Thevenin Theorem

Thevenin theorem states that for

> linear electrical networks any combination of voltage sources, current sources, and resistors with two terminals is equivalent to a single voltage source V_{TH} and a resistor R_{TH} in series.

Note that the theorem generalizes for time harmonic cases where an impedance is in series with a voltage source.

Question:
What implications does this theorem have?

The theorem guarantees that such an equivalent expression exists for a certain class of circuits.

Note the difference here,

- if there would NOT be a theorem that such an equivalent exists you would not know if you could construct it for a given circuit.
- But if the preconditions match you know that it exists $\Rightarrow$ it is worth to try to find a recipe that would allow on to determine the equivalent.

Fig. 1 shows an example of a circuit and its Thevenin equivalent.

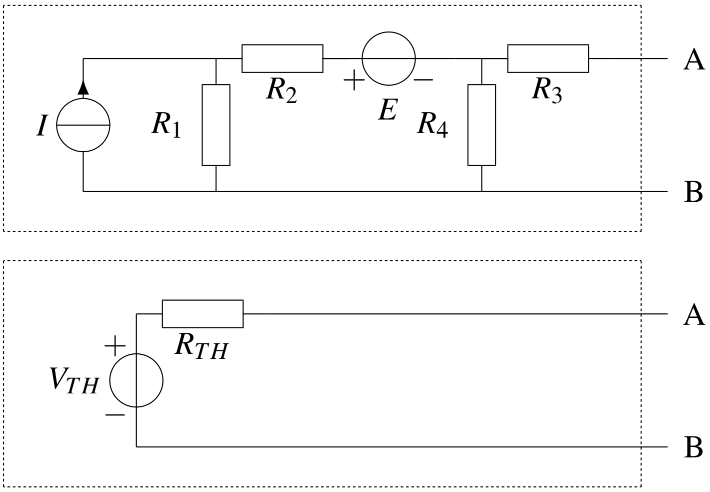


Figure 1: Example: A circuit and its Thevenin equivalent

A recipe to find the equivalent:

1. Find the *open–circuit* voltage V_{OC} between terminals A and B.
2. Find the short–circuit current I_{SC} through terminals A and B.
3. Voltage source in the Thevenin equivalent $V_{TH} = V_{OC}$, the equivalent resistance is

   $$R_{TH} = \frac{V_{TH}}{I_{SC}}.$$

   The equivalent resistance can also be obtained as

   (a) Inactivate the sources: Replace the independent voltage sources with short circuits, and independent current sources with open circuits.

   (b) Calculate the resistance between terminals A and B. This is R_{TH}.

4. Note that when impedances are used, we determine equivalent impedance and work with phasors.

Norton equivalent

Another equivalent circuit is so called Norton equivalent circuit which comprises an equivalent current source I_N in parallel with an equivalent resistance R_N. It is related to the Thévenin equivalent as:

$$\begin{aligned} R_N &= R_{TH} \\ I_N &= \frac{V_{Th}}{R_{Th}}. \end{aligned}$$

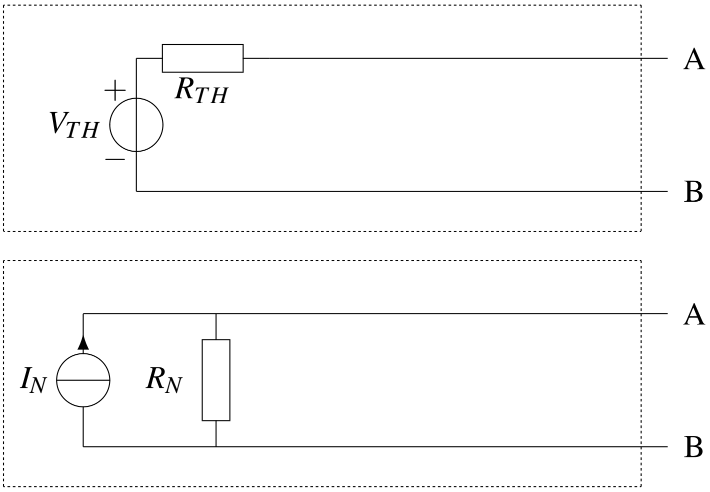
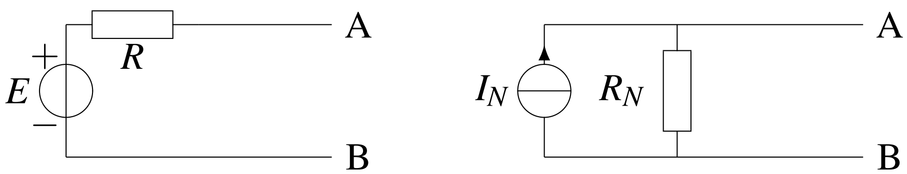


