Electronics Laboratory

Winter semester 2025

Lab 2 – Bipolars

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

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

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Electronics Laboratory
WS 25/26
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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:

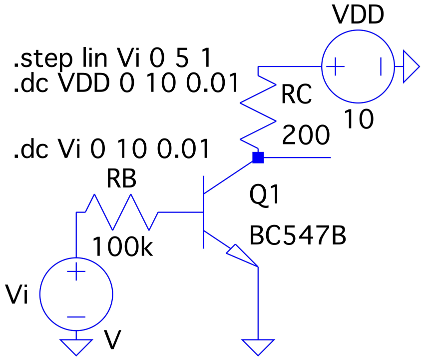

Figure 1: LTSpice circuit diagram with instructions for both the first (bottom) and second (top) task

Plots:

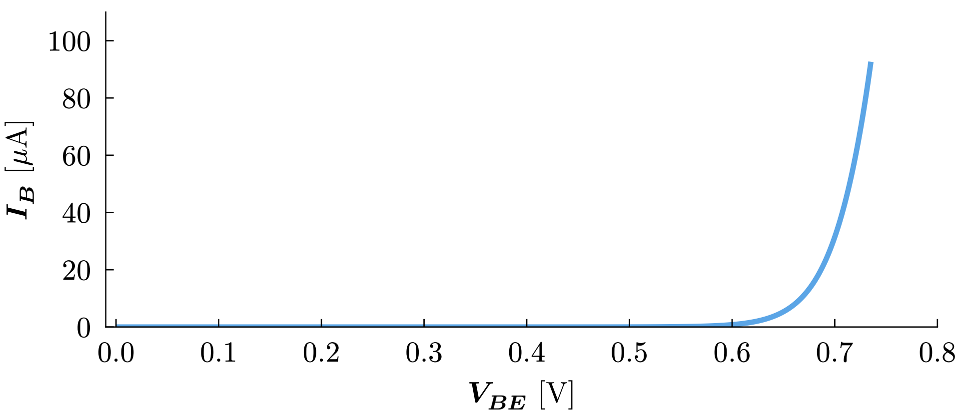

