

task_yh4srwxu1bo1rdy4_with_calculation

Student Group

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resonance, impedance, resonant circuit, exam ee2 SS2024

Exercise E10 Magnetic Circuit

(written test, approx. 10 % of a 120-minute written test, SS2024)

2. Redo the calculation for the impedance Z_{RLC} for the given circuit with an AC voltage source $U_C = 100 \text{ V}$ and a real capacitor $C = 10 \text{ nF}$. What is the equivalent series inductance L in the shown circuit?

Path

$U_C = 100 \text{ V}$

- $f_{\text{und}} = 44 \text{ MHz} \Rightarrow \omega = 2\pi f_{\text{und}} = 276.46 \text{ m}\Omega$
- $|Z_{RLC}(f_r)| = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2} = 100 \text{ m}\Omega$

The formula for the resonance frequency f_r is: $f_r = \frac{1}{2\pi\sqrt{LC}}$

The voltage on the ideal capacitor is $U_C = U \cdot \frac{1}{\sqrt{1 + Q^2}}$ by the Q -factor increased H

best to start with $U_C = U \cdot \frac{1}{\sqrt{1 + Q^2}} \Rightarrow U = U_C \cdot \sqrt{1 + Q^2} = 100 \text{ V} \cdot \sqrt{1 + 39.792^2} = 3979.2 \text{ V}$

The impedance of the real capacitor is $Z_C = \frac{1}{j\omega C} = \frac{1}{j \cdot 276.46 \text{ m}\Omega \cdot 10 \text{ nF}} = -j39.792 \text{ m}\Omega$

The impedance of the real inductor is $Z_L = j\omega L = j \cdot 276.46 \text{ m}\Omega \cdot L$

The impedance of the resistor is $Z_R = R = 20 \text{ m}\Omega$

The total impedance is $Z_{RLC} = Z_R + Z_L + Z_C = 20 \text{ m}\Omega + j\omega L - j39.792 \text{ m}\Omega = 100 \text{ m}\Omega$

A given capacitor shall have the following values:

- $C = 10 \text{ nF}$
- $R = 20 \text{ m}\Omega$
- $L = 1.6 \text{ nH}$

1. What is the impedance Z_{RLC} of this real capacitor for $f_0 = 44 \text{ MHz}$? (Phase and magnitude)

Path

The impedance is based on the resistance R and the reactance $X_{LC} = \omega L - \frac{1}{\omega C}$:

$$\underline{Z}_{RLC} = R + j(\omega L - \frac{1}{\omega C}) = R + j(2\pi f \cdot L - \frac{1}{2\pi f \cdot C})$$

The reactive part is $X_{LC} = 2\pi f \cdot L - \frac{1}{2\pi f \cdot C}$

$$C\}} \\\ &= 2\pi \cdot 44 \cdot 10^6 \cdot \{ \sim \text{MHz} \} \cdot 1.6 \cdot 10^{-9} \cdot \{ \sim \text{H} \} - \\ &\{ \frac{1}{2\pi \cdot 10^6 \cdot \{ \sim \text{MHz} \} \cdot 10 \cdot 10^{-9} \cdot \{ \sim \text{F} \}} \} \\\ &= +0.08062... \sim \Omega \\\ \end{align*}$$

To get the magnitude of the impedance $|\underline{Z}_{\text{RLC}}|$ one can use the Pythagorean Theorem:
$$|\underline{Z}_{\text{RLC}}| = \sqrt{R^2 + X_{\text{LC}}^2} \\\ &= \sqrt{(0.020 \sim \Omega)^2 + (0.08062... \sim \Omega)^2} \\\ &= 0.0830... \sim \Omega \\\ \end{align*}$$

For the phase φ the $\arctan$ can be applied:
$$\varphi = \arctan \left(\frac{X_{\text{LC}}}{R} \right) \\\ &= \arctan \left(\frac{0.08062... \sim \Omega}{0.020 \sim \Omega} \right) \\\ &= 1.3276... \hat{=} +76^\circ \\\ \end{align*}$$

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