Figure 2: Example: A Thevenin equivalent and corresponding Norton equivalent.

TASKS

1. State the source transformation, i.e., how to replace a voltage source in series with a resistor (impedance) with a current source in parallel with a resistor (impedance). . Assume E and R given and find the corresponding I_N and R_N



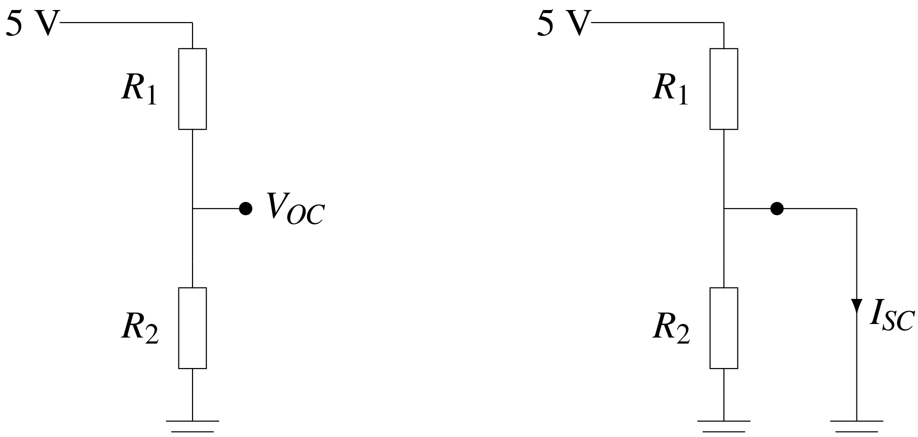
2. Let us analyze the low-frequency amplifier and its bias-point and apply the Thevenin theorem to find the bias point (Q-point) currents i_b, i_c and the voltage at collector.

   (a) Find first the DC equivalent of the circuit. For clarity, replace the potentiomater with two resistors.

(b) Which assumptions about the transistor you need to make? Well, it is rather information you find from datasheet or from the measurements you made last week.

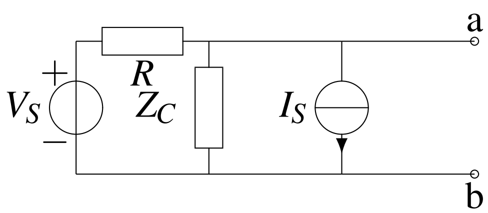
(c) Find values for the components shown in the DC equivalent picture. Assume that the potentiometer is say at 65 %

(d) Find the Thevenin equivalent for the base bias circuit, as seen below.



(e) Use the equivalent to find the base current I_B, the corresponding schematic is shown below. Draw first the equivalent circuit and then solve for I_B.

2* Extra task: Then consider the circuit below, find its Thevenin and Norton equivalents. Let $R = 100\ \Omega$, $Z_C = -j100\ \Omega$, $V_S = 100\angle 0°$ V, and $I_S = 1\angle 90°$ A.



HINT: Superposition principle works well here, see `https://en.wikipedia.org/wiki/Superposition_theorem` (e.g. "inactive" voltage sources are replaced by a short circuit).

Answers: $V_{TH} = -100j$ V, $R_{TH} = 50 - j50\ \Omega$.