Figure 2: Simulated base current over base-emitter voltage

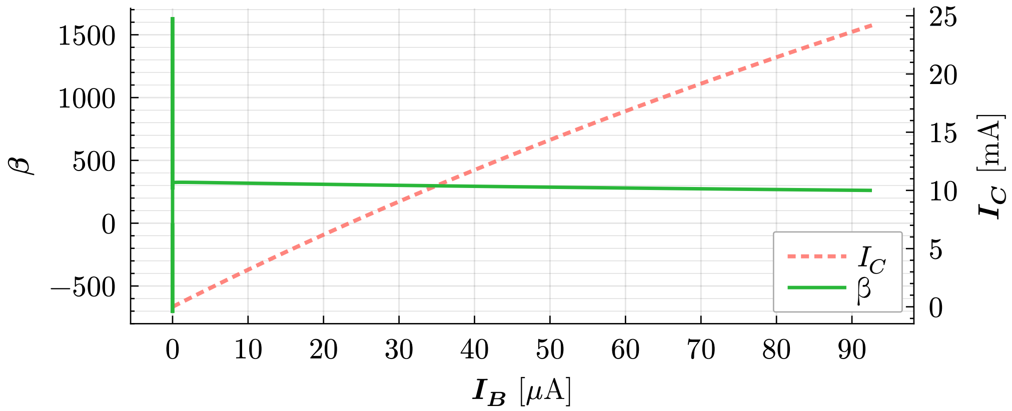

Figure 3: Simulated β and I_C over I_B

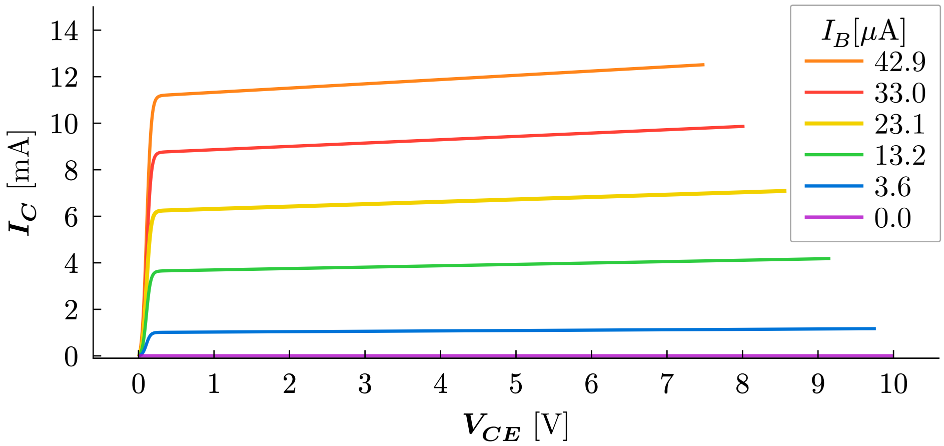

Figure 4: Simulated current through R_C plotted over collector-emitter voltage

Text Questions:

At currents $I_B \lessapprox 0.15\ \mu$A, 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 $I_B > 0.15\ \mu$A, 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:

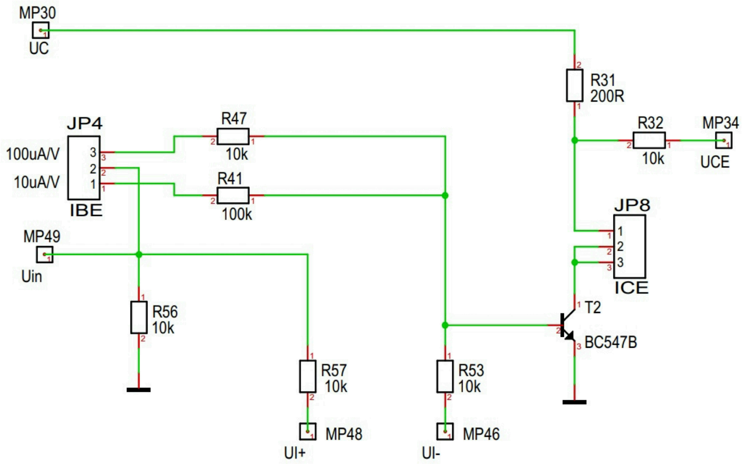

Figure 5: Schematic of the *BJT characteristics* circuit

Plots:

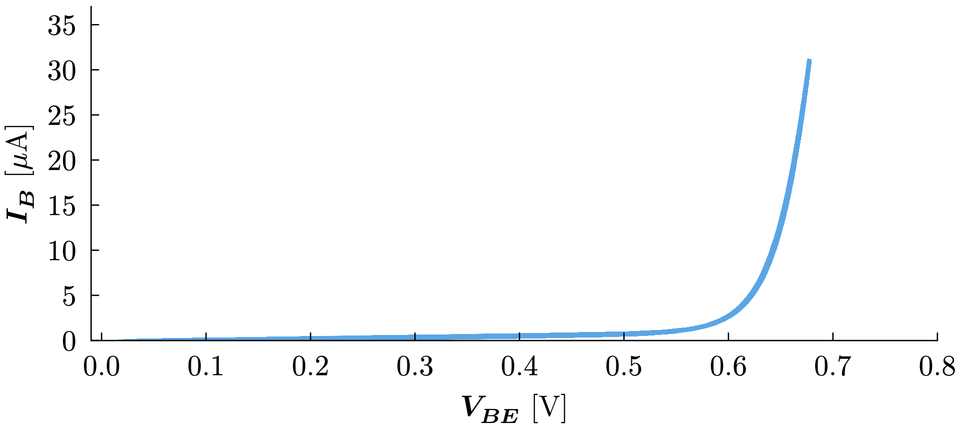

Figure 6: Measured base current over base-emitter voltage

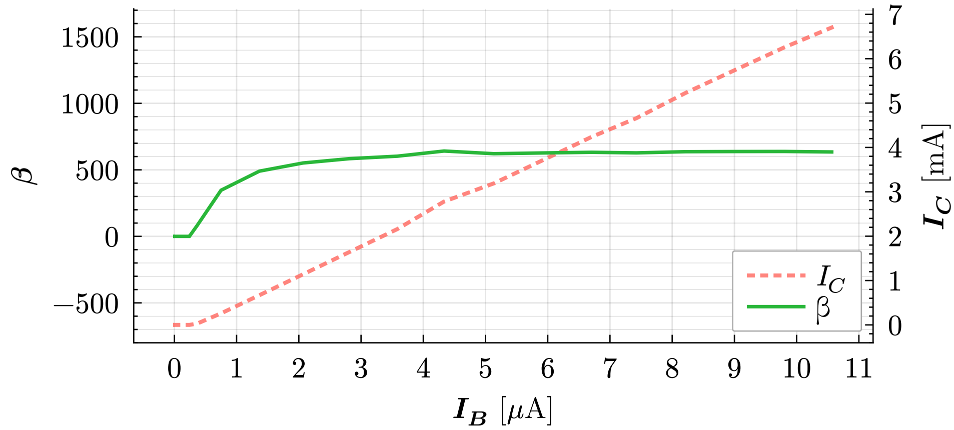

Figure 7: Measured β and I_C over I_B

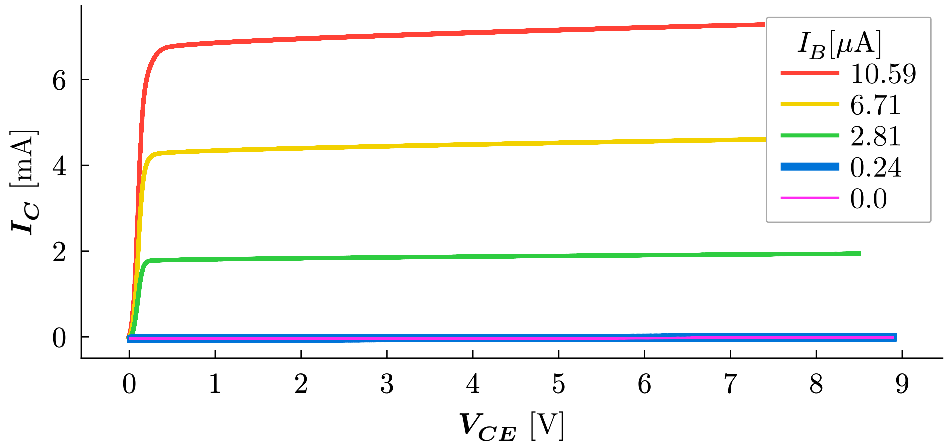

Figure 8: Measured current through R_C plotted over collector-emitter voltage

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 $I_B \approx 0.0\ \mu$A and $I_B \approx 0.24\ \mu$A 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 Figure 9 using two different resistors R_E.

Circuit Diagrams:

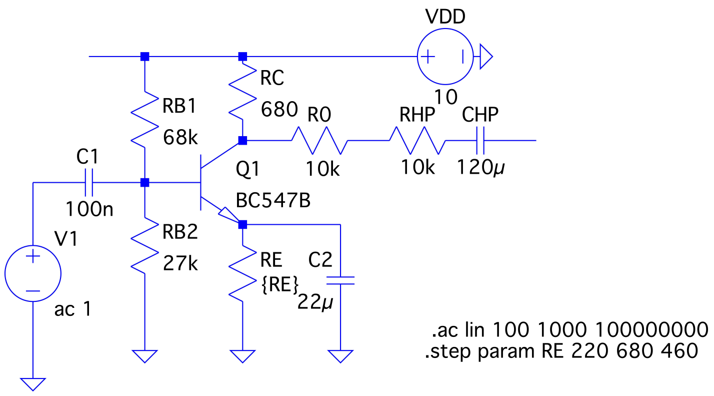

Figure 9: LTSpice circuit diagram for the common emitter amplifier

Plots:

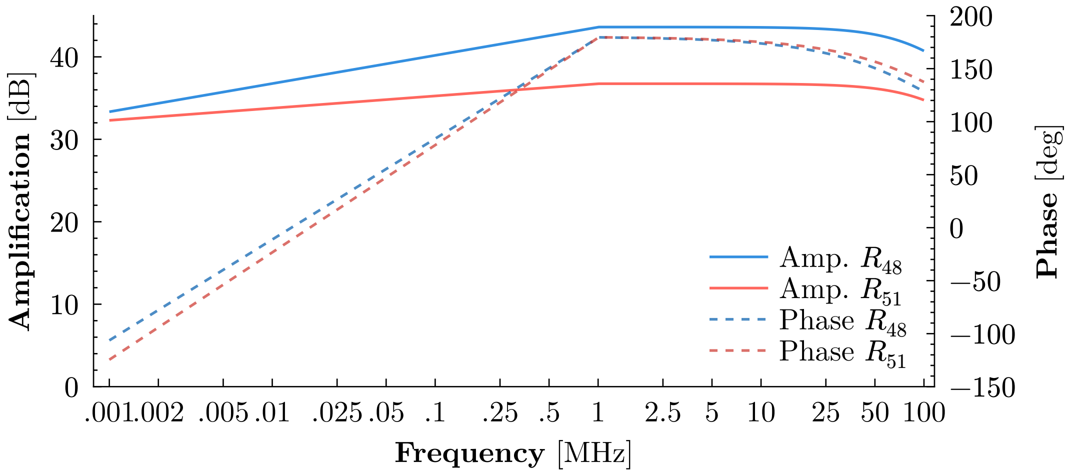

Figure 10: Simulated phase and amplification of the common emitter amplifier for a frequency of 1kHz-100MHz on a $\log_2$ scale. $R_{48} = 220\ \Omega$ and $R_{51} = 680\ \Omega$

Text Questions:

The

Conclusion:

2.3.2. Measurement

Introduction

Circuit Diagrams:

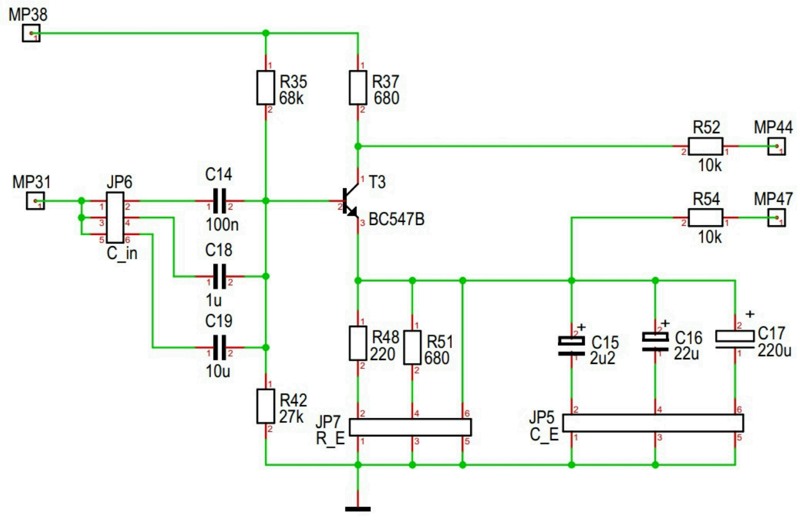

Figure 11: Schematic of the *BJT Amplifier* circuit

Plots:

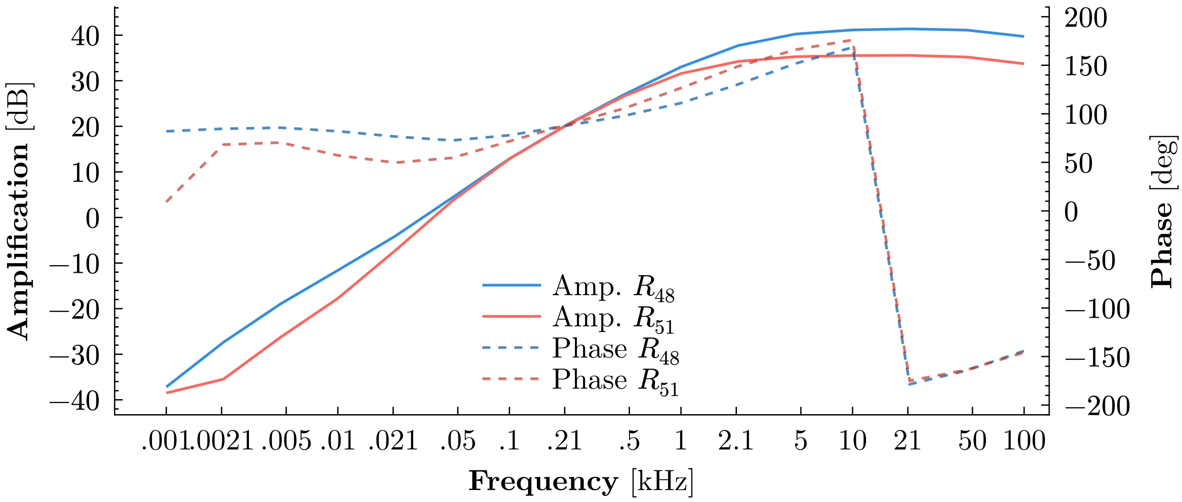

Figure 12: Phase and amplification of the common emitter amplifier for 1Hz-100kHz on a $\log_2$ scale. $R_{48} = 220\ \Omega$ and $R_{51} = 680\ \Omega$

