Portable And Lightweight Oscilloscope

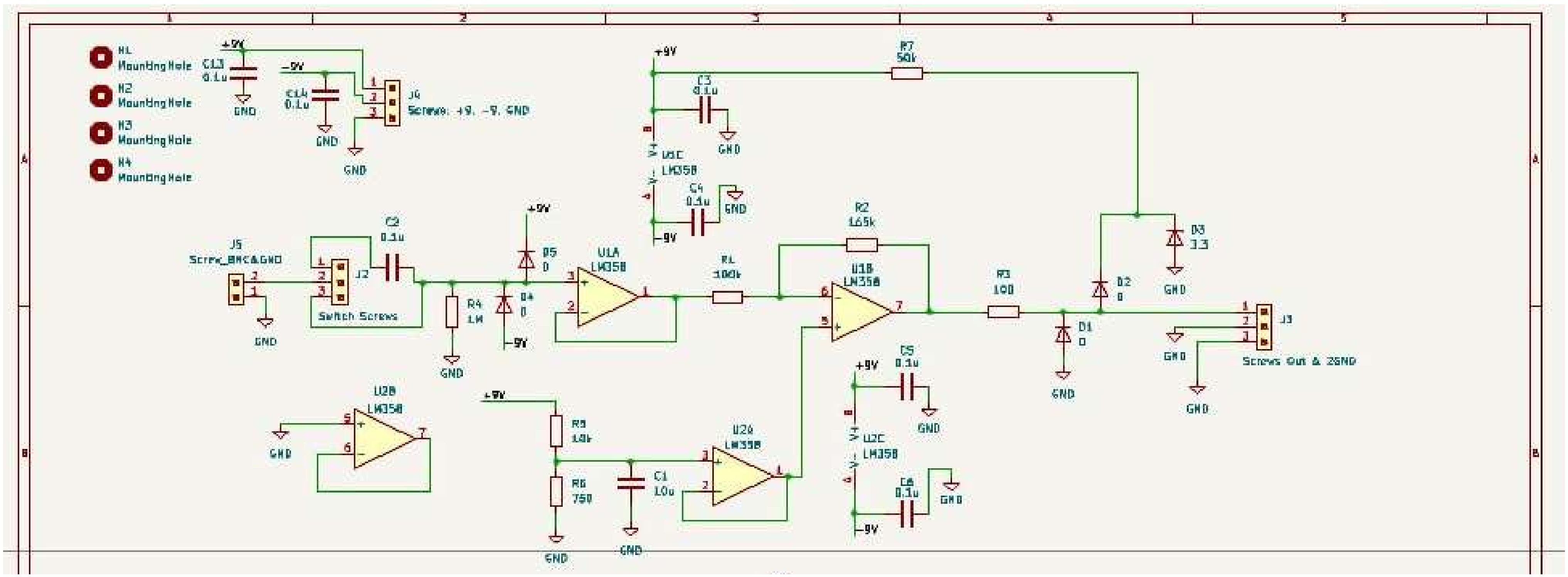
Group 6: Andrew Gondoputro, Luka Radovic, Gavin Le

Project Summary

- Designed a portable, dual-channel digital oscilloscope
- Supports ±10 V analog inputs and 200 kHz sampling per channel
- Built around a Teensy 4.1 with a fully custom analog front end (AFE)
- Real-time signal display on onboard LCD (no PC required)
- Single rotary encoder/button used for all user interaction (pause, trigger, scale)
- Main goals: Low-cost, portable, standalone oscilloscope for student/lab use
- Challenges included:
  - Conditioning ±10 V signals to 0–3.3 V ADC range
  - Achieving stable ADC performance
  - Integrating all blocks into a clean enclosure

