

task_pdkggtyexxy1ktu3_with_calculation

Student Group

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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 the following circuits.

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

Solution

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

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
$$\frac{\underline{U}}{\underline{I}} = R_2 + \underline{X}_{L2} \quad \&= R_2 + j \cdot \omega L$$
 Since $j \cdot \omega L$ is perpendicular to R_2 this can be simplified to:
$$|\frac{\underline{U}}{\underline{I}}|^2 = |R_2|^2 + |\underline{X}_{L2}|^2 \quad \&= \left(\frac{U}{I} \right)^2 = R_2^2 + X_{L2}^2$$

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

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

3. A RC parallel circuit with $C_3 = 4.7 \, \text{nF}$ on an AC current source ($I_{3S} = 1.3 \, \text{A}$, $f_3 = 200 \, \text{kHz}$), which generates a current of $I_{3R} = 1.0 \, \text{A}$ 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 on the first formula:
$$R_3 \cdot \underline{I}_{3R} = \underline{X}_{3C} \cdot \underline{I}_{3C} \\ R_3 = \underline{X}_{3C} \cdot \frac{|\underline{I}_{3C}|}{|\underline{I}_{3R}|} = \frac{1}{2\pi \cdot f \cdot C_3} \cdot \frac{\sqrt{|\underline{I}_3|^2 - |\underline{I}_{3R}|^2}}{|\underline{I}_{3R}|}$$

Final result

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

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