

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.

**Bonus (5 points maximum)**

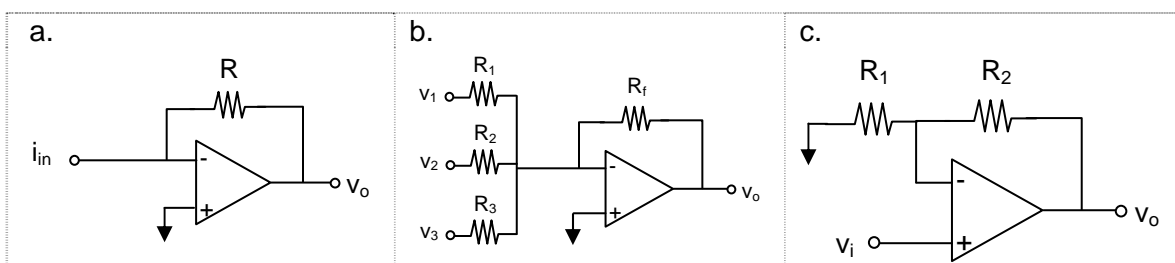
In your reading and in our problem set, you came across the name Nyquist. In what context did the name appear? Describe clearly the guideline that bears the Nyquist name.

**Warm-up (2 pts each)**

1. The range of frequencies that a measurement is sensitive to is called the frequency \_\_\_\_\_.
2. Application of large reverse-bias potentials to diodes can lead to \_\_\_\_\_, resulting in a large current at essentially constant potential.
3. The \_\_\_\_\_ is the span of concentrations over which instrument response is directly proportional to concentration.
4. The \_\_\_\_\_ of a measurement can be described using the slope of the calibration curve for the measurement.

**Answer in a few sentences, or with a calculation. Complete four of the following. Clearly indicate which problem is not to be graded. Show all work for calculations. (10 pts each)**

5. You have a box that contains 50 op-amps and ten each of the following resistors: 1, 2, 5, 10, 20, 50 kΩ. 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.
6. Considering the four types of noise we discussed, what characteristics should a measurement have to minimize the contribution of all four noise sources?
7. Clearly outline the steps you would take to determine the detection limit for an absorbance measurement based around Beer's Law. Identify the data that you would need to collect and how you would use the data to calculate a LOD.
8. There are two key characteristics of an A/D or D/A converter that limit its ability to accurately convert between analog and digital values. Identify each of these parameters and describe how they limit the accuracy of a conversion.
9. Derive the relationship between the input and output signals for **two** of the following circuits. Show all work.

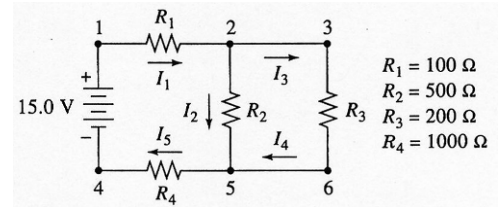


**A little more involved. Complete three of the following. Be clear and concise. Clearly indicate which problem is not to be graded. (14 pts each)**

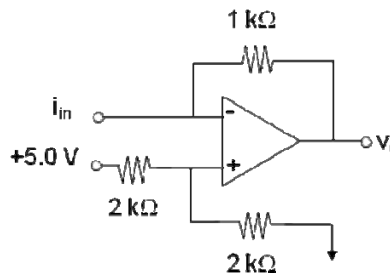
10. For the following circuit, the current,  $I_4$  is 8.65 mA.

Calculate:

- the potential difference across resistor  $R_2$ .
- the current through resistor  $R_4$ .
- the power dissipated by resistor  $R_4$ .
- the potential difference between points 1 and 6.

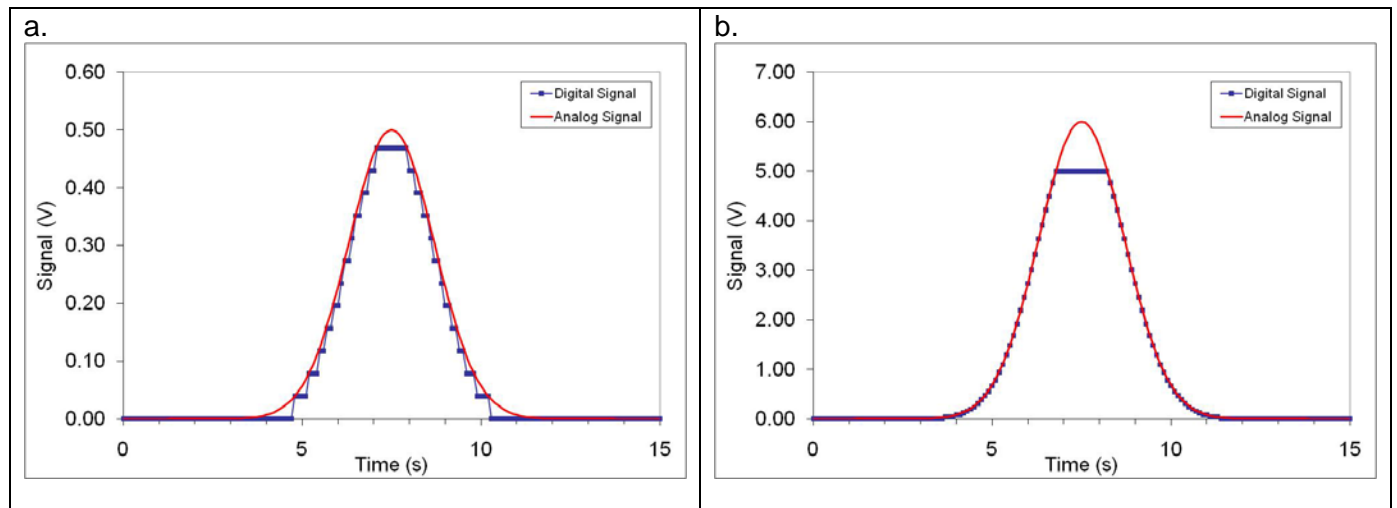


11. Given the circuit below, what output would you expect for a 1.25 mA input current? Derive the relationship between  $v_o$  and  $i_{in}$ . How would you redesign this circuit to make it suitable for measurement of low current signals (micro- to nano-amp signals)?



12. Ensemble averaging and boxcar averaging are two common software-based approaches to improving signal to noise ratios (S/N). Describe the key characteristics of each approach and a scenario where boxcar averaging would be preferred over ensemble averaging for S/N improvement. What pitfalls does one need to be concerned with for each method?

13. The plots below show the digital representation of two Gaussian signals, as acquired by an eight bit analog to digital converter (ADC) with an input range of  $\pm 5.0$  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.



### Possibly Useful Information

$\frac{dQ}{dt} = I = C \frac{dV}{dt}$	$P = IV = I^2R$
$V = IR$	$v_o = A(v_+ - v_-)$
Bilbo Baggins date of birth: September 22, TA 2890	$001 + 001 = 010$
$v_{rms} = \sqrt{4kTR\Delta f}$	henway = ~2-3 pounds
$\Delta f = \frac{1}{3t_r}$	$i_{rms} = \sqrt{2ie\Delta f}$
$S_m = \bar{S}_{bl} + ks_{bl}$	$c_m = \frac{S_m - \bar{S}_{bl}}{m}$