Achievements: Verified performance, clean interface

Analog Front End

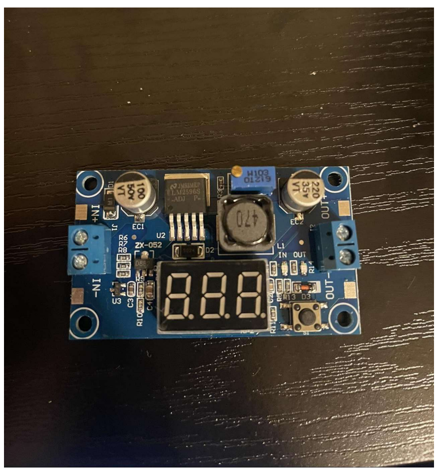


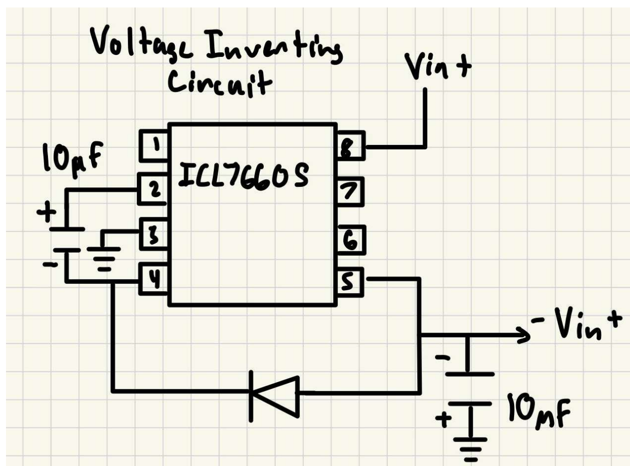
Power Block/Supply and User Interface/Display

