

EE 445L – Lab 9 (Software and Prototype Lab)

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1.0 OBJECTIVES

The objectives for lab 9 were to study ADC conversion, the Nyquist Theorem, aliasing, analog amplifiers, low pass filters, data acquisition systems, and to develop a temperature measurement system using a thermistor.

2.0 HARDWARE DESIGN

See the schematic file

3.0 SOFTWARE DESIGN

See the software files

4.0 MEASUREMENT DATA

4.1 Three Waveforms (Procedure 1)

To see the data points given in the graphs below, please see Procedure1.xls

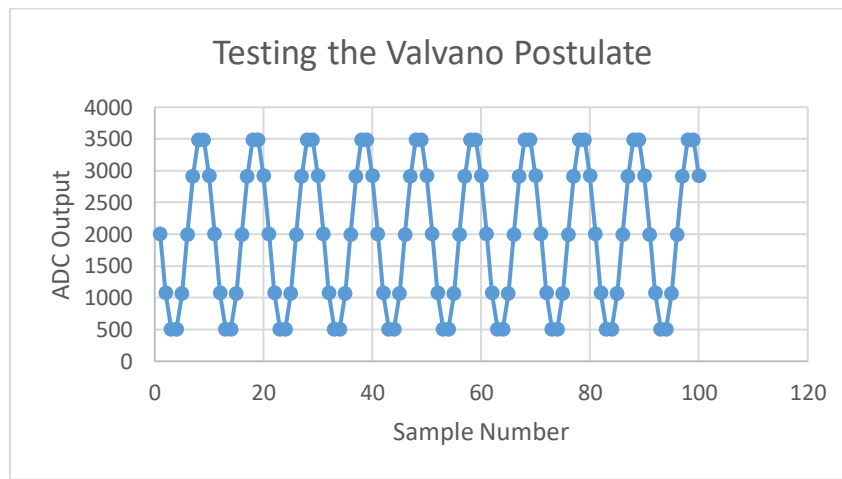


Figure 1: Sampling at 10x the signal frequency gives a nice sine wave and seems to represent the signal rather well.

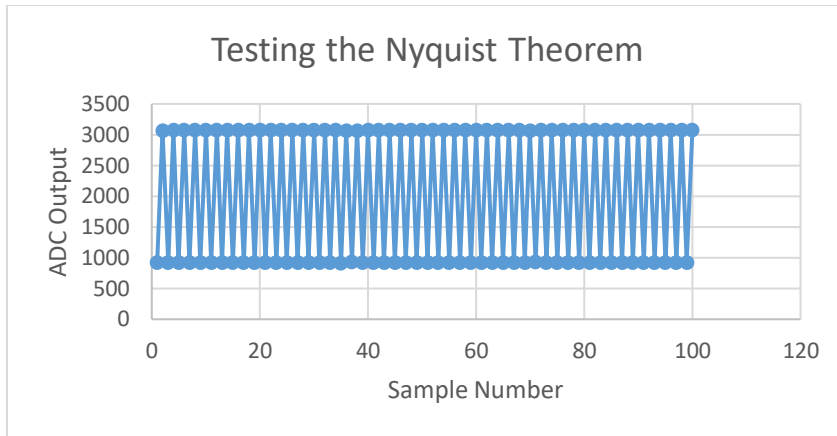


Figure 2: Sampling at greater than 2x the signal frequency seems to capture the data reasonably well, but doesn't give a nice sine wave (this one appears rather jagged). The sine wave in Figure 1 looks nicer since there are more data points taken per period.

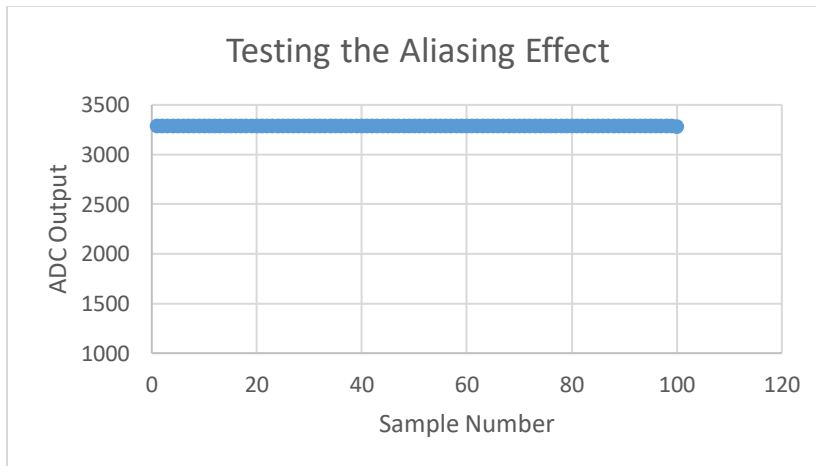


Figure 3: Sampling at 0.5x the signal frequency shows the horrid results of the aliasing effect. The data does not reflect the signal at all. It's not even a sine wave.

