Poznań University of Technology
Faculty of Computing and Telecommunications
Institute of Multimedia Telecommunications

COMPUTER AIDED DESIGN

LABORATORY

Instruction for the laboratory exercise

LTspice: DC analysis

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1. The aim of the exercise

- learning about the possibilities of DC analysis,
  simulation of the resistive voltage divider,
- simulation of the characteristics of a semiconductor diode,
- simulation of static characteristics of a bipolar transistor.

2. The course of the exercise

a) Analysis of the resistive voltage divider

1. Create a divider circuit diagram as shown in Fig. 1a. Use shortcut keys:
   - R – inserts a resistor,
   - G – inserts ground symbol,
   - F2 – open a list of elements,
   - F3 – turns on the connection drawing mode,
   - F4 – inserts a label (out).:

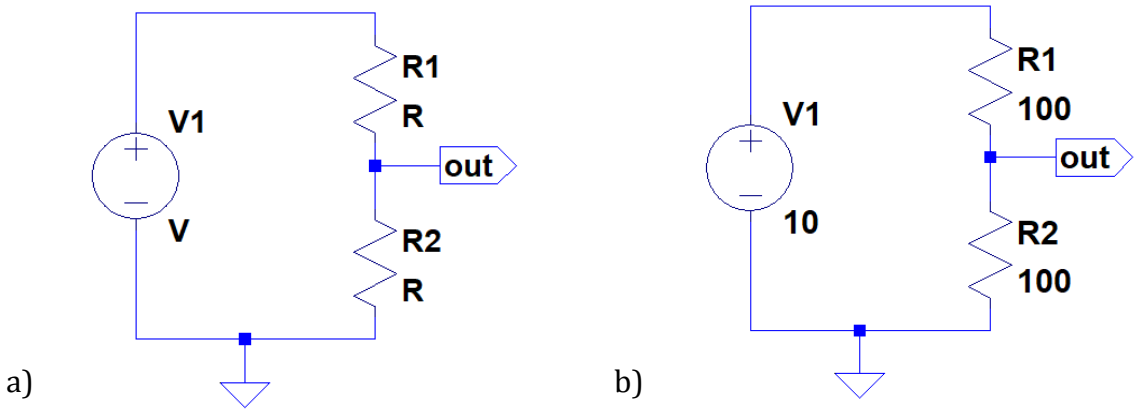


Fig. 1. Diagram of the tested divider circuit.

2. Set the values of the elements as shown in Fig. 1b. Place the mouse cursor on the selected element and right-click RMB (Right Mouse Button).
3. Make a DC analysis. Plot the characteristics of the output voltage V_{out} as a function of the source voltage V_1, i.e. $V_{out} = f(V_{V1})$.
   - Uruchomić edytor komendy symulacyjnej: w menu *Simulate* wybrać *Edit Simulation Command*, wybrać zakładkę *DC Sweep*.
   - Set the analysis parameters as shown in Figure 2.
   - Start the analysis with the *Run* button.
   - Place the mouse cursor on the *out* label, it will take the shape of a red probe and click LMP (Left Mouse Button)
   - Analyze the graph (Fig. 3), use cursors to determine the difference of the output voltage V_{out} for the source voltage $V_1 = 2{,}5V$ and $V_1 = 7{,}5V$. The cursors can be activated by left-clicking (LMB) on the *V(out)* chart label.

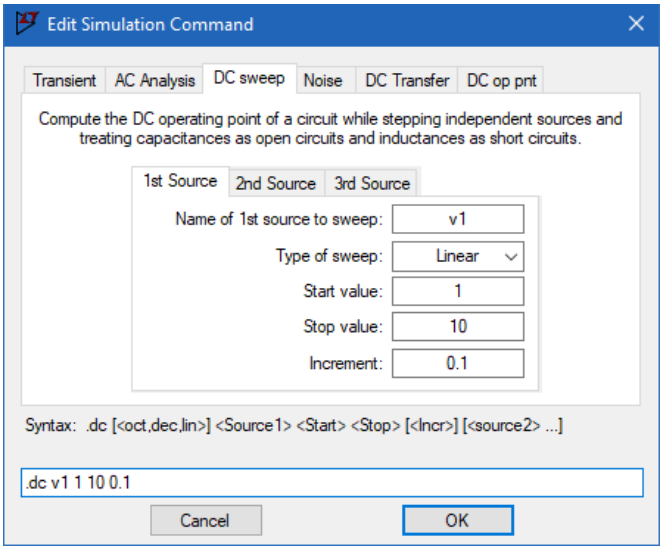


Fig. 2. Setting of DC analysis parameters.

