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1. Find the open-circuit impedance matrix $Z$ of the two-port $T$ shown, in the following steps:
   a. Separate $T$ into two series-connected simpler two-ports $T_1$ and $T_2$;
   b. Find the $Z$ matrices of $T_1$ and $T_2$;
   c. Add $Z_1$ and $Z_2$ to find $Z$.

![Diagram of two-port network with $L_1$, $C$, $L_2$]

2. The gain $G$ in the passband of a Butterworth filter must satisfy
   
   $-1.2 \, \text{dB} < G < 0 \, \text{dB}$ for $|f| < 0.5 \, \text{MHz}$.

   The maximum pole-$Q$ allowed is 3. How much stopband attenuation can be achieved at 1 MHz?

3. Find the transfer function $Av(s) = \frac{V_{out}(s)}{V_{in}(s)}$ of the two-port shown. Assume $R = 5 \, \text{k}$$\Omega$ and $Gm = 0.2 \, \text{mS}$ for all transconductors, and use $C = 50 \, \text{pF}$.

![Diagram of op-amp circuit with $V_{in}$, $R$, and $V_{out}$]
1. \[ Z_{11} = sL_2 + \frac{(1/sC)(sL_1 + 1/sC)}{2/sC + sL_1} \]

\[ = sL_2 + \frac{1}{sC} \left( \frac{s^2L_1C + 1}{s^2L_1C + 2} \right) = Z_{22} \]

\[ Z_{12} = Z_{21} = sL_2 + Z_{11a} \frac{1/sC}{sL_1 + 1/sC} \]

\[ = sL_2 + \frac{1/sC}{s^2L_1C + 2} \]

\[ L_1 \]

\[ L_2 \]
2. \( k = 0.5 / 1 = 0.5 \)

\[
A_1 = \frac{r_3}{2\sqrt{3} \sin \beta_1} = 3
\]

\( \sin \beta_1 \geq 1/6 \)

\( \beta_1 \geq 9^\circ 35.5' \approx 9.6^\circ \)

\( \frac{90^\circ}{n} > 9.6^\circ \), \( n \leq 9.4 \)

\( n_{\text{max}} = 9 = \frac{\log (l/k_1)}{\log 2} \)

\( \log (l/k_1) \approx 2.71 \)

\( k_1 = \frac{1}{512} = \sqrt{\frac{10^{0.12} - 1}{10^{\alpha_3/10}}} \)

\( 10^{\alpha_3/10} \approx 83.429 \)

\( \alpha_3 \approx 49.2 \text{ dB} \)
3. Find the transfer function of the circuits shown.

At $V_{out}$, KCL gives

$$ G(V_{in} - V_{out}) + G_m V_A + G_m V_{out} = 0 $$

At $V_A$,

$$ -G_m V_{out} = SC V_A \rightarrow V_A = -\frac{G_m}{SC} V_{out} $$

From 1st eq.

$$ G V_{in} = (G + \frac{G_m}{SC} - G_m) V_{out} $$

If $G = G_m$,

$$ \frac{V_{out}}{V_{in}} = \frac{G_m}{G_m^2/SC} = \frac{SC}{G_m} = S \frac{5 \times 10^{-11}}{0.2 \times 10^{-3}} $$

$$ H(s) = 3 \times 2.5 \times 10^{-7} $$

$$ R \quad 0 \quad \frac{R}{\frac{1}{G_m} + SC / G_m^2} \quad 0 $$

$$ \frac{V_0}{V_{in}} = \frac{-R, R^2SC}{-R + R^2SC} $$

$$ V_0 = \frac{-R^3SC}{R^2} = RSC $$