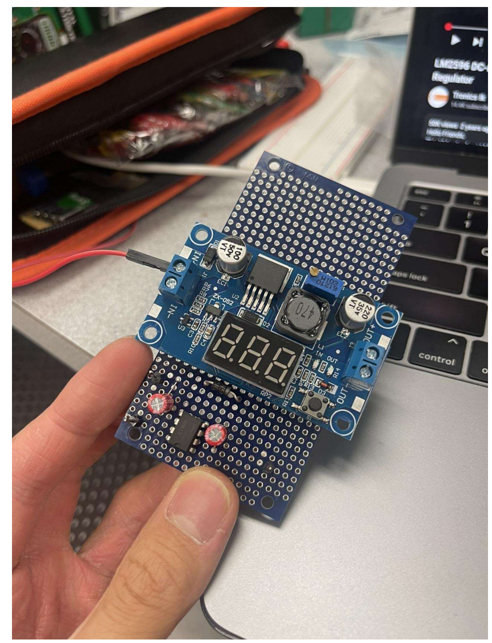
Gavin Le

Power Block/Supply

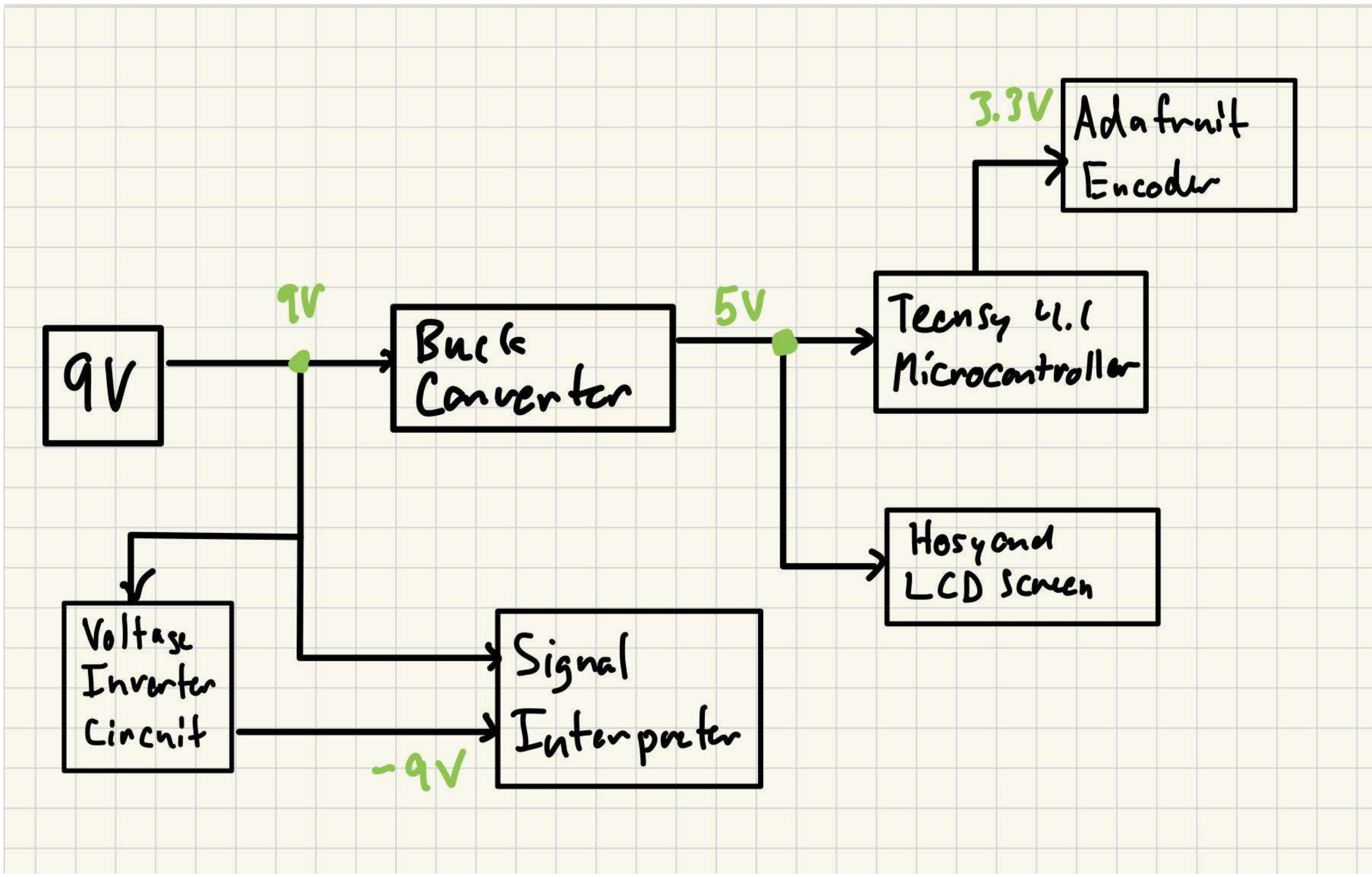
- Step down/convert voltages for the other oscilloscope components
- Eplzon 2596 Buck Converter and Voltage Inverter Circuit
- Each separate block supplies different voltages to different components of the oscilloscope





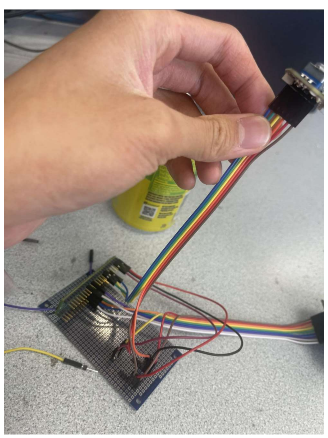


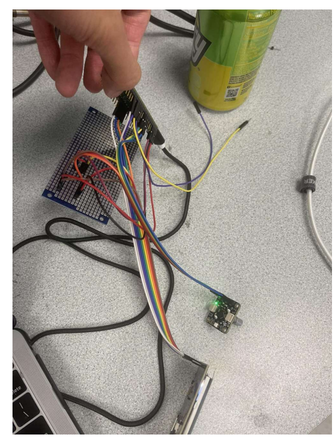
Diagram


9V
9V
Buck Converter
5V
Teensy 4.1 Microcontroller
3.3V
Adafruit Encoder
Hosyond LCD Screen
Voltage Inverter Circuit
-9V
Signal Interpreter

