

task_pdkggtyexxy1ktu3_with_calculation

Student Group

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complex impedance, exam ee1 WS2022

Exercise 1.1 : Impedances at Frequencies

(written test, approx. 18 % of a 60-minute written test, WS2022)

Calculate the **resistor values** which have to be used in the following circuits.

1. A resistor R_1 shall have the same absolute value of the impedance as a capacitor $C_1=40 \text{ nF}$ at $f_1=4 \text{ MHz}$.

Solution

$$\begin{aligned} R_1 &= |\underline{X}_{C1}| = \frac{1}{2\pi \cdot f \cdot C_1} \\ &= \frac{1}{2\pi \cdot 4 \text{ MHz} \cdot 40 \text{ nF}} \end{aligned}$$

Final result

$$R_1 = 1.00 \text{ } \Omega$$

2. A RL series circuit with $L_2=4.7 \text{ } \mu\text{H}$, where an AC voltage source of $U_2=1.0 \text{ V}$ with $f_2=450 \text{ kHz}$ generates a current $I_2=60 \text{ mA}$.

Solution

Series circuit means that the current is constant on every component.

The equivalent impedance for R and L combined is given by
$$\frac{\underline{U}}{\underline{I}} = R_2 + \underline{X}_{L2} = R_2 + \text{j} \cdot \omega L$$
 Since $\text{j} \cdot \omega L$ is perpendicular to R_2 this can be simplified to:
$$\left| \frac{\underline{U}}{\underline{I}} \right|^2 = |R_2|^2 + |\underline{X}_{L2}|^2 \iff \left(\frac{U}{I} \right)^2 = R_2^2 + X_{L2}^2$$

This can be rearranged to get R_2 :
$$R_2 = \sqrt{\left(\frac{U}{I} \right)^2 - X_{L2}^2} = \sqrt{\left(\frac{1 \text{ V}}{60 \text{ mA}} \right)^2 - (2\pi \cdot 450 \text{ kHz} \cdot 4.7 \text{ } \mu\text{H})^2}$$

Final result

$$\begin{aligned} R_2 &= 10.0 \sim \Omega \end{aligned}$$

3. A RC parallel circuit with $C_3=4.7 \sim nF$ on an AC current source ($I_{3S}=1.3 \sim \text{mA}$, $f_3=200 \sim \text{kHz}$), which generates a current of $I_{3R}=1.0 \sim \text{mA}$ through R_3 .

Solution

Parallel circuit means that the voltage is the same on R_3 and C_3 :

$$\underline{U}_3 = R_3 \cdot \underline{I}_{3R} = -j \cdot \underline{X}_{3C} \cdot \underline{I}_{3C}$$
 So it gets clear, that \underline{I}_{3R} is perpendicular to \underline{I}_{3C} (It has to, since R_3 is perpendicular to $-j \cdot \underline{X}_{3C}$, too).

Therefore, the resulting current of the parallel circuit is given as:

$$\begin{aligned} \underline{I}_3 &= \underline{I}_{3R} + \underline{I}_{3C} \\ |\underline{I}_3|^2 &= |\underline{I}_{3R}|^2 + |\underline{I}_{3C}|^2 \\ \underline{I}_3 &= \sqrt{|\underline{I}_{3R}|^2 + |\underline{I}_{3C}|^2} \end{aligned}$$

Back in the first formula:

$$\begin{aligned} R_3 \cdot \underline{I}_{3R} &= \underline{X}_{3C} \cdot \underline{I}_{3C} \\ R_3 &= \underline{X}_{3C} \cdot \frac{|\underline{I}_{3C}|}{|\underline{I}_{3R}|} \\ &= \frac{1}{2\pi \cdot f \cdot C_3} \cdot \frac{\sqrt{|\underline{I}_3|^2 - |\underline{I}_{3R}|^2}}{|\underline{I}_{3R}|} \end{aligned}$$

Final result

$$\begin{aligned} R_3 &= 70.0 \sim \Omega \end{aligned}$$

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