Versuch 4: Transistor

Team 2-13: Jascha Fricker, Benedict Brouwer

8. September 2022

Inhaltsverzeichnis

1 Introduction

In this experiment we examined the properties of a bipolar transistor in combination with an emitter circuit. Therby we measured the characteristic curve of the transistor and tested different konfigurations of the emittercircuit.

2 Theorie

2.1 small signal model

For small deviations around the workingpoint one can use the small signal modell leading to the following equation.

$$\begin{pmatrix} dI_{\mathrm{B}} \\ dI_{\mathrm{C}} \end{pmatrix} = \begin{pmatrix} \frac{1}{r_{\mathrm{BE}}} & S_{\mathrm{r}} \\ S & \frac{1}{r_{\mathrm{CE}}} \end{pmatrix} \begin{pmatrix} dU_{\mathrm{BE}} \\ dU_{\mathrm{CE}} \end{pmatrix} \tag{1}$$

whereby r_{BE}, r_{CE} and the steepness S can be calculated with

$$\frac{1}{r_{\mathrm{BE}}} = \frac{\partial I_{\mathrm{B}}}{\partial U_{\mathrm{BE}}}|_{U_{\mathrm{CE}}} \tag{2}$$

$$\tag{3}$$

$$\frac{1}{r_{\mathrm{CE}}} = \frac{\partial I_{\mathrm{C}}}{\partial U_{\mathrm{CE}}}|_{U_{\mathrm{BE}}} \tag{4}$$

$$\tag{5}$$

$$S = \left.\frac{\partial I_{\mathrm{C}}}{\partial U_{\mathrm{BE}}}\right|_{U_{\mathrm{CE}}} = \frac{qI_{\mathrm{C}}}{k_{\mathrm{B}}T} \tag{6}$$

In addition to that I_{B} can be calculated the following proportionality

$$I_{\mathrm{B}} \propto \exp\left(\frac{qU_{\mathrm{BE}}}{k_{\mathrm{B}}T}\right) \tag{7}$$

3 execution

3.1 workingpoint

A bipolar transistor has a specific basevoltage range (the so called workingpoint) in wich it behaves approxmately linear. This workingpoint is tuned by setting the resistance at the potentiometer R_{12} 1[see circuit diagram] to a point whereby the outputamplitude u_a is maximal and the signal is not distorted. To tune the workingpoint, the loadresistor R_L was removed and a sinusoidal frequency of 5.5 kHz was applied. U_{BE}, U_{CE}, I_{C} where measured with varying R_{C} for further evaluation.

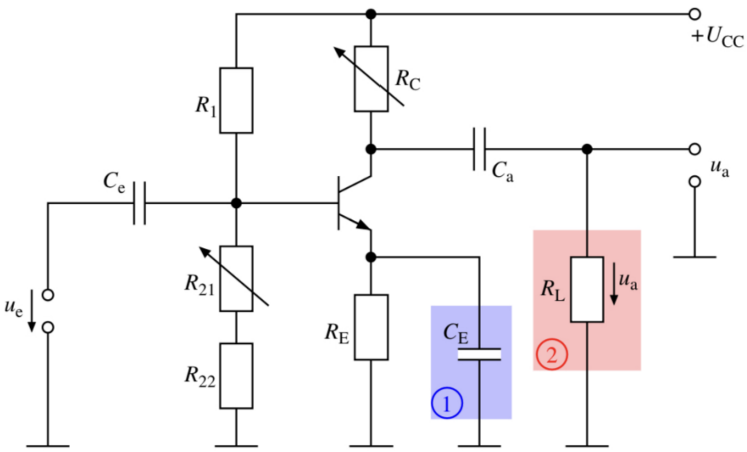

Abbildung 1: emittercircuit:
$R_1 = 47$ kΩ, $R_{22} = 100$ Ω,$R_E = 10$ kΩ, $C_e = 47$ µF,$C_a = 470$ µF, $U_{CC} = 9$ V R_{12}: potentiometer for the workingpoint, R_C: potentiometer 0 - 10 kΩ, u_e: inputvoltage, u_a: outputvoltage

3.2 Amplification of the emittercircuit

To further examine the emittercircuit 1[see circuit diagram] the amplidude quotionet u_a/u_e was measured for varying R_C in different circuit configurations:
1. with capacitor CE but without resistor R_L 2. without capacitor CE and without resistor R_L 3. with capacitor CE and resistor R_L

3.3 Frequency response

In this experiment the input frequency was varied from 6 Hz - 250 kHz to measure the phaseshift and the amplidude quotionet u_a/u_e. Therby circuit 1 with an collectorresistor of R_C was used. In addition to that the oszilloscope was changed to x-y mode to observe lissajous curves.