User Interface/Display

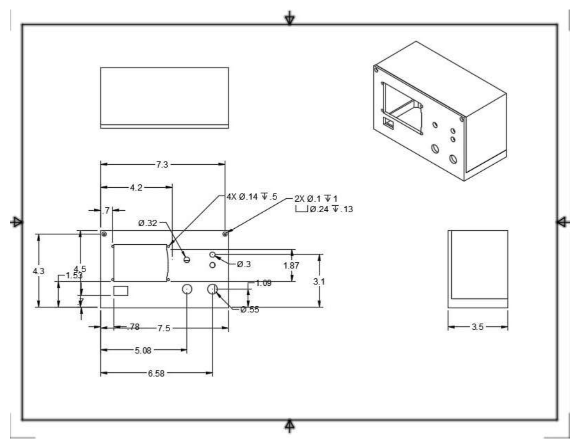
- One Adafruit I2C Stemma QT Rotary Encoder
  - Acts as button and knob
  - Allows for switching between channels, axes, selecting/triggering, and sweeping signals
- Hosyond IPS Capacitive Touch Screen LCD Module
  - Displays time and voltage axes, as well as electric signal
- Teensy 4.1 Microcontroller
  - Handles the code and functions of the oscilloscope
  - Acts as an interface bridge between the encoder and lcd screen



