
VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

ELEKTRONIKA PRE INFORMAČNÉ TECHNOLÓGIE

SEMESTRÁLNY PROJEKT

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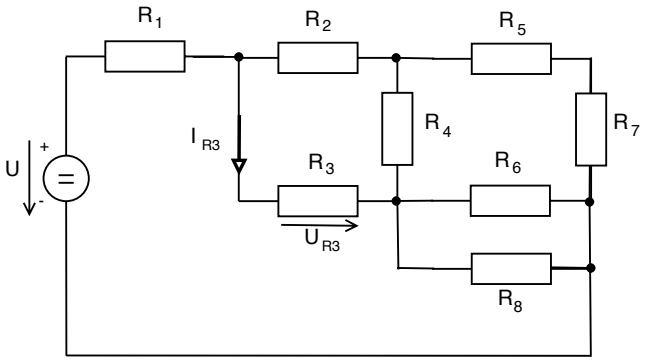
21. DECEMBRA 2015

**1**

Stanovte napätie $U_{R3}$ a prúd $I_{R3}$. Použite metódu postupného zjednodušovania obvodu. A

| sk. | $U$ [V] | $R_1$ [Ω] | $R_2$ [Ω] | $R_3$ [Ω] | $R_4$ [Ω] | $R_5$ [Ω] | $R_6$ [Ω] | $R_7$ [Ω] | $R_8$ [Ω] |
|---|---|---|---|---|---|---|---|---|---|
| C | 100 | 450 | 810 | 190 | 220 | 220 | 720 | 260 | 180 |

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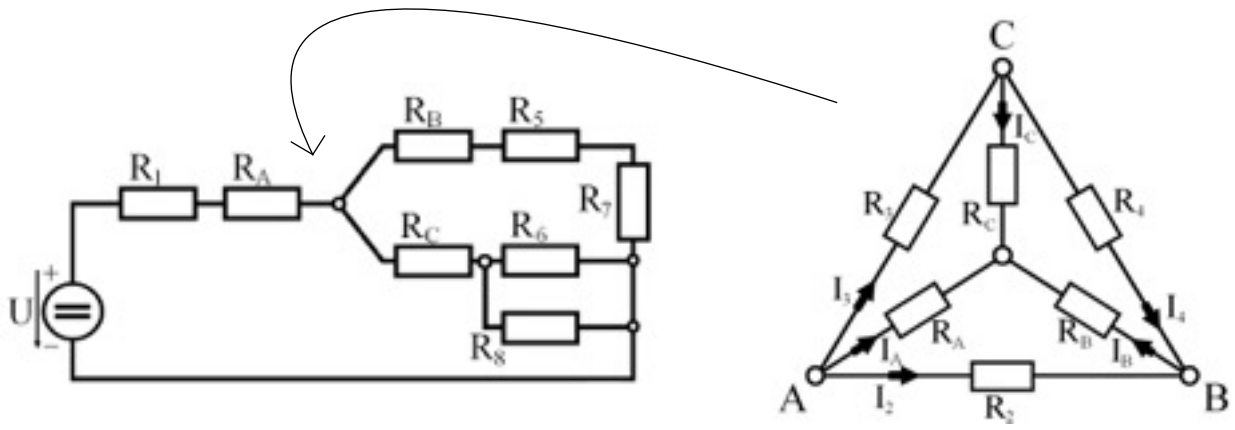
Riešenie:

1. Hviezda: $R_2$, $R_3$, $R_4$

$$R_A = \frac{R_2 \,.\, R_3}{R_2 + R_3 + R_4} = \frac{810 \,.\, 190}{810 + 190 + 220} = 126.1475\ \Omega$$

$$R_B = \frac{R_2 \,.\, R_4}{R_2 + R_3 + R_4} = \frac{810 \,.\, 220}{810 + 190 + 220} = 146.0656\ \Omega$$

$$R_C = \frac{R_3 \,.\, R_4}{R_2 + R_3 + R_4} = \frac{190 \,.\, 220}{810 + 190 + 220} = 34.2623\ \Omega$$

