IMTEK
DEPARTMENT OF MICROSYSTEMS ENGINEERING

universität freiburg

Electronics Laboratory

Winter semester 2025

Lab 2 – Bipolars

Name	Jakob Haverkamp	Reg. Nr.	5932110
Name	Milan Fark	Reg. Nr.	5900383

Score and comments (only for tutors, please leave blank)

Please fill out this cover sheet and submit it with your lab report.

Jakob Haverkamp
Milan Fark
jh1444, mf643

Electronics Laboratory
WS 25/26
Prof. Dr. Hans Zappe

Lab 2 - Bipolars

01. Dezember 2025

2.2 Bipolar Characteristics

2.2.1 Simulation

Introduction

Our goal was to simulate the behaviour of a BC547B bipolar. Figure 1 shows the circuit diagram in LTSpice, Figure 2 shows the Voltage difference from Base to Emitter, when we slowly ramp up the input voltage V_i, which is connected to the base end of the transistor. In Figure 3, we determined β (the current gain), and plotted it and I_C over I_B. To figure out the early voltages of the bipolar, we plotted I_C over V_{CE} and calculated, where I_C is zero, see Figure 4.

Circuit Diagrams:

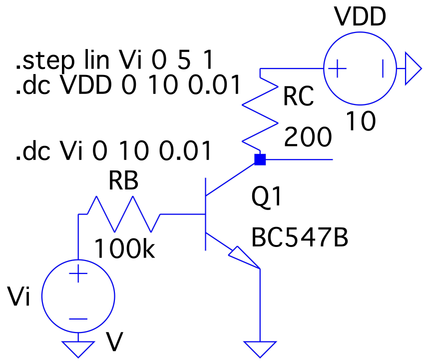

Figure 1: LTSpice circuit diagram with
instructions for both the first (bottom) and second (top) task

Plots:

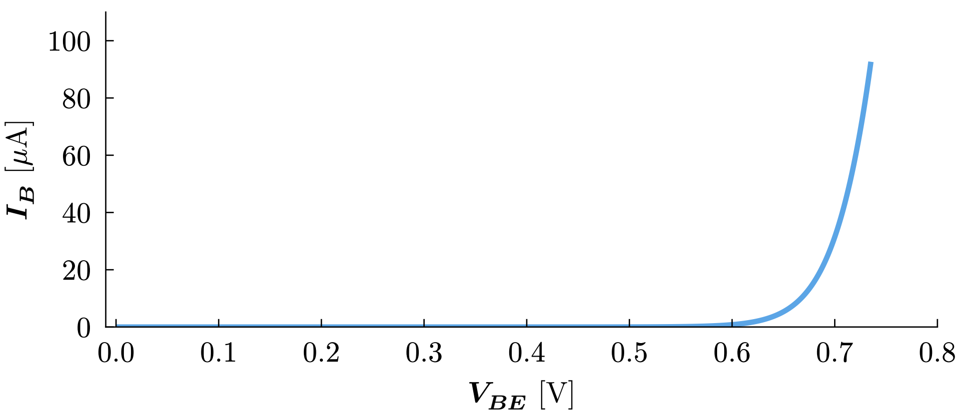

Figure 2: Simulated base current over base-emitter voltage

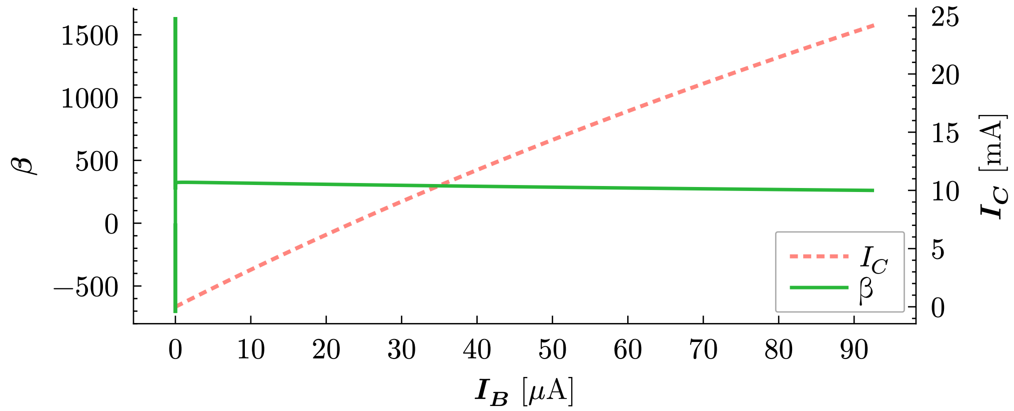

Figure 3: Simulated β and I_C over I_B

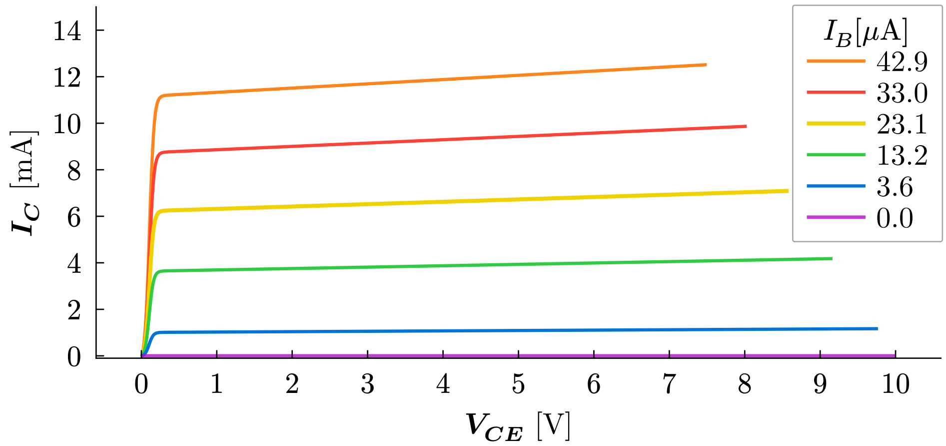

Figure 4: Simulated current through R_C plotted over collector-emitter voltage

Text Questions:

At currents $I_B \lessapprox 0.15$ μA, β does not approximate a single number, but instead jumps a lot, the maximum value being 1641.45 and the minimum -715.27, which happens due to small numbers in the divisor (I_B). For slightly higher currents $I_B > 0.15$ μA, the value for $\beta \approx 325$.

As seen in Figure 3, β is not constant, instead slowly going from $\beta \approx 325$ at the beginning to $\beta \approx 260$ at the end. The effect is seen not only in the graph of beta itself, but also in the fact that I_C flattens when plotted over I_B.

As seen in Table 1, the early voltages for different values of I_B are all very similar, around 61 V. One observable trend is that for higher I_B values, the early voltages slightly decreases.

It is also visible that for $I_B = 0.0$, the value does not make a lot of sense, and is difficult to calculate better, as I_C is close to 0V.

$I_B[\mu A]$	Early voltage [V]
0.0	0.618
3.6	61.088
13.2	60.972
23.1	60.919
33.0	60.883
42.9	60.857

Table 1: Early Voltages

Conclusion:

We successfully simulated the BC547B bipolar characteristics. In the input characteristics we could see it producing a diode curve. We could see the bipolar amplifying the base current by a factor of $\beta \approx 260 - 325$, going down for bigger I_B values. We also noticed the

I_C over V_{CE} curve getting steeper with bigger I_B values and measured an early voltage of $V_E \approx 61V$.

2.2.2. Measurement

Introduction

In this section, we measured the values we simulated earlier. To calculate I_B we measured the voltage drop over the resistor R_{41} and did the same with I_C and R_{31} (Figure 5). We used that to calculate β as well as the early voltages at different base currents.