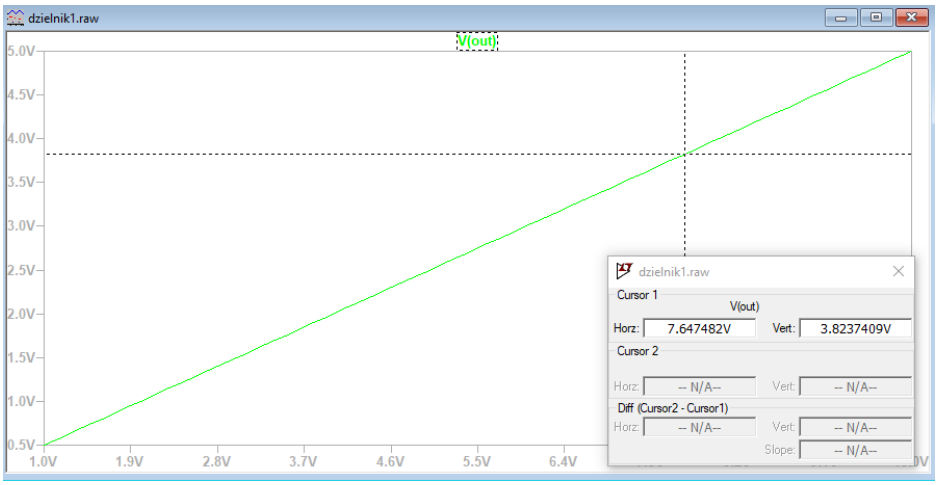


Fig. 3. $V_{out} = f(V_{V1})$ characteristic.

4. Modify the divider circuit as shown in Figure 4. To define the *rr* parameter, use the SPICE'a directive editor (*SPICE directive*). Use the *.op* button .op (last on the right) or use the keyboard shortcut - S.

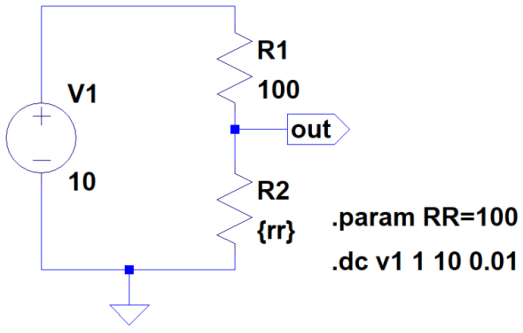


Fig. 4. Define the *rr*=100 parameter.

5. How did the introduced changes affect the operation of the analyzed system?
6. Start the editor of SPICE directives, add a new line:
   - **. step param rr list 50 100 150**
7. Did the introduced changes affect the operation of the analyzed system? How?
8. Using the cursor, read the values of the output voltage V_{out} for the source voltage *V1 = 5V* for all resistance values of the resistor R_2. (use the up and down arrows on the keyboard).

b) Analysis of the voltage divider circuit with load

1. Modify the divider circuit as shown in Figure 5.

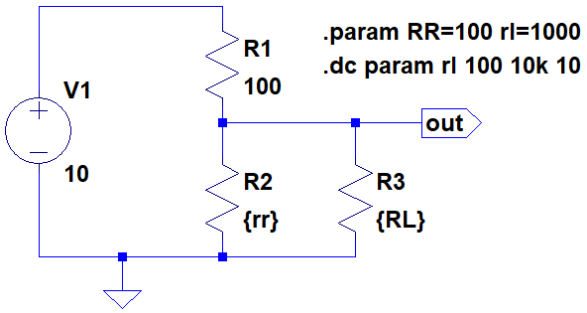


Fig. 5. Resistive voltage divider with load.

2. How did the introduced changes affect the operation of the analyzed system?
3. Run the simulation and display the output voltage V_{out} on the graph.
4. What kind of the characteristics show the graph?
5. What is the value of the output voltage V_{out} for a 1kΩ load?
6. Start the editor of SPICE directives, add a new line:
   - **. step param rr list 50 100 150**
7. Run the simulation and display the output voltage V_{out} on the graph.
8. What is the difference between .dc and .step command?

c) Examine of the influence of temperature on the output voltage

1. Draw the divider circuit according to Figure 6

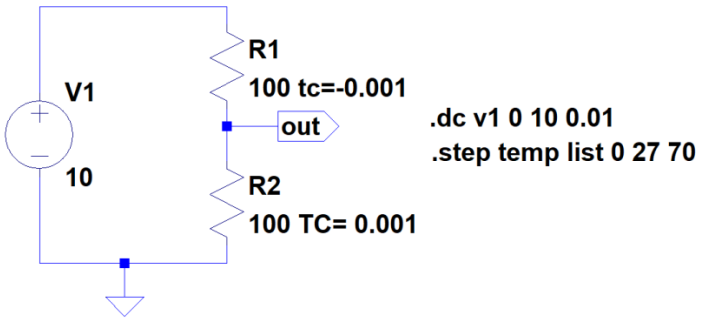


Fig. 6. Temperature influence study.

