

task_yh4srwxu1bo1rdy4_with_calculation

Student Group

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resonance, impedance, resonant circuit, exam ee2 SS2024

Exercise E15 Magnetic Circuit

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

2. For a parallel RLC circuit, the resonance frequency is $f_0 = 44 \text{ MHz}$. The voltage across the capacitor is $U_C = 100 \text{ V}$. The current through the resistor is $I_R = 5 \text{ mA}$. What is the value of the capacitor C in the shown circuit?

Path

- $U_C = 100 \text{ V}$
- $f_0 = 44 \text{ MHz}$
- $I_R = 5 \text{ mA}$

The formula for the resonance frequency f_r is:

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

The voltage across the capacitor is:

$$U_C = I_C \cdot X_C = I_C \cdot \frac{1}{\omega C}$$

The current through the resistor is:

$$I_R = \frac{U}{R}$$

The impedance of the parallel RLC circuit is:

$$Z_{RLC} = \frac{R \cdot X_L \cdot X_C}{R \cdot X_L + X_L \cdot X_C + R \cdot X_C}$$

At resonance, the impedance is purely resistive and equal to R .

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

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

The reactive part is:

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

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

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

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

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Last update: **2024/07/15 23:54**

