

BML800: Research Techniques in Biomedical Engineering
Semester – I, 2020-21, Major Exams
Total Marks: 60

1 A mercury thermometer is used in the COVID ward of a hospital to monitor the temperatures of patients. Thermometers are always kept in an ice-bath (0°C) until measurement are to be made and returned to the bath after every measurement. Nurses are instructed to wait exactly 20s before taking readings due to high patient load and check for 0°C reading before every measurement. For an asymptomatic subject with actual body temperature of 37°C , a nurse noted a temperature reading of 0°C before administering the thermometer and 35°C after the stipulated 20s.

a The same thermometer was then used to measure the temperature of a symptomatic patient with body temperature of 39°C , following the above protocol. What was the relative measurement error in the temperature reading after 20s? [4]

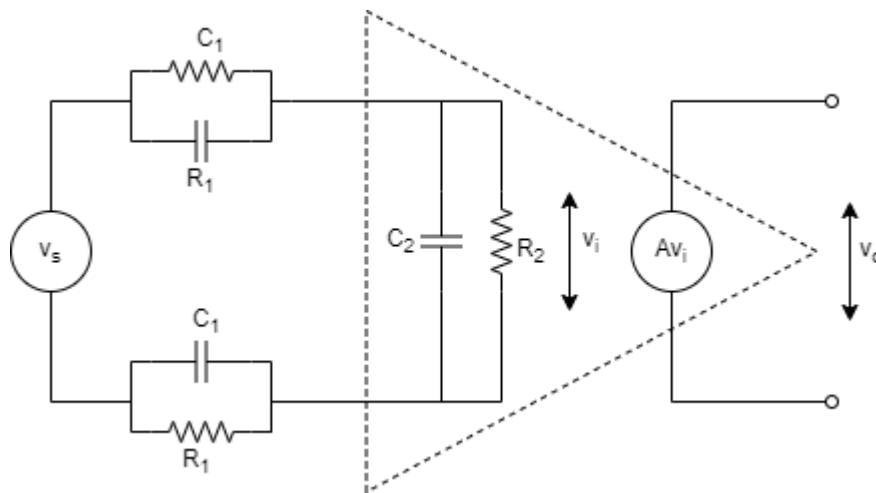
b The above protocol led to major misdiagnosis and you are now tasked with revising the protocol such that the relative error is within 2%. Assuming that all measurements are to be made from 0°C as before. What is your recommendation for the hospital and why? [3]

2 Two biopotential electrodes are placed directly on an excised muscle and connected to a differential bioamplifier. The equivalent circuit is shown below:

a If $C_2 = 0$, and the gain of the amplifier is A , calculate v_o . [4]

b For a finite C_2 , what value of C_2 will lead to the output voltage v_o to be independent of frequency. [4]

c With the value of C_2 value obtained in part (b), if $R_2/R_1 = 10^5$, $A = 10^6$, calculate v_o for $v_s = 1\text{nV}$. [3]



3 Consider a catheter-based pressure measure system with a diaphragm type pressure sensor. Such a system is often modelled as a second-order linear system. It is found that an air bubble is lodged in the catheter very close to the diaphragm. The compliance (or capacitance) of the bubble is 3 times that of the diaphragm.

