DAC with R-$2R$ ladder network (`EC_dac_1.sqproj`)

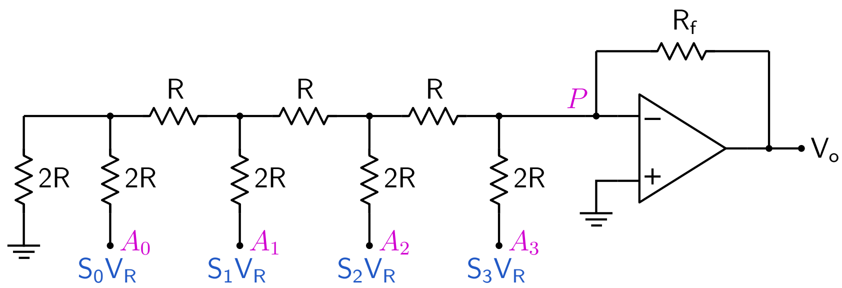

Figure 1: DAC using R-$2R$ ladder network.

Question: In the DAC circuit shown in Fig. 1, $R = R_f = 10\,\text{k}$, and $V_R = 5\,\text{V}$. The digital input number is represented by the variables S_3, S_2, S_1, S_0, with S_3 as the MSB and S_0 as the LSB. The voltage at node A_k is V_R if $S_k = 1$ and 0 V otherwise. Find V_o if S_1 is 1 and S_3, S_2, S_0 are all 0.

Solution:

To obtain V_o, we will replace the R-$2R$ network with its Thevenin equivalent circuit, as shown in Fig. 2. The computation of the Thevenin resistance and Thevenin voltage is shown in Figs. 3 and 4, respectively, where repeated use of Thevenin's theorem has been made to simplify the circuit systematically.

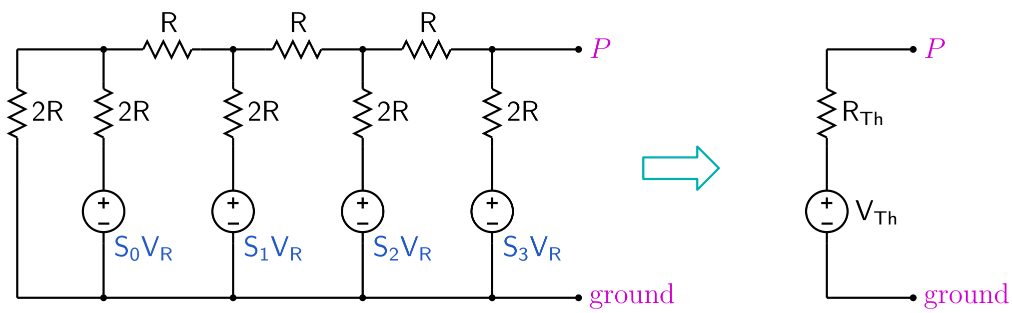

Figure 2: Representation of R-$2R$ ladder with Thevenin equivalent circuit.

Finally, we replace the R-$2R$ network in the original DAC circuit of Fig. 1 with its Thevenin equivalent circuit and obtain the circuit shown in Fig. 5. This circuit is simply an inverting amplifier, and the output voltage is given by

$$V_o = -\frac{R_f}{R}\,V_{\text{Th}} = -\frac{V_R}{8} = -0.625\,\text{V}, \tag{1}$$

