DEPARTMENT OF ELECTRONICS AGH UST

LABORATORY
OF
ELECTRONIC ELEMENTS

Current Sources

REV. 1.0a

1. THE GOAL OF THE EXERCISE

The objective of the exercise is a practical verification of several types of current sources that are based on bipolar junction transistors.

2. THE UTILIZED MODELS AND ELEMENTS

During the exercise following components will be used:

- NI ELVIS Prototyping Board (ELVIS) connected with PC,
- Virtual measurement devices:
  - `Two-Wire Current-Voltage Analyzer (2-Wire)`
  - `Digital Multimeter (DMM),`
  - `Variable Power Supplies (VPS)`
- Set of electronic elements listed in Table 1.

Table 1. Values of electronic elements required to perform the exercise

Resistors	2x2kΩ, 4.7kΩ, 6.2kΩ, 11kΩ, 43kΩ, 62kΩ
Transistors	4xBFP519

3. PREPARING THE DRAFT

3.1. Look at datasheets, identify, and draw the footprint with terminals for bipolar junction transistor BFP519.

3.2. Try to analyse in a qualitative way the current source shown in Figure 3.1.

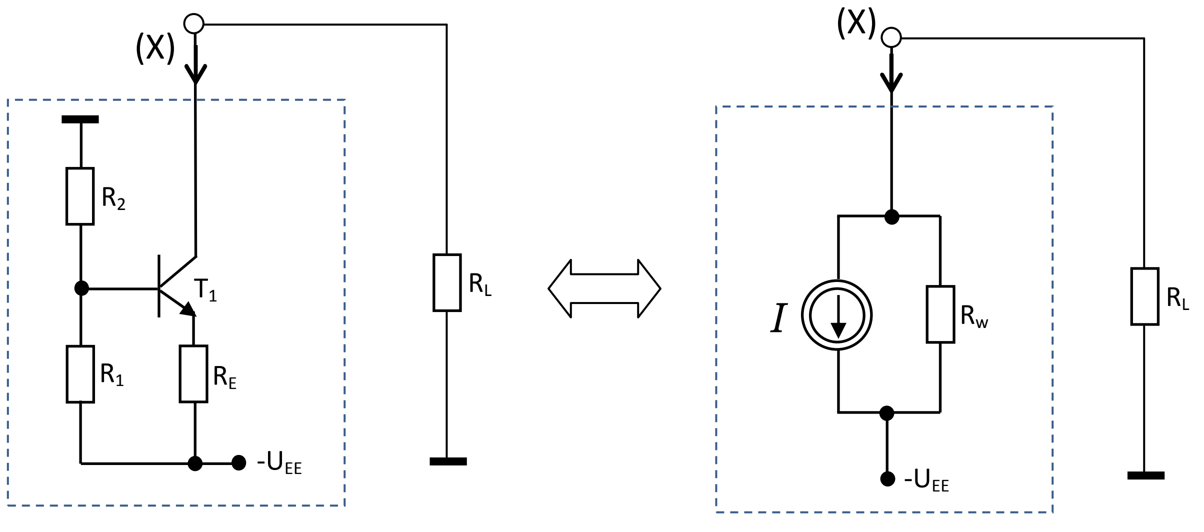


Fig. 3.1. Basic current source based on one bipolar junction transistor.

3.3. Try to deduce the formula (3.1), describing the value of the current source I. When deriving the formula skip the importance of the transistor base current.

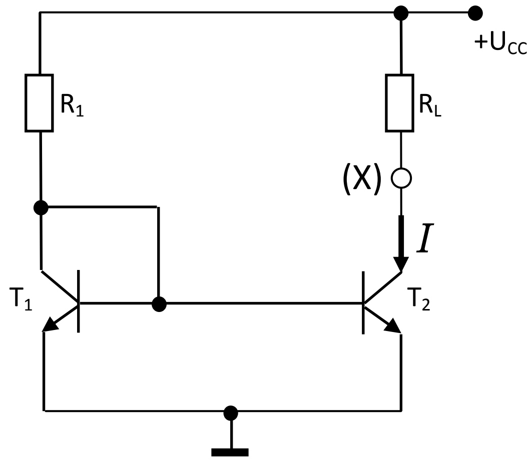
$$I = \frac{U_{EE}\frac{R_1}{R_1 + R_2} - U_{BE}}{R_E} \tag{3.1}$$

3.4. * Try to deduce the formula (3.2), describing the value of the internal resistance R_w of the current source. Instead of the transistor, one should use its small-signal equivalent model ($R_B=R_1 \| R_2$).

$$R_w = R_E \| (r_{be} + R_B) + r_{ce}\left(1 + g_m \frac{R_E \cdot r_{be}}{R_E + r_{be} + R_B}\right) \tag{3.2}$$

* - extra task

3.5. Try to deduce the formula (3.3), describing the value of the current I of the current mirror shown in Fig. 3.2. Note, that $U_{BE1}=U_{BE2}$, moreover transistor T_1 works in a diode mode (U_{CE1}-U_{BE1}).