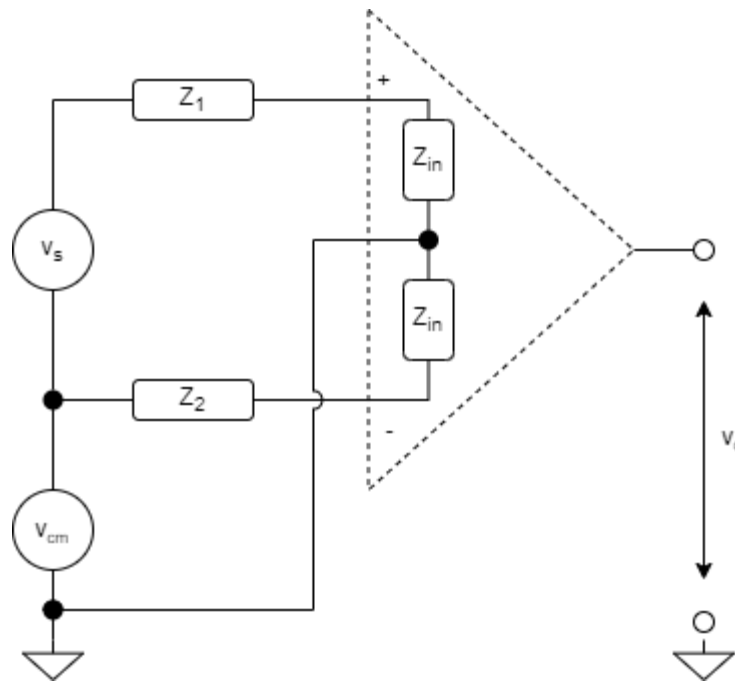
a Draw the equivalent circuit model of the catheter system making suitable assumptions. [3]

- b If the system was critically damped prior to the introduction of the bubble. Calculate the damping ratio after the bubble was introduced. [3]
- c How would you recommend that we restore the system to being critically damped without affecting the natural frequency of the system (by a significant amount)? [2]

OR

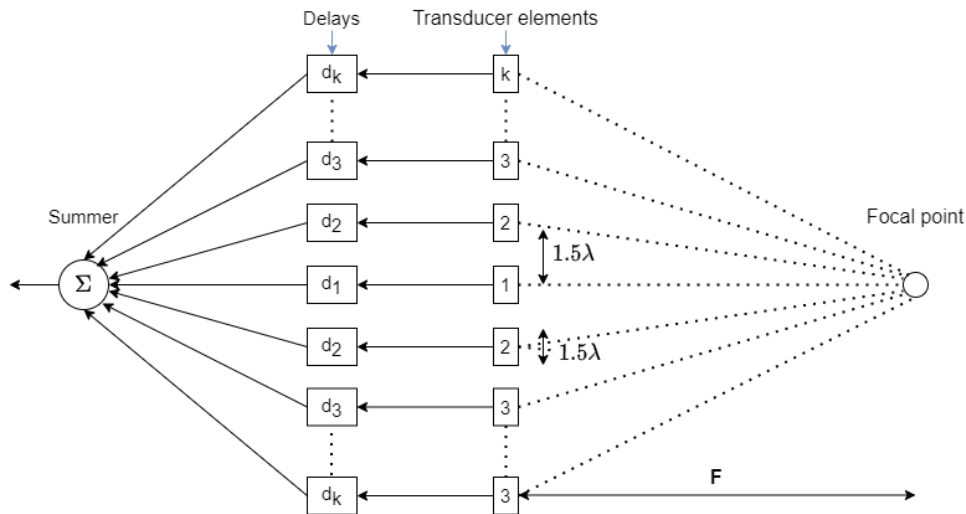
3 Consider the biopotential measurement system in the figure below. Even after careful matching, the difference between the two electrode impedances ($Z_2 - Z_1$) was found to be $10k\Omega$. A common mode voltage of $0.1\mu V$ was found to be interfering with both input traces.

- a Derive an expression for V_o , in terms of the CMRR of the amplifier and differential gain A_{diff} . [3]
- b To find the effect of this common-mode noise, the inputs are tied together ($V_s = 0V$). Find V_o , assuming $Z_{in} \gg Z_1, Z_2$, and $A_{diff} = 10^6$, $CMRR = 100dB$. [3]
- c Now, find V_o , when $V_s = 1\mu V$. [2]



