dummy

Student Group

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Exercise E1 Machine-Vision Strobe Unit: Charging and Safe Discharge of a Flash Capacitor

A. ... After which time is the capacitor discharged to one half, and what is the capacitor voltage then?

Result

Solution

Solution

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

Solution

$$u_R(t) = 447.2\,e^{-t/4.47{\rm ms}}~{\rm V}$$

1. What voltage must the capacitor have so that it stores the required energy?

For the charging process:

At the beginning of charging, the capacitor behaves like a short circuit, so

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

Solution

with

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

In engineering practice, a capacitor is considered practically fully charged after about $5T$.

Thus,

$$\begin{align*} U &= 447.2~{\rm V} \\ T &= 4.47~{\rm ms} \end{align*}$$

So the practical discharge time is

$$\begin{align*} W_e &= \frac{1}{2} C U^2 \\ U &= \sqrt{\frac{2W_e}{C}} = \sqrt{\frac{2 \cdot 0.1~{\rm J}}{1 \cdot 10^{-6}~{\rm F}}} \\ &= \sqrt{200000}~{\rm V} \approx 447.2~{\rm V} \end{align*}$$

$$\begin{align*} R &\ge \frac{U}{I_{\rm max}} = \frac{447.2~{\rm V}}{0.1~{\rm A}} \end{align*}$$

So the capacitor voltage rises exponentially from 0 to $447.2~{\rm V}$, while the resistor voltage falls exponentially from $447.2~{\rm V}$ to 0.

The complete stored capacitor energy is converted into heat in the resistor:

The voltage at half energy is

$$\begin{align*} W_R = W_e = 0.1~{\rm J} \end{align*}$$

$$\begin{align*} U' = \frac{U}{\sqrt{2}} = \frac{447.2~{\rm V}}{\sqrt{2}} = 316.2~{\rm V} \end{align*}$$

For the discharge through the internal resistance:

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

with

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

Set $u_C(t)=U'$:

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

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

Exercise E2 Sensor Input Buffer: Source, T-Network and Capacitor

A. ... A capacitor smooths the node voltage. At first, the load is disconnected. After the capacitor is fully charged, a measurement load is connected by a switch.

Result

Solution

Solution

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

\Omega} \\ R_3 &= 3.33~{\rm k\Omega} \\ C &= 2~{\rm \mu F} \\ R_L &= 5~{\rm

load has

What is the capacitor voltage after it is fully charged?

Solution

Practical settling time:

Using the equivalent voltage source of the network on the left-hand side, the open-circuit voltage is

\begin{align*} U_{0e} &= \frac{R_2}{R_1+R_2}\,U \\ &= \frac{10~{\rm k\Omega}}{2~{\rm k\Omega}+10~{\rm k\Omega}}\cdot 12~{\rm V} \\ &= 10~{\rm V} \end{align*}

After full charging, the capacitor voltage equals this voltage.

inductors, air core coil, magnetic field, hall sensor, transient response, current density, chapter1 1

Exercise E3 Hall-Sensor Calibration Coil: Short Air-Core Coil

An air-core coil is chosen because it avoids hysteresis and remanence effects. The coil is wound as a short cylindrical coil.

Solution

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

The heat dissipated in the winding resistance up to the practical final time $5T$ is

The current density is

For this interval the integral is approximately

The wire cross section is

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

Therefore,

\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*}

Thus

The total wire length is approximated by the number of turns times the mean circumference:

\begin{align*} W_R &\approx RI^2\cdot \frac{7}{2}T \\ &= 0.0556~{\rm

\begin{align*} l_{\rm Cu} &= N \cdot \frac{7}{2}\pi \cdot 18~{\rm mm} \\ &\approx 1571~{\rm mm} = 1.571~{\rm m} \end{align*}

\Omega\cdot (1 - {\rm A})^2 \cdot 25 \cdot 208.9~{\rm \mu s} = \\ &\approx 17.058 \cdot 10^{-6} = 1.71 Ws} \end{align*}

Thus,

\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*}