complex impedance, exam ee1 WS2022

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

2. A RLC series circuit with $L=4.7 ~\mu{\rm H}$ is driven at $f_3=450 ~{\rm kHz}$, which generates a current $I_3=60 ~{\rm mA}$. Calculate the resistor values R_2 and R_3 and the voltage U_3.
Result: $R_3=200 ~\Omega$, $R_2=10.0 ~\Omega$, $U_3=21.3 ~{\rm V}$

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

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 $$\begin{align*} {{\underline{U}}\over{\underline{I}}} &= R_2 + \underline{X}_{L2} \\ &= R_2 + {\rm j} \cdot \omega L \end{align*}$$ Since $\underline{\omega L}$ is perpendicular to R_2 this can be simplified to: $$\begin{align*} \left| {{\underline{U}}\over{\underline{I}}} \right|^2 &= |R_2|^2 + |\underline{X}_{L2}|^2 \\ \left({{U}\over{I}} \right)^2 &= {R_2}^2 + {X_{L2}}^2 \\ \end{align*}$$ Therefore, the resulting current of the parallel circuit is given as: $$\begin{align*} \underline{I}_{3} &= \underline{I}_{3R} + \underline{I}_{3C} \\ |\underline{I}_{3}|^2 &= |\underline{I}_{3R}|^2 + |\underline{I}_{3C}|^2 \\ I_3^2 &= I_{3R}^2 + I_{3C}^2 \\ I_{3R}^2 &= I_3^2 - I_{3C}^2 \\ I_{3R} &= \sqrt{I_3^2 - I_{3C}^2} \\ I_{3R} &= \sqrt{\left(60~{\rm mA} \right)^2 - (2\pi \cdot 450~{\rm kHz} \cdot 4.7 ~ {\rm µH})^2 } \\ \end{align*}$$ Back to the first formula: $$\begin{align*} R_3 \cdot {I}_{3R} &= {X}_{3C} \cdot {I}_{3C} \\ R_3 &= {X}_{3C} \cdot {{{I}_{3C}}\over{{I}_{3R}}} \\ &= {{1}\over{2\pi \cdot f \cdot C_3}} \cdot {{\sqrt{|{I}_{3}|^2 - |{I}_{3R}|^2}}\over{{I}_{3R}}} \\ \end{align*}$$

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Last update: **2023/04/02 00:27**