Op-amp circuits (EC_schmitt_3.sqproj)

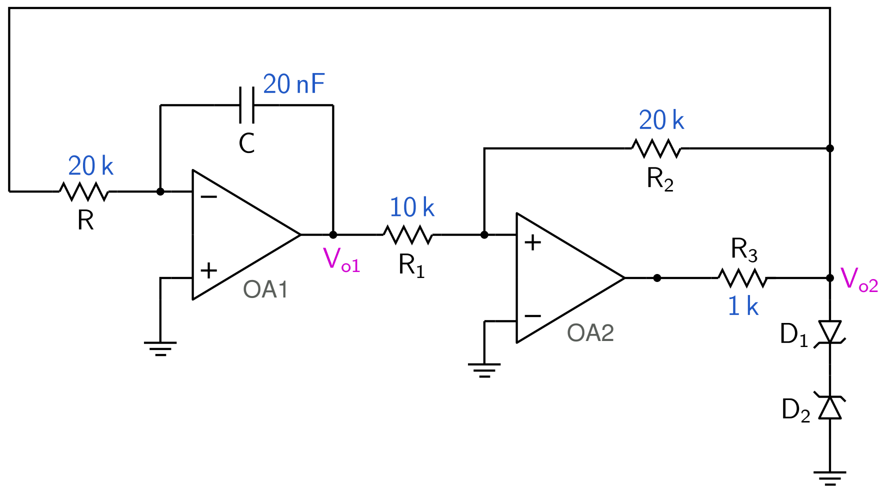


Figure 1: Oscillator circuit using a Schmitt trigger.

Question: In the oscillator circuit shown in Fig. 1, the Zener diodes have $V_Z = 5.0\,\text{V}$ and $V_{\text{on}} = 0.7\,\text{V}$.

(a) Draw the waveforms $V_{o1}(t)$ and $V_{o2}(t)$.

(b) Find the oscillation frequency.

Solution:

The circuit of Fig. 1 can be redrawn as an integrator and a Schmitt trigger connected in a loop, as shown in Fig. 2 (a). For the integrator, we have

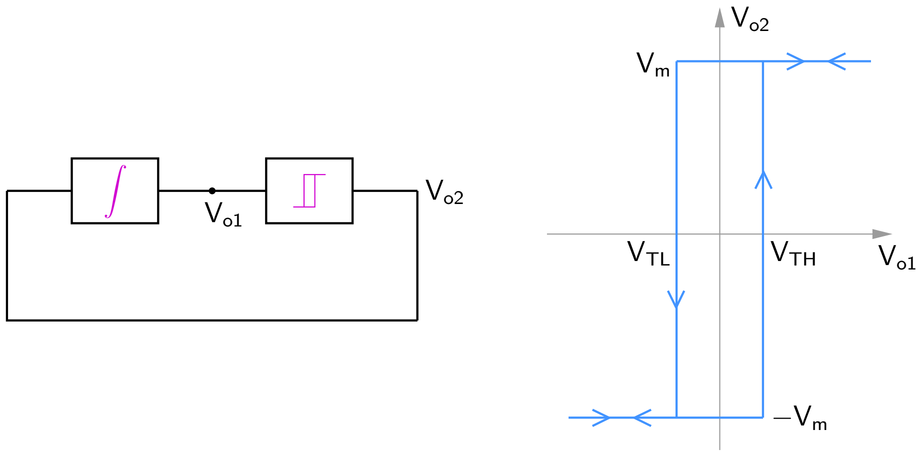
$$V_{o1} = -\frac{1}{RC}\int V_{o2}dt. \tag{1}$$

For the Schmitt trigger, the relationship between the output V_{o2} and the input V_{o1} is given by the plot in Fig. 2 (b), where

$$V_m = V_Z + V_{\text{on}}, \tag{2}$$

V_Z and V_{on} being the reverse breakdown voltage and turn-on voltage, respectively, of the diodes. The tripping points V_{TH} and V_{TL} are given by

$$V_{TH} = \frac{R_1}{R_2}V_m, \quad V_{TL} = -\frac{R_1}{R_2}V_m. \tag{3}$$



(a) (b)

Figure 2: (a) Oscillator circuit of Fig. 1 redrawn as a block diagram, (b) Input-output relationship for the Schmitt trigger part.

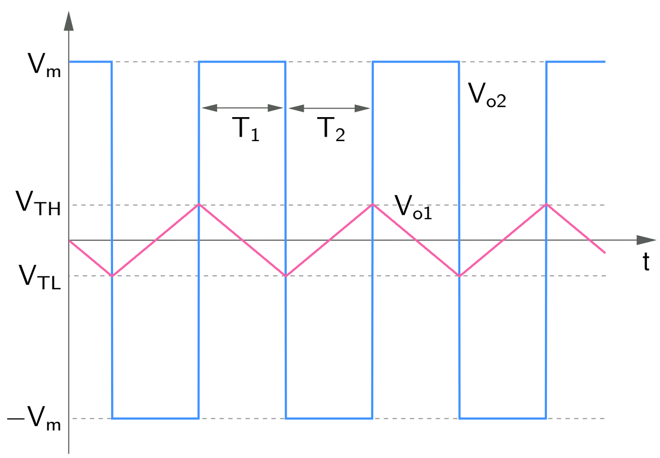


Figure 3: V_{o1} and V_{o2} waveforms for the oscillator circuit of Fig. 1.

From Eq. 1, we see that, when V_{o2} is $+V_m$, the integrator output V_{o1} will decrease linearly. Similarly, when V_{o2} is $-V_m$, V_{o1} will increase linearly, as shown in Fig. 3.

To compute the oscillation frequency, we can use the integrator relationship (Eq. 1) and obtain for the T_1 part in Fig. 3

$$V_{o1} = -\frac{1}{RC}\int V_{o2}dt \;\rightarrow\; \frac{dV_{o1}}{dt} = -\frac{1}{RC}V_{o2} = -\frac{1}{RC}V_m. \tag{4}$$

Since the input to the integrator is constant $(= V_m)$ during this interval, we can write

$$\frac{dV_{o1}}{dt} = \frac{V_{TL} - V_{TH}}{T_1} = -\frac{1}{RC}V_m. \tag{5}$$

Solving for T_1, we get

$$T_1 = RC\,\frac{V_{TH} - V_{TL}}{V_m} = RC\,\frac{2\,\dfrac{R_1}{R_2}\,V_m}{V_m} = 2RC\,\frac{R_1}{R_2}. \tag{6}$$

Carrying out the same procedure for the T_2 part in Fig. 3, we get $T_2 = T_1 = 2RC\,\dfrac{R_1}{R_2}$. The period of oscillation is therefore

$$T = T_1 + T_2 = 4RC\,\frac{R_1}{R_2}. \tag{7}$$

For the component values given in Fig. 1, we get $T = 0.8$ msec, and frequency of oscillation $f = 1.25$ kHz.

SequelApp Exercises: Find the period of oscillation in the following cases, with other parameter values the same as in Fig. 1. Verify your answers using SequelApp.

1. R_1 is changed from 10 k to 5 k.
2. R is changed from 20 k to 10 k.
3. V_Z of the Zener diodes is changed from 5 V to 8 V.