BME154L (Palmeri)

Spring 2010

Exam #2

Instructions:

- Write your name at the top of each page.
- Show all work (this is *critical* for partial credit!).
- Only work in the space provided. Ask for extra paper if necessary.
- Read through each complete question before starting to work (this may save you some time).
- <u>Remember to include units with all answers and label all plot axes.</u>
- Clearly box all answers.
- Assume that all components are ideal unless otherwise stated.

In keeping with the Duke Community Standard, I have neither given nor received aid in completion of this examination.

Signature:______________________________________

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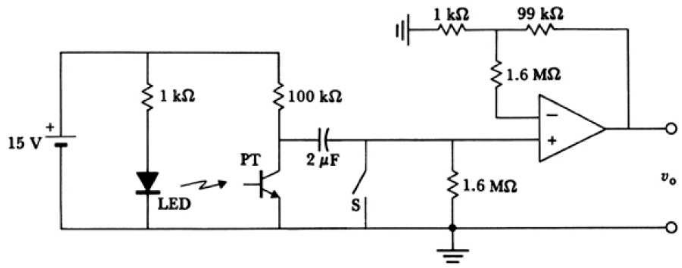
Problem #1 15 points



Above is a photodetection circuit for a photoplethysmograph...

(a) *Briefly* describe:

1. The purpose of a photoplethysmograph,
2. The physical principles underlying its function, including the relationship between the power emitted from the LED and the power detected by the phototransistor (PT).

(b) What is the purpose of the 2 μF capacitor in the circuit?

(c) What is the purpose of the op amp in the circuit?

Problem #2   15 points

(a) Sketch the frequency power spectrum for a delta function.

(b) Sketch the frequency power spectrum for white noise.

(c) How can two signals that are very different in the time domain have the same power spectra?

(d) The sliding window averager can be implemented as a convolution operation between your signal and a RECT function, where the width of the RECT is a function of the number of samples in your averaging window. Based on this knowledge, a sliding window averager behaves like what type of filter? Justify your answer using the convolution property in the frequency domain (sketches are fine/preferred over lots of words!).

Problem #3 10 points

A data transmission line has a throughput of 1 Mbit/s. A doctor wants to remotely monitor respiratory rate using tidal volumes ($\approx$ 500 mL) from an intubation tube using a pneumotachometer. The default temporal sampling rate on the pneumotachometer is 100 kHz, but with 32-bit precision per sample, the bandwidth of the transmission line will be exceeded.

(a) What does a pneumotachometer directly measure, and how is that useful in the content of measuring tidal volumes?

(b) What can be done to reduce the amount of data that is transmitted without compromising the ability to accurately report respiratory rate.

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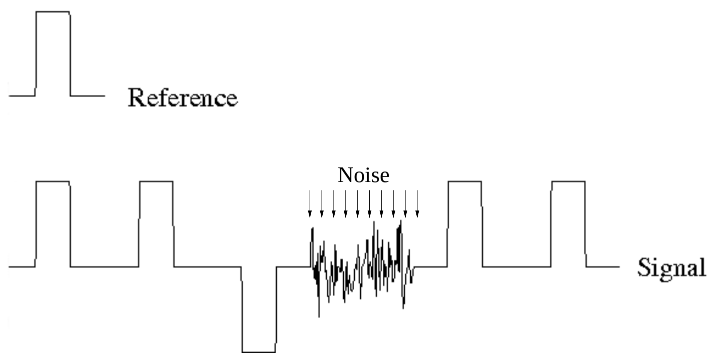
Problem #4 10 points

A clinician is using thermodilution methods to measure the cardiac output for a patient; unfortunately the clinician is a bit sloppy and has an error of $\pm10\%$ on the estimated bolus volume injected and a $\pm$ 20% error on the initial temperature of the bolus after rapid injection. What are the maximum errors associated with the calculated flow rates associated with these two measurement errors?

Problem #5 15 points



(a) Sketch the cross correlation function between the signal above and the specified reference.

(b) Assuming that the "true" signal includes the periodic RECT waveforms, sketch the block diagram for a device that will remove regions of noise like that shown in the middle of the signal without distorting the RECT waveforms; you can either use the signal, your correlation signal, or both signals as the input to your device. *The logic and progression of your signal processing steps is more important than dealing with the details of the circuits you would use to perform given functions. For example, if you need a peak detector, just have a block for peak detection with inputs related to your threshold criteria; you don't need to use comparators, differentiators, etc. to get a peak.*

Problem #6   35 points

(a) Sketch a normal ECG signal for a single heart beat, including the waveforms associated with atrial depolarization, ventricular depolarization and ventricular repolarization (label these on the sketch).

(b) *Briefly* describe the characteristic/defining ECG signal features associated with first-, second-, and third-degree heart block.

(c) *Briefly* describe the differences between an asynchronous and a synchronous pacemaker.

(d) When is the worst time during a cardiac cycle to deliver a shocking pulse? Why is this?

(e) Sketch the block diagram for a rate-responsive pacemaker being used to treat third-degree heart block. Your device has several design criteria/considerations:

1. Ability to set the resting and maximum heart rate thresholds,
2. Have the heart rate increase linearly as a function of demand,
3. Use one thermistor to use to monitor a physiologic system to determine metabolic demand for your pacemaker. Specify the physiologic system you are monitoring, the location of your measurements in the body, and the output of the circuit that you are utilizing for the rest of your device,
4. You have access to an ECG trace.

The logic and progression of your signal processing steps is more important than dealing with the details of the circuits you would use to perform given functions. For example, if you need a peak detector, just have a block for peak detection with inputs related to your threshold criteria; you don't need to use comparators, differentiators, etc. to get a peak.

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Problem #7 EXTRA CREDIT (2 points)

Forget to label your axes on one of your plots? Forget to study a certain topic? Well, here's your chance to earn a couple of points back thanks to Duke's recent basketball success.

Duke's fourth national championship came against Butler on Monday; list the schools that Duke has defeated for the first three championships and the years those games were played.

1.
2.
3.
4. Butler (2010)