

task_yh4srwxu1bo1rdy4_with_calculation

Student Group

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Exercise E5 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

$U_C = 100 \text{ V}$

- $f_{\text{res}} = 44 \text{ MHz} = 44 \cdot 10^6 \text{ Hz}$
- $|Z_{RLC}(f_r)| = R = 20 \text{ m}\Omega$

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

The voltage on the ideal capacitor is $U_C = U \cdot Q$ (voltage by the Q -factor increased)

best to use $Q = \frac{U_C}{U} = \frac{100 \text{ V}}{5 \text{ V}} = 20$

The impedance of the capacitor is $Z_C = \frac{1}{j\omega C} = \frac{1}{j \cdot 2\pi \cdot 44 \cdot 10^6 \cdot 10 \cdot 10^{-9}} = -j \cdot 0.020 \text{ }\Omega$

The impedance of the inductor is $Z_L = j\omega L = j \cdot 2\pi \cdot 44 \cdot 10^6 \cdot L$

The total impedance is $Z_{RLC} = R + Z_L + Z_C = 20 \text{ m}\Omega + j \cdot 2\pi \cdot 44 \cdot 10^6 \cdot L - j \cdot 0.020 \text{ }\Omega$

At resonance, the imaginary part is zero: $2\pi \cdot 44 \cdot 10^6 \cdot L = 0.020$

$L = \frac{0.020}{2\pi \cdot 44 \cdot 10^6} = 7.2 \cdot 10^{-8} \text{ H} = 72 \text{ nH}$

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

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

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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