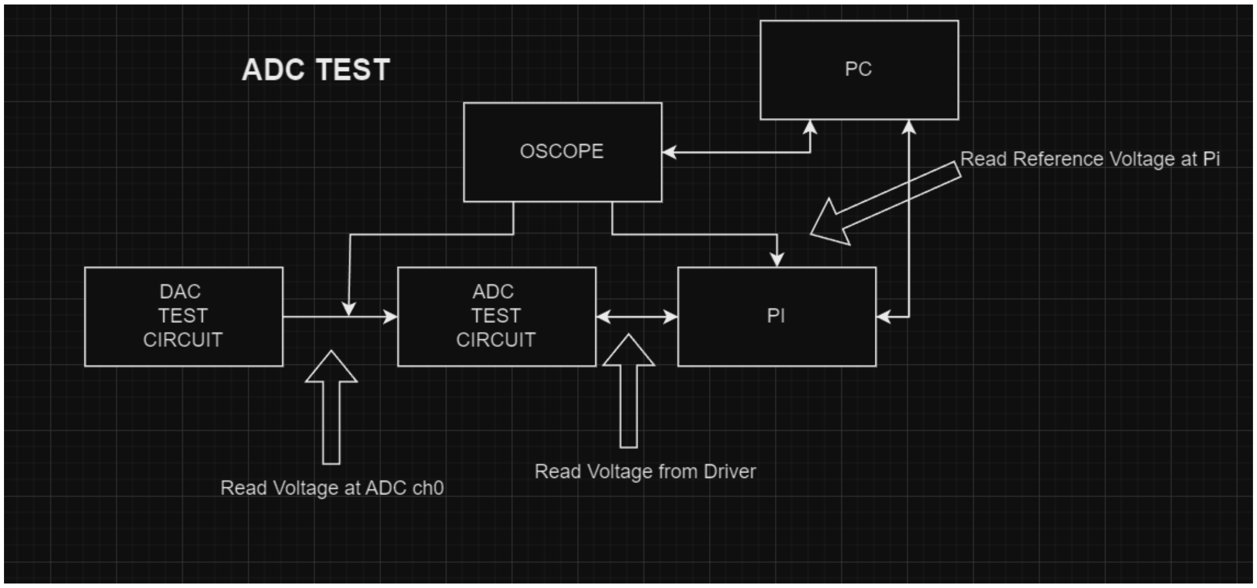
ADC Verification

Goal: Write ADC firmware, Interface ADC hardware with Pi to get < 1% error margin

- **Sub-Goal: Test and develop automated testing environment for onboard benchmark testing**

Test Setup High Level



Made Automated Testing Script that got the reference voltage, DAC Output/ADC Input, ADC/Pi Reading and ADC timing.

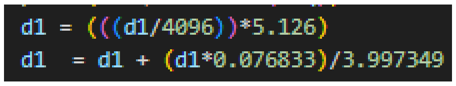
- Step 1
  - Run code on AVR microcontroller that has a steady voltage, sweep, and frequency sweep (4.1Vp)
  - Link to github
- Step 2
  - Write Python Script that interfaces with the Keysight Oscilliscope to get reliable data for data analysis in this test I am using the oscope to use reference voltage for ADC and ADC input to compare the pi software
  - Link to github
- Step 3
  - Make the setup in an easy repeatable and easy debuggable manner (lol)
- Step 4
  - Write a data analysis script that easily shows the oscope vs pi software and percent difference
  - Link to github
- Step 5
  - Write bash script that all these parts in the proper sequence and correctly file handling
- Step 6
  - Use Excel to find adjustment equation to best fit the input and read value

- Step 7
    - Troubleshoot hardware and software until goal is meet

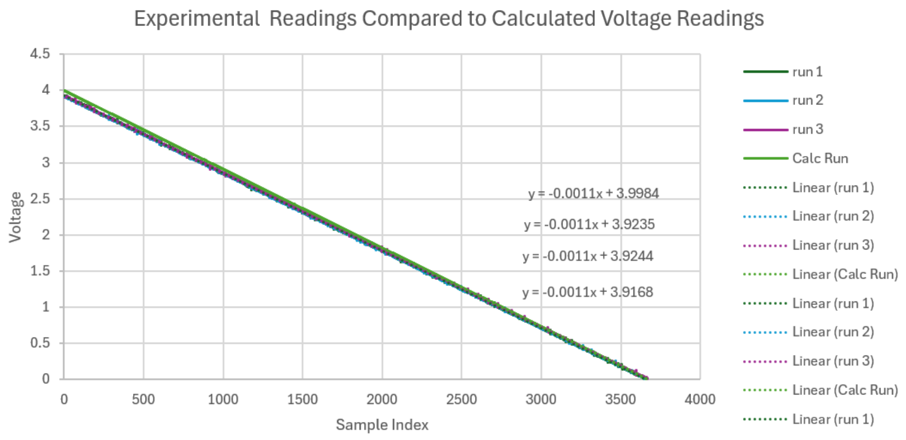
Updates made to test

- Pi script for ADC time is 40ms -> 0.2ms with c++ file handling in bash
- Python script improved +20ms read to 0.12 ms over **166x** speed improvement read time with separate read and processing

