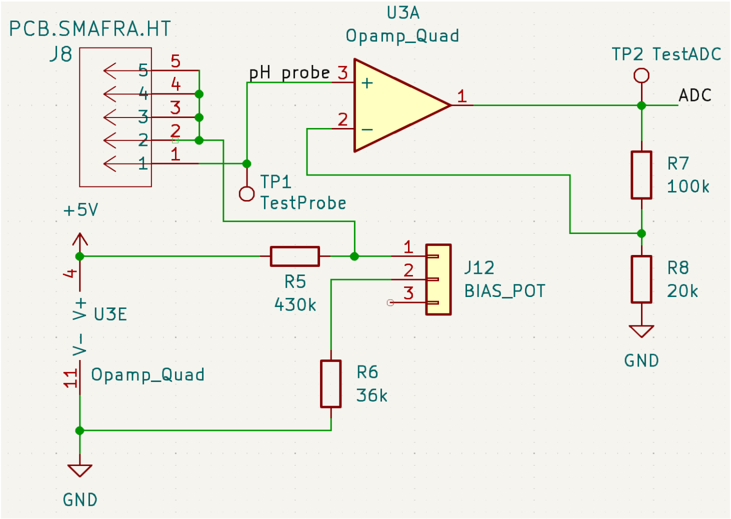


Figure 11: pH circuit schematic

Sensor Difficulties

- Op-amp circuitry worked separately
  - Direct connection to MCU read 0 V or 0.53 V
- No electrode output on multimeter or PCB

Possible Solutions

- Buffer op-amp between reference voltage and electrode
- Add a buffer to ADC path

Requirements	Verification	Results
AC-DC wall adapter to provide 7-12V for Arduino	Measure Vin to GND using Multimeter	Measured Value of 12.26V
Emergency/Full System Shut Down Switch	Connect wall adapter and ensure button operating correctly by measurement voltage using Multimeter	Continuity of switch tested, and power flowed to system when switch was in on position and no power flowed when in off position
System produces 5 +/- 0.1V output for pH system and microcontroller	Validate using Multimeter over linear regulator	Measured 5.04V output from the linear regulator and at the components utilizing it

Table 2: All requirements and verification needed for the Power Subsystem

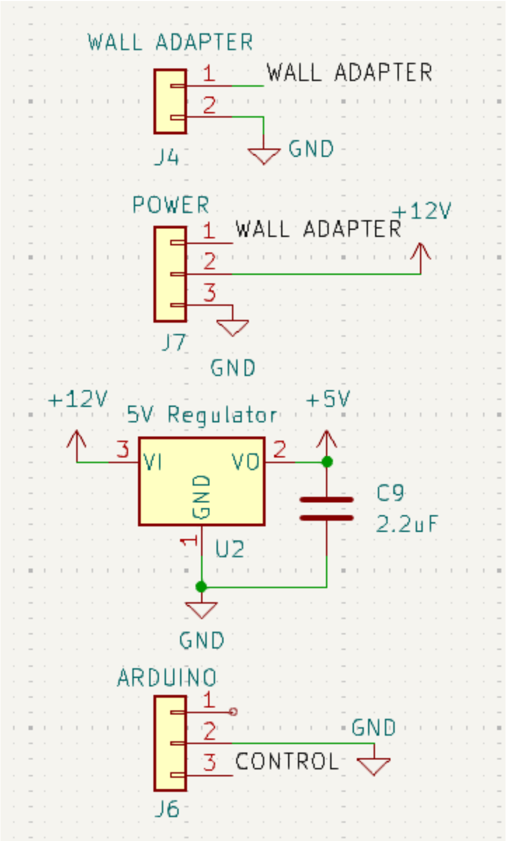


Figure 12: Power Subsystem schematic

Control Subsystem R&V Tables

Requirements	Verification	Results
Microcontroller ensures syringe limits	With syringe attached and counter set record move distance based on volume and adjust until it sweeps range	Iteration testing setting to 500 counts recording 2ml and then adjusted to 5000 counts for 20ml
Arduino data stored and calculated to screen	Monitor screen printouts of data set and endpoint	Saw proper values on the LCD for each incoming value
Arduino will use I2C for to LCD	Setup libraries for I2C interface, divide incoming UART value by 1024 and multiply by 14 to get pH	LCD screen properly displayed waiting message and took in proper values from UART
Microcontroller communicates over UART to Arduino	Baud rate to 9600, using transmit pin of microcontroller to receiver of Arduino, test char and then two char by UART	Ensure proper receipt of these messages by display of Arduino