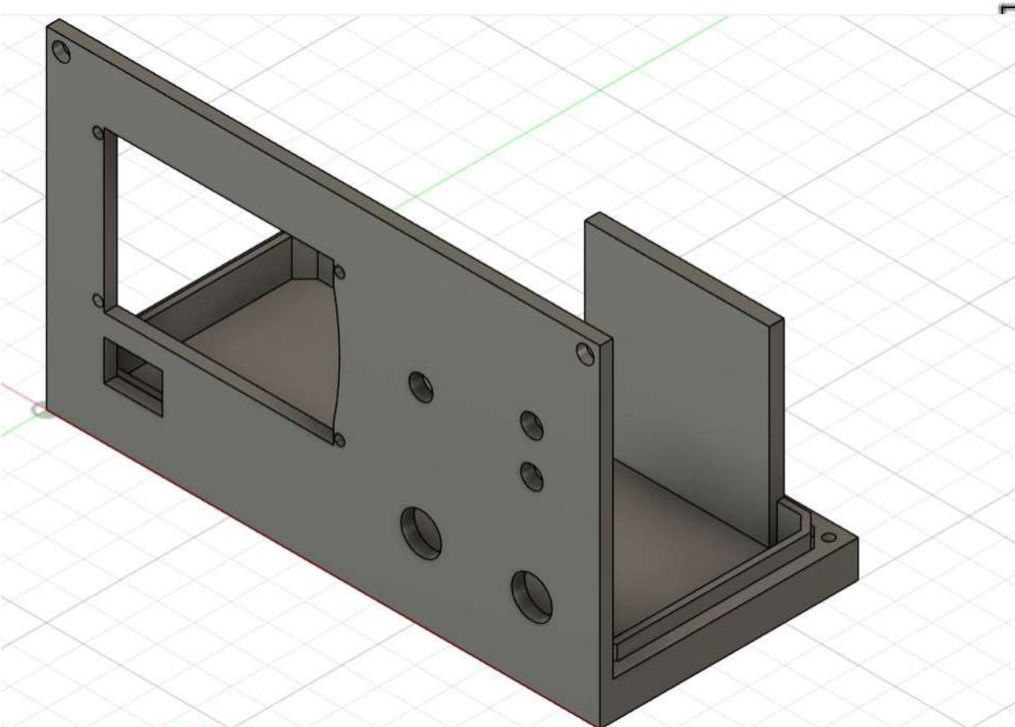


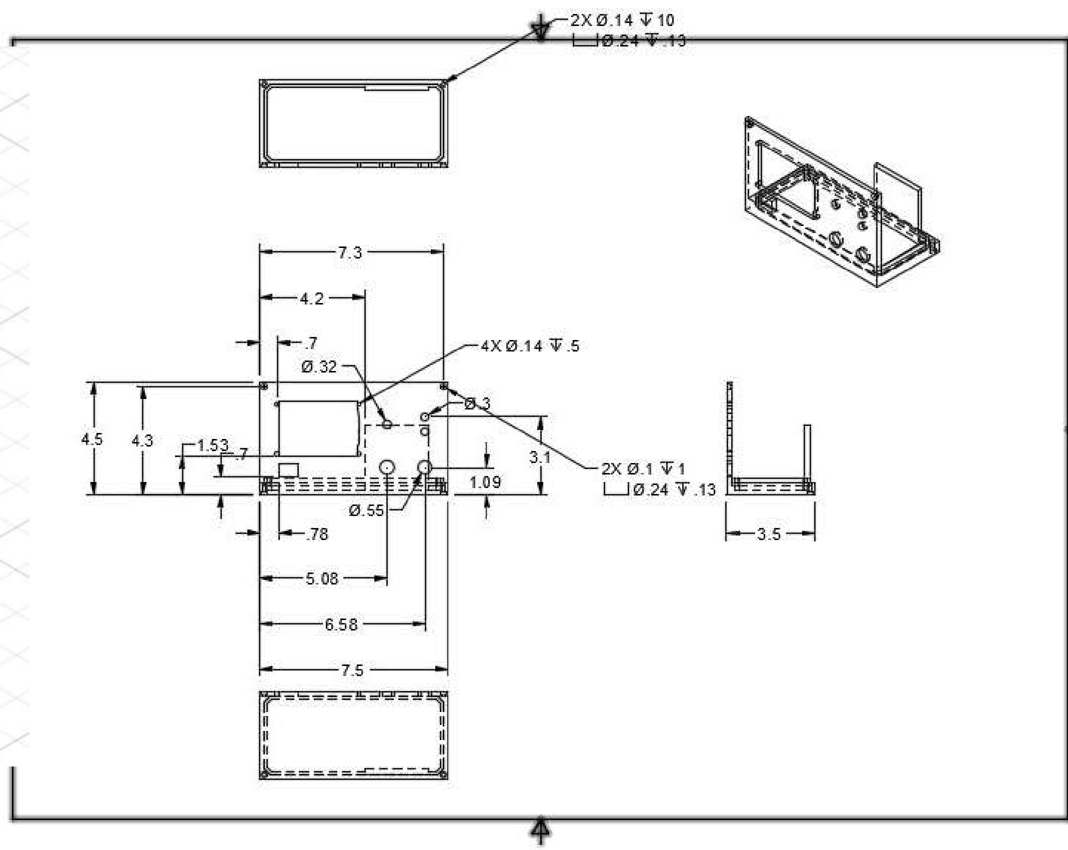
Enclosure

- Made in CAD for exact measurements -> 3D Printed in PLA Plastic
- Sizing of: 3.5 x 4.5 x 7.5in
- Slots for each UI component to fit properly either through tolerances or screws
- Interior holding all other blocks with proper placement

