**ELT-61306: Basics of Medical Electronics** April 14, 2014

**Name:** _____

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**Rules:**

- The use of calculator is allowed during the exam.

1. (20 points) Figure 1 represents the interface of a silver-silvercloride ($Ag - AgCl$) electrode with a saline ($Cl^-$ , $Na^+$) electrolyte.

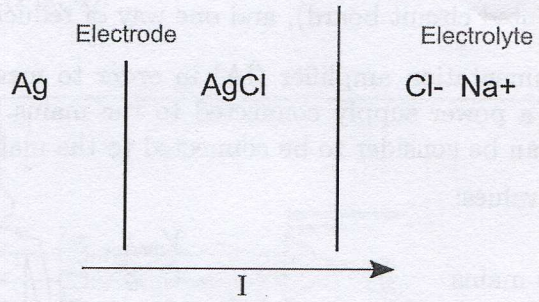


Figure 1: Interface electrode-electrolyte for a Ag-AgCl electrode in a saline solution.

Describe the processes taking place when a current flows from electrode to electrolyte.

**Tip:** You should mention at leas: (If an electric current is a flow of electric charges) what is the particle, charge, and direction that defines the current in the electrode? What is the particle, charge, and direction that defines the current in the electrolyte. The chemical reaction in the interface $Ag - AgCl$ only for the mentioned current direction. Is is an oxidation or reduction reaction?. The chemical reaction in the interface $Ag - electrolyte$ only for the mentioned current direction.

2. We have design the differenential amplifier in Figure 2. For amplifying differential voltage.

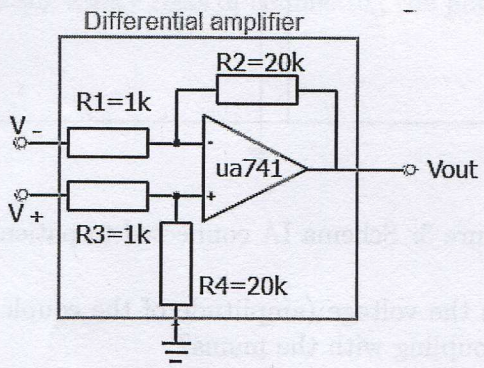


Figure 2: Differential amplifier.

(a) (5 points) Calculate the differential gain of the amplifier.

(b) (10 points) Calculate the offset error at the output due to the Input offset voltage of the Operational Amplifier if, according to the OpAmp's datasheet it is $v_{IO} = 1mV$.

(c) (10 points) Calculate the the worst common-mode gain if we select resistors with a $\pm 1\%$ margin error.

3. (20 points) List the four types of EMC coupling, one example of each type of coupling we can find a PCB (printed circuit board), and one way of reducing the effects.

4. We are using an instrumentation amplifier (IA) in order to measure the ECG signal. The IA is powered by a power supply connected to the mains. Therefore, the input impedances of the IA can be consider to be connected to the main ground (Fig. 3).

   Consider the following values:

| | | |
|---|---|---|
| Main power source | $V_{main}$ | $220V@50Hz$ |
| Coupling of patient to mains | $C_{pow}$ | $30pF$ |
| Coupling of patient to ground | $C_{body}$ | $3pF$ |
| Input impedance IA | $Z_{in}$ | $10G\Omega \| \| 150pF$ |
| Common mode ratio IA at $50Hz$ and $G_d = 100$ | $CMRR@50Hz$ | $120dB$ |
| Resistive value interface skin-electrode | $Z_e$ | $20k\Omega \pm 10\%$ |

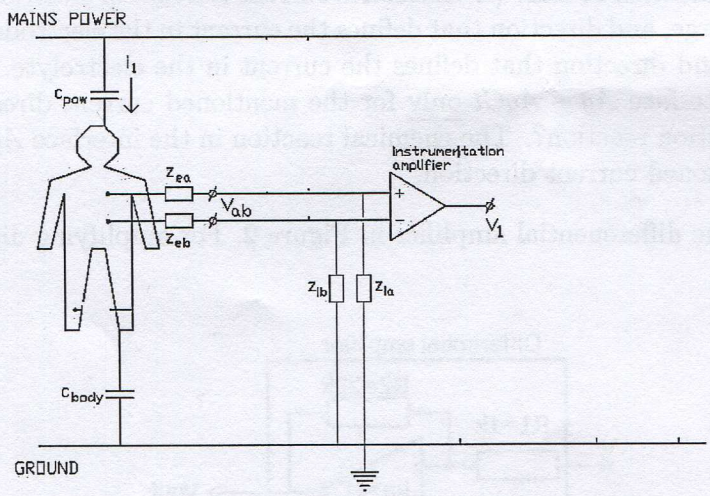


Figure 3: Schema IA connected to patient.

(a) (5 points) What is the voltage (amplitude of the coupled signal) at the body due to the capacitive coupling with the mains?

(b) (5 points) What is the amplitude of the common mode voltage measured at the inputs of the IA?

(c) (5 points) What is the amplitude of the error at the output of the IA due to the common mode voltage measured at the inputs of the IA?

(d) (5 points) What is the amplitude of the differential voltage measured at the inputs of the IA for the worst case?

(e) (5 points) What is the amplitude of the error at the output of the IA due to the differential voltage measured at the inputs of the IA?

In order to reduce this error we connect the patient directly to ground (through and electrode) as seen in (Fig. 4).

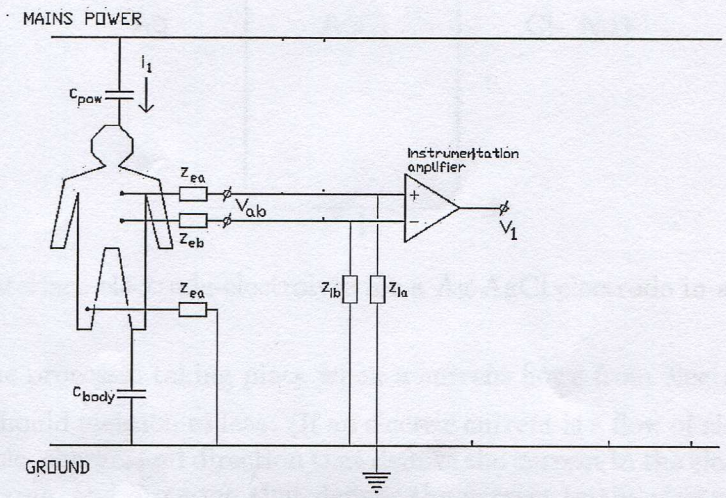


Figure 4: Schema IA connected to patient. Patient grounded.

(a) (10 points) What is the new amplitude of the error at the output of the IA due to the differential voltage measured at the inputs of the IA?

(b) (5 points) Although the error is considerably reduced, this configuration is not a good idea. What are the safety risks of connecting the patient directly to the main ground?.