Lab 9: Temperature Data Acquisition System

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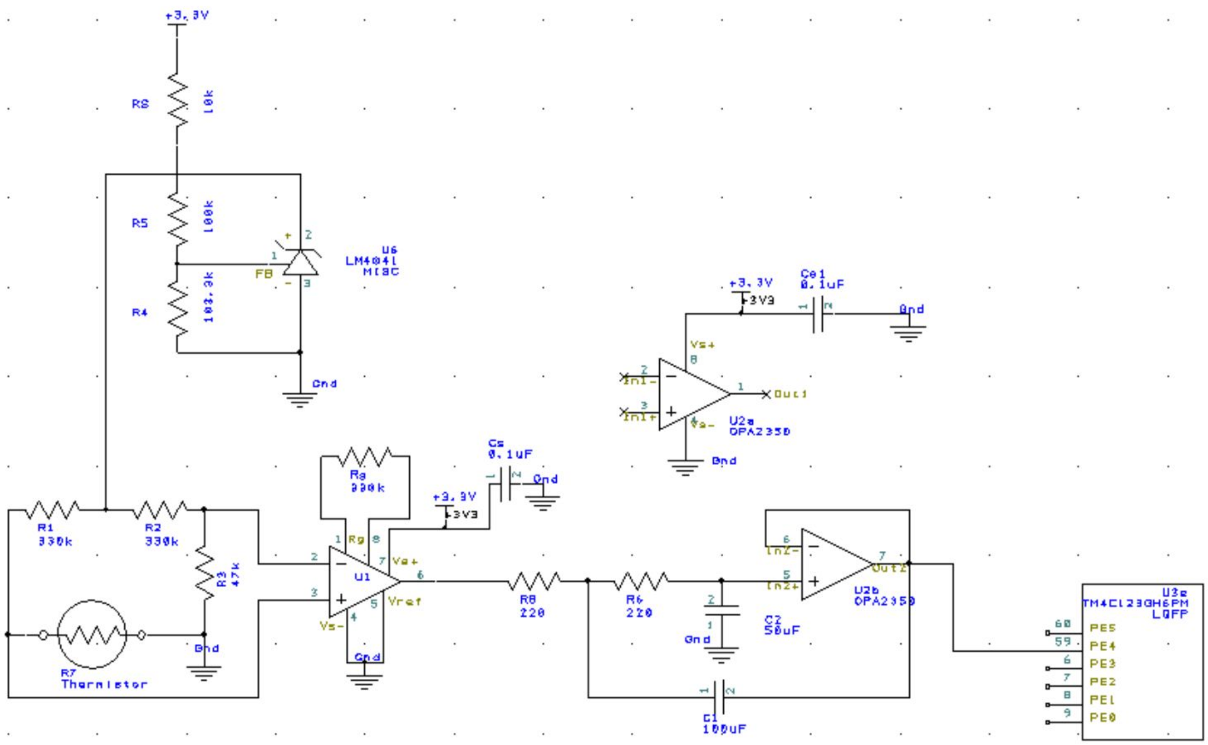
Objective

- Study ADC conversion and the Nyquist Theorem
- Develop a temperature measurement system using a thermistor

