Op-amp circuits (`EC_schmitt_1.sqproj`)

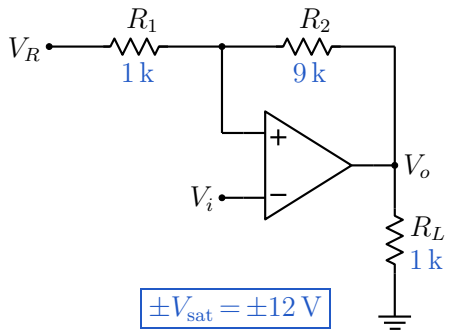


Figure 1: Schmitt trigger circuit.

Question: For the Schmitt trigger circuit shown in Fig. 1, plot V_o versus V_i for (a) $V_R = 0\,\text{V}$, (b) $V_R = 5\,\text{V}$.

Solution:

(a) With $V_R = 0\,\text{V}$, the circuit is the "standard" inverting Schmitt trigger with the V_o-V_i relationship shown in Fig. 2 (a). The output voltage changes from $+V_{\text{sat}}$ to $-V_{\text{sat}}$ at $V_i = V_{TH}$ (see Fig. 2 (b)), and it corresponds to $(V_+ - V_-)$ changing sign. To find V_{TH}, we need to find V_+ with $V_o = +V_{\text{sat}}$. In other words,

$$V_{TH} = V_+|_{V_o=+V_{\text{sat}}} = +V_{\text{sat}} \times \frac{R_1}{R_1 + R_2} = (+12\,\text{V}) \times \frac{1\,\text{k}\Omega}{10\,\text{k}\Omega} = 1.2\,\text{V}, \tag{1}$$

where the op-amp input current, which is negligibly small, has been ignored. Similarly,

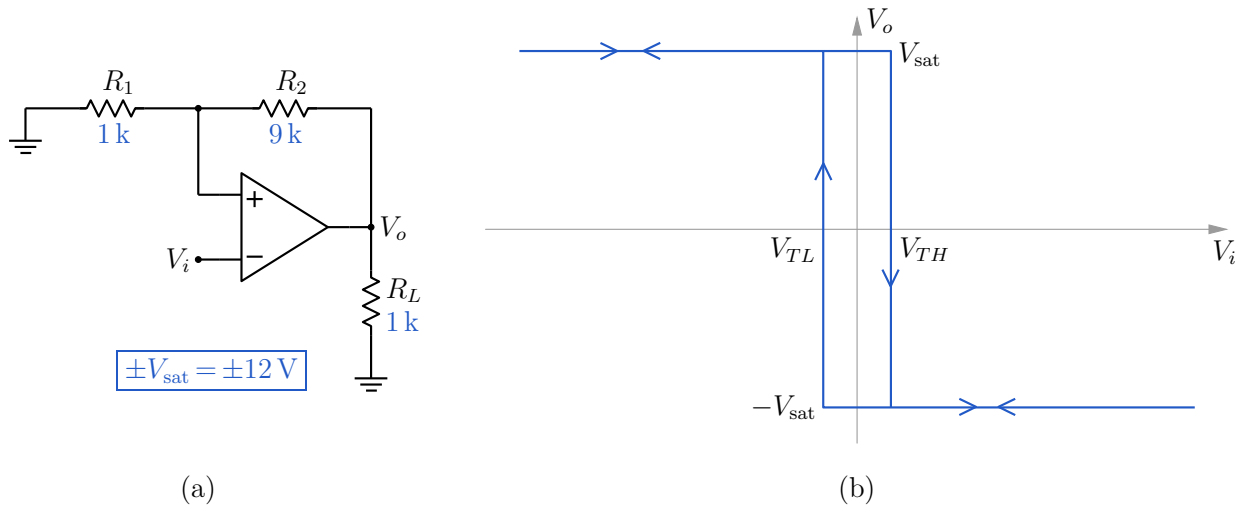
$$V_{TL} = V_+|_{V_o=-V_{\text{sat}}} = -V_{\text{sat}} \times \frac{R_1}{R_1 + R_2} = (-12\,\text{V}) \times \frac{1\,\text{k}\Omega}{10\,\text{k}\Omega} = -1.2\,\text{V}. \tag{2}$$