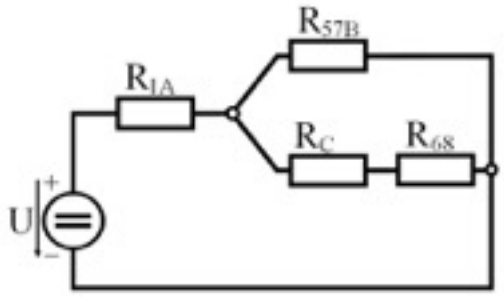


2. Sériové spojenie $R_1$, $R_A$
Sériové spojenie $R_5$, $R_7$, $R_B$
Paralelné spojenie $R_6$, $R_8$

$$R_{1A} = R_1 + R_A = 450 + 126.1475 = 576.1475\ \Omega$$

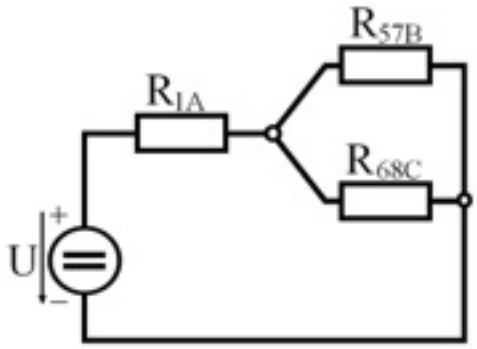
$$R_{57B} = R_5 + R_7 + R_B = 220 + 260 + 146.0656 = 626.0656\ \Omega$$

$$R_{68} = \frac{R_6 \,.\, R_8}{R_6 + R_8} = \frac{720 \,.\, 180}{720 + 180} = 144\ \Omega$$



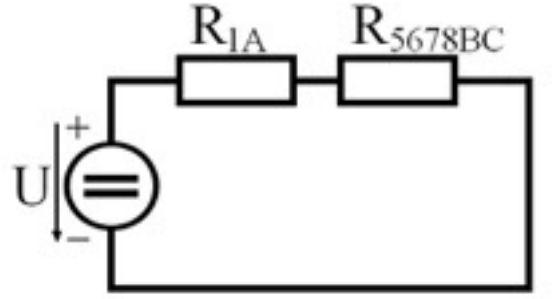

3. Sériové spojenie $R_C$, $R_{68}$

$$R_{68C} = R_{68} + R_C = 144 + 34.2623 = 178.2623\ \Omega$$



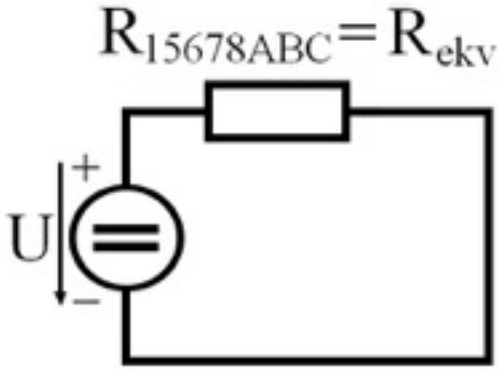

4. Paralelné spojenie $R_{57B}$, $R_{68C}$

$$R_{5678BC} = \frac{R_{57B} \,.\, R_{68C}}{R_{57B} + R_{68C}} = \frac{626.0656 \,.\, 178.2623}{626.0656 + 178.2623} = 138.7542\ \Omega$$



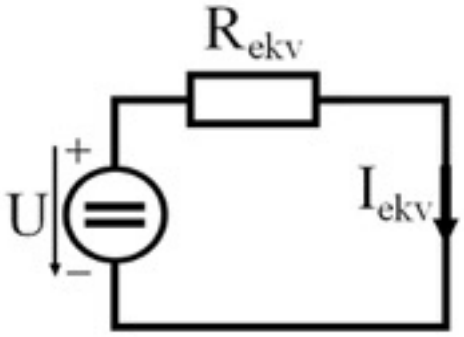
5. Sériové spojenie $R_{1A}$, $R_{5678BC}$, vypočet celkového odporu prúdu $R_{ekv}$

$$R_{15678ABC} = R_{1A} + R_{5678BC} = 576.1475 + 138.7542 \ = 714.9017\ \Omega = R_{ekv}$$




6. Výpočet celkového prúdu v obvode $I_{ekv}$

$$I_{ekv} = \frac{U}{R_{ekv}} = \frac{100}{714.9017} = 0.1399\ A$$




7. Výpočet $I_3$ a $U_3$

$$U_2 = U_3 \ , \ I_3 = \frac{U_3}{R_3} \ , \ I_3 = I_{ekv} - I_2 = I_{ekv} - \frac{U_3}{R_2}$$