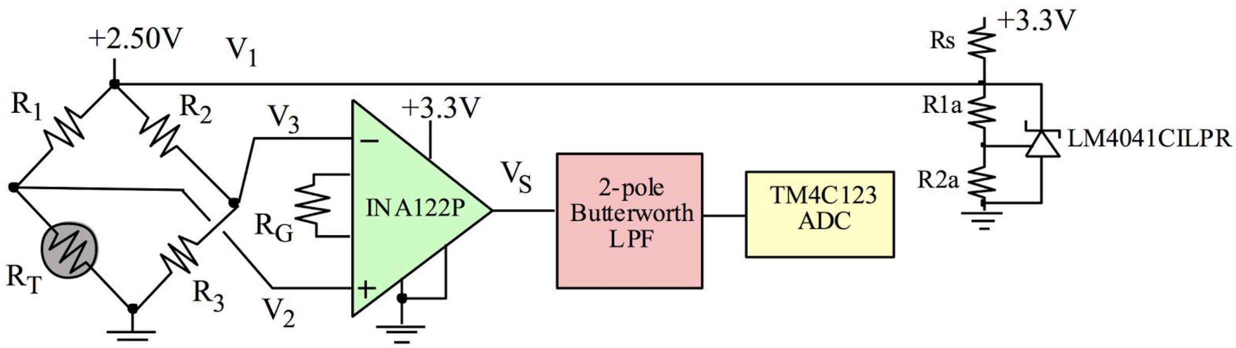
Hardware



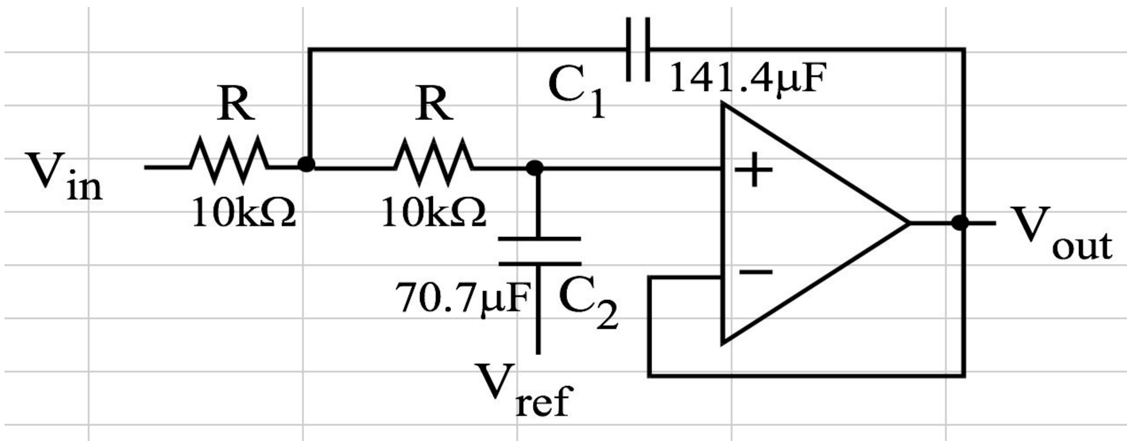
Software

See lab9.zip for all the code. Calibration file is also included.

Resistors and Capacitors:



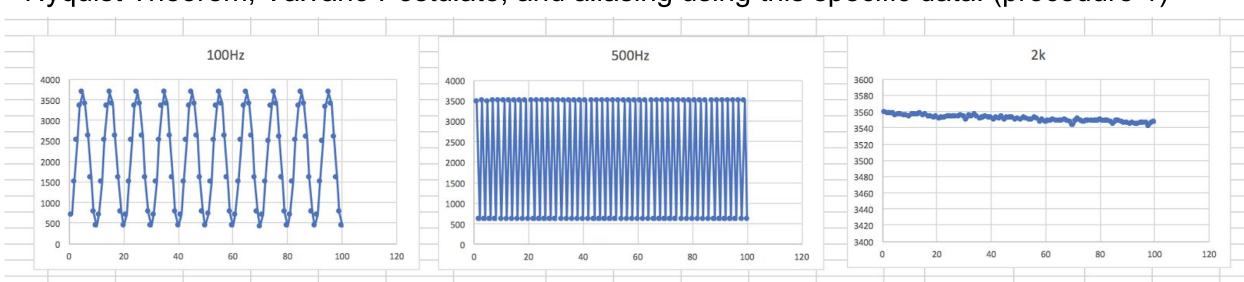
R1 = 330 kΩ   R2 = 330 kΩ   R3 = 47 kΩ   Rs = 10kΩ
R1a = 100kΩ   R2a = 103.3kΩ   Rg = 330 kΩ



R = 220 Ω   C1 = 100μF   C2 = 50 μF

Measurement Data

1) Plot the results by connecting the data points with a straight line. Describe the concepts of Nyquist Theorem, Valvano Postulate, and aliasing using this specific data. (procedure 1)



Nyquist Theorem: The sampling frequency must be at least twice the maximum frequency in the original signal in order for the sample to uniquely determine the signal, shown in the middle graph.

