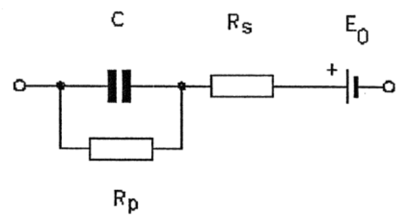
SYDE544 Assignment 2: Bio-potential Electrode and Amplifiers

Due: Fri. Feb 12, 2021.

Instructions: You should submit a PDF file in LEARN. Photos or scans of hand-written answering sheets (in good quality) are also acceptable. In the latter case, please make sure you just submit one single file, not in multiple files.

Part one: Model of Bio-potential Electrode

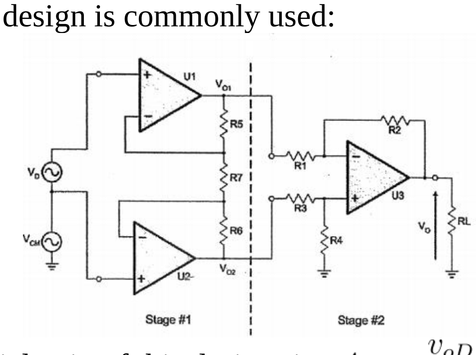
1. Identify the physical origin of each component (C, R_p, R_s and E_0) in the following equivalent circuit of a bio-potential electrode (Note this is the electrode-electrolyte interface, not the electrode-electrolyte-skin interface)



2. During the lectures, we exclusively discussed electrodes used for surface recordings (placed on the surface of the skin). Now please discuss how each of above components might change for invasive electrodes, such as a needle or a wire.

Part two: Bio-potential amplifiers

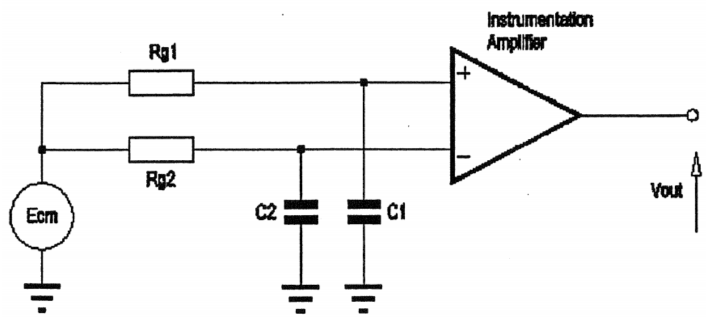
3. In order to improve CMRR of bio-potential amplifier with a design with single OA, the follow three-OA design is commonly used:



What is the differential gain of this design, *i.e.* $A_D = \dfrac{v_{oD}}{v_D}$?

4. What is the CMRR of the design in question 3?

5. An ideal instrumentation amplifier is connected to a bio-potential source with two co-axial cables ($C1$ and $C2$) and two electrodes (R_{g1} and R_{g2}), as shown in the figure below. Assuming the instrumentation amplifier has both infinite CMRR and input impedance, while its differential gain is A_D, what will the actual CMRR be, considering the effect of the cables and the electrodes? Sketch the CMRR against frequency, and identify all break frequencies. (Note the graph below only depicted the case of common mode input. You should re-draw the graph for the case of differential input)



6. Assume the two cables are identical standard 3-meter co-axial with $C1 = C2 = 58pf/m$, and the resistance of the two electrodes are: $R_{g1} = 10k\Omega$ and $R_{g2} = 11k\Omega$. In what range does the amplifier's CMRR falls below 80dB and what is the CMRR at 60 Hz?

Part three: Electric safety in bio-potential recording

7. In the ICU of a hospital, a patient with a trans-venous catheter connected to an external pacemaker, which is operated by batteries and is considered as isolated (from the Main). The patient is lying on a hospital bed. The height and posture of the bed is adjustable with an electric motor.
Unfortunately, the ground lead of the motor of the bed is broken and the metal bed rail is no longer connected to the ground. Now capacitive coupling between the motor and the bed rail exists. A nurse comes to check on the patient, He/she touches the electrode lead of the pacemaker. The patient, in the effort to turn his face to talk to the nurse, is holding on the metal bed railing. The nurse, in order to see the patient better, switches on a bedside light whose switch toggle is grounded.
Assuming the following parameters:
Patient and Nurse:

Skin resistance	$R_{ps} = R_{ns} = 100k\Omega$
Body resistance	$R_{pb} = R_{nb} = 500\Omega$

Hardware:

Electrode lead resistance	0Ω
Electrode contact resistance	$R_e = 1k\Omega$
Motor/rail coupling capacitance	$C_c = 2500$ pF
Motor voltage	$V_{ac} = 120$ V ac @ 60 Hz

Determine:

a) The electrical equivalent circuit of the situation;
b) What will happen to the nurse at the instant when he/she touches the light switch?
c) What will happen to the patient?