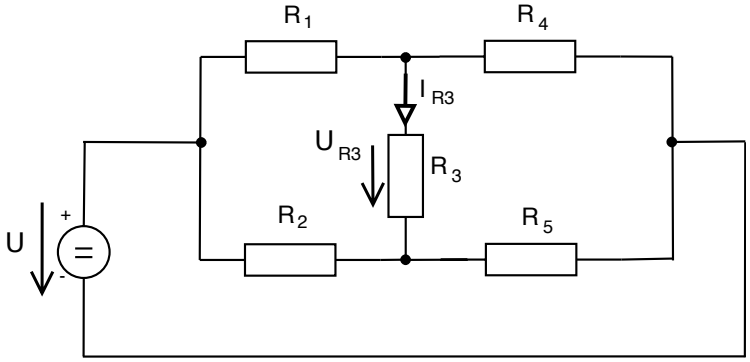
$$\frac{U_3}{190} = 0.1399 - \frac{U_3}{810} \quad \rightarrow \quad U_3 = 21.5306\ V$$

$$I_3 = \frac{U_3}{R_3} = \frac{21.5306}{190} = 0.1133\ A = 113.3\ mA$$

**2**

Stanovte napätie $U_{R3}$ a prúd $I_{R3}$. Použite metódu Théveninovej vety.

| sk. | $U$ [V] | $R_1$ [Ω] | $R_2$ [Ω] | $R_3$ [Ω] | $R_4$ [Ω] | $R_5$ [Ω] |
|---|---|---|---|---|---|---|
| H | 220 | 360 | 580 | 205 | 560 | 350 |

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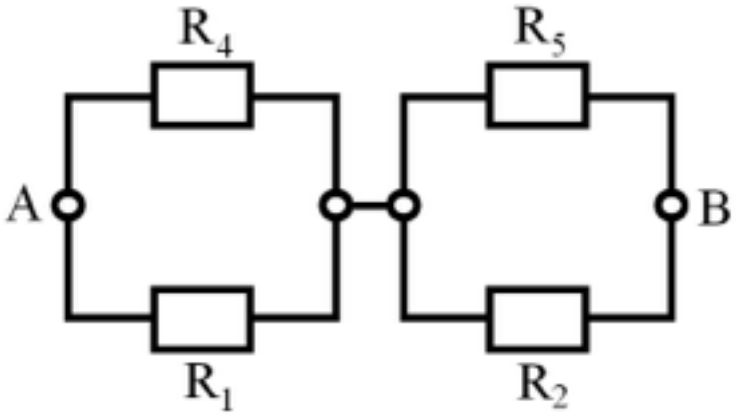
Riešenie:

1. Výpočet $R_i$

$$R_i = \frac{R_1 \,.\, R_4}{R_1 + R_4} + \frac{R_2 \,.\, R_5}{R_2 + R_5} = \frac{360 \,.\, 560}{360 + 560} + \frac{580 \,.\, 350}{580 + 350} = 437.41\ \Omega$$



2. Výpočet $U_i$

$I_x \,.\, R_1 + I_x \,.\, R_4 \text{ - } U_i = 0$

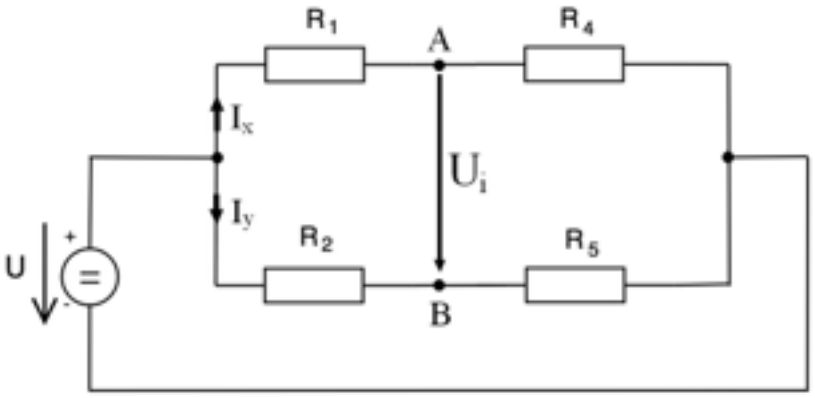
$360 \,.\, I_x \; + 560 \,.\, I_x \text{ - } 220 = 0$

