Versuch 4: Transistor

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Contents

1 Introduction

In this experiment we examine the properties of a bipolar transistor as a class A amplifier. To observe the proporties we measured the characteristic curve of the transistor and tested different configurations of the emitter circuit.

2 Theorie

2.1 Small Signal Model

For small deviations around the operating point 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

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

$$\frac{1}{r_{\mathrm{CE}}} = \frac{\partial I_{\mathrm{C}}}{\partial U_{\mathrm{CE}}}|_{U_{\mathrm{BE}}} \tag{3}$$

$$S = \left.\frac{\partial I_{\mathrm{C}}}{\partial U_{\mathrm{BE}}}\right|_{U_{\mathrm{CE}}} = \frac{qI_{\mathrm{C}}}{k_{\mathrm{B}}T} \tag{4}$$

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

$$I_{\mathrm{B}} \propto \exp\left(\frac{qU_{\mathrm{BE}}}{k_{\mathrm{B}}T}\right) \tag{5}$$

3 Execution

3.1 Operating Point

A bipolar transistor has a specific basevoltage range (the so called operating point) in which it behaves approximately linear. This operating point is tuned by setting the resistance at the potentiometer R_{12} 1[see circuit diagram] to a point whereby the output amplitude u_a is maximal and the signal is not distorted. To tune the operating point, the load resistor 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.

3.2 Amplification of the Emittercircuit

To further examine the emitter circuit 1[see circuit diagram] the amplitude ratio 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}

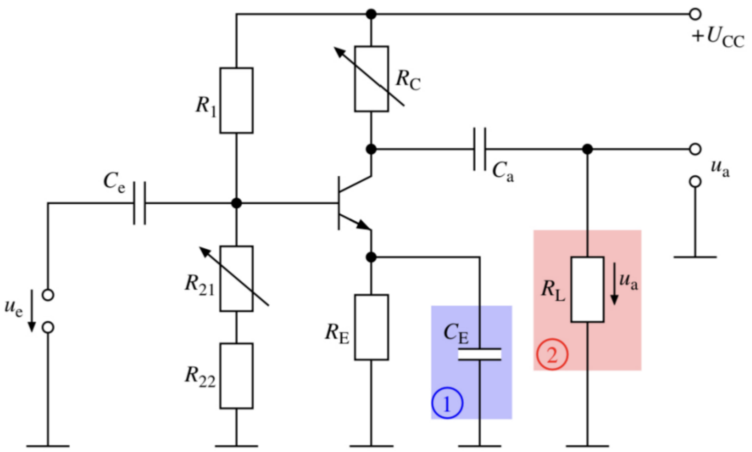

Figure 1: emittercircuit:
$R_1 = 47$ kΩ, $R_{22} = 100$ Ω,$R_E = 10$ kΩ, $C_e = 47$ µF,$C_a = 470$ µF, $U_{CC} = 9$ V R_{12}: potentiometer for the operating point, R_C: potentiometer 0 - 10 kΩ, u_e: inputvoltage, u_a: outputvoltage

3.3 Frequency Response

In this experiment the input frequency was varied from 6 Hz - 250 kHz to measure the phaseshift and the amplidude ratio u_a/u_e. Here circuit 1 with an collector resistor 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

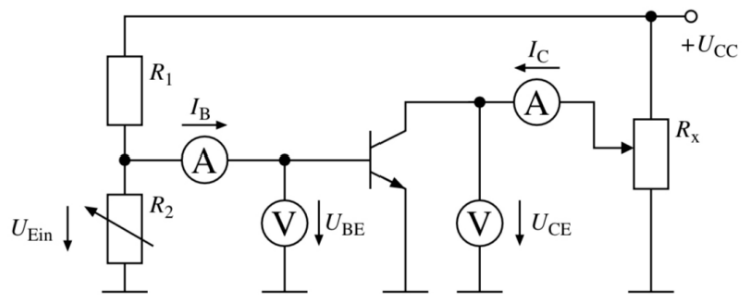

Figure 2: characteristic curve$R_1 = 1$ kΩ, $R_2 = 220$ Ω

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 schematic 2. Therby U_{CE} was dialed in to match the results from experiment 1 4.2 with $R_{\text{C}} = 5$ kΩ. Afterwards the output characteristic curve $I_{\text{C}} = f(U_{\text{CE}})|_{U_{\text{BE}}}$ 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.