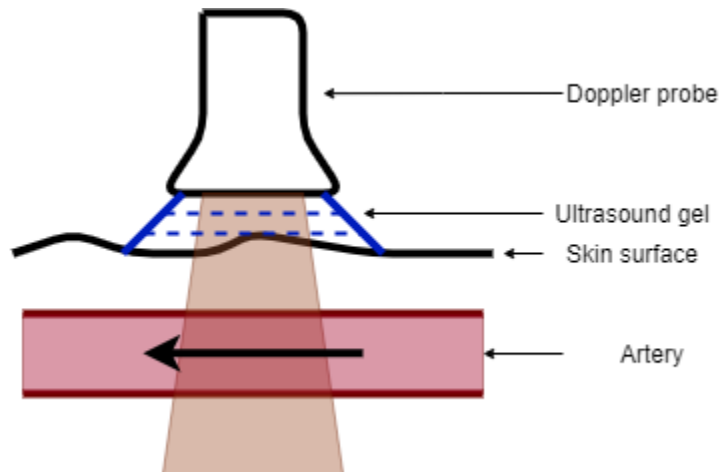
4 The figure below shows a 5MHz ultrasound transducer with kerf and element width of 1.5λ . Receive beamforming is being performed with 5 elements.

- a Calculate the appropriate delays for elements 1 and 2 for a delay-and-sum beamforming process when the focal point (F) is at 4cm (see figure). Assume speed of sound = $1500m/s$. (HINT: Simple geometry is all you need) [3]
- b In receive beamforming, the focal point is moved continuously. Obviously delays corresponding to every focal point cannot be stored in memory. Derive an equation that describes the beamformer delay (d_k), for any transducer element k , as a function of the speed of sound, wavelength and the focal distance (F). [4]
- c A lateral resolution of 1 wavelength is desired at 5cm focal depth, what is the minimum number of elements to be recruited for dynamic receive aperture. [2]

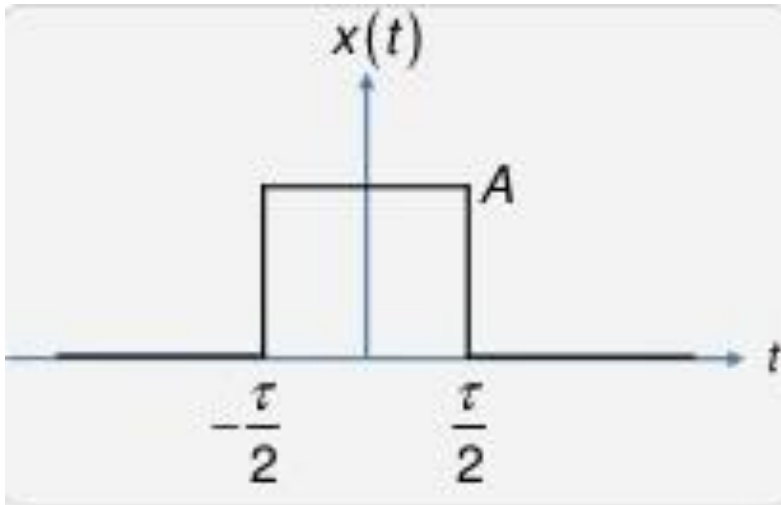


5 A CW Doppler system is being used to measure the velocity of blood in an artery as shown below.

- Draw a block diagram of a CW Doppler ultrasound system and explain how you can obtain the amplitude and phase components of the incoming signal? [3]
- The operator is unable to see any significant velocity change. Explain why? [2]
- [BONUS: Extra Marks]** The operator, being a novice also forgot to apply ultrasound gel (a water based gelatinous substance) to the patient's skin. As a result, he was not able to get a clear B-mode or Doppler image. What is the function of this gel? [+2]



6 What is the strength of the frequency $2\pi/\tau$ (rad/sec) in the rectangular pulse shown below? Does the strength depend on τ ? Justify. (Assume $A=1$)



[5]

7 What is the uncertainty principle in time-frequency joint representation? Write the explicit expression. [3]

8 Justify the following statement: "Measured EEG cannot determine if activity is excitatory or Inhibitory". You may use figure(s) to make it better interpretable. [4]

10 What are the different components of daVinciR surgical system? Write 1-2 lines about each component. [3]

11 The average IQ of the adult population is 100. A researcher believes the average IQ of adults is lower. A random sample of 5 adults are tested and scored 69, 79, 89, 99, 109. Is there enough evidence to suggest the average IQ is lower? Mention the p-value that you have chosen. T-table is attached. [5]