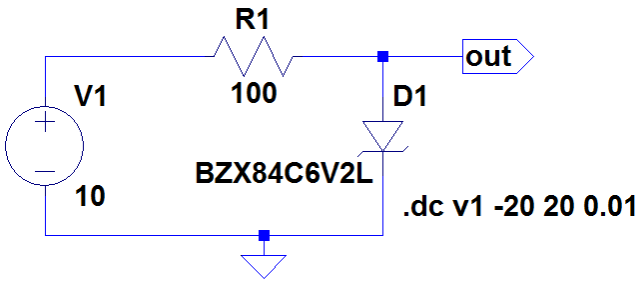
2. In the resistance values of the resistors, add the temperature coefficients TC.
3. The TC factor determines the change in the resistance value according to the equation (1):

$$R = R_{NOM} \cdot (1 + TC \cdot (Temperatura - T_{NOM})) \quad (1)$$

4. Similarly as in the previous point, plot the characteristic $U_{out} = f(T)$.
5. What is the value of the output voltage Uout at 25°C?

d) Determination of the characteristics of a semiconductor diode

1. Determine the characteristics of the Zener diode. Draw a simulation scheme according to Figure 7.



Rys. 7. A circuit for measuring the characteristics of a Zener diode.

2. After inserting the diode symbol (e.g. the d button), select the diode type by right clicking on it and selecting the *Pick New Diode* button.
3. Plot the characteristics of the current flowing through the diode as a function of the voltage at the diode V(out), for this purpose, after the simulation, click LMB on the diode, the cursor will take the shape of a current clamp meter, then change the voltage range of the horizontal axis, in the place **V1** enter **V(out)** (Fig. 8).

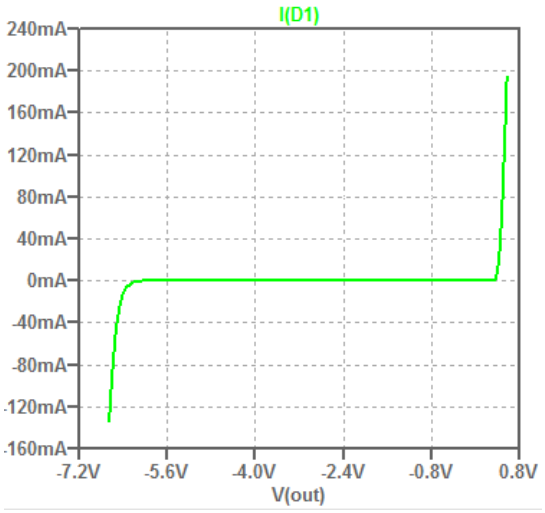
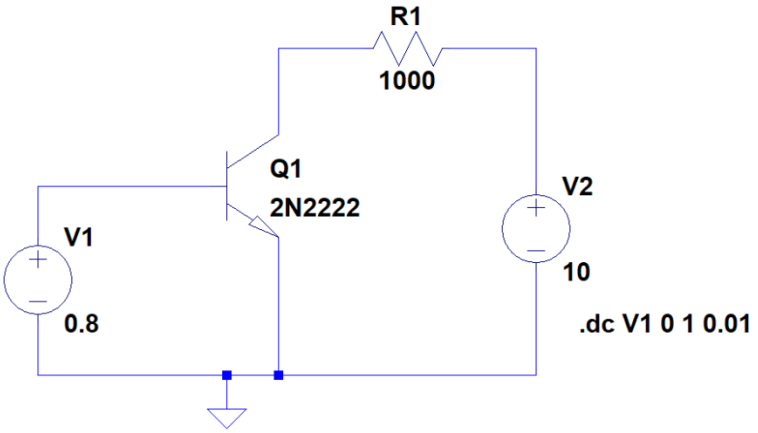


Fig. 8. Zener diode characteristics.

e) Study of a bipolar transistor

1. Find the input characteristics of the bipolar transistor $I_B = f(U_{BE})$. Draw a simulation scheme according to Figure 9.



Rys. 9. Circuit for determination of the input characteristic.