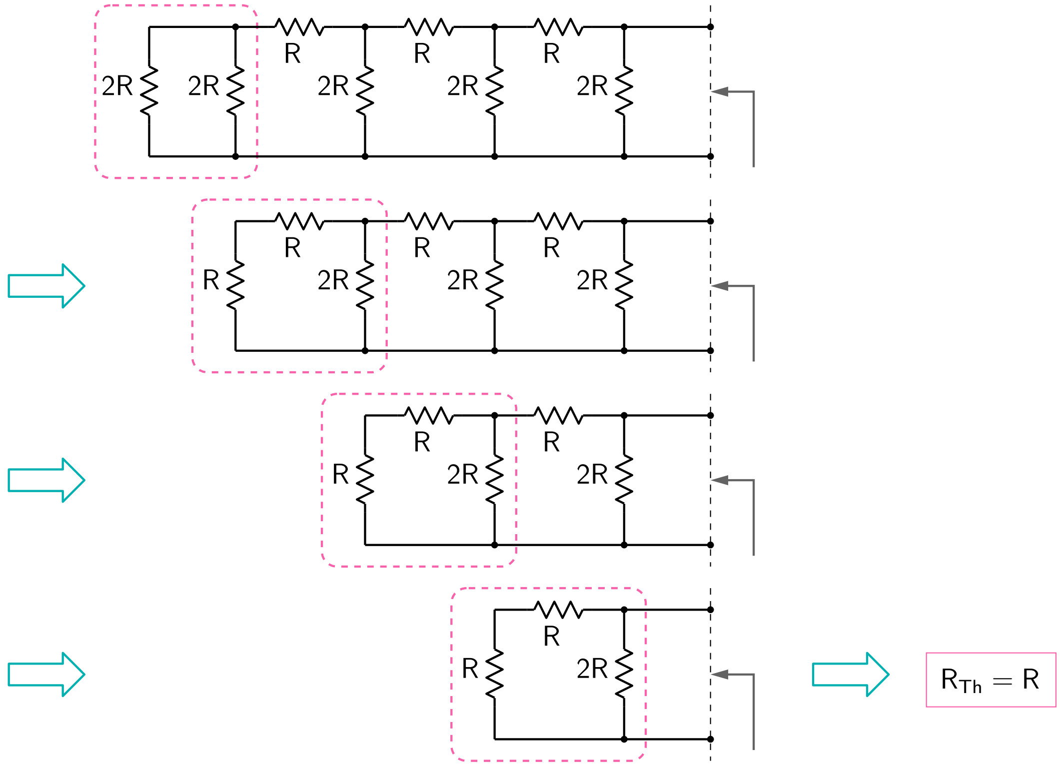

Figure 3: Thevenin resistance calculation for the R-$2R$ ladder network.

since R_f and R are equal.

SequelApp Exercises: Answer the following and verify using SequelApp.

1. Find V_o for the following input binary numbers.

   (a) $S_3S_2S_1S_0 = 1000$.

   (b) $S_3S_2S_1S_0 = 0100$.

   (c) $S_3S_2S_1S_0 = 0001$.

2. Using superposition, find V_o for the following input binary numbers.

   (a) $S_3S_2S_1S_0 = 1001$.

   (b) $S_3S_2S_1S_0 = 1010$.

3. Find the input binary numbers ($S_3S_2S_1S_0$) which will give the following outputs.

   (a) $V_o = -1.875\,\text{V}$.

   (b) $V_o = -1.5625\,\text{V}$.

