



Exam with Model Answer

Answer the following questions with the aid of drawing and equations as possible.

Question (1): [16 Marks] Differentiate between

a) Bonded and un-bonded strain gauges.

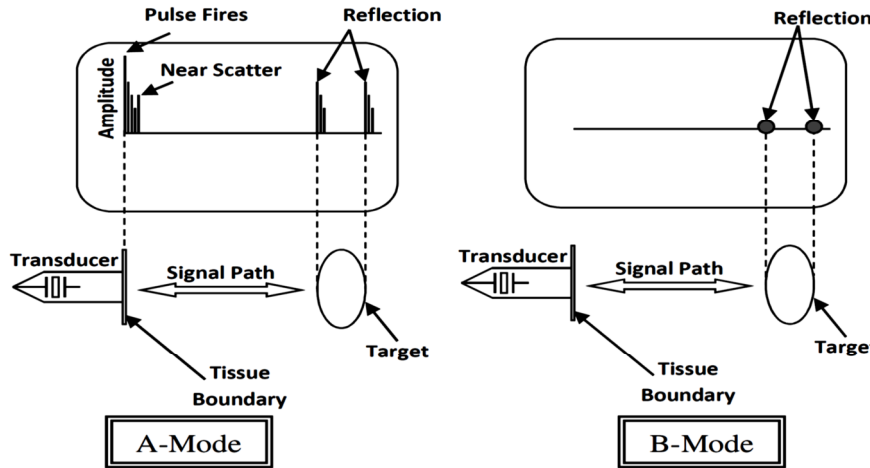
- Draw each of them as seen in your text book.
- Unbonded strain gauges can be constructed so that they are linear over a wide range of applied force but are very delicate.
- The bonded strain gauge is generally more rugged but is linear over a smaller range of forces.

b) Operational and instrumentation amplifiers.

The main difference is: we can use the operational amplifier in any configuration as inverting, non-inverting, comparator ...etc. where the instrumentation amplifier is only a differential amplifier configuration.

Other difference will be in the CMRR for each of them.

c) A-mode and B-mode ultrasound scanner.



In the A-mode, the amplitude of the received signals deflects the display beam vertically. In the B-mode, the brightness of the beam is modulated by this amplitude.

d) Depolarization, repolarization and hyperpolarization stages in the action potential.

Solve by yourself taking into consideration that the action potential consists of two main parts, depolarization then repolarization after these two parts the membrane potential can be more polarized than normal and this is called hyperpolarization.

Question (2): [12 Marks] Say true or false and why?

1) Solving for the action potential using Nernst and Goldman equations result different values.

False → Goldman and Nernst equations are used to solve for the rest potential, not the action potential.

2) Microelectrodes are used for high frequency signals measurements.

False → Microelectrodes have very high impedance and this with the electrode capacitance act as a low pass filter, hence the high frequency signals will be rejected.

3) The higher the gauge factor the higher the sensitivity of the strain gauge used.

True → The greater the gauge factor means a greater change of resistance per unit length, hence a greater sensitivity of the element.

Question (3): [8 Marks]

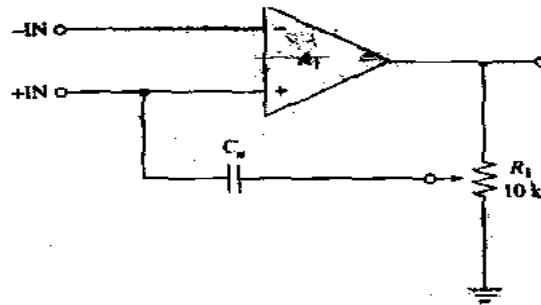
a) To overcome the effects of capacitance in high impedance electrodes, a strategy must be done. Explain with equations the effect of this capacitance on the measured bio-potential signal then explain and draw this strategy.

Microelectrodes have very high impedance, so the capacitance with the high impedance makes a low pass filter (LPF); so this electrode is suitable for low frequency bio-signal measurements only.

$$f = 1/2\pi RC; \text{ as } R \text{ and } C \text{ increase } \rightarrow f \text{ decrease.}$$

Method used for neutralizing the capacitance of the microelectrode and associated circuitry. A neutralization capacitance, C_n is in the positive feedback path along with a potentiometer voltage divider. The value of this capacitance is: $C_n = \frac{C}{A-1}$

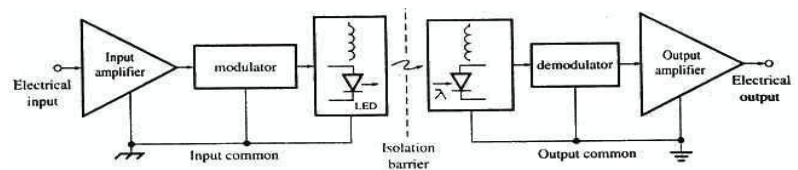
Where C_n is the neutralization capacitance
 C is the total input capacitance
 A is the gain of the amplifier



Capacitance nulling circuit.

b) Why we use isolation amplifiers in biomedical instrumentation? Draw the block diagram of the basic design of an isolation amplifier and explain the function of each block.

The isolation amplifier is used to protect the patient from electrical shocks. Isolation amplifier consists of five stages listed below:



- Input and output amplifiers to get the signal and amplify it.
- The modulator to convert the electrical signal to other type that can be transferred over the isolation barrier.
- The demodulator returns back the signal to its original form (electrical signal).
- The isolation barrier is the region where the input and output are totally isolated.
- The isolation and coupling may be optically, thermally or magnetically.

Question (4): [8 Marks]

a) The electrode half-cell potential becomes a serious problem in bioelectric signals acquisition because of the tremendous difference between these dc potentials and the biopotentials. What are the strategies used to overcome the effects of the massive half-cell potential offset.