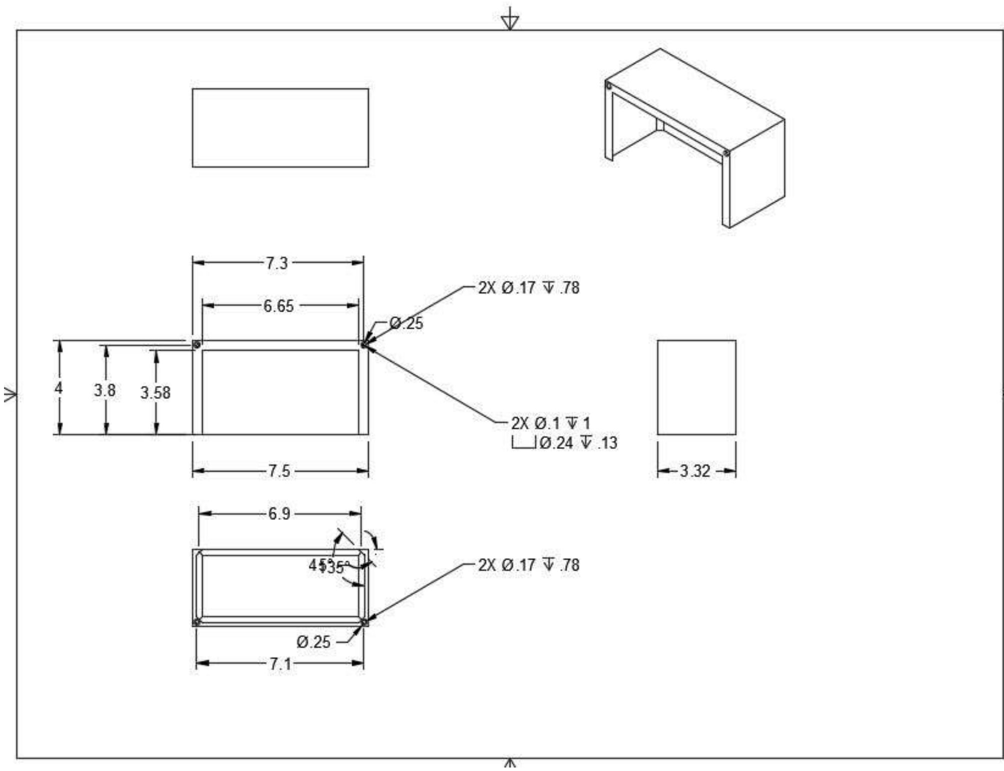


Bottom Piece

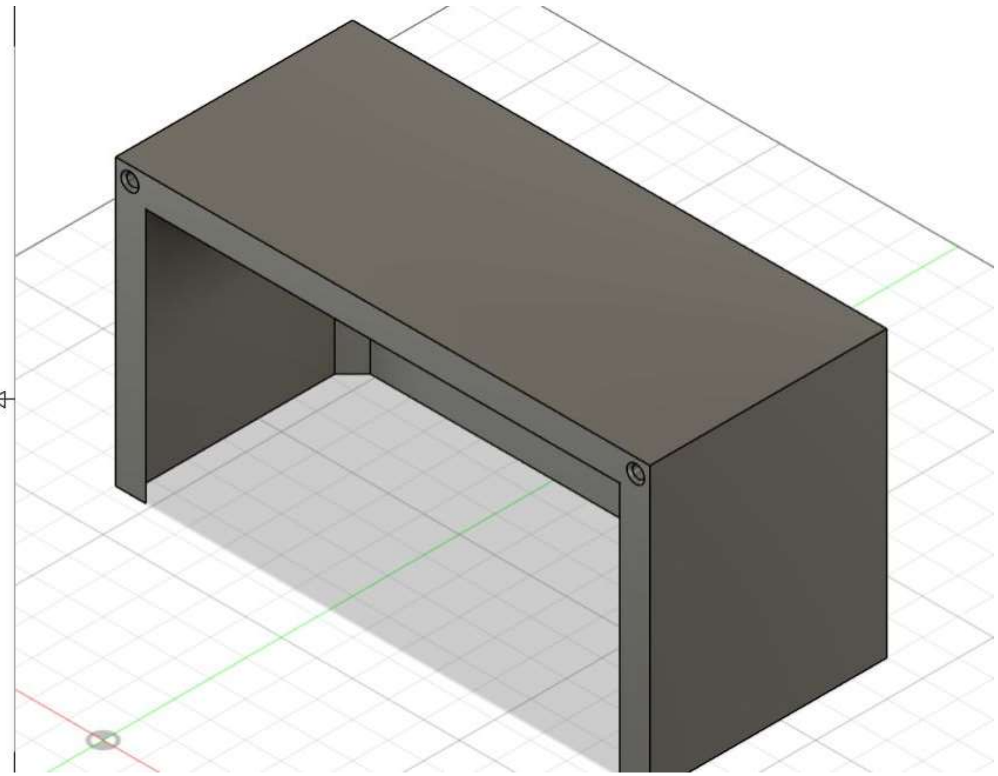




Top Piece



7.3
6.65
2X Ø.17 ↧.78
Ø.25
4
3.8
3.58
2X Ø.1 ↧1
⌴Ø.24 ↧.13
7.5
3.32
6.9
45°
35°
2X Ø.17 ↧.78
