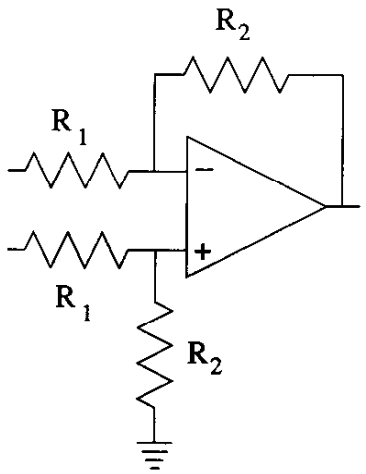
Name: _____
October 24, 1996
Instructor: C. Davila

EACH PROBLEM WORTH 10 POINTS.
MEAN = 42.9/60

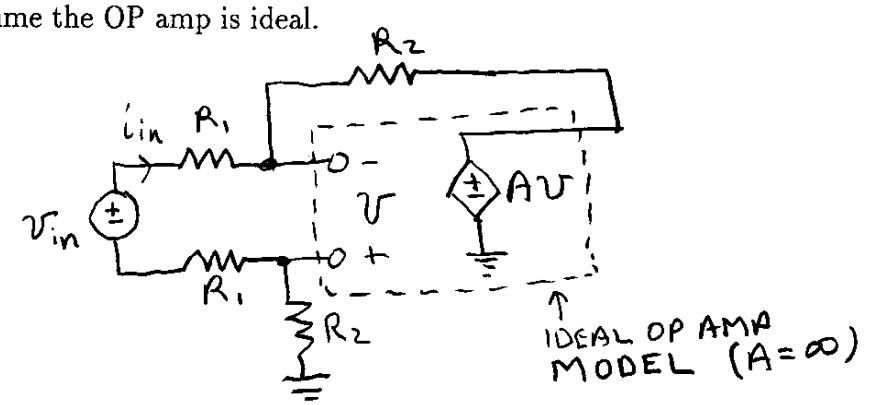
SOLUTIONS

EE 5345 Midterm Exam

1. Find and expression for the input impedance Z_{in} for the differential amplifier shown below:



Assume the OP amp is ideal.



KVL: $v_{in} = 2(R_1+R_2)\,i_{in} + Av$

$v = 2R_1 i_{in} - v_{in}$

$\Rightarrow v_{in} = 2(R_1+R_2)\,i_{in} + A2R_1 i_{in} - A v_{in}$

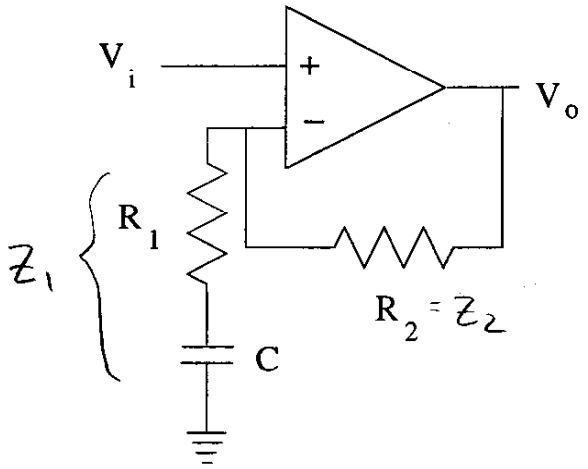
$v_{in}(1+A) = [2(R_1+R_2) + A2R_1]\,i_{in}$

$Z_{in} = \frac{v_{in}}{i_{in}} = \frac{2(R_1+R_2) + A2R_1}{1+A} \rightarrow \underline{\underline{2R_1}}$

2. Find an expression for the transfer function

$$H(j\Omega) = \frac{V_o(j\Omega)}{V_i(j\Omega)}$$

then sketch a Bode plot (dB vs logΩ) of $|H(j\Omega)|$ for $R_1 = 10k\Omega$, $R_2 = 30k\Omega$, and $C = 1\mu F$.



