task_p8yrdjr60k6bvc4n_with_calculation

Student Group

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Table of Contents

Exercise E15 (Dis)Charging Capacities
(written test, approx. 14 % of a 60-minute written test, SS2023)

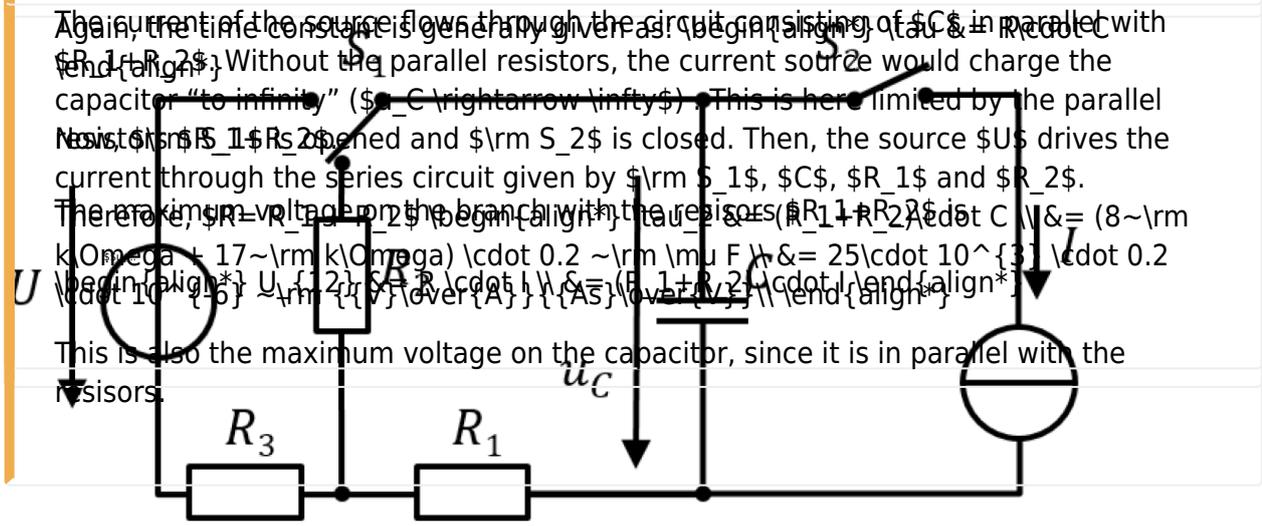The circuit contains a charging circuit with R_1,R_2 and a current source shown in the diagram below. The capacitor is charged to the steady state. The switch S_1 switches to the situation shown in the drawing. What is the new time constant?

- $U = 10 ~\rm V$
- $C_1 = 200 ~\rm nF$
- $R_1 = 8.0 ~\rm k\Omega$
- $R_2 = 17 ~\rm k\Omega$

Solution

$$\begin{align*} \tau_2 &= 3.36 ~\rm ms \end{align*}$$

Solution

$$\begin{align*} u_C(t) &= U_0 \cdot(1-e^{-t/\tau}) \\ &= 10~\rm V \cdot(1-e^{-4~ms/3~ms}) \end{align*}$$

Again, the time constant is generally given as: $\begin{align*} \tau &= R\cdot C \end{align*}$ Without the parallel resistors, the current source would charge the capacitor "to infinity" ($u_C \rightarrow \infty$). This is here limited by the parallel resistors.

Now, $\rm S_1$ is opened and $\rm S_2$ is closed. Then, the source U drives the current through the series circuit given by $\rm S_1$, C, R_1 and R_2.
Therefore, $R= R_1 + R_2$ $\begin{align*} \tau &= (R_1+R_2)\cdot C \\ &= (8~\rm k\Omega + 17~\rm k\Omega) \cdot 0.2 ~\rm \mu F \\ &= 25\cdot 10^{3} \cdot 0.2 \cdot 10^{-6} ~\rm {{V}\over{A}}{{As}\over{V}}\\ \end{align*}$

The maximum voltage on the branch with the resistors is $\begin{align*} U_{12} &= R \cdot I \\ &= (R_1+R_2)\cdot I \end{align*}$

This is also the maximum voltage on the capacitor, since it is in parallel with the resistors.

U · R_3 · R_1 · u_C · I

Before t_0 all switches are switched as shown and the capacitor is fully discharged.
At $t_0=0 ~\rm s$ the switch S_1 shall switch to the voltage source.

1. Calculate the time constant for charging the capacitor.

Solution

The time constant is generally given as: $\begin{align*} \tau &= R\cdot C \end{align*}$

Once S_1 is closed and S_2 is open at t_0, the source U drives the current through the series circuit given by S_1, C, R_1 and R_3.
Therefore, $R= R_1 + R_3$ $\begin{align*} \tau_1 &= (R_1+R_3)\cdot C \\ &= (8~\rm k\Omega + 7~\rm k\Omega) \cdot 0.2 ~\rm \mu F \\ &= 15\cdot 10^{3} \cdot 0.2 \cdot 10^{-6} ~\rm {{V}\over{A}}{{As}\over{V}}\\ \end{align*}$

Solution

Both courses of the voltage for charging and discharging are described with an exponential function. However, the curve for charging increases first steep and flattens out for longer time scales ($\propto (1-e^{-x})$).

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