Table 3: All requirements and verification needed for the Control Subsystem

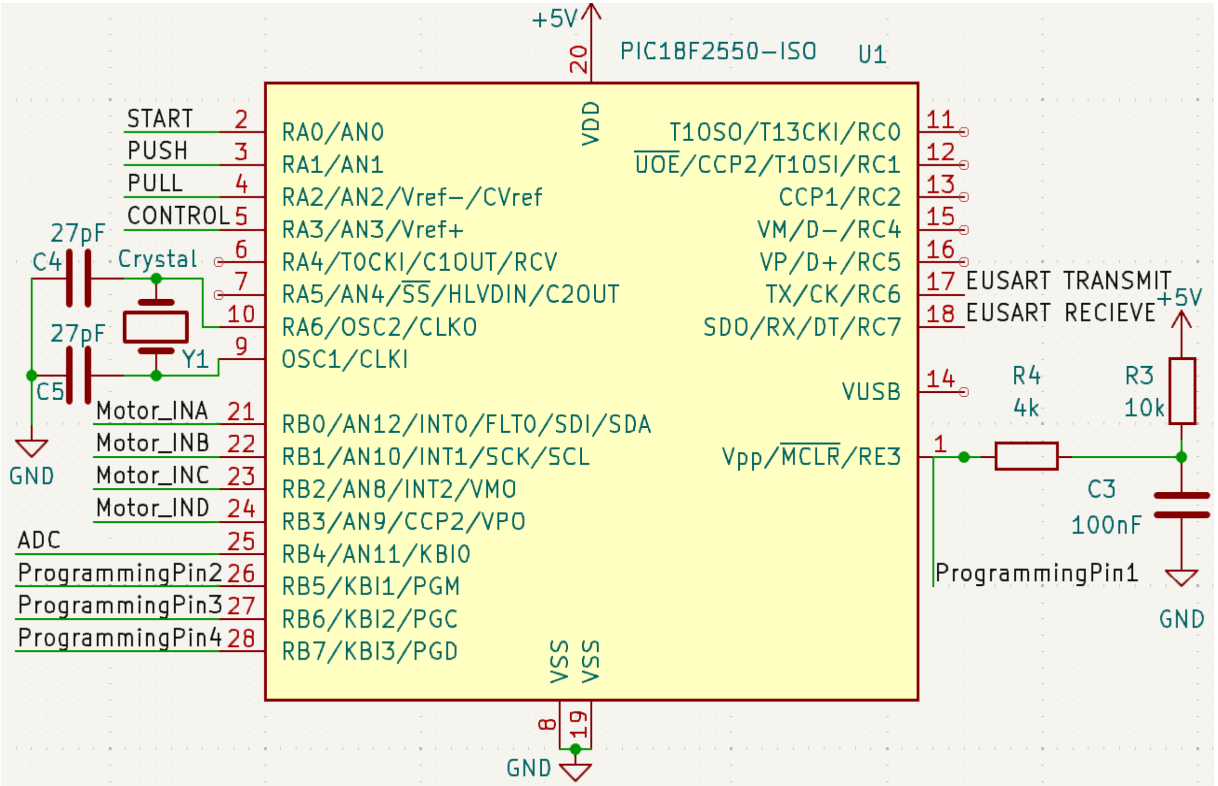


Figure 13: PIC18F2550 schematic

PIC Difficulties

- A/D Port Configuration Control bits

Solution

- Turning all I/O pins to Analog
- Comparing voltages based on the 10-bit Digital conversion

Motor Subsystem R&V Tables

Requirements	Verification	Results
Microcontroller control inputs correlate to 12V, and needed current draw from motor driver	Observe motor movement for control signals, measure voltage and current using Multimeter	Proper functionality was achieved with around 12V and 0.8A
The motor driver circuit must not overheat	Ensure L298N driver IC not too hot for operation using stress testing	Saw continuous steps heated quick but piecewise lead to lower heat generation
Motor must produce enough force to push and pull syringe	Test that the motor can produce enough force to for syringe and linear motion	Testing proved successful for to push both at varying speeds

Table 4: All requirements and verification needed for the Motor Subsystem

No External Modules

- Learned of no motor drivers allowed one week before the final PCB order
- Created circuitry using L298N IC on PCB

Introduced New Issues

- Changed microcontroller signals to motor
- Intense heating on L298N chip
  - Thermal paste, heat sink, resistors for 2 A
- Short bursts of high RPM instead of continuous motion

