dummy

Student Group

First Name	Surname	Matrikel Nr.

Table of Contents

Exercise E1 Machine-Vision Strobe: Capacitor Charging and Safe Discharge

... must be safely discharged before maintenance.

Solution

Data: \begin{align*} C &= 1~{\rm \mu F} \\ W &= 0.1~{\rm J} \\ I_{\rm max} &= 100~{\rm mA} \end{align*}

Assume the DC charging source is adjusted to the required final capacitor voltage.

1. What voltage must be present across the capacitor so that it stores the required energy?

Solution

with

\begin{align*} W(t) &= \frac{1}{2} C u_C^2(t) \end{align*}

\begin{align*} W &= \frac{1}{2} C U^2 \\ U &= \sqrt{\frac{2W}{C}} = \sqrt{\frac{2 \cdot 0.1~{\rm J}}{1~{\rm \mu F}}} = \sqrt{200000}~{\rm V} \approx 447.2~{\rm V} \end{align*}

\begin{align*} \tau &= RC \approx 4.47~{\rm ms} \end{align*}

A practical standard value would be about $4.7~{\rm k\Omega}$.

In engineering practice, a capacitor is usually considered fully charged after about 5τ.

\begin{align*} U_0 &= 447.2~{\rm V} \\ RC &= 4.47~{\rm ms} \end{align*}

\begin{align*} t_{\rm charge} &\approx 5\tau \approx 5 \cdot 4.47~{\rm ms} \approx 22.4~{\rm ms} \end{align*}

Initial and final values:

\begin{align*} u_C(0) &= 0 & u_C(\infty) &= U_0 \\ u_R(0) &= U_0 & u_R(\infty) &= 0 \end{align*}

The capacitor voltage rises exponentially, while the resistor voltage falls exponentially.

The energy stored initially in the capacitor is

\begin{align*} W_0 &= 0.1~{\rm J} \end{align*}

With

After full discharge, the capacitor energy is zero, so the entire initial energy is converted into heat in the resistor:

\begin{align*} R_i C &= 10~{\rm M\Omega} \cdot 1~{\rm \mu F} = 10~{\rm s} \end{align*}

\begin{align*} W_R &= W_0 = 0.1~{\rm J} \end{align*}

we get

In a real design, the resistor must therefore be checked for pulse-load capability.

\begin{align*} t &= \frac{10~{\rm s}}{2}\ln(2) \approx 3.47~{\rm s} \end{align*}

The voltage at this instant is

\begin{align*} u_C &= U_0 \cdot \frac{1}{\sqrt{2}} = \frac{447.2~{\rm V}}{\sqrt{2}} \approx 316.2~{\rm V} \end{align*}

Exercise E2 Industrial Sensor Interface: Buffered Measurement Node

... network. The capacitor at the output node is used to smooth the signal and to provide a stable voltage for a short measurement cycle. At first, the measurement electronics are disconnected. Once the capacitor is fully charged, a switch closes and the measurement load is connected.

Solution

Data: \begin{align*} U &= 12~{\rm V} \\ R_1 &= 2~{\rm k\Omega} \\ R_2 &= 10~{\rm k\Omega} \end{align*}

1. What is the voltage across the capacitor after it is fully charged?

Solution

\begin{align*} U_C(\infty) &= R_2 \cdot \frac{R_2}{R_1 + R_2} \\ &= 12~{\rm V} \cdot \frac{10~{\rm k\Omega}}{2~{\rm k\Omega} + 10~{\rm k\Omega}} \\ &= 12~{\rm V} \cdot \frac{10}{12} \\ &= 10~{\rm V} \end{align*}

In practice, the capacitor is considered fully charged after about $5\tau_1$:

\begin{align*} t_{\rm charge} &\approx 5\tau_1 = 5 \cdot 10~{\rm ms} = 50~{\rm ms} \end{align*}

So the load voltage starts at $10~{\rm V}$ and decays exponentially to $5~{\rm V}$.

Exercise E3 Hall-Sensor Test Bench: Air-Core Calibration Coil

For the calibration of a Hall sensor, a reproducible magnetic field is needed. An air-core design is chosen because it avoids hysteresis and remanence effects of iron cores. The coil is wound as a short, single-layer cylindrical coil.

Solution

Data: \begin{align*} l &= 22~{\rm mm} \\ d &= 20~{\rm mm} \\ d_{\rm Cu} &= 0.8~{\rm mm} \end{align*}

The current rises from $0~\rm A$ to $1~\rm A$.

The current rises exponentially:

\begin{align*} i(t) &= \left(1-e^{-t/\tau}\right) \end{align*}

with the time constant

\begin{align*} \tau = \frac{L}{R} \end{align*}

A useful engineering rule is: after about 5τ, the current has reached more than 99% of its final value.

Mathematically, the exact final value is reached only after infinite time.

So the sketch starts at $0~\rm A$, rises steeply at first, and then approaches $1~\rm A$ asymptotically.

First, determine the copper cross-sectional area:

$$\begin{align*} A_{\rm Cu} &= \frac{\pi}{4} d_{\rm Cu}^2 = \frac{\pi}{4}(0.8~{\rm mm})^2 \\ &= 0.503~{\rm mm^2} \end{align*}$$

The mean length of one turn is approximately the circumference:

$$\begin{align*} l_{\rm turn} &\approx \pi d = \pi \cdot 20~{\rm mm} = 62.83~{\rm mm} \end{align*}$$

Thus, the total wire length is

$$\begin{align*} l_{\rm Cu} &= N \cdot l_{\rm turn} = 25 \cdot 62.83~{\rm mm} \\ &= 1570.8~{\rm mm} = 1.571~{\rm m} \end{align*}$$

Now calculate the resistance:

$$\begin{align*} R &= \rho_{\rm Cu}\frac{l_{\rm Cu}}{A_{\rm Cu}} \\ &= 0.0178~{\rm \Omega\,mm^2/m}\cdot\frac{1.571~{\rm m}}{0.503~{\rm mm^2}} \\ &\approx 0.0556~{\rm \Omega} \end{align*}$$

From:
https://wiki.mexle.org/ - **MEXLE Wiki**

Permanent link:
https://wiki.mexle.org/dummy?rev=1774572386

Last update: **2026/03/27 01:46**