Update made to firmware

- Made adjustment formula to get correct result
    - Formula to go from ADC read bit to voltage is
        - 

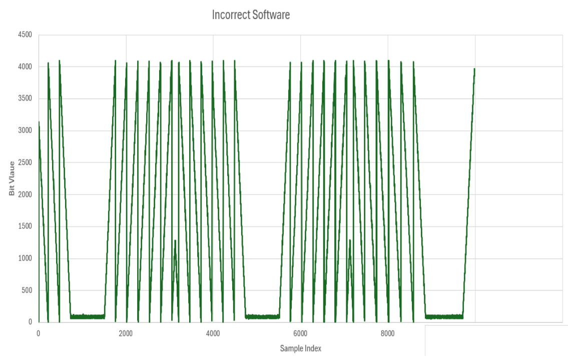
```
d1 = (((d1/4096))*5.126)
d1  = d1 + (d1*0.076833)/3.997349
```

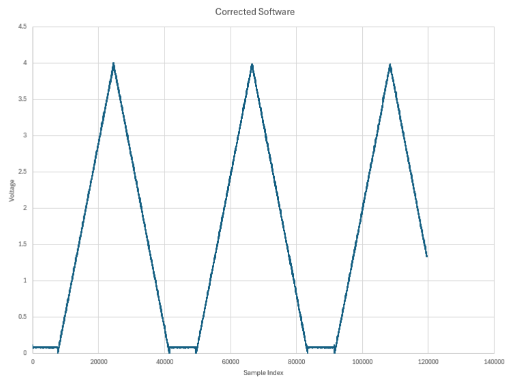
    - I got this formula by sweeping from 0-3.99V and compared the lines and calculated the adjustments needed to make the reading match the actual value
    - 

        - This shows 3 experimental runs compared to an ideal run and I noticed it was off by 0.076833 volts at 3.99 volts so I use that relationship to calculated how to adjust each reading.

- Fix control byte and second bit for tx buffer (MOSI) & Pre-define rx buffer (MISO)

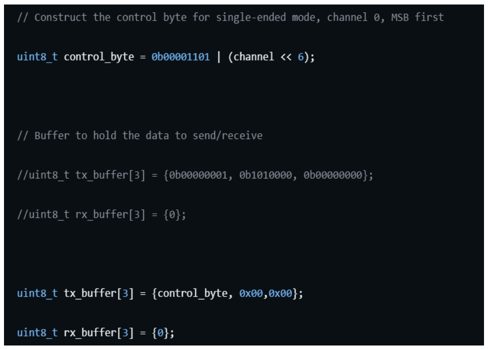
Before After



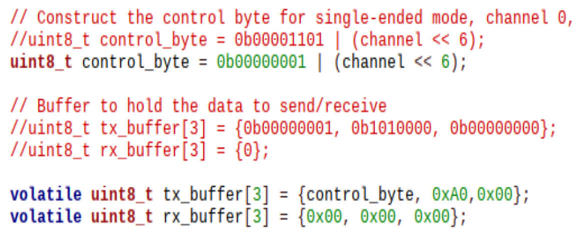


- left is in bit value and right is in voltage but they are proportional 0-4.1V sweep with a 1 second gap at 0 volts