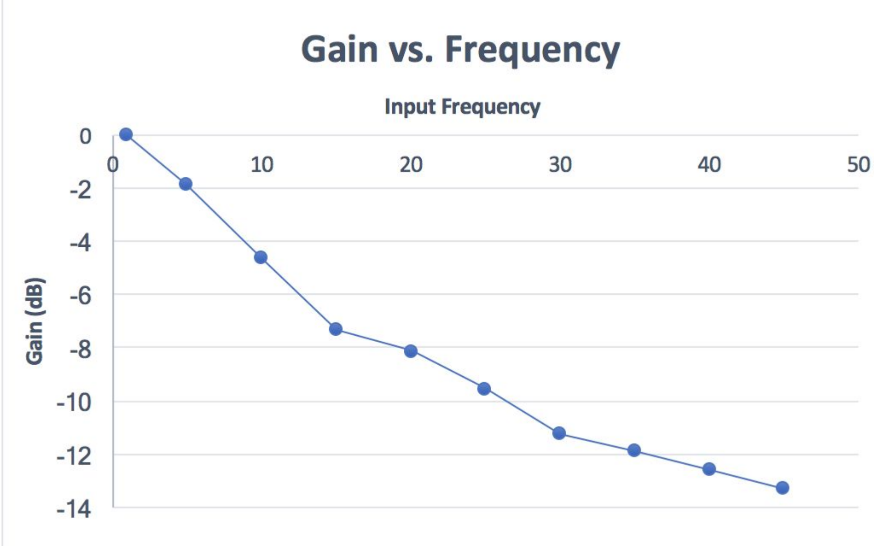
Valvano Postulate: The sampling frequency must be at least ten times the maximum frequency in the original signal in order for the reconstructed digital sample to look like the original signal, shown in the first graph.
Aliasing: The phenomenon where the reconstructed signal from the samples does not represent the intended signal, but some other signal. The reconstructed signal is related to the original signal through aliasing.

2) Record the voltage values at strategic places in your analog circuit. What voltage output do you get when the thermistor is disconnected? What voltage output do you get when the thermistor wires are shorted?

	V1 (V)	V2 (V)	V3 (V)	Vs (V)
short	2.494	0	0.312	0.002
58k	2.494	0.382	0.312	0.396
100k	2.494	0.571	0.312	1.479
122k	2.494	0.662	0.312	2.001
169k	2.494	0.837	0.312	3.001
open	2.494	2.414	0.312	3.174

3) Record the sine-wave amplitudes of the input and output voltages. Calculate the gain at each frequency. Plot the gain versus frequency response of your circuit.

input Freq	input (mV)	Vs (mV)	Vout (mV)	Gain (dB) (20log(Vout/Vs))
1	188	1020	1020	0.000
5	188	1020	820	-1.896
10	188	1020	600	-4.609
15	188	1020	440	-7.303
20	188	1020	400	-8.131
25	188	1020	340	-9.542
30	188	1020	280	-11.229
35	188	1020	260	-11.873
40	188	1020	240	-12.568
45	188	1020	220	-13.324



4) Creating a table showing the true temperature (xti as determined by the Fluke meter), and measured temperature (xmi using your device). Calculate average accuracy.

Trial	Measured Temp	True Temp	Average Accuracy
1	20.32	20	98.42%
2	20.32		
3	20.33		
4	20.31		
5	20.3		

5) record 10 independent temperature measurements. Calculate the standard deviation of these data and report S as reproducibility.

Trial	Temperature [C]	Reproducibility [C]	
1	24.19	0.0064	
2	24.18		
3	24.18		
4	24.17		
5	24.18		
6	24.18		
7	24.17		
8	24.17		
9	24.18		
10	24.17		

Analysis and Discussion

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

The Nyquist theorem states that in order to uniquely determine the input signal, you must sample at twice the maximum expected frequency. This is important in this lab because we are sampling an analog signal and we must make sure we are using a high enough sampling rate to reconstruct it digitally.

2) Explain the difference between resolution and accuracy?

Accuracy refers to how close to the 'true' measurement your system is. Resolution is the smallest difference in value that your system can detect.

3) Derive an equation to relate reproducibility and precision of the thermometer.

Reproducibility = precision. Both of these terms refer to the standard deviation of your measurements from the mean.

4) What is the purpose of the LPF?

LPF attenuates the frequencies outside of the passband, which are the noise in this case. The noise frequencies would overlap the temperature change band after sampling, hence we want to eliminate them.

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

First of all, the voltage vs. temperature curve is still not linear, but just not as nonlinear as the resistance vs. temperature curve.

The reason it becomes more linear: because voltage across the thermistor does not change linearly with the resistance of the thermistor. R1 in the circuit divides the voltage with R_T, so the equation relating V_3 to R_T is $V_3 = 2.5 \times \frac{R_T}{R_T + R_1}$. Therefore, this nonlinear relationship offsets the nonlinearity in R vs. T by some extent, resulting a more linear curve.

6) There are four methods (a,b,c,d) listed in the 4) 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 chose to use small table lookup (≈50 entries) with linear interpolation in between, instead of the nonlinear equation. The nonlinear equation will be more accurate since it's the actually equation that describes the relationship between temperature and ADC values. But calculations involving exponentials would cause a high time complexity and jitter (in our case we use hardware triggering so jitter is out of concern).