4.2 Static Circuit Performance (Procedure 2)

	A	B	C	D
1	Replace thermistor with this resistor value	Expected V2 (mV)	Expected (V2 - V3) (mV)	Expected Vs (mV)
2	62 kohm	256	42	376
3	51 kohm	215	2	18
4	82 kohm	322	109	970
5	120 kohm	448	235	2093
6	150 kohm	523	309	2759
7				
8		Actual V2 (mV)	Actual (V2 - V3) (mV)	Actual Vs (mV)
9		235.4	28.3	249.5
10		190.7	13.2	8.4
11		297.4	106.7	922
12		427	214.6	2016
13		478	293.6	2610
14				
15		V2 Percentage Error	(V2 - V3) Percentage Error	Vs Percentage Error
16		8.046875	32.61904762	33.64361702
17		11.30232558	560	53.33333333
18		7.639751553	2.110091743	4.948453608
19		4.6875	8.680851064	3.678929766
20		8.604206501	4.98381877	5.40050743

Figure 4: shows the measurements at strategic locations when the thermistor was replaced with the above values. V2, V2-V3, Vs are the voltages indicated in the Therm12.xls file. V2 is the voltage drop from the positive terminal of the INA122P to ground. V2-V3 is the voltage drop from the positive terminal to negative terminal of the INA122P. Vs is the INA122P's output voltage

Note: the huge percentage error in C17 and D17 is due to the fact that voltmeter isn't accurate when reading such low voltages (it reads about 20 mV of noise when not connected to anything) (which makes those values recorded not really useable). Figure 5 indicates this.

Voltage out when thermistor disconnected = 3.2 V

Voltage out when thermistor wires are shorted = 22 mV. This value is basically noise (as in zero volts).



Figure 5: shows voltage reading when not connected to anything (~20 mV of noise)

4.3 Dynamic Circuit Performance (Procedure 3)

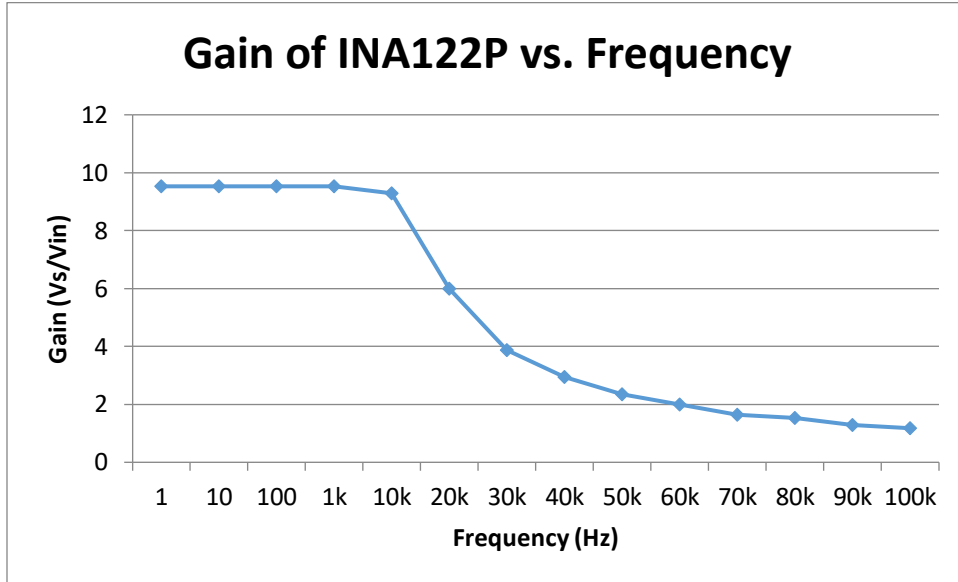


Figure 6: For specific values, see Procedure3.xls. The gain starts to roll off around 10kHz and approaches one as frequency approaches infinity.