(b) With $V_R = 5\,\text{V}$ (see Fig. 3 (a)), the basic operation of the circuit remains the same; however, the tripping points V_{TH} and V_{TL} get shifted, as shown in Fig. 3 (b). V_{TH} is found by calculating V_+ when $V_o = +V_{\text{sat}}$.

$$\begin{aligned} V_{TH} &= V_+|_{V_o=+V_{\text{sat}}} = +V_{\text{sat}} \times \frac{R_1}{R_1 + R_2} + V_R \times \frac{R_2}{R_1 + R_2} \\ &= (+12\,\text{V}) \times \frac{1\,\text{k}\Omega}{10\,\text{k}\Omega} + (5\,\text{V}) \times \frac{9\,\text{k}\Omega}{10\,\text{k}\Omega} \\ &= 5.7\,\text{V}, \end{aligned} \tag{3}$$

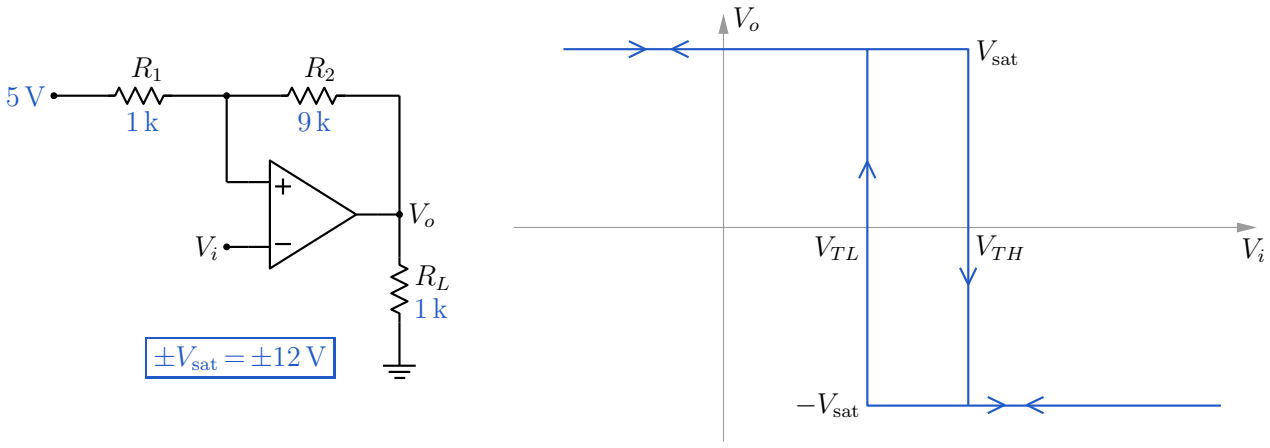
where once again, we have neglected the op-amp input current. Similarly, V_{TL} can be found by evaluating V_+ when $V_o = -V_{\text{sat}}$.

$$\begin{aligned} V_{TL} &= V_+|_{V_o=-V_{\text{sat}}} = -V_{\text{sat}} \times \frac{R_1}{R_1+R_2} + V_R \times \frac{R_2}{R_1+R_2} \\ &= (-12\,\text{V}) \times \frac{1\,\text{k}\Omega}{10\,\text{k}\Omega} + (5\,\text{V}) \times \frac{9\,\text{k}\Omega}{10\,\text{k}\Omega} \\ &= 3.3\,\text{V}. \end{aligned} \tag{4}$$



(a) (b)

Figure 2: (a) Schmitt trigger of Fig. 1 with $V_R = 0\,\text{V}$, (b) V_o versus V_i relationship.



(a) (b)

Figure 3: (a) Schmitt trigger of Fig. 1 with $V_R = 5\,\text{V}$, (b) V_o versus V_i relationship.

SequelApp Exercises:

1. For the Schmitt trigger of Fig. 1, find V_{TH} and V_{TL} in the following situations, other circuit parameters being the same as in the figure.

   (a) $V_R = 2\,\mathrm{V}$.

   (b) $V_R = -2\,\mathrm{V}$.

   (c) $V_R = 5\,\mathrm{V}$, $R_1 = 4\,\mathrm{k}$.

2. With $V_{\mathrm{sat}} = 12\,\mathrm{V}$ and $R_2 = 9\,\mathrm{k}$, find R_1 and V_R required to obtain $V_{TL} = 1\,\mathrm{V}$ and $V_{TH} = 3\,\mathrm{V}$.

Verify your answers using SequelApp.