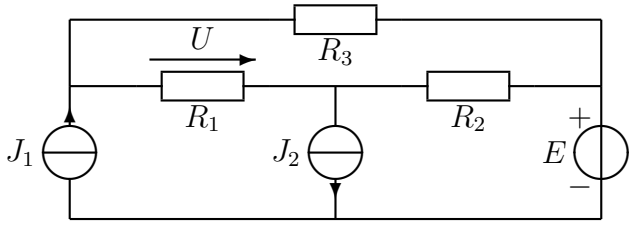
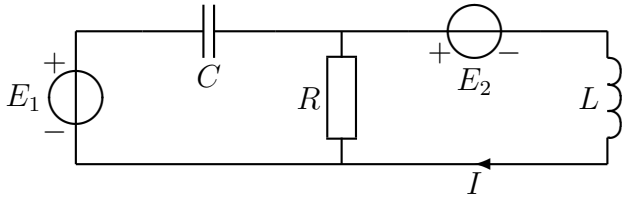
ELEC–C4210 SÄHKÖTEKNIIKKA JA ELEKTRONIIKKA Kimmo Silvonen

1. välikoe 18.10.2022. **1. mellanförhör 18.10.2022.**

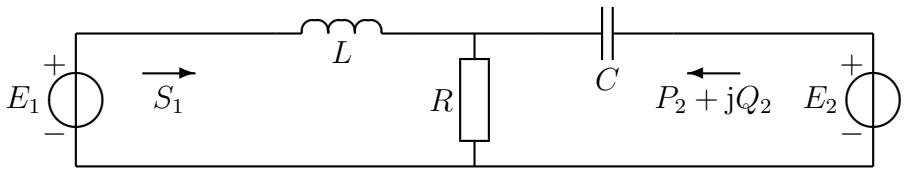
1. Laske jännite U.
1. Beräkna spänningen U.
$R_1 = 2\ \Omega$, $R_2 = 4\ \Omega$, $R_3 = 8\ \Omega$, $E = 14$ V, $J_1 = 2$ A, $J_2 = 3$ A.



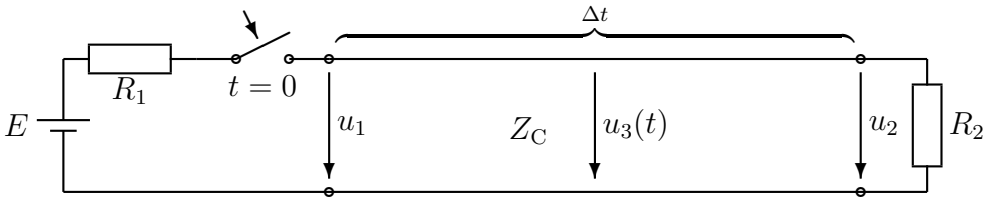
2. Laske virta I.
2. Beräkna strömmen I.
$R = 10\ \Omega$, $L = 0{,}5$ H, $C = 0{,}02$ F, $\omega = 10\ \frac{\text{rad}}{\text{s}}$, $E_1 = 10\angle 0°$ V, $E_2 = 20\angle 90°$ V.



3. Tiedämme, että E_1 luovuttaa kompleksisen tehon $S_1 = 50 - \text{j}50$ VA. Kuinka suuri on E_2:n luovuttama pätöteho P_2?
3. Vi vet, att den komplexa effekten av E_1 är $S_1 = 50 - \text{j}50$ VA. Beräkna den genomsnittliga effekten P_2 som tas från spänningskällan E_2.
$R = 2\ \Omega$, $L = 0{,}4$ H, $C = 0{,}1$ F, $\omega = 5\ \frac{\text{rad}}{\text{s}}$, $E_1 = 10\angle 0°$ V, E_2=?



4. Miten kauan kestää, että siirtojohdon keskikohdan jännite $u_3(t)$ ylittää 98% loppuarvostaan?
4. Hur lång tid tar det för spänningen $u_3(t)$ i mitten av transmissionslinjen att överstiga 98 % av slutvärdet?
$R_1 = 50\ \Omega$, $R_2 = 85\ \Omega$, $Z_\text{C} = 40\ \Omega$, $E = 13{,}5$ V, $\Delta t = 2$ ms.

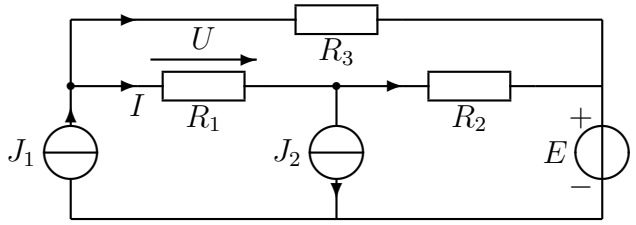


Resultat och svar kan hittas i MyCo.
Ratkaisut ja tulokset tulevat MyCoon.

