

aufgabe_7.2.6_mit_rechnung

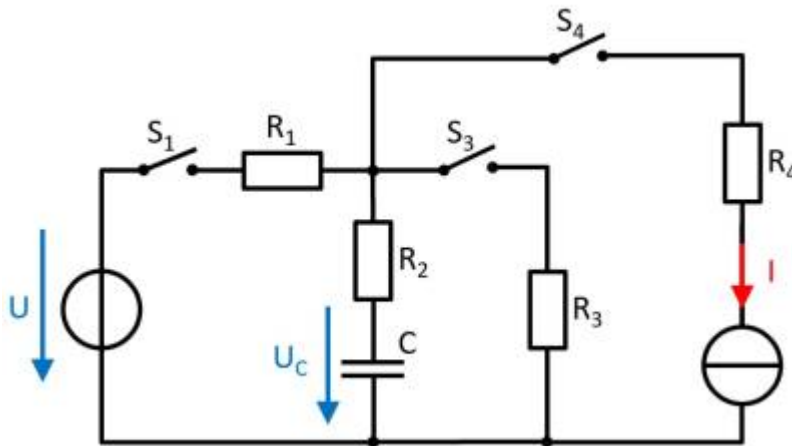
Student Group

First Name	Surname	Matrikel Nr.

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The circuit shown right is given with the following data:

- $U = 10 \text{ V}$
- $I = 4 \text{ mA}$
- $R_1 = 100 \text{ }\Omega$, $R_2 = 80 \text{ }\Omega$, $R_3 = 50 \text{ }\Omega$, $R_4 = 10 \text{ }\Omega$
- $C = 40 \text{ nF}$

At first, the voltage drop on the capacitor $u_C = 0$, and all switches are open. The switch S_1 will be closed at $t = 0$.

Simulation

1. Determine the time constant τ for this charging process.

Tips

- What equivalent circuit can be found for the mentioned states of the switches?
- What parameter do you need to determine τ ?
- The charging current is flown through which component?

Solution

The electrical components R_1 , R_2 , and C are connected in series with a source U . The time constant τ is therefore:
$$\tau = (R_1 + R_2) \cdot C$$

$$= 180 \text{ }\Omega \cdot 40 \text{ nF}$$

Final value

$$\tau = 7.2 \text{ }\mu\text{s}$$

2. What is the value of the voltage $u_C(t)$ drop over the capacitor C at $t=10 \text{ }\mu\text{s}$

μs ?

Solution

$$\begin{aligned} U_C(t) &= U \cdot (1 - e^{-t/\tau}) \quad \parallel U_C(t) = 10 \text{ V} \cdot (1 - e^{-10 \cdot 10^{-6}/7.2 \cdot 10^{-6}}) \end{aligned}$$

Final value

$$\begin{aligned} U_C(t) &= 7.506 \text{ V} \rightarrow 7.5 \text{ V} \end{aligned}$$

3. What is the value of the stored energy in the capacitor, when it is fully charged?

Solution

$$\begin{aligned} W_C &= \frac{1}{2} C U^2 \quad \parallel = \frac{1}{2} \cdot 40 \text{ nF} \cdot (10 \text{ V})^2 \end{aligned}$$

Final value

$$\begin{aligned} W_C &= 2 \text{ } \mu\text{J} \end{aligned}$$

4. Determine the new time constant when the switch S_1 will be opened and the switch S_3 will be closed simultaneously.

Solution

The capacitor C discharges by the series connected resistors R_2 und R_3 .

$$\begin{aligned} \tau &= (R_2 + R_3) \cdot C \quad \parallel = 130 \text{ } \Omega \cdot 40 \text{ nF} \end{aligned}$$

Final value

$$\begin{aligned} \tau &= 5.2 \text{ } \mu\text{s} \end{aligned}$$

5. When the capacitor is completely discharged, all switches will be opened. The switch S_4 will be closed at $t = 0$.

What is the voltage u_C at the capacitor C after $t = 1 \text{ } \mu\text{s}$?

Tips

- Through the current source there is a continuous flow of electric charge into the capacitor.
- The resistors passed by the current on the way to the capacitor are irrelevant. They only increase the voltage of an ideal current source to guarantee the current.

Solution

$$\begin{aligned} \text{The voltage } u_C \text{ is in general: } u_C &= \frac{Q}{C}. \text{ In this case, the constant current } I \text{ results in } Q = \int I \text{ d}t = I \cdot t \\ \begin{aligned} u_C(t) &= \frac{Q}{C} \quad \parallel u_C(t) = \frac{I \cdot t}{C} \\ u_C(1 \text{ } \mu\text{s}) &= \frac{4 \text{ mA} \cdot 1 \text{ } \mu\text{s}}{40 \text{ nF}} = \frac{4 \cdot 10^{-3} \text{ A} \cdot 1 \cdot 10^{-6} \text{ s}}{40 \cdot 10^{-9} \text{ F}} \end{aligned} \end{aligned}$$

Final value

$$U_C(1\sim{\rm \mu s}) \approx 1\sim{\rm V}$$

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