

task_yh4srwxu1bo1rdy4_with_calculation

Student Group

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resonance, impedance, resonant circuit, exam ee2 SS2024

Exercise E1 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 capacity C_S in the shown circuit?

Path

$U_C = 100 \text{ V}$

- $f_{\text{und}} = 44 \text{ MHz} \Rightarrow \omega = 88 \cdot 10^6 \text{ s}^{-1}$
- $|Z_{RLC}(f_r)| = R = 20 \text{ m}\Omega$

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

The voltage on the ideal capacitor is $U_C = U \cdot Q = 100 \text{ V} \cdot 5 = 500 \text{ V}$

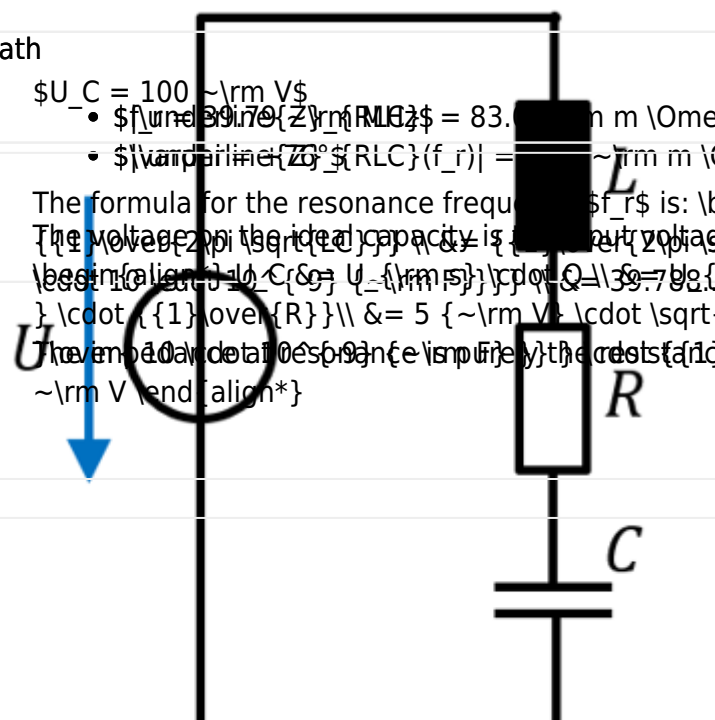
The impedance of the capacitor is $Z_C = \frac{1}{j\omega C} = \frac{1}{j \cdot 88 \cdot 10^6 \cdot 10 \cdot 10^{-9}} = -j113.6 \text{ m}\Omega$

The impedance of the inductor is $Z_L = j\omega L = j \cdot 88 \cdot 10^6 \cdot 1.6 \cdot 10^{-9} = j140.8 \text{ m}\Omega$

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

The total impedance is $Z_{RLC} = Z_R + Z_L + Z_C = 20 \text{ m}\Omega + j140.8 \text{ m}\Omega - j113.6 \text{ m}\Omega = 20 \text{ m}\Omega + j27.2 \text{ m}\Omega$

The equivalent series capacity C_S is $C_S = \frac{1}{\omega^2 L} = \frac{1}{(88 \cdot 10^6)^2 \cdot 1.6 \cdot 10^{-9}} = 7.9 \cdot 10^{-9} \text{ F} = 7.9 \text{ nF}$



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 $X_{LC} = \omega L - \frac{1}{\omega C}$:

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

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

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

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

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

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

