The report for this lab should be a brief but complete technical paper and should be done in that style. The style is rather formal and objective. For examples, see experimental journal articles in Physical Review Letters, IEEE Transactions on Nuclear Science or (especially) on the arxiv.org web site. The spell checker is your friend. Use it. Although you are working in groups, each student must write his or her own report. It should include the following items (not necessarily in this order):

1. Title, author name, list of partners, brief Abstract stating what you measured, your results with errors and comparison(s) with the accepted value(s). (Hint: it’s easiest write this last. It is really a summary. Also, be sure to put the results in the abstract.)

2. Brief overview of what Johnson noise is. Give a reference to the Physics 122 Lab writeup (or the text by Melissinos and Napolitano) and the appropriate sections in Horowitz and Hill for the theory - no need to repeat that.


4. Brief description of the measurement circuit explaining the purpose of the major components in the block diagram.

5. Describe the data acquisition (DAQ) VI and the connection to the Johnson noise circuit. What was the sampling frequency you used?

6. Describe the measurement of $g(f)$ and provide a plot of the function. Is the high frequency corner frequency as expected? Is the response still flat in the range 100 Hz to 1 kHz? What is the gain at the Nyquist critical frequency relative to the midband gain for your noise measurement? Evaluate the effect of aliasing on your power measurement.

7. Explain briefly how the noise $< V_n^2 >$ within some bandwidth is related to the sum of $|H_n|^2/N^2$ within the bandwidth (start with Parseval’s theorem for the discrete Fourier transform). (Reference: Essick, Ch. 10 plus my note linked to the Johnson noise lab discussion on the web page.)

8. Explain briefly why you expect $< V_n^2 >$, the mean squared noise signal at the output within your bandwidth, to be

$$< V_n^2 > = (e_A^2 + 4kTR)G^2(f_2 − f_1) ≡ a_0 + a_1R.$$ 

Define the quantities in the relation. (Reference: Horowitz and Hill, 2nd Ed., Sec. 7.17.)

9. Include a table of the $< V_n^2 >$ vs. $R$ data you are fitting. Be sure to use the accurate $R$ values from the supplied table rather than the marked nominal values on the Johnson noise test box. Give your values of $G$, $F_1$, $f_2$ and $T$. (added 5/11)
10. Use a LabVIEW linear least squares VI (with errors) to fit the function above (see the SmartSite wiki and Essick, Ch. 10). From the fitted parameters, find $e_A^2$, Boltzmann’s constant $k$ and the errors in these quantities using the covariance matrix from the fit plus errors in other quantities (such as $G^2$, $R$, $V$, etc.) as appropriate. Also evaluate how well the data are described by the curve using the $\chi^2$ test (state the number of degrees of freedom).

11. Compare with the accepted value of Boltzmann’s constant.

12. Compare $e_A$ with what you expect from the op-amp specifications in a non-inverting amplifier configuration (see Horowitz and Hill, p. 447 and the 116C class notes on noise).

13. Comment on the reasonableness (or otherwise) of your results.

14. Items mentioned in class recently (2011) which contribute to the error in your $k$ measurement:

   (a) Be sure to estimate the error in your measurement of $g$. State what voltmeter you used and its accuracy.

   (b) Estimate the accuracy and least count of the NI ADC in the DAQ card on the scale(s) you used. (The VI default scale is -0.5 V to 0.5 V.)