

task_7el8zljglaazxtw_with_calculation

Student Group

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resonant circuit, exam ee2 SS2022

Exercise E1 Series Resonant Circuit**(written test, approx. 10 % of a 120-minute written test, SS2022)**

2. What is the resonance frequency of the circuit shown in the figure? The circuit consists of an AC voltage source U with an effective value $U_0 = 100 \text{ V}$, a resistor $R = 10 \text{ }\Omega$, an inductor $L = 60 \text{ }\mu\text{H}$, and a capacitor $C = 10 \text{ nF}$.

At resonance, the impedance of the circuit is purely real and its magnitude is $Z_0 = R$. Which value would C_0 have for the given f_0 ?

Path: $C = 10 \text{ nF}$

$$R = 10 \text{ }\Omega$$

Path: $L = 60 \text{ }\mu\text{H}$

$$C = 10 \text{ nF}$$

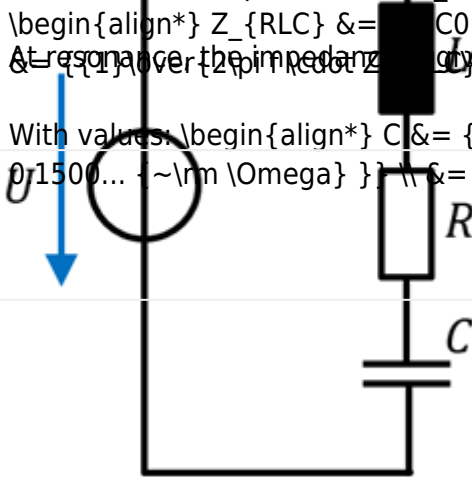
The resonance frequency is given as $f_0 = \frac{1}{2\pi\sqrt{LC}}$

$$\Rightarrow C = \frac{1}{4\pi^2 f_0^2 L} = \frac{1}{4\pi^2 (100 \text{ MHz})^2 \cdot 60 \cdot 10^{-6} \text{ H}} = 10 \text{ nF}$$

What is the impedance of the circuit at resonance? The impedance is purely real and its magnitude is $Z_0 = R$.

$$Z_{RLC} = R + j\omega L - \frac{j}{\omega C} \quad \text{At resonance } Z_{RLC} = R$$

$$\text{With values: } C = \frac{1}{4\pi^2 (100 \text{ MHz})^2 \cdot 60 \cdot 10^{-6} \text{ H}} = 10 \text{ nF}$$



1. What is the impedance $\underline{Z}_{RLC}$ of this real capacitor for $f_0 = 100 \text{ MHz}$? (Phase and magnitude)

Path

The impedance $\underline{Z}_{RLC}$ is given by: $\underline{Z}_{RLC} = R + j\omega L - \frac{j}{\omega C}$

$$\underline{Z}_{RLC} = R + j\omega L - \frac{j}{\omega C} \quad \Rightarrow \quad \underline{Z}_{RLC} = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

Putting in the numbers, only for the reactive part X_{LC} : $X_{LC} = \omega L - \frac{1}{\omega C}$

$$\begin{aligned} X_{LC} &= 2\pi \cdot 100 \text{ MHz} \cdot 60 \cdot 10^{-6} \text{ H} - \frac{1}{2\pi \cdot 100 \text{ MHz} \cdot 10 \cdot 10^{-9} \text{ F}} \\ &= 2\pi \cdot 100 \cdot 10^6 \text{ Hz} \cdot 60 \cdot 10^{-6} \text{ H} - \frac{1}{2\pi \cdot 100 \cdot 10^6 \text{ Hz} \cdot 10 \cdot 10^{-9} \text{ F}} \\ &= -121.45 \text{ m}\Omega \end{aligned}$$

With the real and imaginary parts, we can derive the magnitude and phase:

$$\begin{aligned} Z_{\text{RLC}} &= \sqrt{R^2 + \{X\}_{\text{LC}}^2} \quad \&= \sqrt{(88 \sim \text{m}\Omega)^2 + (-121.45 \sim \text{m}\Omega)^2} \quad \&= 150.0... \sim \text{m}\Omega \\ \end{aligned}$$

$$\begin{aligned} \varphi &= \arctan \left(\frac{\{X\}_{\text{LC}}}{R} \right) \quad \&= \arctan \left(\frac{-121.45 \sim \text{m}\Omega}{88 \sim \text{m}\Omega} \right) \quad \&= -0.9437... \\ &= -54.07...^\circ \quad \end{aligned}$$

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