- Move CS pin from main function to ADC read function

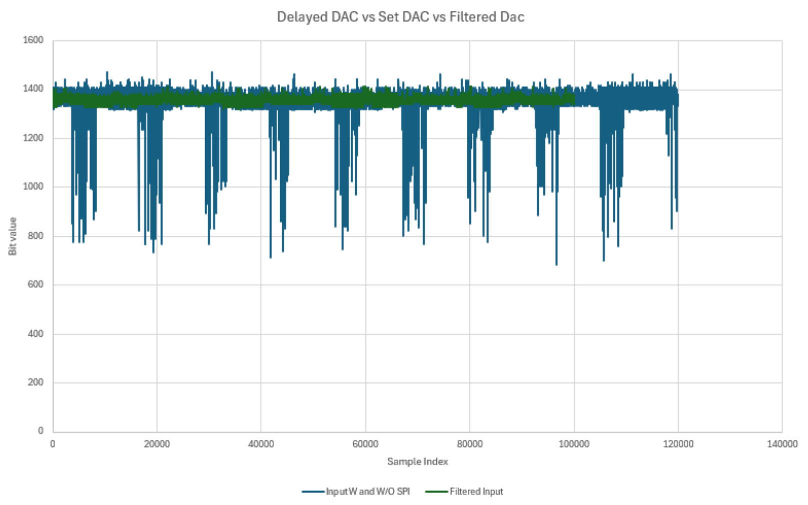


```
// Construct the control byte for single-ended mode, channel 0, MSB first

uint8_t control_byte = 0b00001101 | (channel << 6);



// Buffer to hold the data to send/receive

//uint8_t tx_buffer[3] = {0b00000001, 0b1010000, 0b00000000};

//uint8_t rx_buffer[3] = {0};



uint8_t tx_buffer[3] = {control_byte, 0x00,0x00};

uint8_t rx_buffer[3] = {0};
```



```
// Construct the control byte for single-ended mode, channel 0,
//uint8_t control_byte = 0b00001101 | (channel << 6);
uint8_t control_byte = 0b00000001 | (channel << 6);

// Buffer to hold the data to send/receive
//uint8_t tx_buffer[3] = {0b00000001, 0b1010000, 0b00000000};
//uint8_t rx_buffer[3] = {0};

volatile uint8_t tx_buffer[3] = {control_byte, 0xA0,0x00};
volatile uint8_t rx_buffer[3] = {0x00, 0x00, 0x00};
```

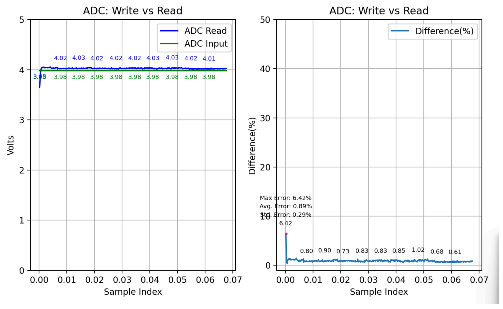
Update to Hardware

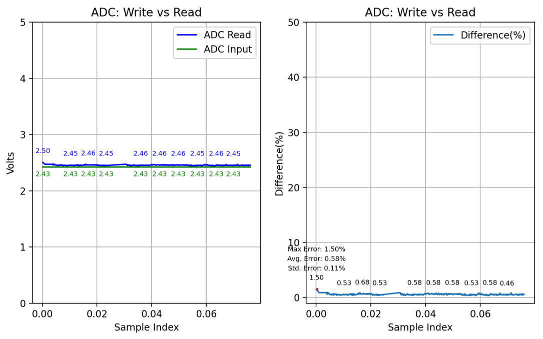
- added a RC filter to minimize SPI from AVR uController (Arduino) and BCM2877 (Pi) interference that introduces noise
    - 

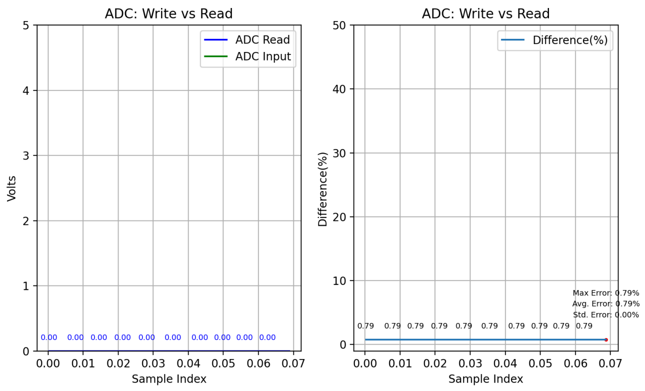
        - The blue line shows the unfiltered input line with alternating SPI and Not SPI interference and the green is the same line with an RC filter of 22uF cap and 200 Ohm resistor giving us a lot cleaner data *NOTE*: cut off frequency
- Possibly adding buffer to minimize input impedance for the S/H circuitry of the ADC

