2024

Chem 420 (Module1)

FINAL ASSIGNMENT

DUE : 4 PM ON FEBRUARY 16TH

1. Download the 10 data files (A2Q1_runx.dat) from the Canvas page. These correspond to an ensemble averaging experiment with a different number (x) of co-adds. For each dataset, determine the magnitude of both the signal and the noise as well as the S/N ratio ? Use these results to show how the S/N improves with the number of co-added measurements. (I expect a graph).

2. Provide the decimal equivalent for the following binary numbers. The most significant bit is the left-most digit.

Binary Number	Decimal Equivalent
000111	
10101010	
110110	
111001 + 1010	

3. Prove that the roll-off for all low pass filters in a Bode plot is -20 dB. Hint : Assume $R^2 >> Xc^2$ in the roll-off region.

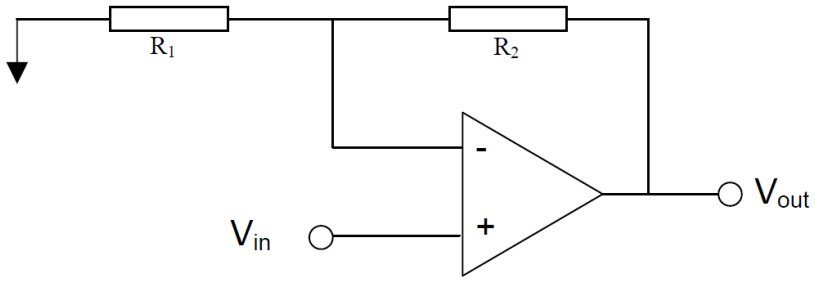
4. A student wants to measure a 10 mV, 10 Hz ac signal but the signal is buried under high frequency noise.

   a) Design a low-pass filter that will attenuate the noise above 100 Hz by at least a factor of 10 and will have a time constant less than 25 ms. The only components you have at your disposable are a 10 µF capacitor and several 10kΩ and 4.7 kΩ resistors.

   b) How much does your low-pass filter affect your signal at 10 Hz ?

   c) What's the 3dB value for your filter ?

5. Pictured below is a buffer amplifier with gain (also known as a non-inverting amplifier).



Show that the output voltage for this circuit is given by the following equation

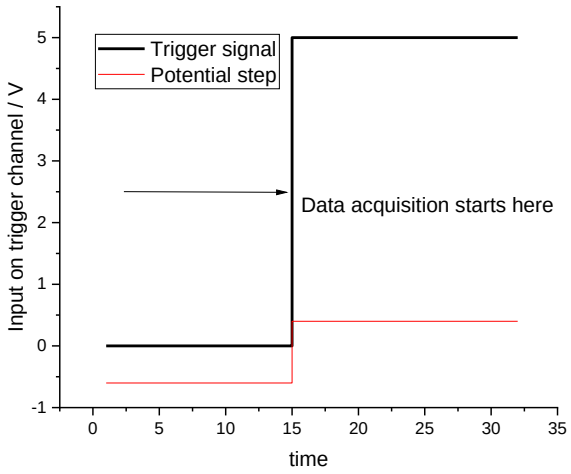
$$V_{out} = V_{in}\left(\frac{R_2}{R_1} + 1\right)$$

6. An Ion Selective Electrode (ISE) with an internal reference electrode produces a voltage of 1.0V. What must be the input resistance of the circuit used to measure this voltage if the loading error is not to exceed 0.1% ? The output resistance of a typical ISE is 20 MΩ.

7. Build an operational amplifier circuit that will produce a linear voltage ramp output that starts at -0.15 V and increases (makes more positive) the output voltage at a rate of 10 mV/s. Use a 1.5 V battery as the voltage source. This can be done using only two op-amps.

