task_pdkggtyexxy1ktu3_with_calculation

Student Group

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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 the resistor values $R_2=34.7 ~\Omega$ and $R_3=21.3 ~\Omega$ is connected to a voltage source with $U_3=1.0 ~{\rm V}$, which generates a current $I_3=50 ~{\rm mA}$.
Result: $f=450 ~{\rm kHz}$, $L=4.7 ~{\rm \mu H}$, $C=40 ~{\rm nF}$

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

Solution

\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*}

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

\begin{align*} R_1 &= \underline{X}_{C1} \\ &= {{1}\over{2\pi \cdot f \cdot C_1}} \\ &= {{1}\over{2\pi \cdot 4~{\rm MHz} \cdot 40~{\rm nF}}} \\ \end{align*}

Since ${\rm nF}$ 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*}

$\underline{I}_{3R}$ is perpendicular to $\underline{I}_{3C}$ (It has to, since R_3 is perpendicular to ${\rm j}\cdot{X}_{3C}$ 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 \\ I_3^2 &= I_{3R}^2 + I_{3C}^2 \\ I_{3C}^2 &= I_3^2 - I_{3R}^2 \\ I_{3C} &= \sqrt{I_3^2 - I_{3R}^2} \\ &= \sqrt{\left({{U_3}\over{R_3}} \right)^2 - \left({{U_3}\over{R_2}} \right)^2} \\ &= \sqrt{\left({{1.0~{\rm V}}\over{60~{\rm mA}}} \right)^2 - \left({{1.0~{\rm V}}\over{34.7~\Omega}} \right)^2} \\ &= 0.0466~{\rm A} \end{align*}

This can be plugged into the R_2 branch: \begin{align*} |\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} \\ &= \sqrt{\left({{U_3}\over{R_3}} \right)^2 - \left({{U_3}\over{R_2}} \right)^2} \\ &= \sqrt{\left({{1.0~{\rm V}}\over{60~{\rm mA}}} \right)^2 - \left({{1.0~{\rm V}}\over{34.7~\Omega}} \right)^2} \\ &= 0.0288~{\rm A} \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*}