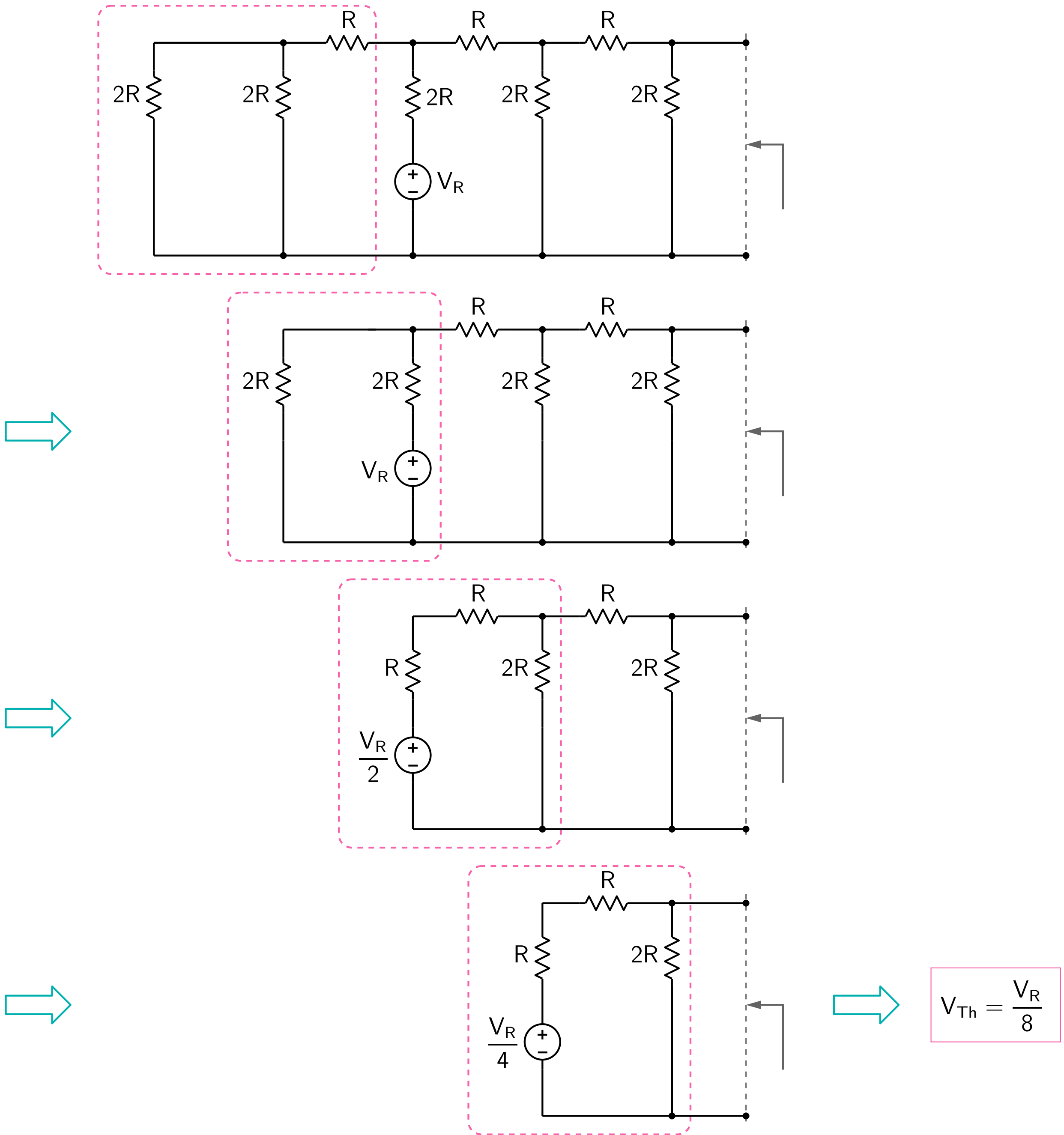

Figure 4: Thevenin voltage calculation for the R-$2R$ ladder network.

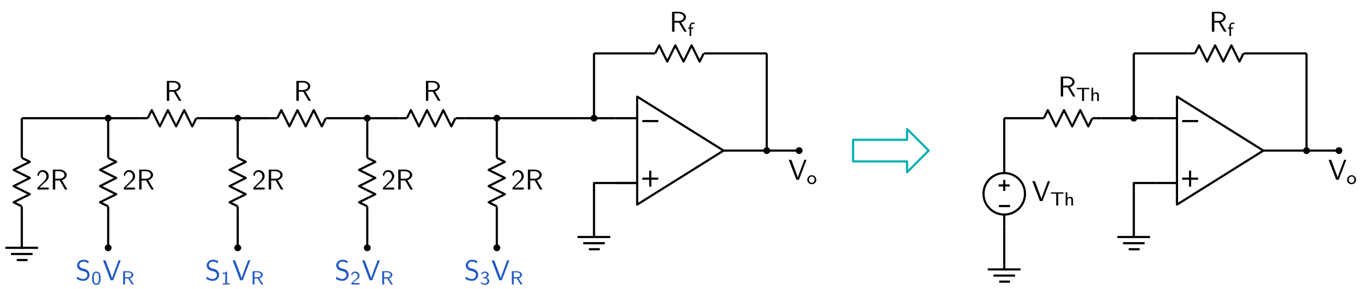

Figure 5: Original DAC circuit with R-$2R$ ladder network replaced with its Thevenin equivalent circuit.