4 Evaluation and Results

4.1 Preliminary Considerations

4.1.1 Measuring of the characteristic Values

The characteristic Values of a transistor are different for each operating point. Therefore the measurements have to be done with the Voltages already applied. While measuring, there is already a Voltage aplied. This could messs with the Multimeter leadiging to wrong measurements, if it assumes free floating ends. This also meand, that the resistance of the power supply and the resistor has to be taken into account, as is is essantialy a second path for energy to flow parallel. Lastly the test Voltage, which the multimeter uses to probe the resistance could be greater than the maximum of the small signal model, so that the multimeter measures outside the linear section.

4.1.2 Transformation of y to h parameters

The dependency of i_1, i_2, u_1 and u_2 can also be written in h parameter form as

$$\begin{pmatrix} u_1 \\ i_1 \end{pmatrix} = \begin{pmatrix} r_{BE} & -S_r r_{BE} \\ S r_{BE} & \frac{\frac{1}{r_{BE} \cdot r_{CE}} - S_r \cdot S}{r_{BE}} \end{pmatrix} \begin{pmatrix} i_1 \\ u_2 \end{pmatrix} \tag{6}$$

4.2 Characteristic Curve (Assignment 7)

As shown in table 4.2 some basevalues were recorded which 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

Table 1: Base values

The characteristic input curve is plottet in figure 3. With the slope of the tangent one can calculate the base resistance $r_{\text{BE}} = 3.92$ kΩ with equation 2. The operating temperature $T = 272{,}2$ K can be obtained by using the fitparameters from the exponetial fit and equation 5. Although the operating temperature has the correct magnitude it should be at least 30 K higher. With this operating temperature and equation 4 the steepness S can be calculated as shown in figure 4.2.

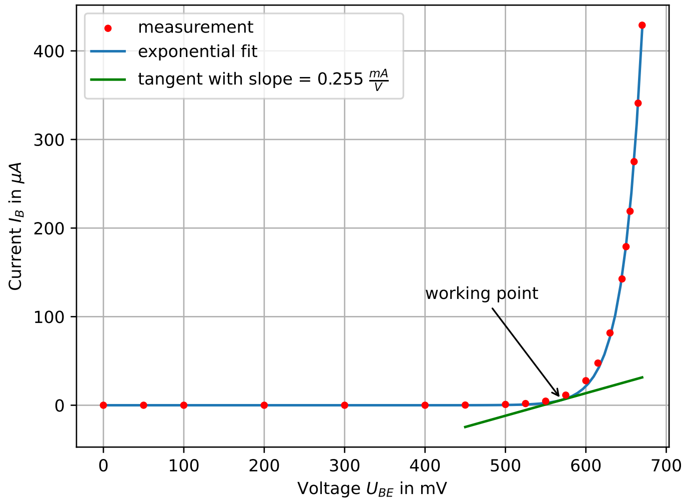

Figure 3: Characteristic curve from the input

The characteristic output curve is plottet in figure 4.

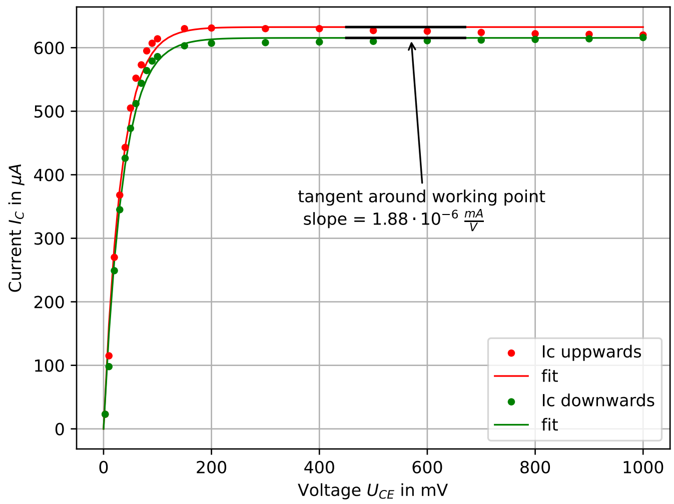

Figure 4: Characteristic curve from the output