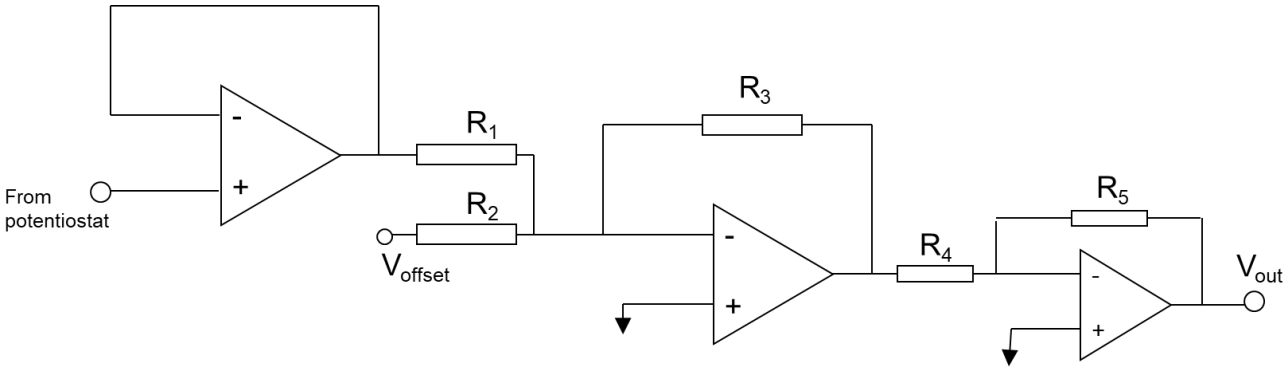
8. Calculate the rms thermal noise associated with a 1.0 MΩ load resistor operated at room temperature if an oscilloscope with a 1 MHz bandwidth is used. If the bandwidth is reduced to 100 Hz, by what factor will the thermal noise be reduced ?

9. A graduate student in my lab needs to design a circuit that will trigger the acquisition of a specific detector. The detector will start acquiring data when it registers a signal rising from 0 V to 5.0 V and crosses a threshold of 2.5 V. See bold black line in the graph below.



The student wants the data acquisition trigger signal to be synched to the potential she applies to a working electrode in an electrochemical experiment. She steps the potential from -0.6 V to +0.4 V.

a. Here is the student's proposed circuit. Provide appropriate values for the circuit elements in the table below.

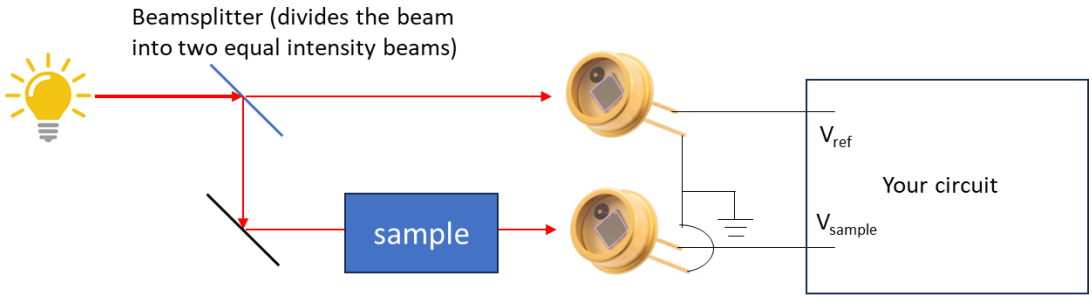


Element	Value (specify units)
R_1	
R_2	
R_3	
R_4	
R_5	
V_{offset}	

b. The circuit above is built and found to be unstable due to noise from RF frequencies at the CLS. Adjust the circuit above to filter signals above 10 MHz to less than 10% of their nominal levels.

c. Calculate the useful bandwidth (i.e. frequency range where the final output will reach the trigger threshold for the input shown in red in the figure above) of your modified circuit assuming that your bandwidth is limited by your passive circuit elements and not the op-amps.

10. Often in laser spectroscopy, the greatest source of noise is caused by intensity fluctuations in the laser source. One way to reduce the noise is to use a version of a balanced-detector scheme as shown in the diagram below.



This is based on the assumption that the two photodiode detectors have identical responsivity. Provide a circuit to process the reference and sample beams that will remove common mode noise. Assume ideal behaviour in your op-amps.