2. Check the influence of temperature changes (0, 25, 70°C) on the shape of the curve characteristic.
3. What are the base current values for each temperature value for voltage $U_{BE} = 0,7V$?
4. Determine the output characteristics of the bipolar transistor $I_C = f(U_{CE})$ for the given base current values: 10µA, 20µA i 30µA. Create a simulation scheme according to Figure 10.

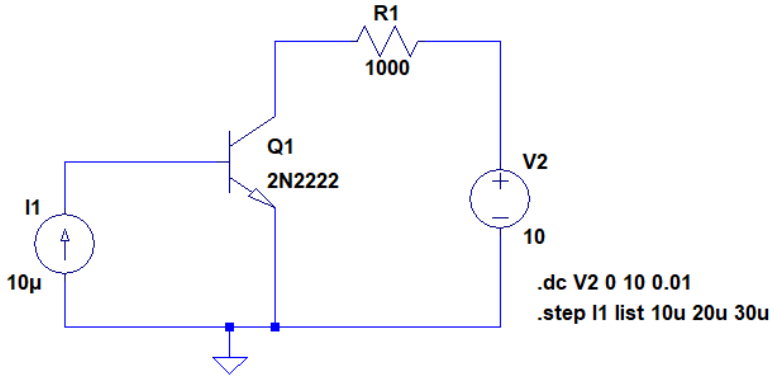


Fig. 10. Circuit for the output characteristics determination for given values of the base current I_B.

5. Show the output characteristics of the transistor $I_C = f(U_{CE})$ for the specified values of the current gain of the transistor β. Set the values of the *bf* parameter in the transistor model to 100, 250 and 500. Prepare the simulation circuit according to Figure 11.
6. What is the nominal value of the current gain β of the tested transistor?

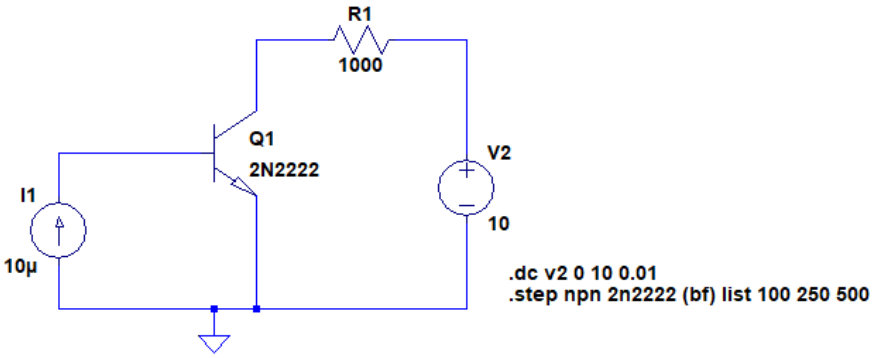


Fig. 11. Determining the output characteristics for different values of the current gain β.

3. Tasks for students to do homework (obligatory)

1. Examine and compare the forward and backward characteristics for the rectifier diode and the Shottky diode.
2. For the circuit shown in Figure 12, calculate and set the values of R_1 and R_2 resistances so that the static operating point of the transistor is: I_C = 5mA and U_{CE} = 5V.
   (see: https://www.youtube.com/watch?v=5T84Jzcgj7M
   or https://www.youtube.com/watch?v=qKIEyN_y3d4)

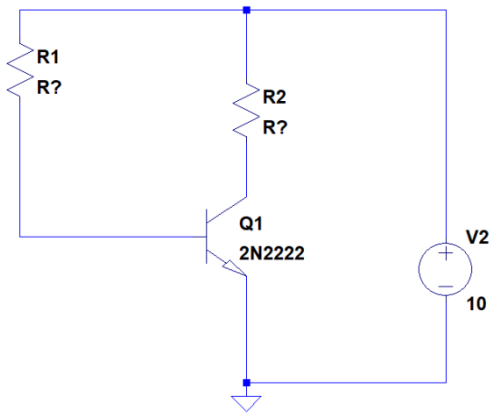


Fig. 11. Determination of the static operating point of the transistor.

4. Additional tasks

Install the Micro-Cup 12 program (free).
(https://www.spectrum-soft.com/download/download.shtm)
Repeat DC analysis:

- point a) (Analysis of the resistive voltage divider)
- point e) (Study of a bipolar transistor)

in Micro-Cup 12.
(manual: https://www.spectrum-soft.com/down/ug12.pdf)
You can see also: https://www.youtube.com/watch?v=8QLY_NVrPCA
or https://www.youtube.com/watch?v=giSpB5etKgM

5. Report

Should contain:

- all schemes of simulated systems,
- simulation results,
- answers to the questions contained in the manual,
- conclusions.