Half-wave rectifier (EC_diode_6.sqproj)

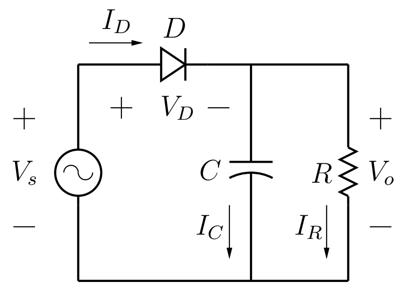

Figure 1: Half-wave rectifier.

Question: In the half-wave rectifier circuit shown in Fig. 1, the source voltage has an amplitude $V_m = 15\,\mathrm{V}$ and frequency $f = 50\,\mathrm{Hz}$. Consider the diode to be ideal (i.e., $V_{\mathrm{on}} = 0\,\mathrm{V}$). With $R = 500\,\Omega$, what is the minimum value of C if the output ripple is to be limited to $V_R = 1\,\mathrm{V}$? What is the peak diode current $i_D^{\max}$ in that case?

Solution:

Fig. 2 shows V_i, V_o, V_D, I_D, and I_C versus time. When the diode is off, the capacitor discharges through the load resistor (see the interval T_2 in the figure). The capacitor current is nearly constant and is given by

$$C\,\frac{dV_o}{dt} \approx C\,\frac{V_R}{T} = I_R^{\mathrm{avg}} = \frac{V_m + (V_m - V_R)}{2} \times \frac{1}{R}. \tag{1}$$

Solving this equation, we get

$$C = \frac{14.5\,\mathrm{V}}{500\,\Omega} \times \frac{20 \times 10^{-3}\,\mathrm{sec}}{1\,\mathrm{V}} = 580\,\mu\mathrm{F}. \tag{2}$$

The peak diode current can be estimated by first computing ωT_c in Fig. 2 as

$$(V_m - V_R) = V_m \cos(-\omega T_c) \rightarrow \omega T_c = \cos^{-1}\left(1 - \frac{V_R}{V_m}\right) = \cos^{-1}\left(1 - \frac{T}{RC}\right). \tag{3}$$

The peak diode current is then given by

$$\begin{aligned}
I_D^{\mathrm{peak}} &= C\frac{d}{dt}\left(V_m \cos\omega t\right)\bigg|_{t=-T_c} + \frac{V_m - V_R}{R} \\
&= -\omega C V_m \sin(-\omega T_c) + \frac{14\,\mathrm{V}}{500\,\Omega} \\
&= \omega C V_m \sin\omega T_c + 0.028 \\
&= \left[(2\pi \times 50\,\mathrm{Hz}) \times (580 \times 10^{-6}\,\mathrm{F}) \times (15\,\mathrm{V}) \times \sin 21^\circ\right] + 0.028 \\
&= 0.98 + 0.028 \approx 1\,\mathrm{A}.
\end{aligned}$$

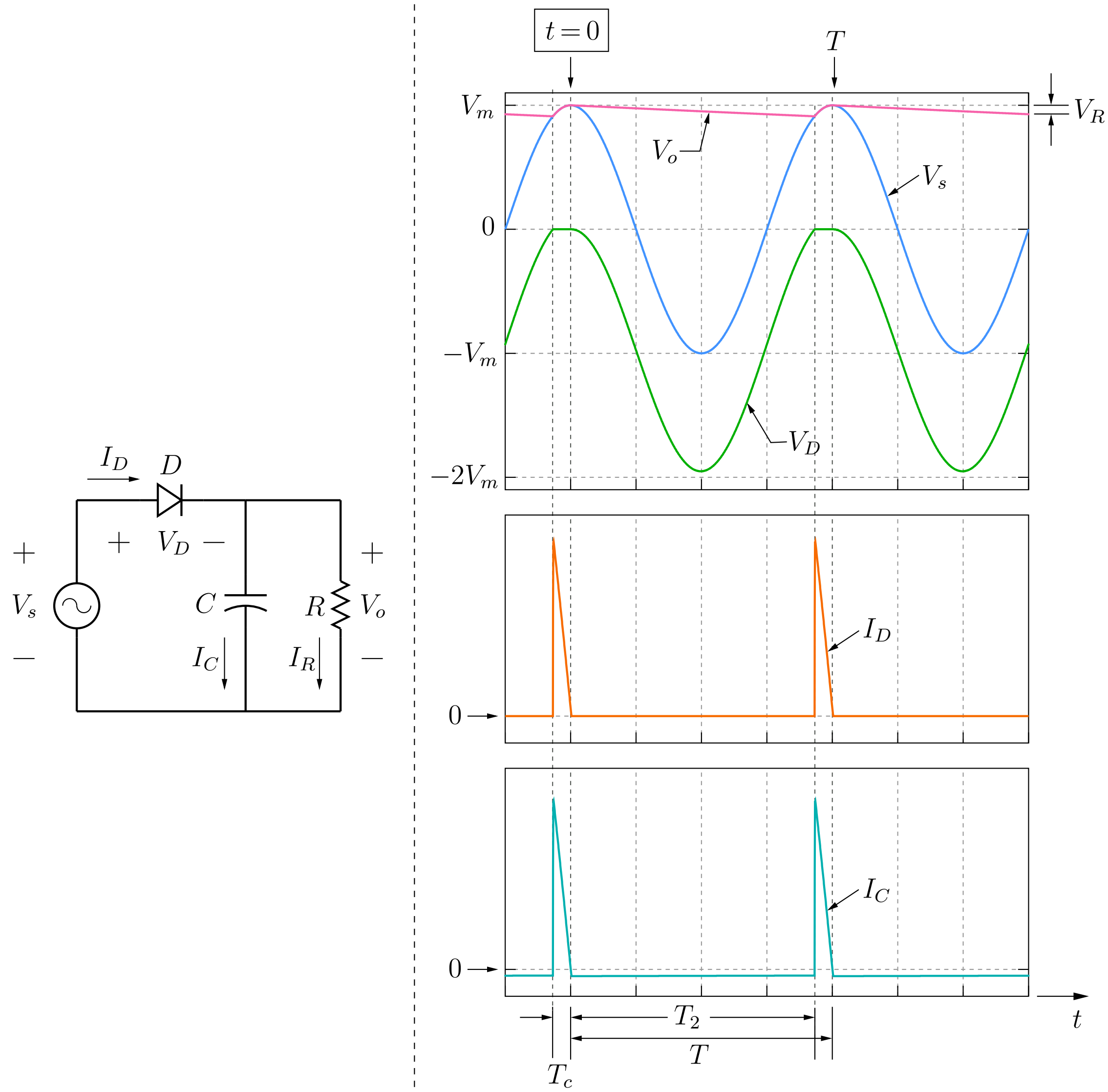

Figure 2: Voltage and current waveforms for a half-wave rectifier.

SequelApp Exercises: If R is $200\,\Omega$, what is the minimum value of C required to limit the ripple voltage V_R to $1.5\,\text{V}$? What is $i_D^{\max}$ in that case?

Verify your answer using SequelApp.