$I_x = 0{,}2391 \; A$

$I_y \,.\, R_2 + I_y \,.\, R_5 \text{ - } U_i = 0$

$580 \,.\, I_y + 350 \,.\, I_y \text{ - } 220 = 0$

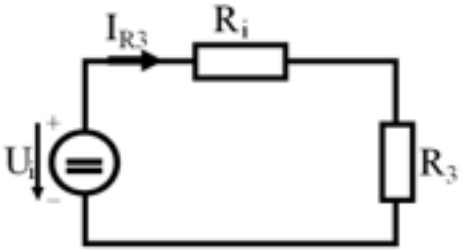
$I_y = 0.2366 \; A$




$$U_i = I_y \,.\, R_2 \text{ - } I_x \,.\, R_1 = 137.228 \text{ - } 86.076 = 51.152 \; V$$

3. Výpočet $I_3$

$$I_{R3} = \frac{U_i}{R_i + R_3} = \frac{51.152}{437.41 + 205} = 0.0796 \; A = 79.6 \; mA$$



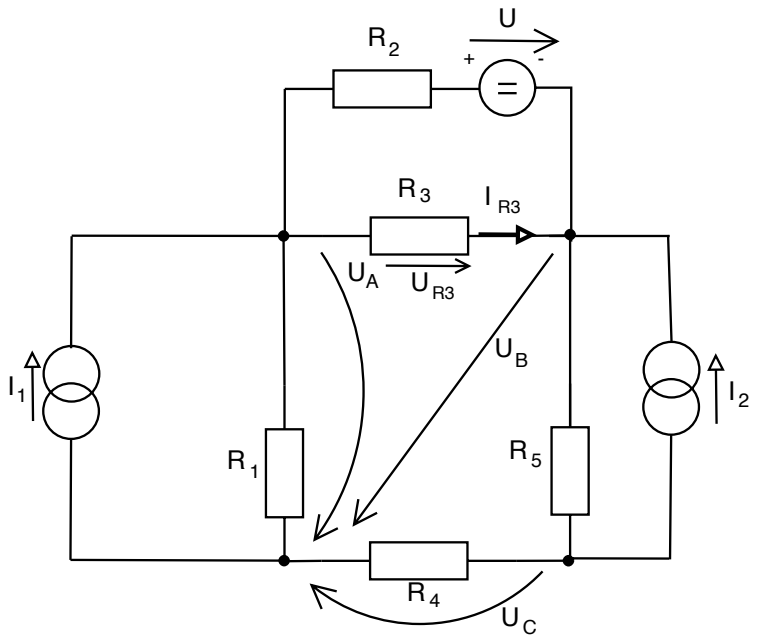

4. Výpočet $U_3$

$$U_{R3} = I_{R3} \,.\, R_3 = 0.0796 \,.\, 205 = 16.318 \; V$$

**3**

Stanovte napätie $U_{R3}$ a prúd $I_{R3}$. Použite metódu uzľových napätí ($U_A$, $U_B$, $U_C$).

| sk. | $U$ [V] | $I_1$[A] | $I_2$[A] | $R_1$ [Ω] | $R_2$ [Ω] | $R_3$ [Ω] | $R_4$ [Ω] | $R_5$ [Ω] |
|---|---|---|---|---|---|---|---|---|
| C | 110 | 0.85 | 0.75 | 440 | 310 | 560 | 200 | 300 |

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Riešenie:

1. Zostavenie rovníc pre uzly

$A$: $I_1 + I_{R2}$ - $I_{R3}$ - $I_{R1} = 0$

$B$: $I_{R3} + I_2$ - $I_{R2}$ - $I_{R5} = 0$

C: $I_{R5}$ - $I_2$ - $I_{R4} = 0$

2. Riešenie sústavy rovníc

$A$: $$I_1 + \frac{U_B + U - U_A}{R_2} - \frac{U_A - U_B}{R_3} - \frac{U_A}{R_1} = 0$$