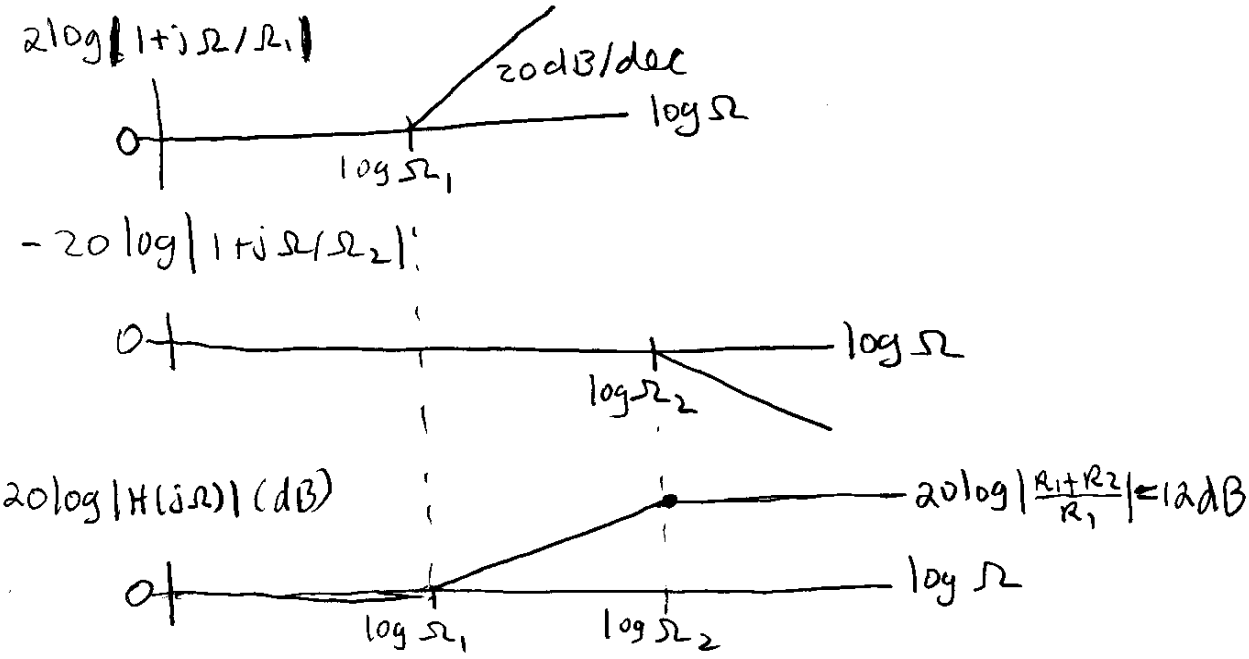
$Z_1 = R_1 + 1/j\Omega C$

$$\frac{V_o}{V_i} = \frac{Z_1 + Z_2}{Z_1} = \frac{R_1 + 1/j\Omega C + R_2}{R_1 + 1/j\Omega C} = \frac{1 + j\Omega(R_1+R_2)C}{1 + j\Omega R_1 C}$$

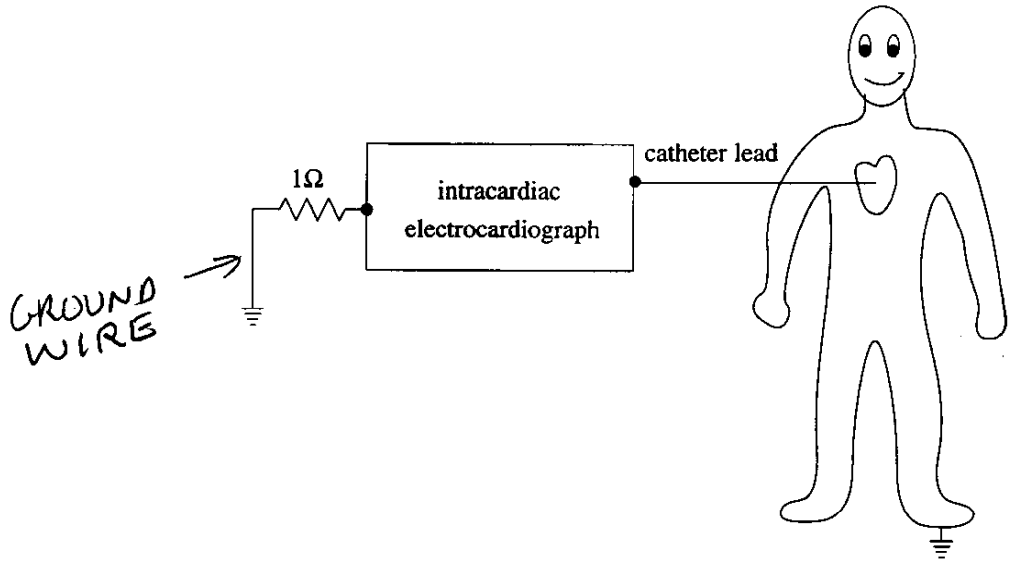
$$H(j\Omega) = \frac{1 + j\Omega/\Omega_1}{1 + j\Omega/\Omega_2}$$

$\Omega_1 = \frac{1}{(R_1+R_2)C} = 25$ rad/s

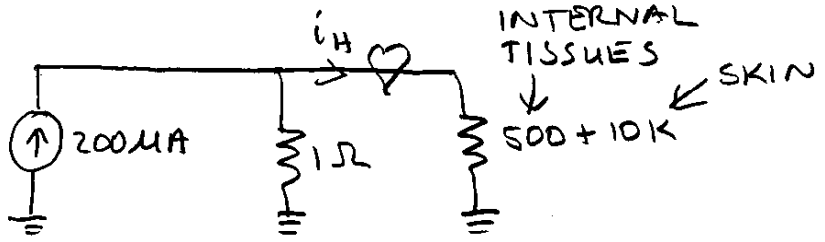
$\Omega_2 = \frac{1}{R_1 C} = 100$ rad/s



3. A technician measures the leakage current between the chassis and ground on an intracardiac electrocardiograph and finds it to be $200\mu A$. The electrocardiograph has a 0-resistance intracardiac lead connected to the chassis. This lead is subsequently connected to a patient's heart in the ICU. The patient touches a grounded object as shown. Make appropriate assumptions about tissue resistances, and determine whether a microshock hazard exists. Fully justify your answer.