ELEC–C4210 SÄHKÖTEKNIIKKA JA ELEKTRONIIKKA Kimmo Silvonen

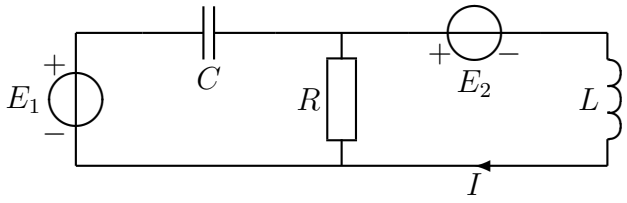
1. välikoe 18.10.2022. 1. mellanförhör 18.10.2022.

1. Laske jännite U.
1. Beräkna spänningen U.
$R_1 = 2\ \Omega$, $R_2 = 4\ \Omega$, $R_3 = 8\ \Omega$, $E = 14$ V, $J_1 = 2$ A, $J_2 = 3$ A.



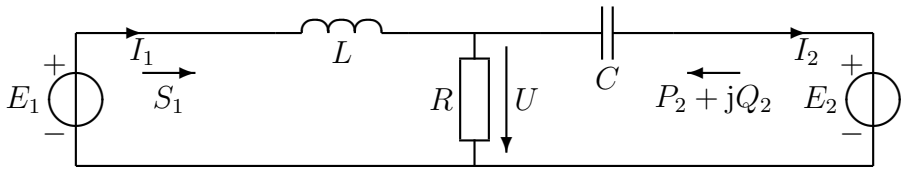
$$J_1 = I + I_{R3} \Rightarrow I_{R3} = J_1 - I \tag{1}$$
$$I = J_2 + I_{R2} \Rightarrow I_{R2} = I - J_2 \tag{2}$$
$$R_3 I_{R3} - R_2 I_{R2} - R_1 I = 0 \tag{3}$$
$$R_3(J_1 - I) - R_2(I - J_2) - R_1 I = 0 \Rightarrow I = \frac{R_3 J_1 + R_2 J_2}{R_3 + R_2 + R_1} = 2 \tag{4}$$
$$U = R_1 I = 4\ \mathrm{V} \tag{5}$$

2. Laske virta I.
2. Beräkna strömmen I.
$R = 10\ \Omega$, $L = 0{,}5$ H, $C = 0{,}02$ F, $\omega = 10\ \frac{\mathrm{rad}}{\mathrm{s}}$, $E_1 = 10\angle 0°$ V, $E_2 = 20\angle 90°$ V.



$$R(I_1 + I) + E_2 + \mathrm{j}\omega L I = 0 \Rightarrow I_1 = \frac{-RI - E_2 - \mathrm{j}\omega L I}{R} \tag{6}$$
$$E_1 + R(I_1 + I) + \frac{1}{\mathrm{j}\omega C} I_1 = 0 \tag{7}$$
$$\Rightarrow E_1 + RI + \left(R + \frac{1}{\mathrm{j}\omega C}\right)\left(\frac{-RI - E_2 - \mathrm{j}\omega L I}{R}\right) = 0 \tag{8}$$
$$I = \frac{-E_1 + \left(R + \frac{1}{\mathrm{j}\omega C}\right)\left(\frac{E_2}{R}\right)}{R - \left(R + \frac{1}{\mathrm{j}\omega C}\right)\left(\frac{R + \mathrm{j}\omega L}{R}\right)} = \frac{E_2 - E_1 + \frac{1}{\mathrm{j}\omega C}\frac{E_2}{R}}{R - \left(R + \frac{1}{\mathrm{j}\omega C}\right)\left(1 + \frac{\mathrm{j}\omega L}{R}\right)} \tag{9}$$
$$= \frac{E_2 - E_1 + \frac{1}{\mathrm{j}\omega C}\frac{E_2}{R}}{-\mathrm{j}\omega L - \frac{1}{\mathrm{j}\omega C}\left(1 + \frac{\mathrm{j}\omega L}{R}\right)} = \frac{\mathrm{j}\omega C(E_2 - E_1) + \frac{E_2}{R}}{\omega^2 LC - \left(1 + \frac{\mathrm{j}\omega L}{R}\right)} \tag{10}$$
$$= \frac{\mathrm{j}0{,}2(E_2 - E_1)R + E_2}{-\mathrm{j}\omega L} = \frac{\mathrm{j}0{,}2(20\mathrm{j} - 10)R + 20\mathrm{j}}{-\mathrm{j}5} \tag{11}$$
$$= -0{,}2(4\mathrm{j} - 2)R - 4 = -8\mathrm{j} = 8\angle -90°\ \mathrm{A} \tag{12}$$

3. Tiedämme, että E_1 luovuttaa kompleksisen tehon $S_1 = 50 - \mathrm{j}50$ VA. Kuinka suuri on E_2:n luovuttama pätöteho P_2?
3. Vi vet, att den komplexa effekten av E_1 är $S_1 = 50 - \mathrm{j}50$ VA. Beräkna den genomsnittliga effekten P_2 som tas från spänningskällan E_2.
$R = 2\ \Omega$, $L = 0{,}4$ H, $C = 0{,}1$ F, $\omega = 5\ \frac{\mathrm{rad}}{\mathrm{s}}$, $E_1 = 10\angle 0°$ V, E_2=?.