$B$: $$\frac{U_A - U_B}{R_3} + I_2 - \frac{U_B + U - U_A}{R_2} - \frac{U_B - U_C}{R_5} = 0$$

C: $$\frac{U_B - U_C}{R_5} - I_2 - \frac{U_C}{R_4} = 0$$

$$A: \quad 0.85 + \frac{U_B + 110 \text{ - } U_A}{310} \text{ - } \frac{U_A \text{ - } U_B}{560} \text{ - } \frac{U_A}{440} = 0 \quad \left| . 190960 \right|$$

$$B: \quad \frac{U_A \text{ - } U_B}{560} + 0.75 \text{ - } \frac{U_B + 110 \text{ - } U_A}{310} \text{ - } \frac{U_B \text{ - } U_C}{300} = 0 \quad \left| . 260400 \right|$$

$$C: \quad \frac{U_B \text{ - } U_C}{300} \text{ - } 0.85 \text{ - } \frac{U_C}{200} = 0 \quad \left| . 600 \right|$$

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$$A: \quad \text{-}1391 \,.\, U_A + 957 \,.\, U_B = \text{ - } 230076$$

$$B: \quad 1305 \,.\, U_A \text{ - } 2173 \,.\, U_B + 868 \,.\, U_C = \text{ - } 102900$$

$$C: \quad 2 \,.\, U_B \text{ - } 5 \,.\, U_C = 450$$

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$$M = \begin{bmatrix} \text{-}1391 & 957 & 0 \\ 1305 & \text{-}2173 & 868 \\ 0 & 2 & \text{-}5 \end{bmatrix}, \quad N = \begin{bmatrix} \text{-}230076 \\ \text{-}102900 \\ 450 \end{bmatrix}$$

$$D = \begin{bmatrix} \text{-}1391 & 957 & 0 \\ 1305 & \text{-}2173 & 868 \\ 0 & 2 & \text{-}5 \end{bmatrix} \begin{bmatrix} \text{-}1391 & 957 \\ 1305 & \text{-}2173 \\ 0 & 2 \end{bmatrix} \text{ - } 15113215 + 2414776 + 6244425 = \text{ - } 6454014$$

$$D_1 = \begin{bmatrix} \text{-}230076 & 957 & 0 \\ \text{-}102900 & \text{-}2173 & 868 \\ 450 & 2 & \text{-}5 \end{bmatrix} \begin{bmatrix} \text{-}230076 & 957 \\ \text{-}102900 & \text{-}2173 \\ 450 & 2 \end{bmatrix} \text{ - } 2449775740 + 373804200 \text{ - } 399411936 \text{ - } 492376300 = \text{ - } 2218936104$$

$$D_2 = \begin{bmatrix} \text{-}1391 & \text{-}230076 & 0 \\ 1305 & \text{-}102900 & 868 \\ 0 & 450 & \text{-}5 \end{bmatrix} \begin{bmatrix} \text{-}1391 & \text{-}230076 \\ 1305 & \text{-}102900 \\ 0 & 450 \end{bmatrix} \text{ - } 715669500 + 543324600 + 1501245900 = \text{ - } 1673590800$$

$$U_A = \frac{D_1}{D} = \frac{\text{ - } 2218936104}{\text{ - } 6454014} = 343.8071 \; V$$

$$U_B = \frac{D_2}{D} = \frac{\text{ - } 1673590800}{\text{ - } 6454014} = 259.3101 \; V$$

3. Výpočet $U_{R3}$, $I_{R3}$

$$U_{R3} = U_A \text{ - } U_B = 343.8071 \text{ - } 259.3101 = 84.497 \; V$$

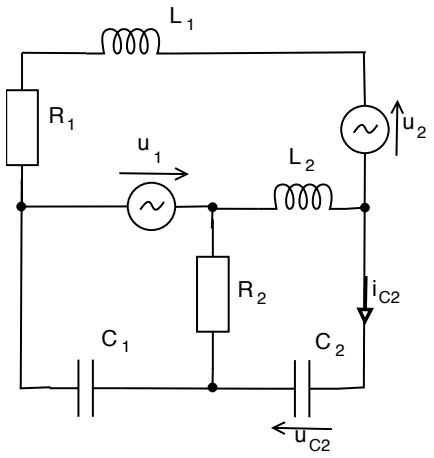
$$I_{R3} = \frac{U_{R3}}{R_3} = \frac{84.497}{560} = 0.1509 \; A$$

4

Pre napájacie napätie platí: $u_1 = U_1 \cdot \sin(2\pi f\ t)$, $u_2 = U_2 \cdot \sin(2\pi f\ t)$.
Vo vzťahu pre napätie $u_{C2} = U_{C2} \cdot \sin(2\pi f\ t + \phi_{C2})$ určte $|U_{C2}|$ a $\phi_{C2}$. Použite metódu smľučkových prúdov.