Circuit Diagrams:

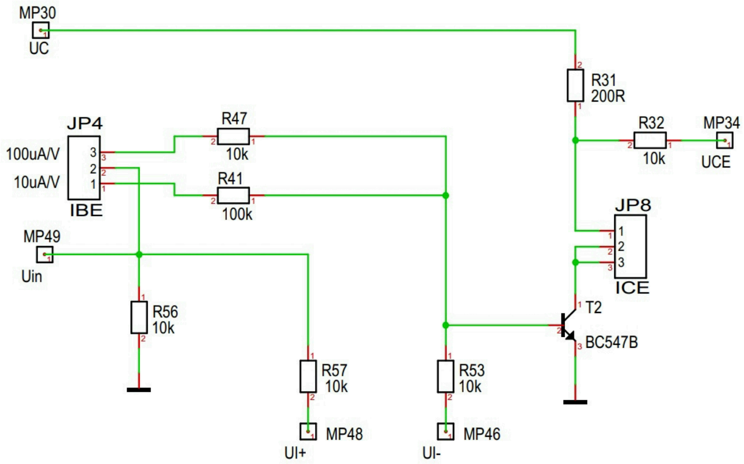

Figure 5: Schematic of the *BJT characteristics* circuit

Plots:

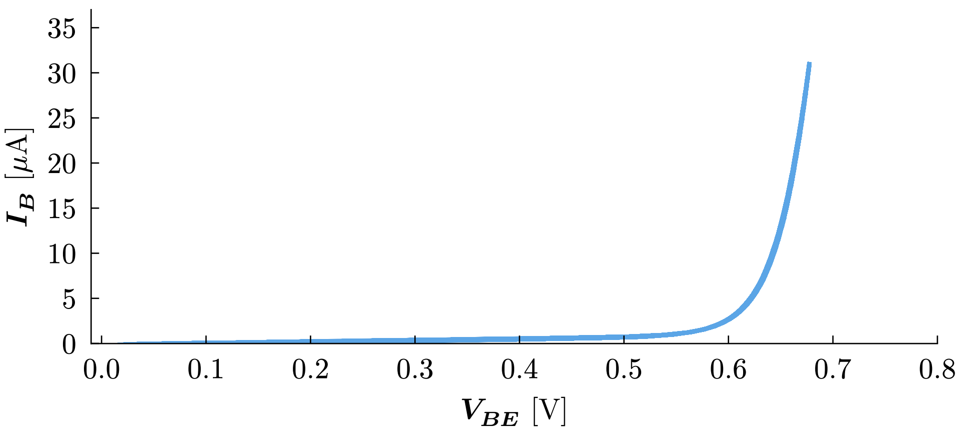

Figure 6: Measured base current over base-emitter voltage

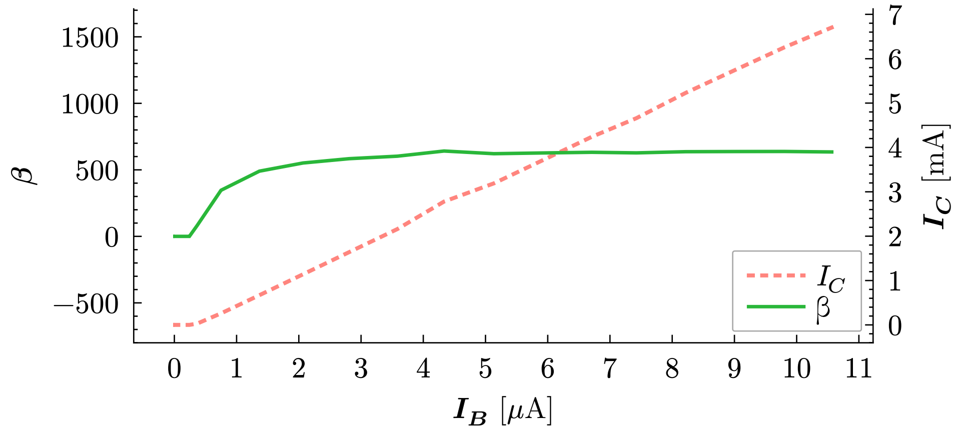

Figure 7: Measured β and I_C over I_B

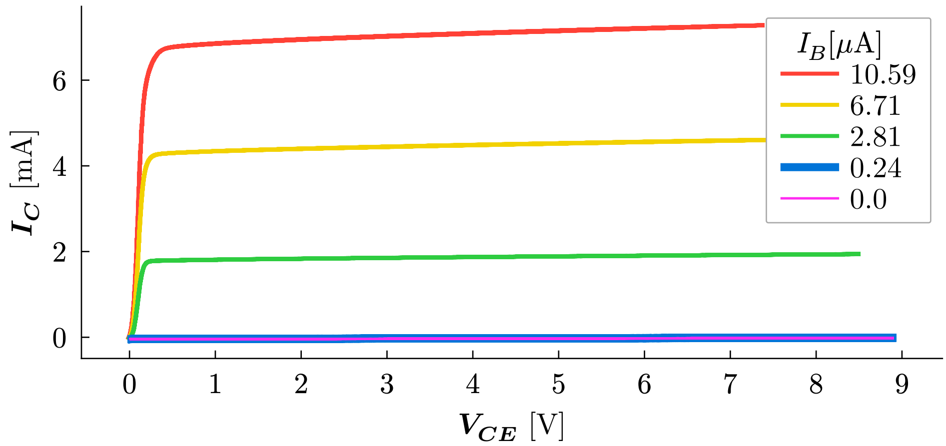

Figure 8: Measured current through R_C plotted over collector-emitter voltage

Text Questions:

In Figure 7 we connected a hand-multimeter between pins 1 and 2 of *JP8* to measure I_C as a function of I_B. Due to the limited amount of measurements (n=20), the curve is a little wobbly.

β is, different to the simulation, not getting lower over time (and therefore I_C is not getting less steep), instead staying around $\beta \approx 630$.

The relevant early voltages calculated form measurements in Table 2 are quite similar to each other, around 105-110 V.

