Magnitude/Frequency/Magnitude-Frequency Scaling

Circuit Theory and Devices

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Magnitude Scaling

- Magnitude scaling is the process of increasing all impedance in a network by a factor, such that the frequency response remaining unchanged
- Multiply impedances of each circuit elements by a constant k_m
- Before scaling, $Z_R = R, Z_L = j\omega L, Z_C = 1/j\omega C$
- After scaling the impedances

$$Z_R{}' = k_m Z_R,\ Z_L{}' = k_m Z_L,\ Z_C{}' = k_m Z_C$$

- Scaled component values $R' = k_m R, L' = k_m L, C' = C/k_m$
- What would be the effect of magnitude scaling on Q-factor and resonant frequency for series RLC circuit?

Frequency Scaling

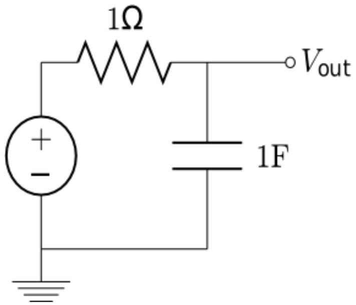
- **Frequency scaling is the process of shifting the frequency response of a network up or down the frequency axis while leaving the impedance the same**
- **Multiply frequency by a constant k_f keeping the impedance same i.e. $\omega' = k_f \omega$**
- **Before scaling, $Z_R = R, Z_L = j\omega L, Z_C = 1/j\omega C$**
- **After frequency scaling, $Z_L = j\,(\omega k_f)L', Z_C = 1/j\,(\omega k_f)C'$**
- **Scaled component values $R' = R, L' = L/k_f, C' = C/k_f$**
- **What would be the effect of magnitude scaling on Q-factor and resonant frequency for series RLC circuit?**

Magnitude/Frequency Scaling

- **Scaling in magnitude and frequency results in**

$$R' = k_m R, L' = (k_m L)/k_f, C' = C/(k_m k_f)$$

Example 1:



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3-dB cut-off frequency: $f = \frac{1}{2\pi}$ Hz

Requirement: 3-dB cut-off frequency = 1 kHz and C' = 1 nF

Step 1: Frequency scaling factor = $\mathbf{1000/\frac{1}{2\pi} = 2000\,\pi}$

Step 2: Magnitude scaling factor, $k_m = C/(C' k_f) = 1.59 * 10^5$

Step 3: Scaled resistor value,

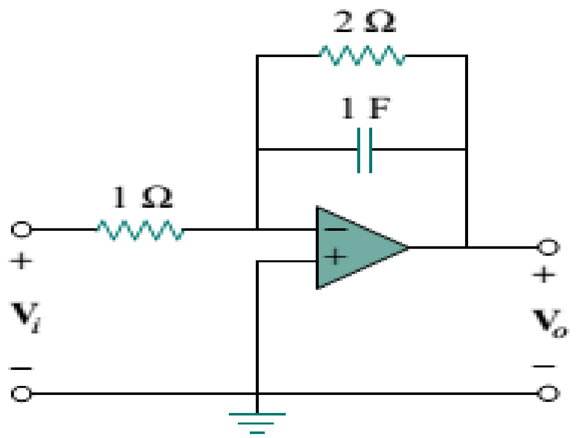
$$R' = k_m R = 1.59 * 10^5 * 1 = 1.59 * 10^5 \Omega$$

Magnitude/Frequency Scaling

Example 2:

3-dB cut-off frequency: $\boldsymbol{\omega}$ = 1 rad/s

Requirement: 3-dB cut-off frequency = 200 rad/s and C' = 1 μF



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Solution

Step 1: Frequency scaling factor = **200/1 = 200**
Step 2: Magnitude scaling factor, $k_m = C/(C' k_f)$ **= 5000**
Step 3: Scaled resistor value,

$$R' = k_m R = 5000 * 1 = 5000\,\Omega$$

$$R'_2 = 2R' = 10000\,\Omega$$