Pozn: Pomocné smery šípok napájacích zdrojov platia pre špeciálny časový okamih ($t = 2\omega$).

| sk. | $U_1$ [V] | $U_2$ [V] | $R_1$ [Ω] | $R_2$ [Ω] | $L_1$ [mH] | $L_2$ [mH] | $C_1$ [µF] | $C_2$ [µF] | $f$ [Hz] |
|---|---|---|---|---|---|---|---|---|---|
| C | 35 | 45 | 105 | 130 | 220 | 70 | 230 | 85 | 75 |

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Riešenie:

1. Vyjadrenie rovníc pre sľučky

$$I_1 \,.\, \left(j\ 2\pi f L_1 + j\ 2\pi f L_2 + R_1\right) \text{ - } I_3 \,.\, \left(j\ 2\pi f L_2\right) \text{ - } U_1 \text{ - } U_2 = 0$$

$$I_2 \,.\, \left(\text{-}j\ \frac{1}{j\ 2\pi f\ \mathrm{C}_1} + R_2\right) \text{ - } I_3 \,.\, R_2 + U_1 = 0$$

$$I_1 \,.\, \left(\text{-}j\ 2\pi f L_2\right) \text{ - } I_2 \,.\, R_2 + I_3 \left(j\ 2\pi f L_2 + \frac{1}{j\ 2\pi f\ \mathrm{C}_2} + R_2\right) = 0$$

2. Riešenie rovníc

$$I_1 \,.\, \left(105 + j\ 136.6593\right) + I_3 \,.\, \left(\text{-}j\ 32.9867\right) = 80$$

$$I_2 \,.\, \left(130 \text{ - } j\ 9.2264\right) \text{ - } I_3 \,.\, 130 = \text{ - } 35$$

$$I_1 \,.\, \left(\text{-}j\ 32.9867\right) \text{ - } I_2 \,.\, 130 + I_3 \,.\, \left(130 + j\ 8.0212\right) = 0$$

$$M = \begin{bmatrix} 105 + j\,136.6593 & 0 & -j\,32.9867 \\ 0 & 130 - j\,9.2264 & -130 \\ -j\,32.9867 & -130 & 130 + j\,8.0212 \end{bmatrix}, \; N = \begin{bmatrix} 80 \\ -35 \\ 0 \end{bmatrix}$$

$$D = \begin{bmatrix} 105 + j\,136.6593 & 0 & -j\,32.9867 \\ 0 & 130 - j\,9.2264 & -130 \\ -j\,32.9867 & -130 & 130 + j\,8.0212 \end{bmatrix} \begin{bmatrix} 105 + j\,136.6593 & 0 \\ 0 & 130 - j\,9.2264 \\ -j\,32.9867 & -130 \end{bmatrix} = 170637.8554 - j\,16376.7149$$

$$D_3 = \begin{bmatrix} 105 + j\,136.6593 & 0 & 80 \\ 0 & 130 - j\,9.2264 & -35 \\ -j\,32.9867 & -130 & 0 \end{bmatrix} \begin{bmatrix} 105 + j\,136.6593 & 0 \\ 0 & 130 - j\,9.2264 \\ -j\,32.9867 & -130 \end{bmatrix} = -453402.1209 - j\,278738.135$$

$$I_3 = I_{C2} = \frac{D_3}{D} = \frac{-453402.1209 - j\,278738.135}{170637.8554 - j\,16376.7149} = -2.4475 - j\,1.8713\ A$$

3. Výpočet $U_{C2}$ a $\phi_{C2}$

$$U_{C2} = I_{C2} \,.\, X_{C2} = I_{C2} \,.\, \frac{-j}{2\pi f\ C_2} = -46.7179 + j\,61.1031\ V$$

