

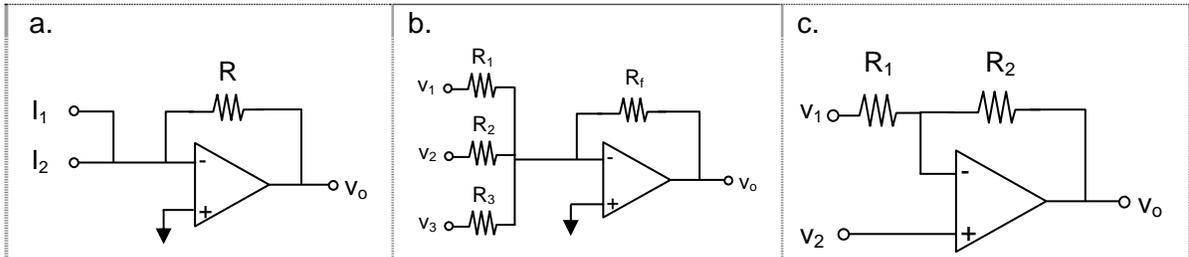
Complete these problems on separate paper and staple it to this sheet when you are finished. Please initial each sheet as well. Clearly mark your answers. **YOU MUST SHOW YOUR WORK TO RECEIVE CREDIT.**

Warm-up

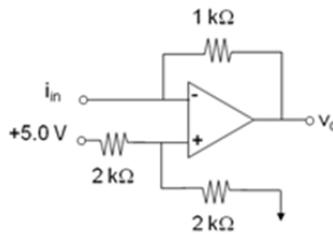
1. The range of frequencies that a measurement is sensitive to is called the frequency _____ . (2 pts)
2. Application of large reverse-bias potentials to diodes can lead to _____ , resulting in a large current at essentially constant potential. (2 pts)
3. The _____ does not use a detector such as an electron multiplier to count ions. Instead, an image charge is measured and converted to a signal. (2 pts)
4. The _____ of a measurement can be described using the slope of the calibration curve for the measurement. (2 pts)
5. Clearly outline the steps you would take to determine the detection limit for an absorbance measurement based around Beer's Law ($A = abc$). Identify the data that you would need to collect and how you would use the data to calculate a LOD. (10 pts)

Electronics: Complete TWO of the problems 6-8. Clearly indicate which problem is not to be graded. Show all work for calculations. (12 pts each)

6. You have a box that contains 50 op-amps and ten each of the following resistors: 1, 2, 5, 10, 20, 50 k Ω . Design a circuit to do the following calculation: $v_{out} = 30(v_1 + 2v_2) - 10v_3$ (You may not need all of the components in your box.). You do not need to do calculations to prove your result; it just needs to be correct.
7. Derive the relationship between the input and output signals for **two** of the following circuits. Show all work.



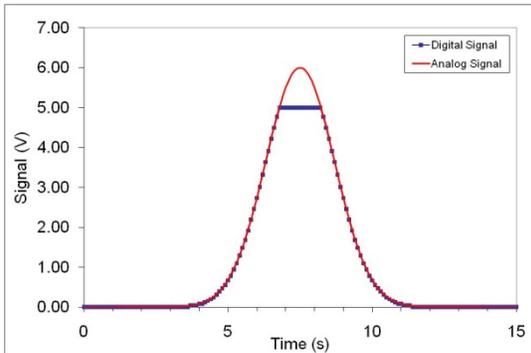
8. Given the circuit below, what output would you expect for a 1.25 mA input current? Derive the relationship between v_o and i_{in} . How would you redesign this circuit to make it suitable for measurement of low current signals (micro- to nano-amp signals)?



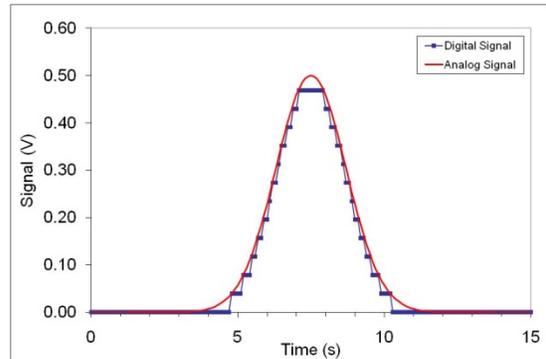
A/D Conversion, Signals and Noise: Complete TWO of the problems 9-11. Clearly indicate which problem is not to be graded. Show all work for calculations. (12 pts each)

9. Ensemble averaging (also known as *coadding*) and boxcar averaging are two common software-based approaches to improving signal to noise ratios (S/N). Concisely describe each approach and a scenario where boxcar averaging would be preferred over ensemble averaging for S/N improvement. What pitfalls need to be considered for each method?
10. Considering the four types of noise we discussed, what characteristics should a measurement have to minimize the contribution of all four noise sources simultaneously?
11. The plots below show the digital representation of two Gaussian analog signals, as acquired by an eight bit analog to digital converter (ADC) with an input range of ± 5.0 V. In neither case is the conversion ideal. For each case, explain what has led to the non-ideal conversion and suggest a solution to each problem that does not involve buying a new ADC.

a.



b.



Mass Spectrometry: Complete *THREE* of the problems 12-15. Clearly indicate which problem is not to be graded. Show all work for calculations. (12 pts each)

12. Mass spectra from electron impact (EI) sources are typically much more complicated than those from chemical ionization (CI), explain why this is the case. Why do typical MS instruments designed for organic mass spectrometry often have both EI and CI capabilities?
13. The overall resolving power of a mass spectrometer is the result of limitations from all components of the MS. Describe how each of the following serves to limit resolution in a MS experiment.
 - a. The ionization source (such as an ICP source)
 - b. The mass analyzer (such as a quadropole)
 - c. The detector (such as an electron multiplier)
14. Electrospray ionization (ESI), matrix-assisted laser desorption ionization (MALDI) and atmospheric pressure chemical ionization (APCI) are relatively new approaches to ionizing large molecules. Compare how ions are formed in each process and discuss the similarities and differences in the spectra observed from the sources.
15. Currently, two of the most popular mass analyzers are the quadrupole mass filter and the time of flight mass analyzer. These two devices have very different principles of operation. Clearly describe how each device serves to separate ions and the key benefits and limitations of each device.

Possibly Useful Information

$\frac{dQ}{dt} = I = C \frac{dV}{dt}$	$P = IV = I^2R$
$V = IR$	$v_o = A(v_+ - v_-)$
$v_{rms} = \sqrt{4kTR\Delta f}$	$001 + 001 = 010$
$\Delta f = \frac{1}{3t_r}$	$i_{rms} = \sqrt{2ie\Delta f}$
$S_m = \bar{S}_{bl} + ks_{bl}$	$c_m = \frac{S_m - \bar{S}_{bl}}{m}$
$\lambda = \frac{RT}{\sqrt{2}\pi d^2 N_A P} \approx \frac{5 \text{ cm}}{\text{mtorr}}$	$\frac{m}{z} = \frac{B^2 r^2 e}{2V} = F_c$
$F_M = Bzev = \frac{mv^2}{r} = F_c$	$k = 1.38 \times 10^{-23} \text{ JK}^{-1}$

