task_f64r8g2jf4pdomfi_with_calculation

Student Group

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Exercise E1 Conversion: Energy, Power and Area

A Tesla Model 3 has an average consumption of $16~{\rm kWh}\over{100~{\rm km}}$ and an usable battery capacity of $60~{\rm kWh}$. Solar panels produces per $1~\rm m^2$ in average in December $0.2~{{{\rm kWh}}\over{{\rm m^{2}}}}$. The car is driven $50~{\rm km}$ per day. The size of a distinct solar module with $460~{\rm W_p}$ (Watt peak) is $1.9~{\rm m} \times 1.1~{\rm m}$.

1. What is the average power consumption of the car per day?

Result

Solution

$$\begin{align*} {{W}\over{l}} &= {{16~{\rm kWh}}\over{100~{\rm km}}} = 0.16 {{~{\rm kWh}}\over{~{\rm km}}} \\ W &= 50~{\rm km} \cdot 0.16 {{~{\rm kWh}}\over{~{\rm km}}} = 8~{\rm kWh} \end{align*}$$

Solution

$$\begin{align*} A &= {{8~{\rm kWh}}\over{0.2~{\rm kWh/m^2}}} = 40~{\rm m^{2}} \end{align*}$$

$$\begin{align*} n &= {{40~{\rm m^{2}}}\over{2.1~{\rm m^{2}}}} = 19.04~{\rm panels} \rightarrow 20~{\rm panels} \end{align*}$$

$$\begin{align*} P &= 20~{\rm panels} \cdot 460~{\rm W_p} \end{align*}$$

Exercise E2 Industrial Sensor Interface: Buffered Measurement Node

The capacitor in 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.

Data:

$$\begin{align*} U &= 12~{\rm V} \\ R_1 &= 2~{\rm k\Omega} \\ R_2 &= 10~{\rm k\Omega} \\ R_3 &= 3.33~{\rm k\Omega} \\ C &= 2~{\rm \mu F} \\ R_L &= 5~{\rm k\Omega} \end{align*}$$

Initially, the capacitor is uncharged and the switch S is open.

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

Result

Solution

When the capacitor is fully charged, no current flows through R_3 and the capacitor is fully charged. Therefore, there is no voltage drop across R_3, and the capacitor voltage is equal to the divider voltage of R_1 and R_2:

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

Determine the Thevenin equivalent of the left-hand network as seen from the capacitor/load node.

$$\begin{align*} R_1 \parallel R_2 &= \frac{R_1 R_2}{R_1 + R_2} = \frac{2~{\rm k\Omega} \cdot 10~{\rm k\Omega}}{2~{\rm k\Omega} + 10~{\rm k\Omega}} \end{align*}$$

Thus, the Thevenin resistance is

$$\begin{align*} U_{\rm th} &= 10~{\rm V} \\ R_{\rm th} &= 5.00~{\rm k\Omega} \end{align*}$$

The charging time constant is

$$\begin{align*} \tau_1 &= R_{\rm th} C \\ &= 5.00~{\rm k\Omega} \cdot 2~{\rm \mu F} \\ &= 10~{\rm ms} \end{align*}$$

the time-dependent capacitor voltage is

$$\begin{align*} u_C(t) = 10\left(1 - e^{-t/(10~{\rm ms})}\right)~{\rm V} \end{align*}$$

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

$$\begin{align*} U_L(\infty) &= U_{\rm th} \cdot \frac{R_L}{R_{\rm th} + R_L} \end{align*}$$

Thus, the transient load voltage is

$$\begin{align*} u_L(t) &= u_L(\infty) + \left(u_L(0^+) - u_L(\infty)\right)e^{-t/\tau_2} \end{align*}$$

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

$$t_{\rm charge} \approx 5\tau_1 = 5 \cdot 10~{\rm ms} = 50~{\rm ms}$$

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

... magnetic field. 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:

$$l = 22~{\rm mm} \\ d = 20~{\rm mm} \\ d_{\rm Cu} = 0.8~{\rm mm} \\ N = 25$$

... rise from $0~\rm A$ to $1~\rm A$.

... Therefore:

... The current rises exponentially:

$$i(t) = I\left(1-e^{-t/\tau}\right)$$

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

... with the time constant

$$\tau = \frac{L}{R}$$

$$W = \frac{1}{2}LI^2 = \frac{1}{2}\cdot 7.94\cdot 10^{-6}~{\rm H}\cdot (1~{\rm A})^2$$

... $\approx 1.99~{\rm A/mm^2}$

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:

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

The mean length of one turn is approximately the circumference:

$$l_{\rm turn} \approx \pi d = \pi \cdot 20~{\rm mm} = 62.83~{\rm mm}$$

Thus, the total wire length is

$$l_{\rm Cu} = N \cdot l_{\rm turn} = 25 \cdot 62.83~{\rm mm} \\ = 1570.8~{\rm mm} = 1.571~{\rm m}$$

Now calculate the resistance:

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