1. P1-1, P1-2, P2-1, P2-2, P2-3, P2-4, P2-5, P2-6
2. Table T2-1, Table T2-2, Table T2-3
3. Q2-1 What is the value of the SNR of the temperature signal now that dithering has been added and 160 points averaged per sample? How does the SNR compare to when no dithering was used? Why did this change? Is the value the same as theory would predict or different?
   1. **The value of the SNR is now 71.7 dB with dithering compared to the SNR of 24 without dithering. The signal’s strength was only 24 dB stronger without dithering as opposed to 71.7 stronger with dithering. The dithering helped with seeing the true strength of the signal that was masked by all the noise in the temperature sensor signal reading. The SNR was also improved by sampling the signal at a higher rate. Rather than sampling at only 1x sampling at 160 increases SNR and resolution of the signal, thus increasing SNR. Both oversampling and adding dithering to the signal increases the overall SNR reading of the signal. This proves the theory that oversampling & dithering a signal improves the overall quality of the ADC conversion of the signal.**
4. Q2-2 Compare the SNR when there was no dithering and when dithering plus averaging was used. Which has better SNR, the signal without dithering noise or the signal with dithered noise added and 256 samples were averaged? How many dB better? Why? How does this compare the theoretical improvement?

**a: The signal with dithering noise at 256 samples averaged had a significant increase in SNR. The signal SNR with no dithering had only an SNR of 46, compared to the dithering signal which had an SNR of 75. The difference between the two is a 31-dB difference. This is due to the dithering and the number of samples. The more samples, the better the SNR and the more dithering, the less quantization error and a more precise ADC conversion of the signal. This is exactly what happened in this situation.**

1. Q2-3 If only 16 samples are averaged, what is the SNR with dithering noise and 16 samples averaged? How does this SNR compare to when no dithering noise is added and no averaging is used?

**a: The SNR with dithering of a 16 sampled average is around 55 dB. With no averaging and no dithering, the SNR of the signal drops scientifically to about 24 dB. With no averaging and less dithering, the quantization noise rises causing the true signal to be covered up by the noise, thus losing precision in the ADC conversion and losing power seen form the true signal.**

1. Q2-4 Based on your experimental data, what is the equivalent number of bits in the ADC conversion when dithering noise is used and 256 samples are averaged?

**a: The equivalent number of bits used is 8 bits. This is because 28 = 256. The conversion was done at a resolution of 8 bits.**

1. Q2-5 What is the effective temperature resolution of your final measurement system? Justify your answer.

**a: The most effective temperature resolution for the system is around 19ºC. At this temp, the sensor reacts at a faster rate to a finger touch, than it does in a 21ºC environment. The temperate switch from 19ºC to a finger touch puts the sensor to work due to the drastic change in temperature. In a regular 21ºC environment, it takes the LM61 temperature sensor 30 more samples to change 20 code values from a low temperature to a high temperature, on the other hand; when it comes to cooling down, the temperature sensor gradually slopes down to equilibrium again in a 19ºC environment as opposed to a 21ºC where the LM61 at times will not go back to equilibrium. So 19ºC is the perfect temp range for the sensor to react accordingly for the best results.**

1. Q2-6 What was the value of the variance that you calculated using the running variance method in your code? How did it compare to Excel’s variance calculate on the same data?Was there any difference?

**a: The running variance was different compared to the Exce**

**Write Up:**

Include the cover sheet (following page) on top of your lab report.

**For a lab report grade of B, include the following.**

1. Your lab report must be submitted in MS Word using the IEEE Journal Transactions Format. A template Word document is posted on MyCourses for you to download.
2. Your lab report must use the two column format as given in the template.
3. Include a simple title. Include the names of all your lab partners as co-authors.
4. Include the requested plots and tables
5. Fully label the vertical and horizontal axes of graphs. For example, in some plots the vertical axis is the A/D converter reading as an integer from 0-1023 which represents temperature and the horizontal axis is the sample number. If the vertical axis is in engineering units, label the axis with the units.
6. Place a descriptive caption below each figure. The description that you write in the caption should sufficiently explain what is going on in the figure that a person who could not see the graph (e.g. a blind person using a text-to-speech program) would still be able to understand what the graph is showing.
7. Provide responses to each of the questions.
8. When responding to each question, restate the question in your own words and answer the question. Do not simply copy and paste the question text. For example, Q-1 was “What happened to the signal to noise ratio when the dither signal was added?”

**Do This:**

*As can be seen in figure X  and in table Y, the addition of dithering noise caused the signal to noise ratio to initially increase. However, later when….. was done, the SNR went….*

**Not This:**

*“Q-1 What happened to the signal to noise ratio when the dither signal was added?”*

*It went down.*

1. Briefly discuss of your results. In addition to a general discussion of your results, address the following:

**For a lab report grade of A, include the following.**

Your report will have section headings (see this handout for examples).

Your report need not include the procedure items from this handout.

Your report will not have more than 4 pages. Note that in two column format this is the same as approximately 8 pages of single column data.

Provide correct and well explained answers to the following questions. In your answers, restate the question.

1. For a nasal airflow temperature measurement system, the signal may be a little as 1 degree Celsius (i.e. the observed change in temperature from breathing in to breathing out).
   1. Assuming that no dithering or averaging is done, and a 10 bit A/D conversion is used, what is the signal to noise ratio in dB?
   2. If dithering and averaging is used, what is the SNR?

Note: For both cases, the signal is the variation in temperature (i.e. 1 Celsius) not the nominal temperature (i.e. 26 Celsius).

1. What is the approximate accuracy of the temperature measurement system assuming that the ADC is perfectly accurate and that the temperature sensor (LM61C) has accuracy as specified in its datasheet? Express this in degrees C and in millivolts.
2. What is the approximate precision of the temperature measurement system including the effect of the ADC, dithering, and averaging? Express this in degrees C and in millivolts. Be sure to state your assumptions (e.g. How many samples you averaged).
3. Review the objectives and the learning outcomes at the beginning of the handout. Have you addressed each of these topics in your report?
4. Your lab partner believes that the averaging and dithering process increased the accuracy of the measurement system. You believe that the measurement system has been made more precise but not more accurate. Write one to two paragraphs to explain your position to your lab partner.
   1. Provide supporting data (test results) and/or theory/equations to support any statements you make. Specifically include a section of results where you calculate the accuracy of the measurement system in degrees C and the precision of the system in degrees C.
   2. State any assumptions you made to come up with these results.