3.4 characteristic curve

To measure the characteristic curve of the transistor the circuit was change as shown in the circuit diagram 2. First the entry curve $I_\mathrm{B} = f(U_\mathrm{BE})|_{U_\mathrm{CE}}$ was taken by changing U_BE from 0 to 670 mV and measuring I_B, U_BE and U_CE with multimeters according to the scematic 2. Therby U_CE was dialed in to match the results from experiment 1 4.2 with $R_\mathrm{C} = 5$ kΩ. Afterwards the output characteristic curve $I_\mathrm{C} = f(U_\mathrm{CE})|_{U_\mathrm{BE}}$ was recorded with a varying U_CE from 1 - 10 V by measuring I_C, U_BE and U_CE. This curve was measured in both directions to observe the effect of heat on the transistor.

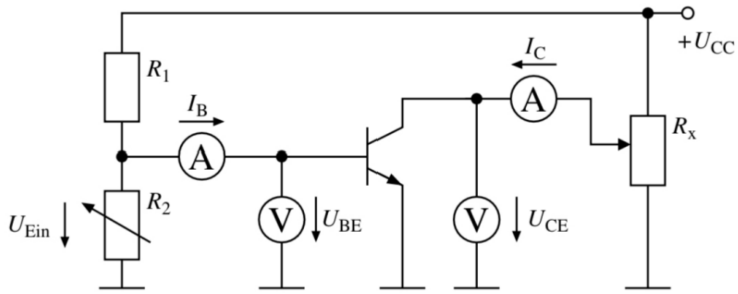

Abbildung 2: characteristic curve$R_1 = 1$ kΩ, $R_2 = 220$ Ω

4 Evaluation and results

4.1 preliminary considerations

4.2 characteristic curve (Assignment 7)

As shown in table 4.2 some basevalues where recorded wich were needed in following experiments. They seem to be in a reasonable range.

R_C in kΩ	U_{BE} in V	U_{CE} in V	I_C in mA	S in 1/Ω
1	0,57	7,86	0,58	0.025
5	0,57	5,53	0,58	0.025
10	0,57	3,22	0,58	0.025

Tabelle 1: Basevalues

The characteristic input curve is plottet in figure 3. With the slope from the tangent one can calculate the Baseresistance $r_{BE} = 3.92$ kΩ with equation 2 and the operating temperature $T = 272{,}2$ K can obtained by using the fitparameters from the exponetial fit and equation 7. Althoug the operating temperature has the correct magnitude it schould be at least 30 K higher. With this operating temperature and equation 6 the steepness S can be calculated as shown in figure 4.2.

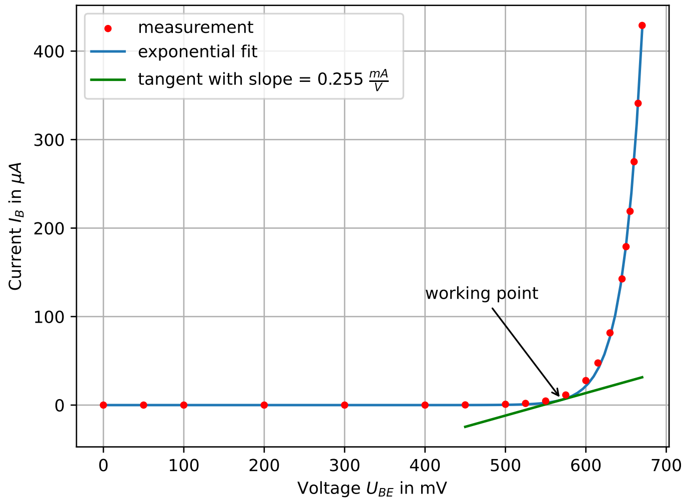

Abbildung 3: Characteristic curve from the input

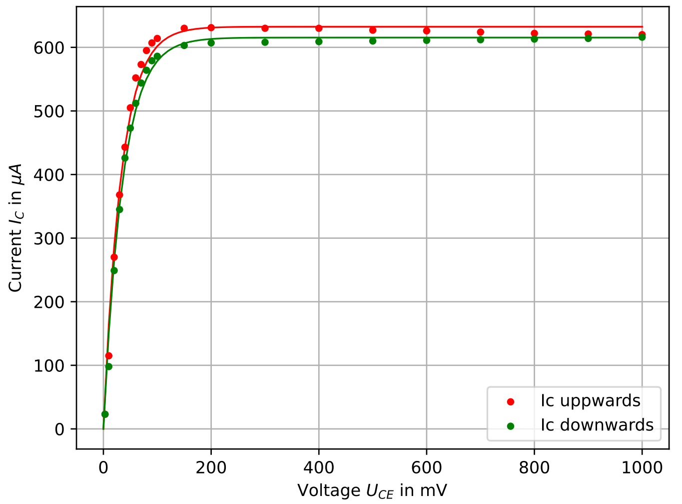

Abbildung 4: Characteristic curve from the output