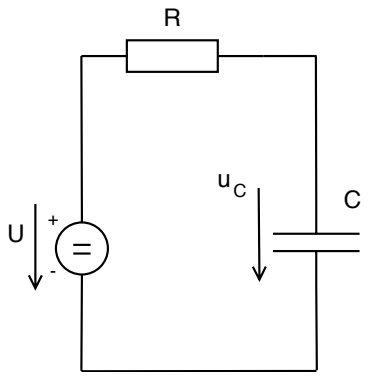
$$\left|U_{C2}\right| = \sqrt{(-46.7179)^2 + (61.1031)^2} = 76.9165\ V$$

$$\varphi_{C2} = \pi - \arctan\left(\frac{61.1031}{46.7179}\right) = \pi - 0.9180 \text{ rad} = 2.2236 \text{ rad}$$

5

Zostavte diferenciálnu rovnicu popisujúcu správanie obvodu na obrázku, ďalej ju upravte dosadením hodnôt parametrov. Vypočítajte analytické riešenie $u_c = f\,(t)$. Urobte kontrolu výpočtu dosadením do zostavenej diferenciálnej rovnice.

| sk. | $U$ [V] | $C$ [F] | $R$ [Ω] | $u_c(0)$ |
|---|---|---|---|---|
| H | 5 | 50 | 40 | 2 |

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Riešenie:

1. Potrebné rovnice

$$u_c' = \frac{1}{C} \,.\, i_c \quad , \quad i_c = \frac{u - u_c}{R}$$

$$u_c' = \frac{1}{C} \,.\, \frac{u - u_c}{R}$$

$$u_c\,(t) = c\,(t) \,.\, e^{\lambda \,.\, t}$$

2. Dosadenie hodnôt parametrov, riešenie rovnice a výpočet $u_c = f\,(t)$

$$u_c' = \frac{1}{50} \,.\, \frac{5 - u_c}{40} = \frac{5 - u_c}{2000}$$

$$2000 \,.\, u_c' + u_c = 5 \quad , \quad \lambda = -\,\frac{1}{2000}$$

$$2000 \,.\, \left( c'\left(t\right) \,.\, e^{-\frac{t}{2000}} + c\left(t\right) \,.\, e^{-\frac{t}{2000}} \,.\, \left( - \frac{1}{2000} \right) \right) + c\left(t\right) \,.\, e^{-\frac{t}{2000}} = 5$$

$$2000 \,.\, c'\left(t\right) \,.\, e^{-\frac{t}{2000}} = 5$$

$$c'\left(t\right) = \frac{5}{2000} \,.\, e^{-\frac{t}{2000}}$$

$$\int c'\left(t\right) = \int \frac{5}{2000} \,.\, e^{-\frac{t}{2000}}$$

$$c\left(t\right) = 5 \,.\, e^{\frac{t}{2000}} + k$$

$$u_c\left(t\right) = \left( 5 \,.\, e^{\frac{t}{2000}} + k \right) \,.\, e^{-\frac{t}{2000}}$$

$$u_c\left(0\right) = 2 \quad , \quad 2 = 5 + k \quad , \quad k = -3$$

$$u_c\left(t\right) = 5 - 3 \,.\, e^{-\frac{t}{2000}}$$

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4. Kontrola dosadením

$$2000 \,.\, \left( -3 \,.\, e^{-\frac{t}{2000}} \,.\, \left( - \frac{1}{2000} \right) \right) + 5 - 3 \,.\, e^{-\frac{t}{2000}} = 5$$

$$3 \,.\, e^{-\frac{t}{2000}} + 5 - 3 \,.\, e^{-\frac{t}{2000}} = 5$$

$$5 = 5$$

| Číslo príkladu | Varianta | Výsledky | |
|---|---|---|---|
| 1. | C | $I_{R3} = 0.1133$ A | $U_{R3} = 21.5306$ V |
| 2. | H | $I_{R3} = 0.0796$ A | $U_{R3} = 16.318$ V |
| 3. | C | $I_{R3} = 0.1509$ A | $U_{R3} = 84.497$ V |
| 4. | C | $\lvert U_{C2} \rvert = 76.9165$ V | $\phi_{C2} = 2.2236$ rad |
| 5. | H | $u_c(t) = 5 - 3 . \ e^{-\frac{t}{2000}}$ | |