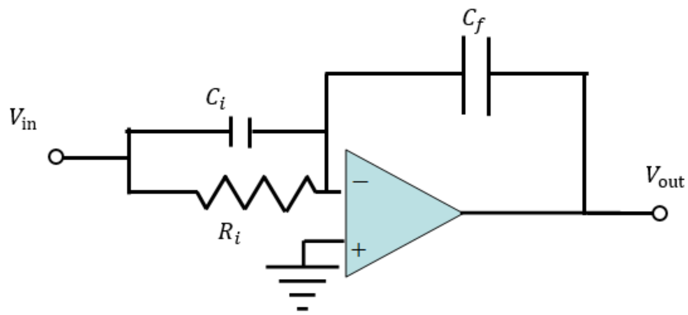
BIEN325: Homework 2 Solutions **Name:____________________**
Winter 2023-24

1. **(From Lecture 2 on Operational Amplifiers. See the slide "Generalized Inverting Amplifier")** For the circuit below, what is the overall gain ($V_{\text{out}}/V_{\text{in}}$) as a function of the frequency ω?



2. **(Lecture on Operational Amplifiers 1, Inverting Amplifier Configuration)** Design an active low-pass filter using a single op-amp with an **inverting** configuration and corner frequency f_c = 500 Hz and Gain = 20, given R_f = 100kΩ.

   a. Sketch the circuit diagram of the filter.
   b. What values are necessary for R_i and C_f to meet the design requirements?
   c. What is the frequency transfer function of the filter $\frac{V_o(jw)}{V_i(jw)}$? (provide the general transfer function with variables only (ie. in terms of: R_f, R_i, C_f, ω, τ, where $\tau \equiv R_f C_f$)

3. **(Lecture on Operational Amplifiers 1, Inverting Amplifier Configuration)** Design an active high-pass filter using a single op-amp with **inverting** configuration for a corner frequency f_c = 2 Hz and Gain = 20 given R_f = 660kΩ.

   a. Sketch the circuit diagram of the filter.
   b. What values are necessary for R_i and C_i to meet the design requirements?
   c. What is the frequency transfer function of the filter $\frac{V_o(jw)}{V_i(jw)}$? (provide the general transfer function with variables only (ie. in terms of: R_f, R_i, C_i, ω, τ, where $\tau \equiv R_i C_i$)

4. **(Lecture on Operational Amplifiers 1, Inverting Amplifier Configuration)** Design an active band-pass filter using a single op-amp in an **inverting** configuration with high-pass corner frequency f_c = 2 Hz, low-pass corner frequency f_c = 500 Hz, given R_i = 33 kΩ and R_f = 100 kΩ.

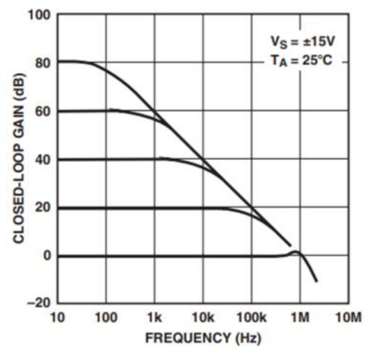
   a. Sketch the circuit diagram of the filter.

   b. What values are necessary for C_i and C_f to meet the design requirements for the band-pass filter?

c. What is the gain of the filter assuming we are in the pass-band? What is the center frequency of the filter?

d. What is the frequency transfer function of the filter $\frac{V_o(j\omega)}{V_i(j\omega)}$? (Provide the general transfer function with variables only (i.e.. in terms of the variables R_f, R_i, C_i, C_f, ω)?

5. **(Lecture on Operational Amplifiers 1, "Reality")** What is the approximate bandwidth of the OP07 op amp if it is put into a configuration with a closed loop gain of 100 given the following Figure TPC 16 from the OP07 specifications sheet?



