BENG 186B Winter 2011

Quiz 3

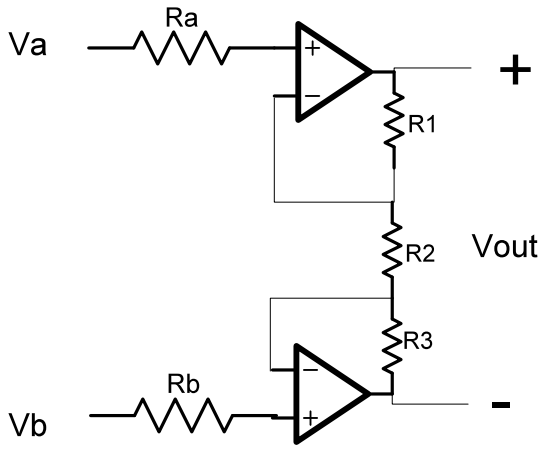
March 4, 2011

NAME (Last, First): _____

- This quiz is closed book, closed note, you may use a calculator for algebra.
- Circle your final answers in the space provided; show your work only on the pages provided.
- Do not attach separate sheets. If you need more space, use the back of the pages.
- Points for each problem are given in [brackets], 100 points total. The quiz is 50 minutes long.

1	/30
2	/25
3	/25
4	/20
Total	/100

1. [**30 pts**] Consider the differential biopotential amplifier shown below. Assume all opamps are ideal.



R_1 = 10 kΩ

R_2 = 1 kΩ

R_3 = 11 kΩ

R_a = 100 kΩ

R_b = 110 kΩ

Definitions:

$V_{out} = A_d\, v_d + A_c\, v_{cm}$

$v_d = v_a - v_b$

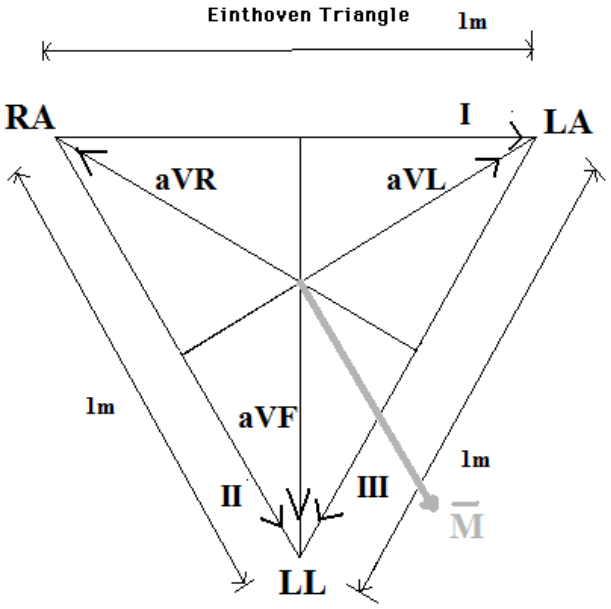
$v_{cm} = (v_a + v_b) / 2$

a. **[10 pts]** Find the differential gain A_d.

b. **[10 pts]** Find the common mode gain A_c. What is the resulting CMRR? Is this value reasonable?

c. **[10 pts]** Now assume that the opamps have input impedance R_{in} = 100 MΩ on each of the inputs to ground. What is now the common mode gain A_c and the resulting CMRR?

2. [**25 pts**] Three electrodes are placed on the body in an equilateral Einthoven triangle with dimensions as shown below. The direction of the cardiac vector is as shown, and its magnitude is $|\vec{M}| = 0.001$ V/m. Find the ECG voltages on the leads I, II, III, aVL, aVR, and aVF.