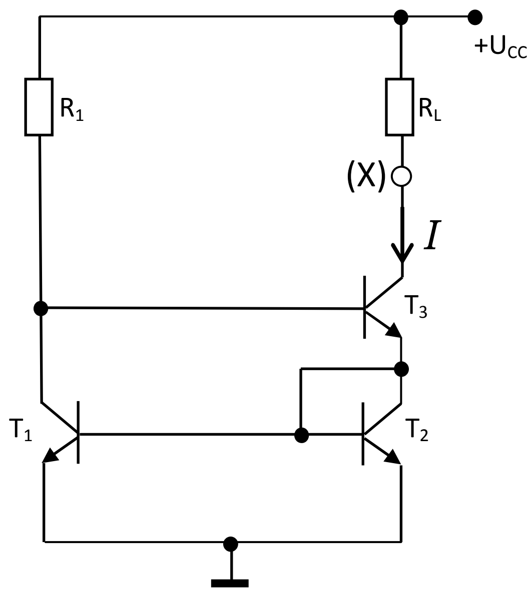


Rys. 3.2. Basic current mirror.

$$I = I_{C2} = \frac{U_{CC} - U_{BE1}}{R_1} \tag{3.3}$$

3.6. Try to deduce the formula (3.4), describing the value of the current I of the Wilson current mirror shown in Fig. 3.3. Note, that $U_{CE1}=U_{BE1}+U_{BE2}$.

$$I = I_{C3} = \frac{U_{CC} - 2U_{BE}}{R_1} \tag{3.4}$$



Rys. 3.3. Wilson current mirror.

4. THE COURSE OF THE EXERCISE

4.1. Connect the elements according to the scheme shown in Fig. 3.1: T_1→BFP519, R_1=43kΩ, R_2= 62kΩ, R_E=2kΩ, $-U_{EE}$=-VPS=-12V. Instead of resistor R_L (removed from the circuit), join DUT+ to point **X**, while GROUND join with DUT-. Launch the 2-Wire Analyzer, set the voltage range from 0 to +10V with a step +0,05V, set the current limit to +20mA. Under these settings, carry out measurements to get *I=f(U)* characteristic of the current source. Next, change the value of the resistor R_E to 4.7kΩ, after that to 11kΩ, and take the current source characteristics for these cases. Record the measurements using „log" option.

4.2. For the scheme from Fig. 3.1, with R_E=2kΩ, instead of 2-Wire Analyzer, connect the joined in series ammeter (DMM) and load resistor R_L=2kΩ, between **X** and the GROUND. Measure the current of the source. Next, change the R_L to 11kΩ and repeat the measurement.

4.3. Connect the elements according to the scheme shown in Fig. 3.2: T_1→BFP519, R_1=11kΩ, $+U_{CC}$=+VPS=+12V. Instead of resistor R_L (removed from the circuit), join DUT+ to point **X**, while the GROUND join with DUT-. Launch the 2-Wire Analyzer, set the voltage range from 0 to +12V with a step +0,05V, set the current limit to +20mA. Under these settings, carry out measurements to get *I=f(U)* characteristic of the current source. Next, change the value of the resistor R_1 to 4.7kΩ, and repeat the measurements. Record the measurements using „log" option.

4.4. Connect the elements according to the scheme shown in Fig. 3.3: T_1→BFP519, R_1=11kΩ, $+U_{CC}$=+VPS=+12V. Instead of resistor R_L (removed from the circuit), join DUT+ to point **X**, while the GROUND join with DUT-. Launch the 2-Wire Analyzer, set the voltage range from 0 to +12V with a step +0,05V, set the current limit to +20mA. Under these settings, carry out measurements to get *I=f(U)* characteristic of the current source. Next, change the value of the resistor R_1 to 4.7kΩ, and repeat the measurements. Record the measurements using „log" option.

5. DATA ANALYSIS

5.1. Draw characteristics *I=f(U)* of the current source, taking into account the measurements collected at point 4.1, for different values of the resistor R_E. Are the measured current values in line with the theoretical ones, according to the formula 3.1?

- for each case, try to estimate graphically the internal resistance R_w of the current source. Assuming that the Early' voltage of the transistor is U_A=200V, β=100, find the small-signal parameters for R_E=2kΩ, at operating point (U_{CE}=5V, I_C=*I*), and next estimate the theoretical value of R_w according to the formula 3.2,

- how would the *I=f(U)* characteristic look like when extrapolated in the direction of negative voltages, that is, if we would change the voltage *U* from -10V to +10V, instead from 0V to +10V. Consider this case only for R_E=2kΩ.

5.2. Clarify, why you obtained different values of current at point 4.2, when R_L=2kΩ and R_L=11kΩ were used, respectively. Why does the current source is not working properly in the latter case? What is the threshold value of R_L, above which the source stops to deliver constant current?

5.3. Draw characteristics *I=f(U)* of the current source, taking into account the measurements collected at point 4.3, for different values of the resistor R_1. Are the measured current values in line with the theoretical ones, according to the formula 3.3?

- for each case, try to estimate graphically the internal resistance R_w of the current source,

- what is the threshold value of R_L, above which the source stops to deliver constant current?

5.4. Draw characteristics *I=f(U)* of the current source taking into account the measurements collected at point 4.4, for different values of the resistor R_1. Are the measured current values in line with the theoretical ones, according to the formula 3.4?

- for each case, try to estimate graphically the internal resistance R_w of the current source,

- what is the threshold value of R_L, above which the source stops to deliver constant current.

5.5. Try to compare and comment the graphically estimated values of R_w for different current sources subjected to measurements during this exercise.

6. LITERATURE

[1] Lecture (P. Dziurdzia)

[2] Behzad Razavi „Fundamentals of Microelectronics"

[3] S. Kuta, „Elektronika" Part 1