task_pdkggtyexxy1ktu3_with_calculation

Student Group

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complex impedance, exam ee1 WS2022

Exercise E1.1 Impedances at different Frequencies
(written test, approx. 18 % of a 60-minute written test, WS2022)

2. A RLC series circuit with the resistor values $R_2=34.7~\Omega$ and $R_3=21.0~\Omega$ is connected to a voltage source with $U_3=1.0~{\rm V}$, which generates a current $I_3=50~{\rm mA}$.
Results, with $f=450~{\rm kHz}$, which generates a current $I_3=50~{\rm mA}$.
1. A resistor R_1 shall have the same absolute value of the impedance as a capacitor $C_1=40~{\rm nF}$ at $f_1=4~{\rm MHz}$.

Solution

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$$\begin{align*} R_1 &= 1.00~\Omega \\ \end{align*}$$

$$\begin{align*} R_2 &= 10.0~\Omega \\ \end{align*}$$

A series circuit means that the current is constant on every component.
The equivalent impedance for R and L combined is given by $$\begin{align*} \underline{U} &= R_2 + \underline{X}_{L2} \\ &= R_2 + {\rm j} \cdot \omega L \end{align*}$$ Since $\underline{C}_1$ is perpendicular to R_2 this can be simplified to: $$\begin{align*} \left| \underline{U} \right|^2 &= |R_2|^2 + |\underline{X}_{L2}|^2 \\ \left(\frac{U}{I} \right)^2 &= R_2^2 + X_{L2}^2 \\ \left(\frac{U}{I} \right)^2 - R_2^2 &= X_{L2}^2 \\ \sqrt{\left(\frac{U}{I} \right)^2 - R_2^2} &= X_{L2} \end{align*}$$

Parallel circuit means that the voltage is the same on R_3 and C_3.
$$\begin{align*} R_1 &= \underline{X}_{C1} \\ &= \frac{1}{2\pi \cdot f \cdot C_1} \\ &= \frac{1}{2\pi \cdot 4~{\rm MHz} \cdot 40~{\rm nF}} \\ \end{align*}$$

$\underline{I}_{3R}$ is perpendicular to $\underline{I}_{3C}$ (It has to, since R_3 is perpendicular to ${\rm j}\cdot\underline{X}_{3C}$ too).
Therefore, the resulting current of the parallel circuit is given as: $$\begin{align*} \underline{I}_{3} &= \underline{I}_{3R} + \underline{I}_{3C} \\ |\underline{I}_{3}|^2 &= |\underline{I}_{3R}|^2 + |\underline{I}_{3C}|^2 \\ |\underline{I}_{3C}|^2 &= |\underline{I}_{3}|^2 - |\underline{I}_{3R}|^2 \\ \sqrt{|\underline{I}_{3C}|^2} &= \sqrt{|\underline{I}_{3}|^2 - |\underline{I}_{3R}|^2} \\ I_{3C} &= \sqrt{\left(\frac{U_3}{R_3} \right)^2 - \left(\frac{U_3}{\omega L} \right)^2} \\ &= \sqrt{\left(\frac{1.0~{\rm V}}{21~\Omega} \right)^2 - \left(\frac{1.0~{\rm V}}{2\pi \cdot 450~{\rm kHz} \cdot 4.7 ~ {\rm µH}} \right)^2} \\ &= \frac{1.0~{\rm V}}{60~\rm mA} \end{align*}$$
Back to the first formula: $$\begin{align*} R_3 \cdot {I}_{3R} &= {X}_{3C} \cdot {I}_{3C} \\ R_3 &= {X}_{3C} \cdot \frac{{I}_{3C}}{{I}_{3R}} \\ &= \frac{1}{2\pi \cdot f \cdot C_3} \cdot \frac{\sqrt{|{I}_{3}|^2 - |{I}_{3R}|^2}}{{I}_{3R}} \\ \end{align*}$$