

# aufgabe\_7.2.6\_mit\_rechnung

## Student Group

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### Exercise 5.2.3: Charging and Discharging of RC elements (exam task, ca. 11 % of a 60-minute exam, WS2020)



The circuit shown right is given with the following data:

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

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  $\tau$  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  $\tau$ ?
- 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  $\tau$  is therefore: 
$$\tau = (R_1 + R_2) \cdot C = 180 \Omega \cdot 40 \text{ nF}$$

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  $t=10 \text{ } \mu\text{s}$

$\mu\text{s}$ ?

Solution

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

Final value

$$U_C(t) = 7.506 \text{ V} \rightarrow 7.5 \text{ V}$$

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

Solution

$$W_C = \frac{1}{2} C U^2 = \frac{1}{2} \cdot 40 \text{ nF} \cdot (10 \text{ V})^2$$

Final value

$$W_C = 2 \text{ } \mu\text{J}$$

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  $R_3$ .

$$\tau = (R_2 + R_3) \cdot C = 130 \text{ } \Omega \cdot 40 \text{ nF}$$

Final value

$$\tau = 5.2 \text{ } \mu\text{s}$$

5. When the capacitor is empty 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

The voltage  $U_C$  is in general:  $U_C = \frac{Q}{C}$ . In this case, the constant current  $I$  results in  $Q = \int I \text{ d}t = I \cdot t$

$$U_C(t) = \frac{Q}{C} = \frac{I \cdot t}{C} \quad U_C(1 \mu\text{s}) = \frac{4 \text{ mA} \cdot 1 \text{ } \mu\text{s}}{40 \text{ nF}} = \frac{4 \cdot 10^{-3} \text{ A} \cdot 1 \cdot 10^{-6} \text{ s}}{40 \cdot 10^{-9} \text{ F}}$$

Final value

$$\begin{aligned} U_C(1\sim{\rm \mu s}) &= 1\sim{\rm V} \end{aligned}$$

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