Similar to the simulation, the measured early voltages for $I_B \approx 0.0$ μA and $I_B \approx 0.24$ μA are not realistic, because I_C is close to 0 A.

$I_B[\mu A]$	Early voltage [V]
0.0	13.690
0.24	12.081
2.81	105.100
6.71	109.670
10.59	104.432

Table 2: Early Voltages

Conclusion

Most characteristics were similar to the simulation, however we could not see beta getting lower over time. We measured the early voltage to be $V_E \approx 105 - 110$. The input characteristics look very similar to the simulation, again producing a diode curve.

2.3. Common Emitter Amplifier

2.3.1 Simulation

Introduction

In this section we used a common emitter amplifier to amplify a small AC signal and plot the amplification and phase shift of this signal. We simulated the circuit shown in Figure 9 using two different resistors R_E, one being $R_{48} = 220\ \Omega$ and the other $R_{51} = 680\ \Omega$.

Circuit Diagrams:

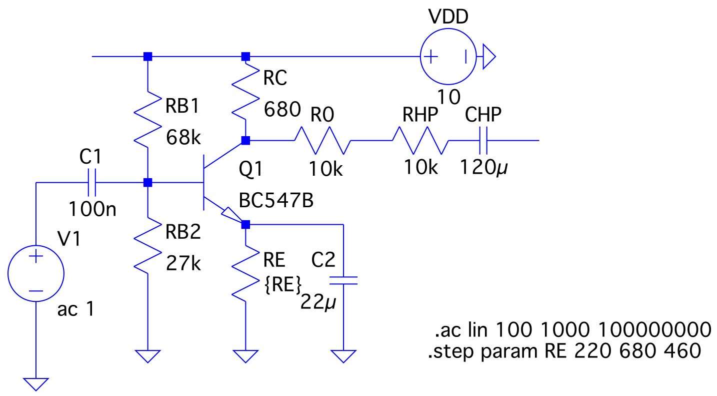

Figure 9: LTSpice circuit diagram for the common emitter amplifier

Plots:

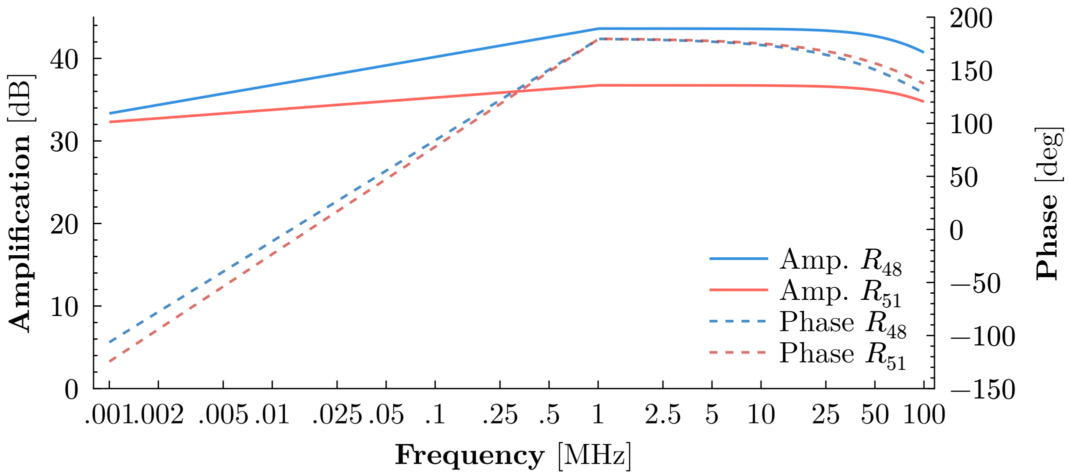

Figure 10: Simulated phase and amplification of the common emitter amplifier for a frequency of 1kHz-100MHz on a $\log_2$ scale. $R_{48} = 220\ \Omega$ and $R_{51} = 680\ \Omega$

Text Questions:

As seen in Figure 10 the amplification of R_{48} is higher than that of R_{51}, because of the higher resistance of R_{51}. The phase shift of R_{48} is slightly more in the lowest frequencies, a little less at the highest frequencies but overall very similar to that of R_{51}. The four graphs all start of increasing linearly until 10 kHz where they start decreasing again.

Conclusion:

The common emitter amplifier has it's highest amplification and phase shift around 10 kHz. The amplification of R_{48} is higher than that of R_{51}.

2.3.2. Measurement

Introduction

In this section we measured the common emitter amplifier we simulated in 2.3.1. using the circuit shown in Figure 11.

Circuit Diagrams:

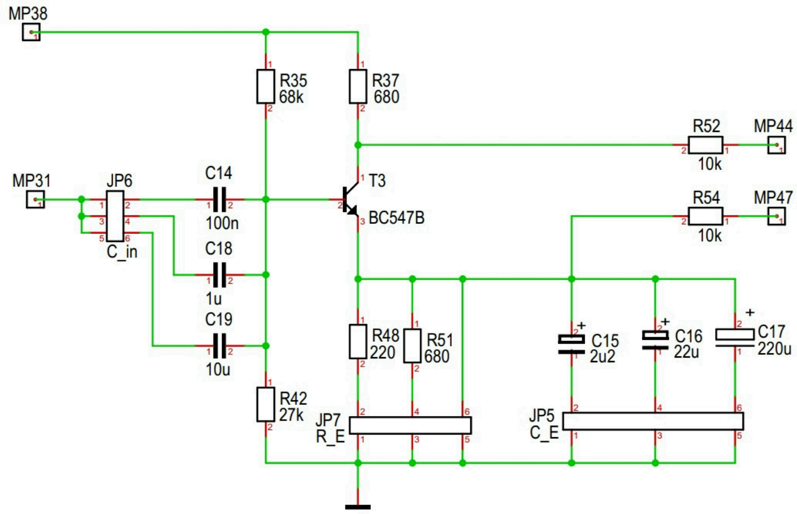

Figure 11: Schematic of the *BJT Amplifier* circuit

Plots:

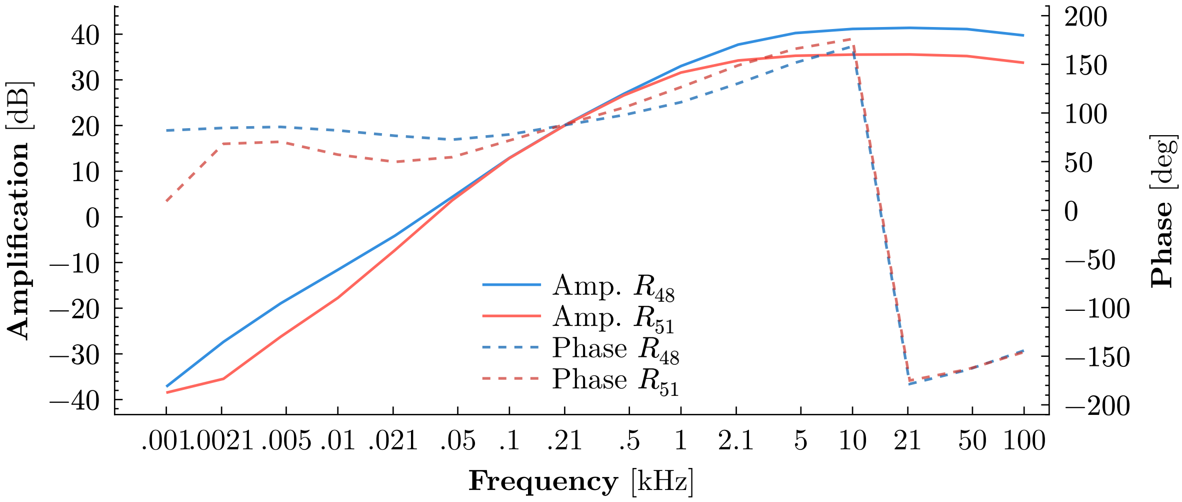

Figure 12: Phase and amplification of the common emitter amplifier for 1Hz-100kHz on a $\log_2$ scale. $R_{48} = 220\ \Omega$ and $R_{51} = 680\ \Omega$

Text Questions:

The phase shift of R_{48} is $\Phi(R_{48}) \approx 168.02°$ and phase shift of R_{51} is $\Phi(R_{51}) \approx 176.45°$.

To calculate the amplification gain for the given system, we calculated the gain between the maximum input and output voltage (so the difference in amplitudes):

$$\text{Amplification } R_{48} = 20 \cdot \log_{10}\left(\frac{\max(V_{\text{out}})}{\max(V_{\text{int}})}\right) \approx 20 \cdot \log_{10}\left(\frac{1.592\text{ V}}{0.015\text{ V}}\right) \approx 40.51\text{ dB}$$

$$\text{Amplification } R_{51} = 20 \cdot \log_{10}\left(\frac{\max(V_{\text{out}})}{\max(V_{\text{int}})}\right) \approx 20 \cdot \log_{10}\left(\frac{0.843\text{ V}}{0.015\text{ V}}\right) \approx 34.62\text{ dB}$$

With the spectrum analysis, we got amplification values of:

$$R_{48}: \ 41.69 \text{ dB}$$
$$R_{51}: \ 36.33 \text{ dB}$$

With the small signal analysis, we calculated the gain and phase shift at 10kHz to be:

$$R_{48}: \ 41.15 \text{ dB and } 168.48°$$
$$R_{51}: \ 35.53 \text{ dB and } 176.11°$$

All calculated values are very similar, also to the graph.

Conclusion

We calculated the amplification of the common emitter amplifier with $R_{48} \approx 41$ dB and with $R_{51} \approx 35$ dB. This experiment also showed the difference of amplification and phase shift in regards to the frequency used.