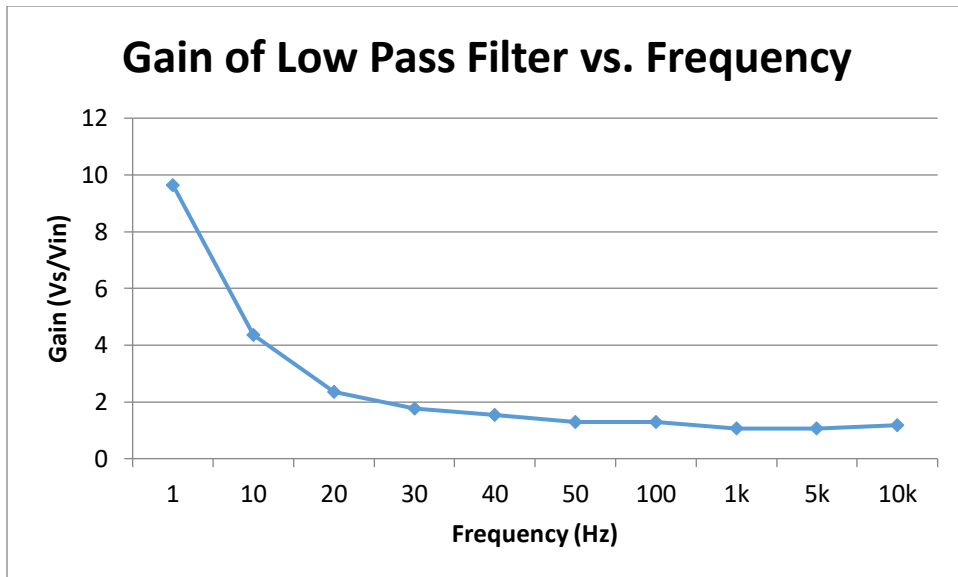


Figure 7: For specific values, see Procedure3.xls. The gain starts to roll off almost immediately and approaches one as frequency approaches infinity.

4.4 Accuracy (Procedure 6)

	A	B	C	D
1	Room Temp By Fluke (degC)	By Thermistor	Difference	Average Accuracy (degC)
2	23	22.55	0.45	0.61
3		22.38	0.62	
4		22.49	0.51	
5		22.28	0.72	
6		22.25	0.75	
7				
8		Summation of Differences:	3.05	

Figure 8: The table above shows 5 measurements taken at room temperature. It shows the differences between our thermistor's readings and our fluke meter's readings as well as our average accuracy. The table shows that our values are, on average, within one degree of the "true" room temperature.

4.5 Reproducibility (Procedure 7)

12	Independent measurements	mean	(x-u)^2	Std Dev
13	21.44	21.445	2.5E-05	0.032015621
14	21.46		0.000225	
15	21.41		0.001225	
16	21.43		0.000225	
17	21.4		0.002025	
18	21.44		2.5E-05	
19	21.43		0.000225	
20	21.45		2.5E-05	
21	21.47		0.000625	
22	21.52		0.005625	

Figure 9: The table above shows 10 measurements taken at room temperature (in a different room) and shows that our data is quite reproducible.

5.0 ANALYSIS AND DISCUSSION

5.1 What is the Nyquist theorem and how does it apply to this lab?

The Nyquist theorem states that in order to correctly represent an analog frequency in digital format, the signal must be sampled at a minimum of twice the frequency of the signal. The frequency of the temperature signal for this lab was between 0 and 10 Hz so we needed to sample it at least 20 times a second.

5.2 Explain the difference between resolution and accuracy?

Resolution is the smallest change in temperature that the system can detect, while accuracy is the measure of difference between the actual temperature and temperature measured by the system.

5.2 Derive an equation to relate the thermometer's reproducibility and precision.

We weren't really sure about this one. We understood reproducibility as standard deviation (since that is what procedure 7 wanted us to do).

Standard deviation is a measure of your distribution's spread.

Precision generally refers to measurements being close to one another.

So, measurements with high precision have a low standard deviation.

The lower the standard deviation, the high reproducibility.

So, precision is directly proportional to reproducibility (if the precision is high, then the reproducibility must also be high).

$$\text{Reproducibility} = (a * \text{precision}) + b$$

5.4 What is the purpose of the LPF?

To filter out high-frequency noise to the system and to prevent aliasing. Aliasing occurs when we try to sample frequencies greater than half our sampling rate, so we can remove those frequencies with a low pass filter.

5.5 If the R versus T curve of the thermistor is so nonlinear, why does the voltage versus temperature curve look so linear?

"Circuits for linearizing thermistor outputs can be comprised of series, parallel, and series-parallel combinations of fixed resistors and additional thermistors"

(<http://www.designworldonline.com/designing-with-thermistors/#>)

Using the knowledge above, we used a bridge to linearize the output of the thermistor (which is why the Voltage vs. Temperature curve looks linear).

5.6 There are four methods (a, b, c, d) listed in the Software Conversion section of methods and constraints. For one of the methods you did not implement, give reasons why your method is better, and give reasons why this alternative method would have been better.

We used method d (small table lookup with linear interpolation in between). This method is better than using a large table lookup since it takes up less memory space, but has the tradeoff of being slower. A large table lookup would basically be a hash function with constant lookup time and zero collisions.

While using a nonlinear equation might be even more accurate than a large table lookup (since it fits the data better), it might not be a good choice considering the computation overhead of a linear equation (those exponentials, multiplications, and floating point numbers boil down to a lot more calculations than a simple linear interpolation involving slope and a few additions).