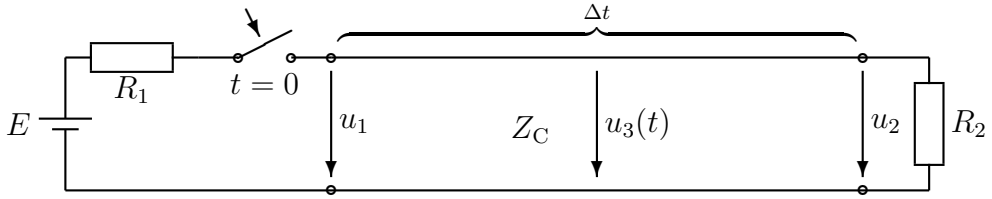


$$S_1 = P_1 + \mathrm{j}Q_1 = E_1 I_1^* \Rightarrow I_1^* = \frac{S_1}{E_1} = 5 - \mathrm{j}5 \Rightarrow I_1 = 5 + \mathrm{j}5 \tag{13}$$
$$U = E_1 - \mathrm{j}\omega L I_1 = 10 - \mathrm{j}2(5 + \mathrm{j}5) = 20 - \mathrm{j}10 \tag{14}$$
$$P = \frac{|U|^2}{R} = \frac{20^2 + 10^2}{2} = 250 \tag{15}$$
$$P = P_1 + P_2 \Rightarrow P_2 = P - P_1 = 200\ \mathrm{W} \tag{16}$$

Tarkistus

$$I_2 = I_1 - I_R = I_1 - \frac{U}{R} = 5 + \mathrm{j}5 - (10 - \mathrm{j}5) = -5 + \mathrm{j}10 \tag{17}$$
$$E_2 = U - \frac{1}{\mathrm{j}\omega C} I_2 = 20 - \mathrm{j}10 + \mathrm{j}2\,(-5 + \mathrm{j}10) = -\mathrm{j}20 \tag{18}$$
$$S_2 = P_2 + \mathrm{j}Q_2 = E_2(-I_2)^* = -\mathrm{j}20(5 - \mathrm{j}10)^* = -\mathrm{j}20(5 + \mathrm{j}10) = 200 - \mathrm{j}100\ \mathrm{VA} \tag{19}$$
$$\mathrm{j}(Q_1 + Q_2) = \mathrm{j}\omega L |I_1|^2 + \frac{1}{\mathrm{j}\omega C} |I_2|^2 \tag{20}$$
$$Q_1 + Q_2 = -50 - 100 = 2(5^2 + 5^2) - 2(5^2 + 10^2) = -150\ \mathrm{VAr} \tag{21}$$

4. Miten kauan kestää, että johdon keskikohdan jännite $u_3(t)$ ylittää 98% loppuarvostaan?
4. Hur lång tid tar det för spänningen $u_3(t)$ i mitten av transmissionslinjen att överstiga 98 % av slutvärdet?
$R_1 = 50\ \Omega$, $R_2 = 85\ \Omega$, $Z_\mathrm{C} = 40\ \Omega$, $E = 13.5$ V, $\Delta t = 2$ ms.



$$u_1(\infty) = u_2(\infty) = u_3(\infty) = \frac{R_2}{R_1 + R_2} E = 8{,}5 \tag{22}$$
$$u_1(0) = \frac{Z_\mathrm{C}}{R_1 + Z_\mathrm{C}} \cdot E = 6 \tag{23}$$
$$\rho_2 = \frac{R_2 - Z_\mathrm{C}}{R_2 + Z_\mathrm{C}} = \frac{9}{25} \tag{24}$$
$$\rho_1 = \frac{R_1 - Z_\mathrm{C}}{R_1 + Z_\mathrm{C}} = \frac{1}{9} \tag{25}$$
$$u_3(0{,}5\Delta t) = u_1(0) = 6 \tag{26}$$
$$u_3(1{,}5\Delta t) = u_1(0) + u_1(0)\rho_2 = 8{,}16 \tag{27}$$
$$u_3(2{,}5\Delta t) = u_1(0) + u_1(0)\rho_2 + u_1(0)\rho_2\rho_1 = 8{,}4 \tag{28}$$

Tämä on 98,8% loppuarvosta. Aikaa kului $2{,}5\Delta t = 5$ ms.