1. Transfer Function Analysis

Consider the following circuit:

\[ \frac{V_x}{V_{in}} = \frac{\frac{R_2}{1 + sR_2C_2}}{\frac{1}{1 + sR_2C_2} + \frac{1}{1 + sR_1C_1}} = \frac{R_2(1 + sR_1C_1)}{R_2(1 + sR_1C_1) + R_1(1 + sR_2C_2)} \]
\[ = \frac{R_2}{R_1 + R_2} \cdot \frac{1 + sR_1C_1}{1 + s(R_1||R_2)(C_1 + C_2)} \]

Also:
\[ \frac{V_{out}}{V_x} = \frac{g_m(R_L||r_o)}{1 + g_m(R_L||r_o)} \cdot \frac{1}{1 + s\frac{(R_L||r_o)C_L}{1 + g_m(R_L||r_o)}} \]

Combining:
\[ \frac{V_{out}}{V_{in}} = \frac{R_2}{R_1 + R_2} \cdot \frac{g_m(R_L||r_o)}{1 + g_m(R_L||r_o)} \cdot \frac{1 + sR_1C_1}{1 + s(R_1||R_2)(C_1 + C_2)} \cdot \frac{1}{1 + s\frac{(R_L||r_o)C_L}{1 + g_m(R_L||r_o)}} \]
For input impedance, since the transistor has infinite input impedance:

\[
Z_{\text{in}} = \frac{R_1}{1 + sR_1C_1} + \frac{R_2}{1 + sR_2C_2} = (R_1 + R_2) \cdot \frac{1 + s(R_1 || R_2)(C_1 + C_2)}{(1 + sR_1C_1)(1 + sR_2C_2)}
\]

b) Let \( R_1 = R_2 = 5 \, k\Omega \), \( C_1 = 90 \, fF \), \( C_2 = 10 \, fF \), \( R_L = 400 \, \Omega \), \( C_L = 50 \, fF \), \( g_m = 10 \, mS \), and \( r_o = 2 \, k\Omega \). Draw the bode plot of the transfer function and the input impedance. What is the mid-band gain (gain at intermediate frequencies)?

The plot is shown below. The mid-band gain is \( \frac{C_1}{C_1 + C_2} \).

![Bode Plot](image1)

![Bode Plot](image2)

c) Using the values in part b, suppose now you want to halve the zero frequency without changing the mid-band gain and minimize pole frequency movement (a common scenario in high-speed link design). If you can only change one component value, which one will it be and what will be its new value? What is the new DC gain?

You would double \( R_1 \). The new DC gain is \( 1/3 \).