2.4. Current source

2.4.1 Simulation

Introduction

The goal was to simulate and characterize the bipolar-based current source shown in Figure 13. In the simulation, the Resistance of the load resistor R_L was varied from 1 $\mu\Omega$ to 10 kΩ with 10 sample points per decade.

Circuit Diagrams:

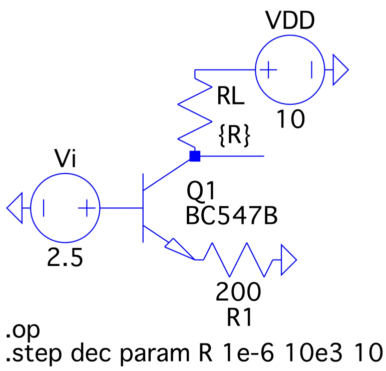

Figure 13: LTSpice circuit diagram with $R_E = 200\Omega$ and $V_i = 2.5$V

Plots:

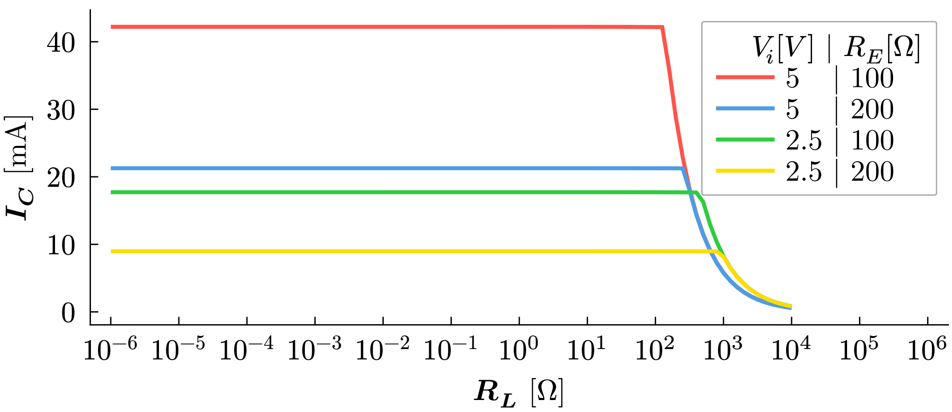

Figure 14: Current through R_L with different values for R_L

Text Questions:

V_i [V]	R_E [Ω]	$I_{C(\max)}$ [mA]
2.5	200	09.98
2.5	100	17.72
5	200	21.27
5	100	42.21

Table 3: Maximum current

V_i [V]	R_E [Ω]	$R_{L(\max)}$ [mA]
2.5	200	794.33
2.5	100	398.11
5	200	251.19
5	100	125.89

Table 4: Maximum load with 5% for deviation from I_C max

Conclusion:

We simulated the maximum current and resistor load for all different cases.

2.4.2. Measurement

Introduction

Section 2.4.2. is about a bipolar based current source, which we used to power light-emitting diodes.

Circuit Diagrams:

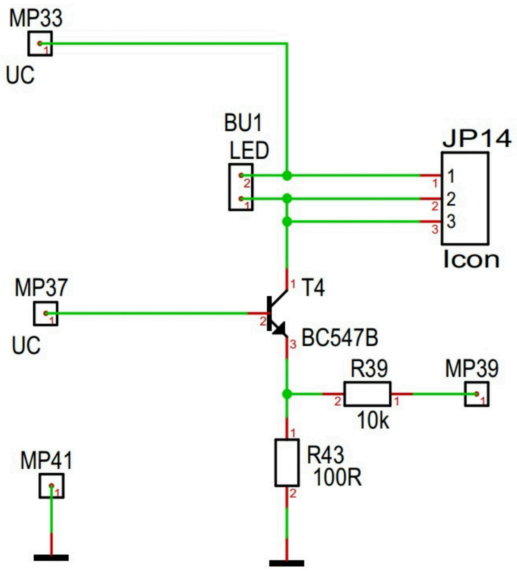

Figure 15: Schematic of the *BJT current source* circuit

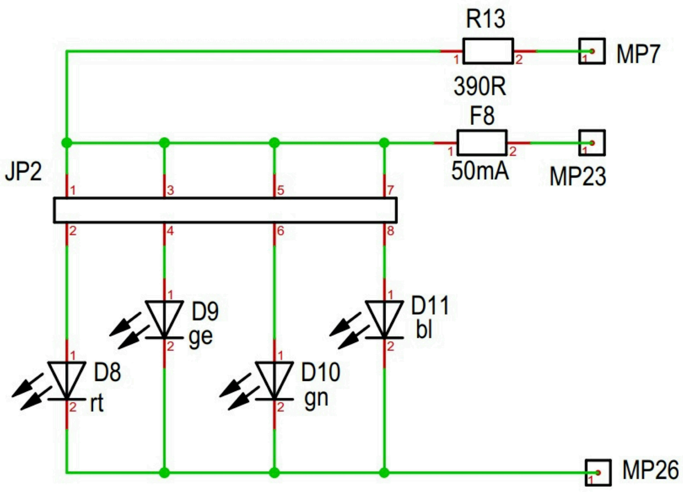

Figure 16: Schematic of the *diode charactieristics* circuit

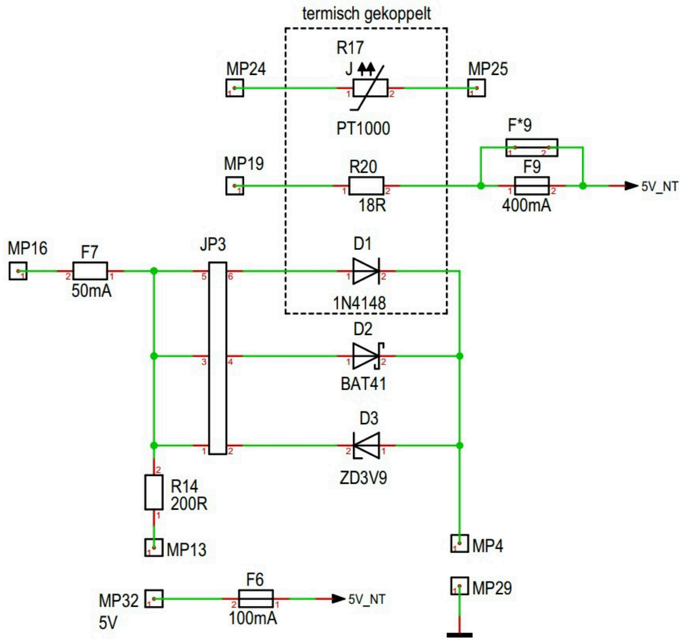

Figure 17: Schematic of the *LED characteristics* circuit

Text Questions:

The collector current is $I_C = 16.29$ mA for $V_i = 2.5$ V and $I_C = 39.19$ mA for $V_i = 5$V

When connected one at a time, the red LED shines brightly with current $I_C = 32.16$ mA. The yellow LED is also bright with $I_C = 32.26$ mA.

The green LED is a little less bright with $I_C = 32.27$ mA and blue LED is unpleasently bright, but not enough to cause permanent eye-damage, with $I_C = 32.17$ mA.

—

With the Zener diode, the red LED is, again, shining bright with $I_C = 36.75$ mA, just like the yellow LED, which is also bright and has a current of $I_C = 36.77$ mA.

The green LED is quite dim with $I_C = 36.69$ mA and the blue LED is again unpleasently bright with $I_C = 36.67$ mA.

Conclusion

We sucessfully measured the characteristics of the current source circuit.

Using the bipolar as a current source caused the blue LED to be very bright, the green LED being the most dim and the red and yellow LEDs to shine bright. Adding the Zener diode led to the collector current to be slightly higher, from around 32 mA to 36 mA.