

task_yh4srwxu1bo1rdy4_with_calculation

Student Group

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resonance, impedance, resonant circuit, exam ee2 SS2024

Exercise E16 Magnetic Circuit

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

2. For a series RLC circuit with a voltage source $U_C = 100 \text{ V}$, a resistor $R = 5 \text{ }\Omega$, an inductor $L = 1.6 \text{ nH}$ and a capacitor $C = 10 \text{ nF}$. What is the resonance frequency f_r and the impedance Z_{RLC} at this frequency?

Path

- $U_C = 100 \text{ V}$
- $f_r = 39.79 \text{ MHz}$
- $Z_{RLC}(f_r) = 5 \text{ }\Omega$

The formula for the resonance frequency f_r is:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

The voltage on the ideal capacitor is the output voltage by the Q -factor increased:

$$U_C = U \cdot Q = 100 \text{ V} \cdot 20 = 2000 \text{ V}$$

The impedance at resonance is purely the resistance:

$$Z_{RLC}(f_r) = R = 5 \text{ }\Omega$$

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 $X_{LC} = j(X_L - X_C)$:

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

The reactive part is

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

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

To get the magnitude of the impedance $|Z_{RLC}|$ one can use the Pythagorean Theorem:
$$|Z_{RLC}| \ \&= \ \sqrt{R^2 + X_{LC}^2} \ \&= \ \sqrt{(0.020 \ \Omega)^2 + (0.08062... \ \Omega)^2} \ \&= \ 0.0830... \ \Omega$$

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

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