- Differential DC amplifier to acquire signal thus the DC component will cancel out.
- Counter Offset-Voltage to cancel half-cell potential.
- AC couple input of amplifier (DC will not pass through).

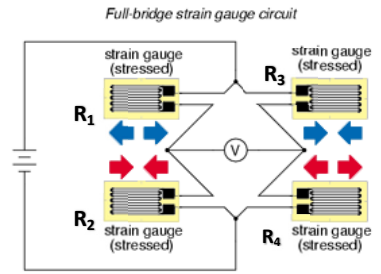
b) Describe how ultrasound wave is generated, and show how 2500 kHz ultrasound signal differs from 2500 kHz radio signal.

Generation of ultrasound:
 The piezoelectric transducer under compression and tension will generate an electric alternating wave and the reverse operation will generate the ultrasound pressure wave.

Ultrasound	Radio wave
Mechanical wave (acoustical).	Electromagnetic wave.
Requires a medium to propagate	Can propagate in outer space.
Transmitted via transducer	Transmitted via antenna

Question (5): [16 Marks]

- 1) A strain gauge transducer is constructed such as the one shown in figure and connected in a whetstone bridge configuration. Assume that all resistors are equal ($R_1=R_2=R_3=R_4=R$). When a force is applied, all resistors changed by the same value " $\pm h$ " according to the figure shown. Drive the equation of the output voltage E_o if the excitation potential is E .



For the forces applied as shown in figure

$$R_1 = R_4 = R+h \quad ; \text{Tension}$$

$$R_2 = R_3 = R-h \quad ; \text{Compression}$$

$$E_o = V_a - V_b$$

$$E_o = E \frac{R_2}{R_2 + R_1} - E \frac{R_4}{R_3 + R_4}$$

$$E_o = E \left(\frac{R-h}{R-h+R+h} - \frac{R+h}{R+h+R-h} \right)$$

$$E_o = E \left(\frac{R-h}{2R} - \frac{R+h}{2R} \right)$$

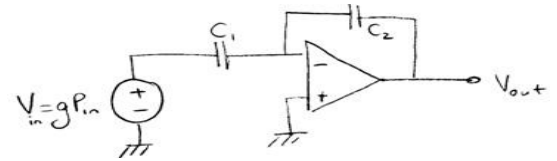
$$E_o = E \left(\frac{R-h-R-h}{2R} \right)$$

$$E_o = E \left(\frac{-2h}{2R} \right)$$

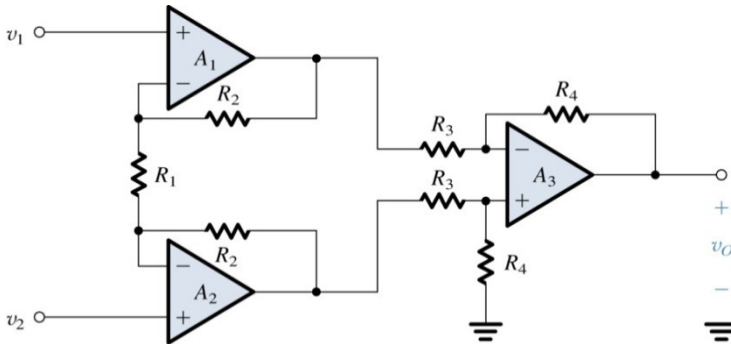
$$E_o = -E \left(\frac{h}{R} \right)$$

A piezoelectric pressure sensor has an input/output relationship $V = gP$ (V =voltage, P =pressure). We are using a charge amplifier. What is the transfer function of the system shown?

Solved exactly in sheets



- 2) Drive the equations for the gain of Op-amp instrumentation amplifier shown below, and then calculate the circuit gain.



In Lecture the resistors are named as follows:

$$R_2 \text{ as } R_x \quad R_1 \text{ is } 2R_y \quad R_3 \text{ is } R_1 \quad R_4 \text{ is } R_2$$

And the output voltage from A1 is V_3 and the output voltage from A2 is V_4

To calculate the gain of the first stage:

The current in the R_x equal the current in $2R_y$

$$\text{Then } I_{R_x} = \frac{V_4 - V_3}{2R_x + 2R_y} = \frac{V_2 - V_1}{2R_y}$$

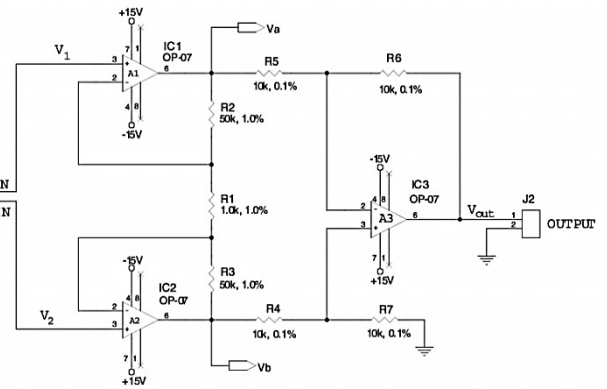
$$\frac{V_4 - V_3}{V_2 - V_1} = \frac{R_x + R_y}{R_y} = 1 + \frac{R_x}{R_y}$$

The gain of the second stage (differential amplifier) equals R_4/R_3 or R_2/R_1 for lecture resistor names.

Then the amplifier total gain equals to

$$\frac{V_o}{V_2 - V_1} = \left(1 + \frac{R_x}{R_y} \right) \left(\frac{R_2}{R_1} \right)$$

Then substitute by $R_1 = R_2 = 10 \text{ k}\Omega$ and $R_x = 50 \text{ k}\Omega$ and $R_y = 0.5 \text{ k}\Omega \rightarrow \text{Gain} = 101$



With best wishes