Diode circuits-3 (`EC_diode_3.sqproj`)

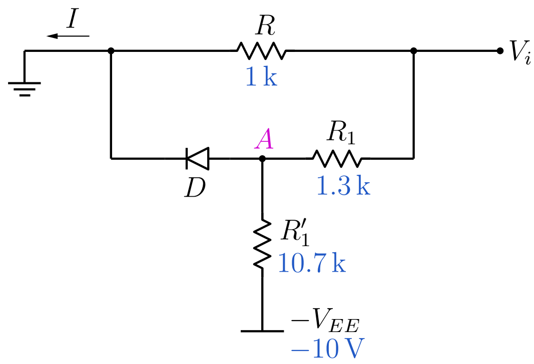

Figure 1: Diode circuit example.

Question: For the diode circuit shown in Fig. 1, plot I versus V_i for $-1\,\text{V} < V_i < 4\,\text{V}$. Assume $V_{\text{on}} = 0.7\,\text{V}$ for the diode.

Solution:

Let us start with $V_i = 0\,\text{V}$. The current through R is zero in this case since its two ends are at the same potential (0 V). If the diode is on, $V_A = 0.7\,\text{V}$. KCL at node A requires $\dfrac{0.7-(-10)}{R_1'} + \dfrac{0.7-0}{R_1} = 0$, which is clearly not possible. We conclude that the diode must be off when $V_i = 0\,\text{V}$.

Let us now obtain the value of V_i for which the diode starts conducting. When the diode is off (see Fig. 2 (a)), the node voltage V_A can be obtained using superposition and is given by

$$V_A = (-V_{EE}) \times \frac{R_1}{R_1 + R_1'} + V_i \times \frac{R_1'}{R_1 + R_1'}. \quad (1)$$

For the numerical values specified in Fig. 1, and with $V_i = 0\,\text{V}$, V_A is $-1.1\,\text{V}$.

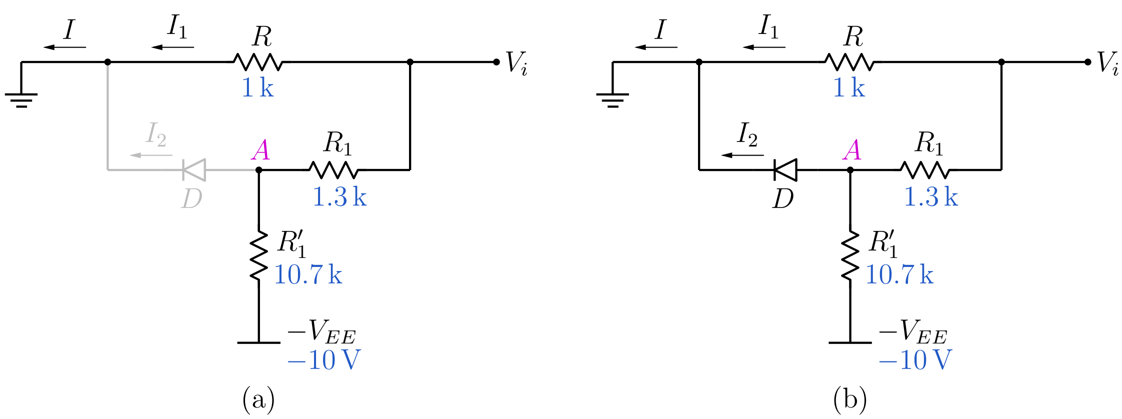

Figure 2: Diode circuit of Fig. 1 with (a) diode off, (b) diode on.

If a negative V_i is applied, we see from Eq. 1 that V_A remains negative, and the diode cannot conduct. If V_i is increased in the positive direction, the second term in Eq. 1 increases, and at some point, V_A becomes equal to $V_{on} = 0.7\,V$. This "break point" can be found by equating V_A in Eq. 1 to V_{on}, giving

$$(-V_{EE}) \times \frac{R_1}{R_1 + R_1'} + V_i \times \frac{R_1'}{R_1 + R_1'} = V_{on} \tag{2}$$

$$\rightarrow V_i^{break} = V_{EE}\,\frac{R_1}{R_1'} + V_{on}\left(1 + \frac{R_1}{R_1'}\right). \tag{3}$$

With the component values given in Fig. 1, we get $V_i^{break} = 2\,V$.

Next, let us find the slope $\dfrac{dI}{dV_i}$. When the diode is off (see Fig. 2 (a)), $I = I_1 = \dfrac{V_i}{R} \rightarrow \dfrac{dI}{dV_i} = \dfrac{1}{R}$.

When the diode is conducting (see Fig. 2 (b)), $V_A = V_{on} = 0.7\,V$, and

$$I = I_1 + I_2 = \frac{V_i}{R} + \frac{V_i - V_A}{R_1} - \frac{V_A - (-V_{EE})}{R_1'}. \tag{4}$$

The slope is now given by $\dfrac{dI}{dV_i} = \dfrac{1}{R} + \dfrac{1}{R_1} = \dfrac{1}{(R \parallel R_1)}$.

To summarise, we can write

$$\begin{aligned} \frac{dI}{dV_i} &= \frac{1}{R}, & V_i < V_i^{break}, \\ &= \frac{1}{(R \parallel R_1)}, & V_i > V_i^{break}. \end{aligned} \tag{5}$$

Using these findings, we obtain the plot shown in Fig. 3.

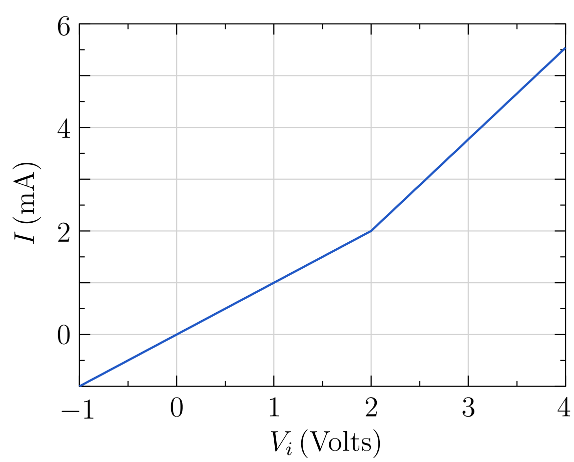

Figure 3: I versus V_i plot for the circuit of Fig. 1.

SequelApp Exercise: With $V_{EE} = 10\,\text{V}$, find R, R_1, R_1' in order to obtain the I versus V_i plot shown in Fig. 4. Verify using SequelApp.

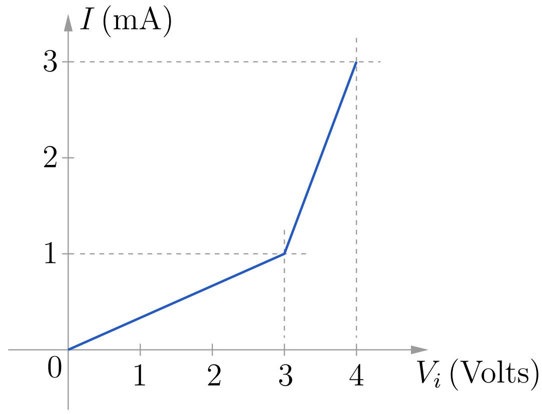

Figure 4: I versus V_i plot for SequelApp exercise.