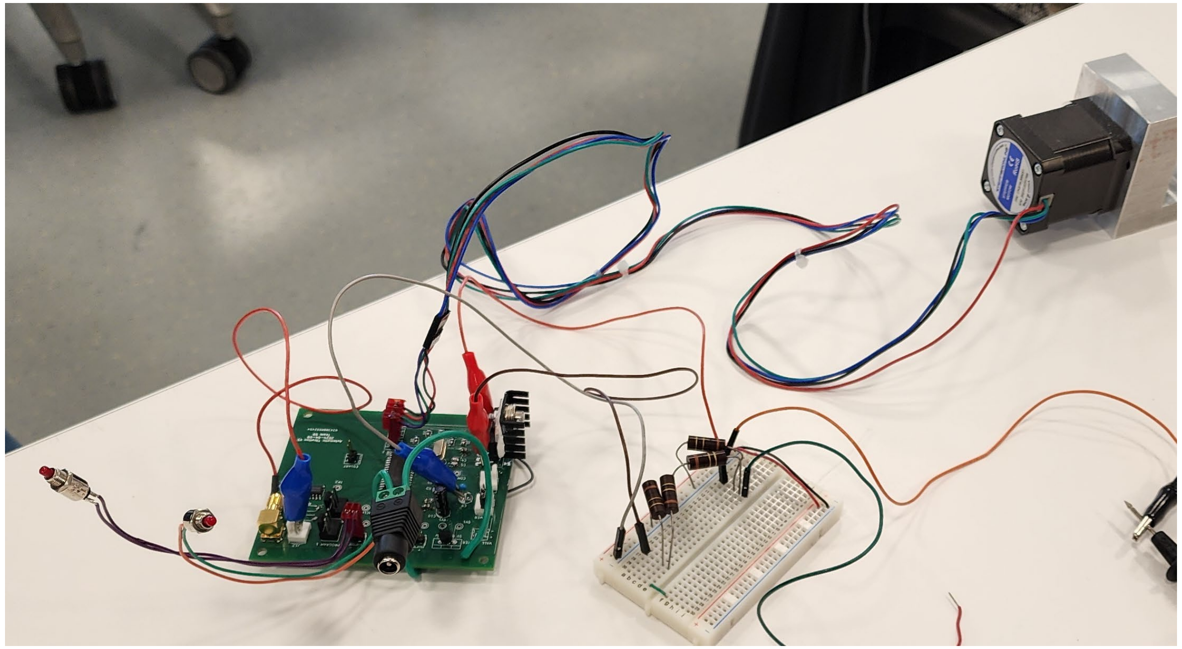


Figure 14: Debugging new motor circuitry

User Interface Subsystem R&V Tables

Requirements	Verification	Results
Start button initiates pushing motor drive	Measure switch voltage, and function output	Movement to proper position, reset and start buttons disabled when function going
Reset button initiates pull motor drive	Measure switch voltage, and function output	Movement to proper position, reset and start buttons disabled when function going
Stop button results in start and reset state to seize	Measure switch voltage, and function output	Proper halt confirmed

Table 5: All requirements and verification needed for the User Interface Subsystem

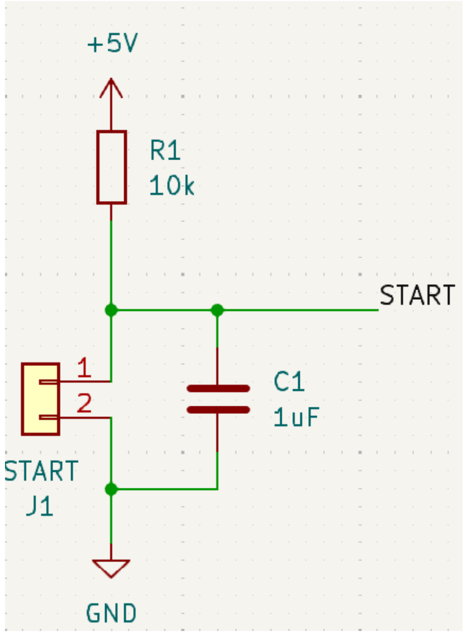


Figure 15: Push Button Schematic

Project Build and Functionality Test

Syringe Driver Testing Data

- A delay is created by looping through a set of "for loops"
- The delay of a single step is 1650 "for loop" cycles
- All recordings were done over 30 seconds

Steps per Revolution	Sets of Revolutions per 30 seconds	Drops per 30 seconds	Operating cycles per Revolution	Wait cycles per Revolution	Duty Ratio (%)	Volume (mL)
10	32	17	16,500	330,000	5	3.10
10	33	16	16,500	330,000	5	
10	31	14	16,500	330,000	5	
20	32	33	33,000	316,800	10.42	N/A
20	32	33	33,000	316,800	10.42	2.20
18	32	43/44	29,700	285,120	10.42	2.40
16	39	43	26,400	253,440	10.42	2.60
14	44	44	23,100	221,760	10.42	2.59
14	44	42	23,100	221,760	10.42	2.00
14	44	27	23,100	221,760	10.42	1.90
14	44	43	23,100	221,760	10.42	2.50
14	44	38	23,100	221,760	10.42	N/A

Table 6: Recordings of data used to determine an accurate duty ratio and step rate for the syringe driver

Conclusion & Future Recommendations

Conclusion

Summary

- Motor subsystem worked as intended
- User interface showed a pH value if connected to voltage source

Recommendations for the Future

- Precision electronics are costly and complicated
- No budget to try another pH electrode
- Create a syringe driver that has less invariance from one section to the next
    - Variance in syringe force
    - Inconsistent linear motion

Ethical Issues

Ethical Issues

Ethics

- Hold Paramount the safety, health, and welfare of the public –IEEE Ethics Code
- Be honest and trustworthy –ACM Code of Ethics
- Must be maintained between team members and community

Safety

- DRS-Division of Research Safety:
    - Chemical Waste and Handling
    - Laboratory Spills
    - Flammability Risks and Management/Preparedness
    - Moving Machinery Risk
    - Proper Clothing and Environment Setup

Thank You
Questions

The Grainger College of Engineering

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