dummy

Student Group

First Name	Surname	Matrikel Nr.

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

Solution

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

\end{align*}

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

At $t=0$, the capacitor is uncharged, therefore the maximum charging current is

\begin{align*} i_{C,\max} = i_C(t=0) = \frac{U}{R} \end{align*}

The resistor voltage falls exponentially:

A practical engineering approximation is that the capacitor is essentially charged after

\begin{align*} u_R(t) = Ue^{-t/T} \end{align*}

\begin{align*} W_e &= \frac{1}{2} C U'^2 \\ U' &= \sqrt{\frac{2W_e}{C}} = \sqrt{\frac{2\cdot 0.1~{\rm J}}{1\cdot 10^{-6}~{\rm F}}} \\ &= 316.2~{\rm V} \end{align*}

\begin{align*} T = RC = 4.47~{\rm ms} \end{align*}

For discharge:

Thus, u_C starts at $0~\rm V$ and approaches $447.2~\rm V$, while u_R starts at $447.2~\rm V$ and falls to $0~\rm V$.

\begin{align*} u_C(t) = U e^{-t/T_2} \end{align*}

with

\begin{align*} T_2 = R_iC = 10~{\rm M\Omega}\cdot 1~{\rm \mu F} = 10~{\rm s} \end{align*}

Set $u_C(t)=U'$:

\begin{align*} Ue^{-t/T_2} &= U' \\ t &= T_2 \ln\left(\frac{U}{U'}\right) \\ &= 10~{\rm s}\cdot \ln\left(\frac{447.2}{316.2}\right) \\ &= 3.47~{\rm s} \end{align*}

rc circuit, thevenin equivalent, transient response, sensor interface, industrial electronics, chapter1 1

Exercise E2 Industrial Sensor Interface: Source, T-Network and Capacitor

... been charged, a load resistor is connected by a switch.

Solution

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

\end{align*}

... stationary voltage ...

k\Omega}} {5 &= 3.33~{\rm k\Omega} \end{align*}

The final value is

Solution

\begin{align*} T' &= R_{\rm e}' C = 2.5~{\rm k\Omega}\cdot 2~{\rm \mu F} = 5~{\rm ms} \end{align*}

Therefore, the capacitor voltage decays exponentially:

\begin{align*} T &= R_{\rm e} C = 5~{\rm k\Omega}\cdot 2~{\rm \mu F} = 10~{\rm ms} \end{align*}

Practical settling time:

With the switch open, use the equivalent source voltage:

\begin{align*} u_C(t) &= U_{0e}' + \left(U_{0e}-U_{0e}'\right)e^{-t/T'} \\ &= 5 + (10-5)e^{-t/5~{\rm ms}}~{\rm V} \end{align*}

k\Omega}}{2~{\rm k\Omega}+10~{\rm k\Omega}}\cdot 12~{\rm V} = 10~{\rm V} \end{align*}

\begin{align*} t_{\rm charge} \approx 5T = 50~{\rm ms} \end{align*}

[inductors](), [air core coil](), [magnetic field](), [sensor calibration](), [transient response](), [current density](), [chapter1 1]()

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

Result

magnetic field. Because there is no iron core, the magnetic behaviour is easy to predict and no remanence occurs.

Solution

Data: \begin{align*} l &= 22~{\rm mm} \\ d &= 20~{\rm mm} \\ d_{\rm Cu} &= 0.8~{\rm mm} \\ N &= 25 \end{align*}

Use the following approximation for the inductance of a short air-core coil:

The coil is then connected to a DC source.

1. Calculate the coil resistance R at room temperature.

The current density is

\begin{align*} J &= \frac{I}{A_{\rm Cu}} = \frac{1~{\rm A}}{0.503~{\rm mm^2}} \\ &= 1.99~{\rm A/mm^2} \end{align*}

Solution

&= 25^2 \cdot \frac{4\pi\cdot 10^{-7}~{\rm Vs/(Am)} \cdot 3.1416\cdot (20~{\rm mm})^2}{4 \cdot 22~{\rm mm}} \cdot \frac{1}{1+\frac{20}{2\cdot 22}} \\ &= 7.71\cdot 10^{-6}~{\rm H} \end{align*}

using the engineering approximation from the solution sheet,

\begin{align*} \int_0^{5T}\left(1-e^{-t/T}\right)^2 dt \approx \frac{7}{2}T \end{align*}

The cross-sectional area of the copper wire is

\begin{align*} A_{\rm Cu} &= \pi\left(\frac{d_{\rm Cu}}{2}\right)^2 = \pi (0.4~{\rm mm})^2 \\ &= 0.503~{\rm mm^2} \end{align*}

therefore

The total wire length is approximately

\begin{align*} W_R &\approx R I^2 \cdot \frac{7}{2}T \\ &= 0.0556~{\rm \Omega}\cdot (1~{\rm A})^2 \cdot \frac{7}{2}\cdot 138.7~{\rm \mu s} \\ &= 27.05\cdot 10^{-6}~{\rm J} \end{align*}

\begin{align*} l_{\rm Cu} &= N\pi d = 25\pi\cdot 20~{\rm mm} \\ &= 1570.8~{\rm mm} = 1.571~{\rm m} \end{align*}

Now the resistance is

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