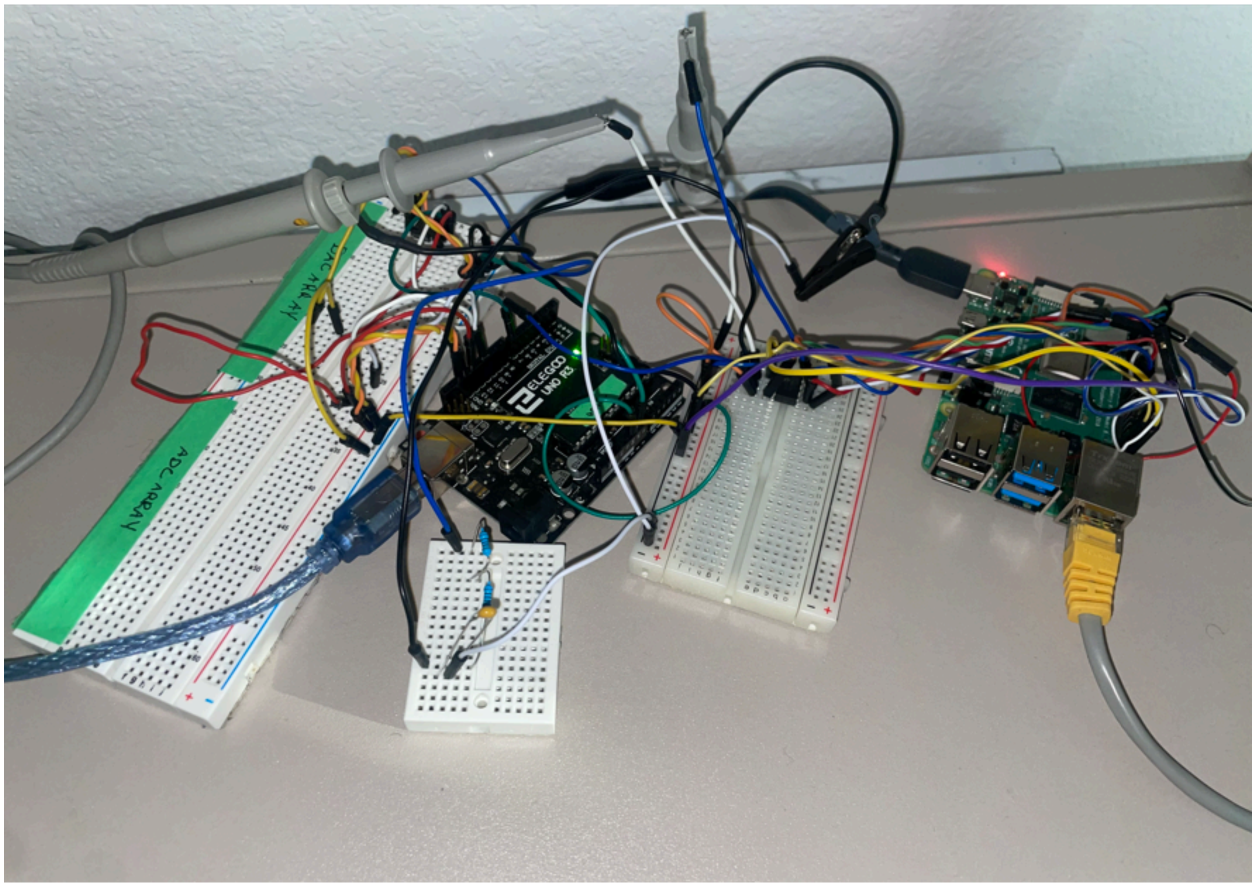
Test Results

- This is data I got before adjusting


ADC: Write vs Read
ADC Read
ADC Input
Volts
Sample Index
4.02 4.03 4.02 4.02 4.03 4.03 4.03 4.02 4.01
3.98 3.98 3.98 3.98 3.98 3.98 3.98 3.98 3.98 3.98
ADC: Write vs Read
Difference(%)
Max Error: 6.42%
Avg. Error: 0.89%
Std. Error: 0.29%
6.42
0.80 0.90 0.73 0.83 0.83 0.85 1.02 0.68 0.61
Sample Index


ADC: Write vs Read
ADC Read
ADC Input
Volts
Sample Index
2.50 2.45 2.46 2.45 2.46 2.46 2.46 2.45 2.46 2.45
2.43 2.43 2.43 2.43 2.43 2.43 2.43 2.43 2.43 2.43
ADC: Write vs Read
Difference(%)
Max Error: 1.50%
Avg. Error: 0.58%
Std. Error: 0.11%
1.50
0.53 0.68 0.53 0.58 0.58 0.58 0.53 0.58 0.46
Sample Index


ADC: Write vs Read
ADC Read
ADC Input
Volts
Sample Index
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
ADC: Write vs Read
Difference(%)
Max Error: 0.79%
Avg. Error: 0.79%
Std. Error: 0.00%
0.79 0.79 0.79 0.79 0.79 0.79 0.79 0.79 0.79 0.79
Sample Index


DAC ARRAY
ADC ARRAY
ELEGOO
UNO R3