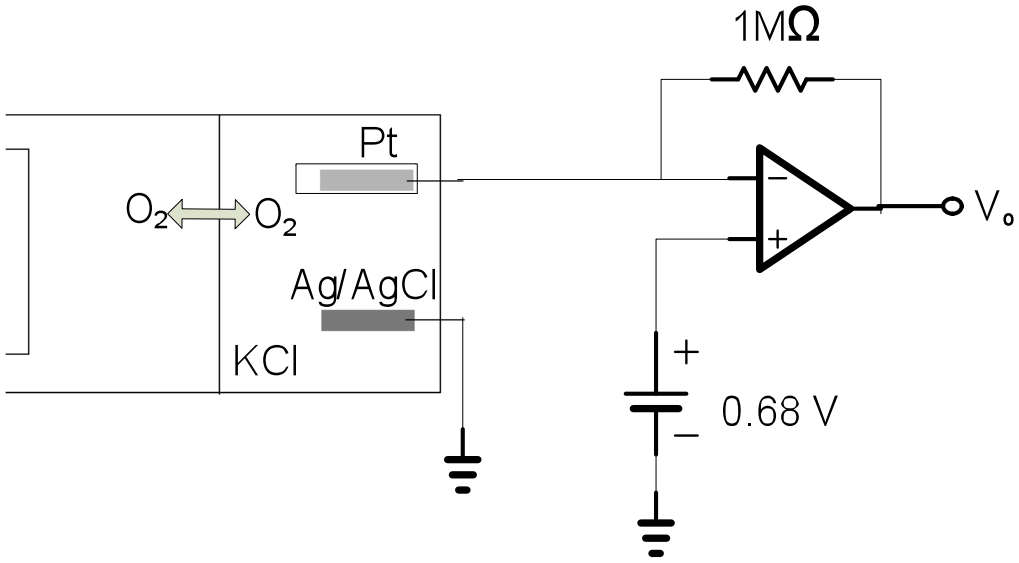
Hints:

$$V_a = \vec{M} \cdot \vec{a}$$

$\cos(\frac{\pi}{3}) = \frac{1}{2} = 0.5$ $\quad \sin(\frac{\pi}{3}) = \frac{\sqrt{3}}{2} \approx 0.87$

$\cos(\frac{\pi}{6}) = \frac{\sqrt{3}}{2} \approx 0.87$ $\quad \sin(\frac{\pi}{6}) = \frac{1}{2} = 0.5$

3. [**20 pts**] A Clark electrode as shown below measures the concentration of oxygen in a blood sample. Oxygen consumption in the cell is proportional to oxygen concentration, and produces a current that is measured by the electronic circuit on the right. The output voltage is measured to be $V_O = 0.72$ V.



Reactions taking place:

$$O_2 + 2\,H_2O + 4\,e^- \rightarrow 2\,H_2O_2 + 4\,e^- \rightarrow 4\,OH^-$$

$$4\,OH^- + 4\,KCl \rightarrow 4\,KOH + 4\,Cl^-$$

$$4\,Ag + 4\,Cl^- \rightarrow 4\,AgCl + 4\,e^-$$

a. **[5 pts]** Find the current flowing through the platinum (Pt) electrode, and indicate the direction of current flow on the diagram above.

b. **[5 pts]** Find the current flowing through the Ag/AgCl electrode, and indicate the direction of current flow on the diagram above.

c. **[5 pts]** Find the rate of oxygen consumption in the cell, in units mol/s. *Hint*: A proton has a charge of $1.6\ 10^{-19}$ C.

d. **[5 pts]** Explain what changes take place to the Ag/AgCl electrode, and how these depend on the currents.

4. [**20 pts**] Circle the best answer (circle only one letter for each question).

a. At the isobestic wavelength:
   i. There is maximum absorbance of light in a substance.
   ii. Two different substances have equal absorptivities.
   iii. Equal concentrations of different substances will absorb different amounts of light.
   iv. Food is cooked fastest in a microwave.
   v. The Beer-Lambert Law is not applicable.

b. The inertance of fluid in a rigid pipe due to its mass can be modeled by a:
   i. Resistor.
   ii. Capacitor.
   iii. Inductor.
   iv. Thermocouple.
   v. Battery.

c. When the ultrasonic transducer and receiver are both perpendicular to the blood vessel, the Doppler frequency shift is:
   i. Dependent on the frequency of the emitted wave.
   ii. Dependent on the speed of the blood flow.
   iii. Positive.
   iv. Zero.
   v. Negative.

d. The bolus injection method to measure cardiac output can be done by injecting:
   i. A warm fluid.
   ii. A chemical dye.
   iii. An X-ray contrast agent.
   iv. All of the above.
   v. None of the above.

e. ISFET stands for
   i. Immunologically Sensitive Field Effect Transistor
   ii. Ion Sensitive Field Effect Transistor
   iii. Immune Sensing For Elevated T-cells
   iv. Immunologically Sensitive Field Effect Thermistor
   v. Ion Sensitive Field Effect Thermistor