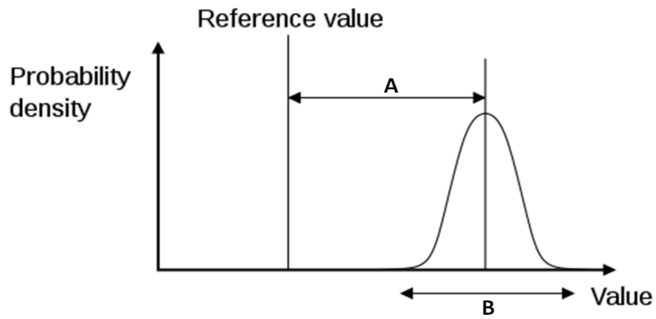
TPC 16. Closed-Loop Response for Various Gain Configurations

6. **(Lecture on Hypothesis Testing, "Sensitivity" and "Specificity")** A new endocrine cancer diagnostic algorithm is tested on 70 subjects. Ten of them have cancer and 60 of them are cancer-free. The diagnostic algorithm has 90% sensitivity and 80% specificity on these subjects. What are the numbers of True Negative and False Positive cases? [show your work]

7. (**Lecture on Hypothesis Testing, "T Test and T Statistic" slides, plus "Converting to Probability"**) A topic of recent clinical interest is the possibility of using drugs to reduce infarct size in patients who have had a myocardial infarction within the past 24 hours. Suppose the mean infarct size in untreated patients is 25 ck-g-EQ/m^2. Furthermore, in 8 patients treated with a drug the mean infarct size is 16 ck-g-EQ/m^2 with a standard deviation of 10 ck-g-EQ/m^2. Is the drug effective in reducing infarct size if we assume $p<0.05$ is significant? (This will be a one-sample t test, with degrees of freedom $n-1$, where n is the number of observations.)

8. (**Lecture on Hypothesis Testing, "Accuracy vs. Precision")** The accuracy and precision of a biomedical instrumentation device is related to the true value and reproducibility of their

measurements. Given the probability density below, which parameter (A or B) represents accuracy, and which on represents precision.



9. (**Lecture on Hypothesis Testing, "T Test and T Statistic" slides**) You perform a study to determine if average bone density is greater (one-tailed test) for women aged 40-44 than for women aged 50-54. The data are shown in Table 1. Assume that you have already performed an F test and **the standard deviations of the two data sets were statistically different.** Use Excel to perform a one-tailed t test, assuming unequal variances, and to decide whether the 50-54 population has lower bone density than the 40-44 population at the 0.05 level. What is the correct p value for this study? (**Please do not retype any of the data**. You can copy and paste the numbers into Excel.)

Bone Density g/cm^2	
Age 40-44	Age 50-54
1.11	1.08
1.12	1.16
1.20	1.11
1.21	1.11
1.20	1.21
1.22	1.24
1.10	1.12
1.21	1.12
1.18	1.16
1.13	1.11
1.16	1.04
1.18	1.18
1.24	1.12
1.12	1.02
1.19	0.98
1.24	1.22
1.23	1.24
1.11	1.14
1.12	1.01
1.16	1.18
1.20	1.17
1.17	1.16
1.15	1.10
1.23	1.10
1.24	1.12

10. **(Lecture on Hypothesis Testing, "Least Squares" slides and "Regression P Value" slide)** A study is performed to determine whether coffee consumption (horizontal axis) is correlated to body mass index (vertical axis). The data are shown below. (1) Use a linear regression ("regression" in Excel's Data Analysis add-in) and the p statistic to determine whether a correlation is statistically significant at the 0.05 level. (2) Plot the data on an x-y scatter plot and show the linear regression with the equation and the R value. (Use markers for the data points and a solid line for the linear regression).

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Coffee Consumption (cups/day)	Body Mass Index (Kg/m^2)
7	20.07
9	18.46
4	16.16
0	22.03
8	19.96
1	17.09
0	18.80
6	20.55
9	18.73
9	22.03
4	18.25
5	15.68
1	18.64
7	18.83
2	18.81

Graduate Content

Create a MATLAB program to do the following. You will use an m file that will call two functions that you create, one to ensemble average a signal, and one to return a signal's mean and standard deviation.

1. Generate a set of signals as an n by m array of Gaussian random numbers withg a mean value of 12 and a standard deviation (σ_G) of 3. Initially let n be 1024 and m be10.
2. Plot the first record as a time series. (e.g., if you call your two dimensional array s, plot s(1,:)).
3. Ensemble average the m records.
4. Plot the ensemble averaged signal.
5. Find the average and standard deviation of each of the original signals and the average and standard deviation of the ensemble averaged signal.
6. Compare the standard deviation of each simulated signal to the standard deviation fed into the Gaussian random number generator.
7. Compare the standard deviation of the ensembled signal to the standard deviation fed into the Gaussian random number generator. Does the result agree with the value σ_G/m?
8. Rerun your code with $m = 100$, and answer the question in Part 7.