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

Assume the OP amp is ideal.

$$V_{in} = \frac{2(R_1+R_2)i_{in} + AV}{2R_1 i_{in} - V_{in}}$$

$$\Rightarrow V_{in} = 2(R_1+R_2)i_{in} + AZR_1 i_{in} - AV_{in}$$

$$V_{in}(1+AZ) = [2(R_1+R_2) + AZR_1]i_{in}$$

$$Z_{in} = \frac{V_{in}}{i_{in}} = \frac{2(R_1+R_2) + AZR_1}{1+AZ} \rightarrow 2R_1$$
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 log\(\Omega\)) of \(|H(j\Omega)|\) for \(R_1 = 10k\Omega\), \(R_2 = 30k\Omega\), and \(C = 1\mu F\).

\[ Z_1 = R_1 + \frac{1}{j\omega C} \]

\[ \frac{V_o}{V_i} = \frac{Z_1 + Z_2}{Z_1} = \frac{R_1 + \frac{1}{j\omega C} + R_2}{R_1 + \frac{1}{j\omega C}} = \frac{1 + j\omega C}{R_1 + 1/j\omega C} \]

\[ H(j\omega) = \frac{1 + j\omega/\Omega_1}{1 + j\omega/\Omega_2} \]

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

\[ \Omega_2 = \frac{1}{R_1C} = 100 \text{ rad/s} \]

\[ 20\log|1 + j\omega/\Omega_1| \]

\[ 20\log|1 + j\omega/\Omega_2| \]

\[ 20\log|H(j\omega)| (dB) \]

\[ 20\log|\frac{R_1 + R_2}{R_1}| \leq 1 \text{ dB} \]
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.

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

So there is no hazard.

If ground wire breaks \(\rightarrow\) 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 \( x = \{1, -1\} \). 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:

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

Write down the filter difference equation.

$$
\Omega_C = \Omega_C T = 0.12\pi
\Omega_A = \Omega_A T = 0.4\pi
$$

PREWARP:

$$
\Omega_C' = \frac{2}{\pi} \tan \left( \frac{\Omega_C}{2} \right) = \frac{2}{\pi} 0.1908
\Omega_A' = \frac{2}{\pi} \tan \left( \frac{\Omega_A}{2} \right) = \frac{2}{\pi} 0.7265
$$

$$
n = \frac{\log \left( 10^{10\Omega_0 - 1} \right)}{2 \log \left( \frac{0.7265}{0.1908} \right)} = 0.8217 \rightarrow 1
$$

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

$$
H(s) = H^0 \left( \frac{s}{\Omega_C} \right) = \frac{\Omega_C'}{s + \Omega_C'}
$$

$$
H(z) = H(s) \bigg|_{s = \frac{z - 1}{1 + z^{-1}}}
\quad = \frac{\Omega_C'}{\frac{1}{\Omega_C'} \left( 1 + z^{-1} \right) + \Omega_C'} = \frac{\frac{2}{\pi} \Omega_C' \left( 1 + z^{-1} \right)}{1 - z^{-1} + \frac{2}{\pi} \Omega_C' \left( 1 + z^{-1} \right)}
\quad = \frac{0.1908 \left( 1 + z^{-1} \right)}{0.1908 \left( 1 + z^{-1} \right) + (0.1908 - 1) z^{-1}} = \frac{0.1908 \left( 1 + z^{-1} \right)}{1 + (0.1908 - 1) z^{-1}}
\quad = \frac{0.1908 \left( 1 + z^{-1} \right)}{1 + 0.6795 z^{-1}}
\quad = 0.1602 \left( 1 + z^{-1} \right)
\quad = 0.6795 y[n-1] + 0.1602 (x[n] + x[n-1])
$$

$y[n] = 0.6795 y[n-1] + 0.1602 (x[n] + x[n-1])$
6. Briefly describe 4 different types of tests that measure leakage current in clinical electrophysiology instruments.

1. **CHASSIS LEAKAGE CURRENT**

   ![Chassis Leakage Current Diagram]

   \(<500\mu A\) NON CONTACTING  
   \(<100\mu A\) CONTACTING

2. **PATIENT LEAD TO GROUND**

   ![Patient Lead to Ground Diagram]

   \(<50\mu A\) SURFACE  
   \(<10\mu A\) INTRACARDIAL

3. **BETWEEN PATIENT LEADS**

   ![Between Patient Leads Diagram]

   \(<50\mu A\) SURFACE  
   \(<10\mu A\) INTRACARDIAL

4. **TESTS SHOULD BE REPEATED W/ CHASSIS GROUNDED.**