# Versuch 4: Transistor

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## 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 $r_{\mathrm{BE}}$, $r_{\mathrm{CE}}$ 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 $I_{\mathrm{B}}$ 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 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. $U_{\mathrm{BE}}$, $U_{\mathrm{CE}}$, $I_{\mathrm{C}}$ where measured with varying $R_{\mathrm{C}}$ for further evaluation.

## 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 $R_{\mathrm{C}}$ in different circuit configurations:

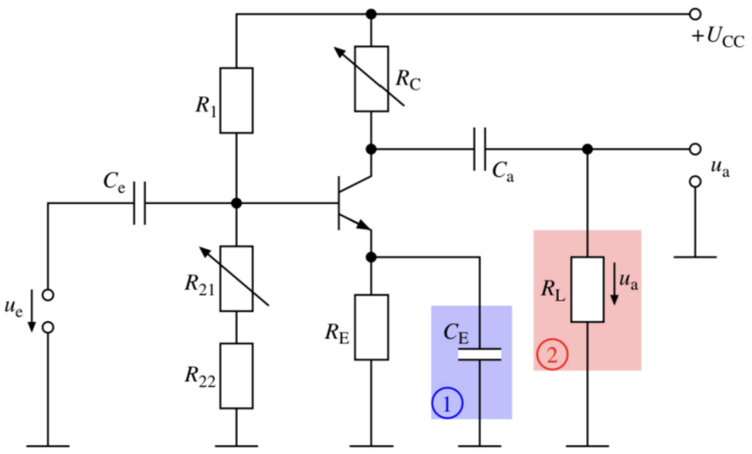


Abbildung 1: emittercircuit:
$R_1$ = 47 kΩ, $R_{22}$ = 100 Ω,$R_E$ = 10 kΩ, $C_e$ = 47 µF,$C_a$ = 470 µF, $U_{CC}$ = 9 V $R_{12}$: potentiometer for the workingpoint, $R_C$: potentiometer 0 - 10 kΩ, $u_e$: inputvoltage, $u_a$: outputvoltage

1. with capacitor $C$E but without resistor $R_{\mathrm{L}}$ 2. without capacitor $C$E and without resistor $R_{\mathrm{L}}$ 3. with capacitor $C$E and resistor $R_{\mathrm{L}}$

### 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 $R_{\mathrm{C}}$ was used. In addition to that the oszilloscope was changed to x-y mode to observe lissajous curves.

### 3.4 characteristic curve

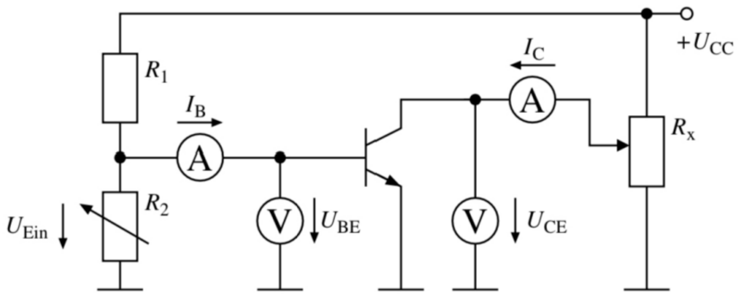


Abbildung 2: characteristic curve$R_1$ = 1 kΩ, $R_2$ = 220 Ω

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 $U_\mathrm{BE}$ from 0 to 670 mV and measuring $I_\mathrm{B}$, $U_\mathrm{BE}$ and $U_\mathrm{CE}$ with multimeters according to the scematic 2. Therby $U_\mathrm{CE}$ was dialed in to match the results from experiment 1 4.2 with $R_\mathrm{C} = 5$ k$\Omega$. Afterwards the output characteristic curve $I_\mathrm{C} = f(U_\mathrm{CE})|_{U_\mathrm{BE}}$ was recorded with a varying $U_\mathrm{CE}$ from 1 - 10 V by measuring $I_\mathrm{C}$, $U_\mathrm{BE}$ and $U_\mathrm{CE}$. This curve was measured in both directions to observe the effect of heat on the transistor.

# 4 Evaluation and results

## 4.1 preliminary considerations

## 4.2 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.

| $R_\mathrm{C}$ in k$\Omega$ | $U_\mathrm{BE}$ in V | $U_\mathrm{CE}$ in V | $I_\mathrm{C}$ in mA | $S$ in 1/$\Omega$ |
|---|---|---|---|---|
| 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 $r_\mathrm{BE} = 3.92$ k$\Omega$ with equation 2. The operating temperature $T = 272{,}2$ K can be obtained by using the fitparameters from the exponetial fit and equation 5. Althoug the operating temperature has the correct magnitude it schould 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.

The characteristic output curve is plottet in figure 4.

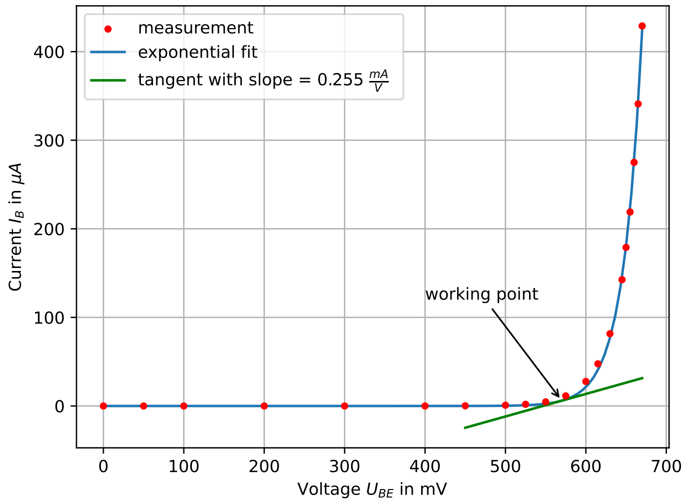


Abbildung 3: Characteristic curve from the input

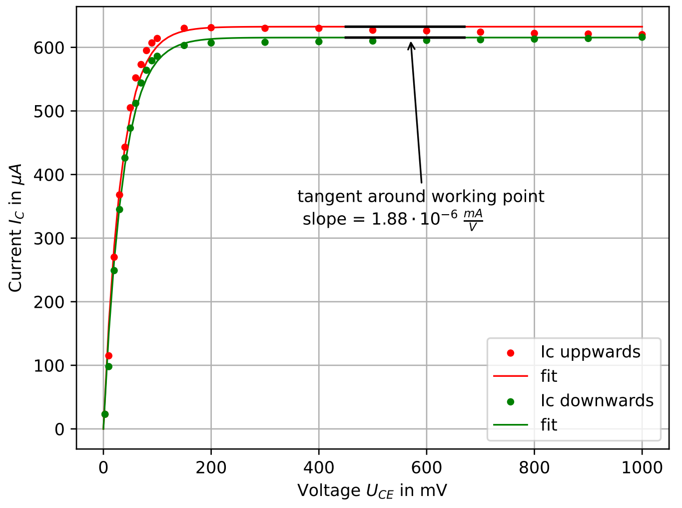


Abbildung 4: Characteristic curve from the output