Ø.25
7.1

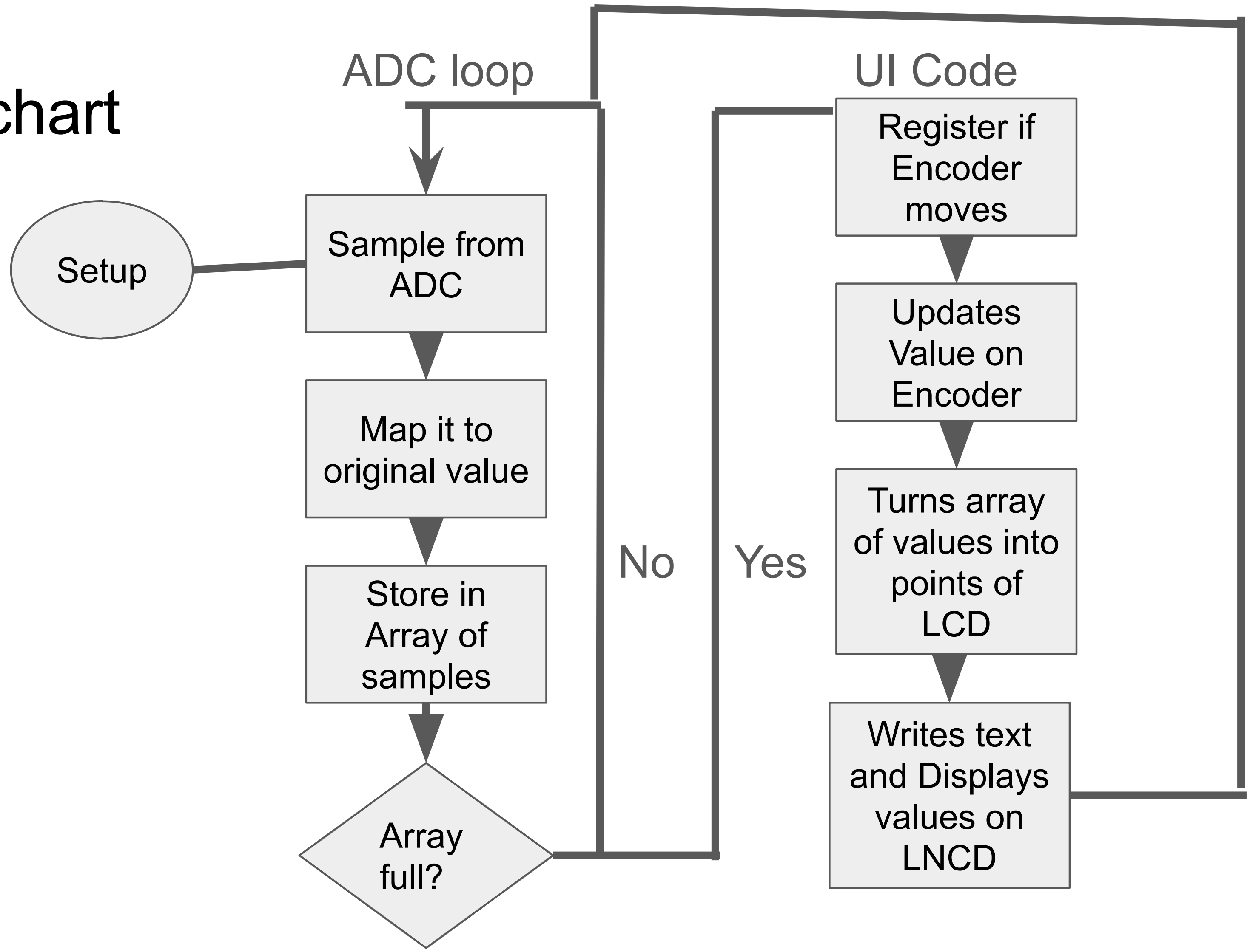


Code

Main Parts:

- **Receiving signals from ADC to sample a high frequency**
- **Receiving User Input from encoder**
- **Coding a User Output on the LCD**