THE 200 μA LEAKAGE CURRENT HAS 2 PATHS TO GROUND, THROUGH GROUND WIRE & THROUGH HEART:



$$i_H = \frac{200 \times 10^{-6} \times 1}{1 + 10.5 \times 10^{3}} = 1.9 \times 10^{-8} < 10\,\mu A$$

SO THERE IS NO HAZARD

IF GROUND WIRE BREAKS → MICROSHOCK

4. A digital lowpass filter has transfer function:

$$H(z) = \frac{1}{1 - 0.9z^{-1}}$$

Find the output of the filter, $y[n], n = 0, \ldots, 4$ for the input $x = \{\underbrace{1}_{n=0}, -1\}$. Assume that $y[n] = 0$ for $n < 0$.

$y[n] = 0.9y[n-1] + x[n]$

$y[0] = 0.9 \times 0 + 1 = 1$

$y[1] = 0.9 - 1 = -0.1$

$y[2] = 0.9(-0.1) = -0.09$

$y[3] = 0.9(-0.09) = -0.081$

$y[4] = 0.9(-0.081) = -0.0729$

5. Design a digital filter using the bilinear transform method that meets the following specifications:

- $T = 10^{-4}$s
- $|H(j\Omega)| = -3$ dB, $\Omega = 1200\pi$ rad/s $= \Omega_c$
- $|H(j\Omega)| < -10$ dB, $\Omega > 4000\pi$ rad/s $= \Omega_a$

write down the filter difference equation.

$$\omega_c = \Omega_c T = 0.12\pi$$
$$\omega_a = \Omega_a T = 0.4\pi$$

PREWARP:

$$\Omega_c' = \frac{2}{T}\tan\left(\frac{\omega_c}{2}\right) = \frac{2}{T}0.1908$$

$$\Omega_a' = \frac{2}{T}\tan\left(\frac{\omega_a}{2}\right) = \frac{2}{T}0.7265$$

$$N = \frac{\log\left(10^{10/10}-1\right)}{2\log\left(\frac{0.7265}{0.1908}\right)} = 0.8217 \rightarrow 1$$

$$H^P(s) = \frac{1}{B_1(s)} = \frac{1}{s+1}$$

$$H(s) = H^P\left(\frac{s}{\Omega_c'}\right) = \frac{\Omega_c'}{s+\Omega_c'}$$

$$H(z) = H(s)\Big|_{s=\frac{2}{T}\frac{1-z^{-1}}{1+z^{-1}}} = \frac{\Omega_c'}{\frac{2}{T}\frac{1-z^{-1}}{1+z^{-1}} + \Omega_c'} = \frac{\frac{T}{2}\Omega_c'(1+z^{-1})}{1-z^{-1}+\frac{T}{2}\Omega_c'(1+z^{-1})}$$

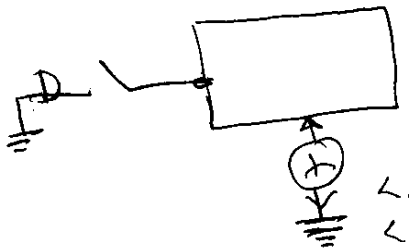
$$= \frac{0.1908(1+z^{-1})}{1.1908+(0.1908-1)z^{-1}} = \frac{\frac{0.1908}{1.1908}(1+z^{-1})}{1+\frac{(0.1908-1)}{1.1908}z^{-1}}$$

$$= \frac{0.1602(1+z^{-1})}{1-0.6795z^{-1}}$$

$$y[n] = 0.6795\,y[n-1] + 0.1602\,(x[n]+x[n-1])$$

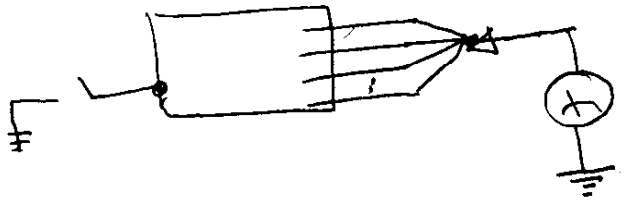
6. Briefly describe 4 different types of tests that measure leakage current in clinical electrophysiology instruments.

1. CHASSIS LEAKAGE CURRENT



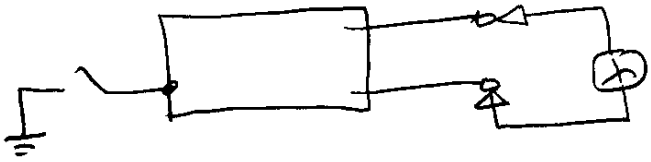
<500UA NON CONTACTING
<100UA CONTACTING

2. PATIENT LEAD TO GROUND



<50UA SURFACE
<10UA INTRACARDIAC

3. BETWEEN PATIENT LEADS



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<10UA INTRACARD.

4. TESTS SHOULD BE REPEATED W/ CHASSIS GROUNDED.