Code Flowchart



Code: Sampling

```
void loop() {
  // DECISION MATRIX POLLING
  if (! ss.digitalRead(SS_SWITCH)) {
    mode += 1 ;
    if (mode > 2){
      mode = 0;
    }
    Serial.print("Mode ");
    Serial.println(mode);
    refresh_screen();
    delay(200);
    if (! ss.digitalRead(SS_SWITCH)) {
      delay(800);
      if (! ss.digitalRead(SS_SWITCH)) {
        trigger();
      }
    }
  }
  int32_t new_position = ss.getEncoderPosition();
  // did we move around
```

```
void gather_samples() {
  //elapsedMicros timer = 0;
  //int x_interval = 5 + mode_values[0];  // time scale micro seconds sampling at 200kHz

  for (int i = 0; i < SAMPLE_COUNT; i++) {
    while (timer < interval_us);  // hold loop until time passed
    timer -= interval;

    ch1_samples[i] = (6.66666*(adc->analogRead(A0, ADC_0))-10);  // Channel 1
    ch2_samples[i] = (6.66666*(adc->analogRead(A1, ADC_1))-10);  // Channel 2
  }
```

Code: User Input

```
void trigger(){
  Trigger = !(Trigger && Trigger);
}

void change_val(int& m, bool increase) {
  if (mode == 0 || mode == 1) { // X or Y scaling
    if (increase) m++;
    else m--;
    m = constrain(m, -10, 10);
  } else if (mode == 2) { // Channel select
    if (increase) m++;
    else m--;
    m = constrain(m, 0, 2);
  }
}
```

```
if (encoder_position > new_position) {
  encoder_position = new_position;
  change_val(mode_values[mode], false);
  Serial.println(mode_values[mode]);
  refresh_screen();
}
else if (encoder_position < new_position){
  encoder_position = new_position;
  change_val(mode_values[mode], true);
  Serial.println(mode_values[mode]);
  refresh_screen();
}
```

Code: User Output

```
void refresh_screen(){

    tft.fillScreen(ILI9341_WHITE);
    tft.setTextColor(ILI9341_BLACK); tft.setTextSize(1);
    tft.setCursor(0, 0);
    tft.print("Mode: ");
    if(mode == 0) tft.println("X Scale");
    else if (mode == 1) tft.println("Y Scale");
    else if (mode == 2) tft.println("Channel Select:");

    tft.print("X_Scale: ");
    tft.print(mode_values[0]);
    tft.print("| Y Scale:");
    tft.print(mode_values[1]);
    tft.print("| Channel ");
    if (mode_values[2] == 2) tft.println("Both");
    else tft.println(mode_values[2]+1);


}
```

```
void draw_sine_wave(float amplitude, float frequency, uint16_t color) {
    tft.fillScreen(ILI9341_WHITE);
    tft.setTextColor(ILI9341_BLACK); tft.setTextSize(1);
    tft.setCursor(0, 0);
    tft.print("Mode: ");
    if(mode == 0) tft.println("X Scale");
    else if (mode == 1) tft.println("Y Scale");
    else if (mode == 2) tft.println("Channel Select:");

    tft.print("X_Scale: ");
    tft.print(mode_values[0]);
    tft.print("| Y Scale:");
    tft.print(mode_values[1]);
    tft.print("| Channel ");
    if (mode_values[2] == 2) tft.println("Both");
    else tft.println(mode_values[2]+1);
    tft.print("Trigger: ");
    if (Trigger) tft.println("On");
    else tft.println("Off");
    // Draw midline
    tft.drawLine(0, SLY / 2, SLX, SLY / 2, ILI9341_LIGHTGREY);
```

Closing

Achieved:

- Safe ±10 V input range
- 200 kHz sampling per channel
- Real-time LCD display with intuitive control
- Fully modular and battery-powered design

Built completely from scratch with protoboards, firmware, and 3D printing
Future improvements:

- Custom PCB for better layout and durability
- Higher-resolution display or waveform features (e.g., FFT mode)
- Expansion to 4+ channels or wireless display integration

Demonstrated that lab-grade tools can be made compact, affordable, and user-friendly