Text Questions:

We calculated phase shift of R_{48} to be $\Phi(R_{48}) \approx 168.02°$
and phase shift of R_{51} to be $\Phi(R_{51}) \approx 176.45°$.

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 in the graph.

Conclusion

The amplification of the common emitter amplifier with $R_{48} \approx 41$ dB and with $R_{51} \approx 35$ dB.

2.4. Current source

2.4.1 Simulation

Introduction

The goal was to simulate and characterize a bipolar-based current source.

Circuit Diagrams:

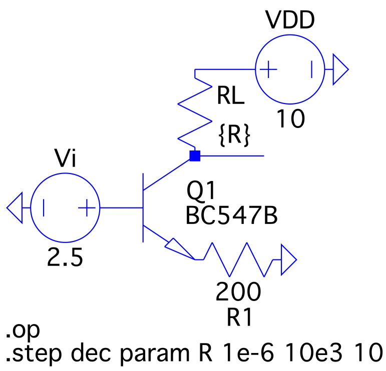

Figure 13: LTSpice circuit diagram with $R_E = 200\Omega$ and $V_i = 2.5$V

Plots:

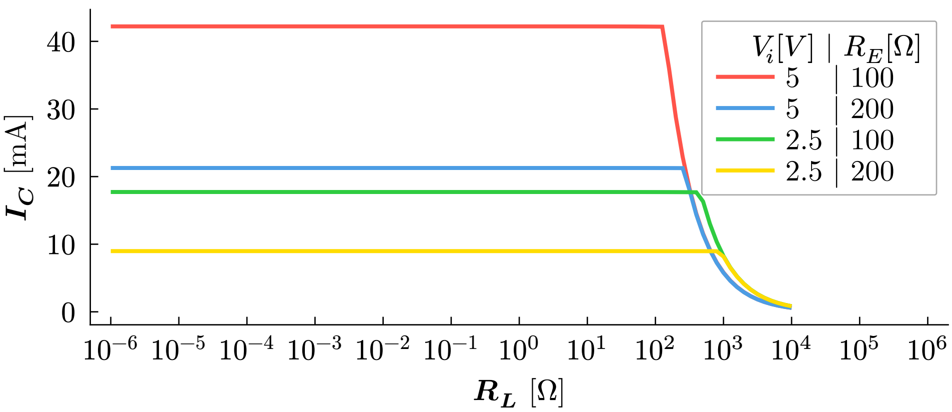

Figure 14: Current through R_L with different values for R_L

Text Questions:

(g)

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

(h)

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

Conclusion:

2.4.2. Measurement

Introduction

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

Circuit Diagrams:

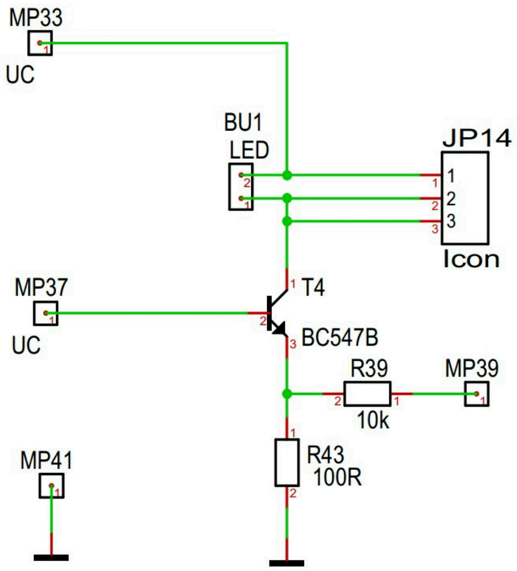

Figure 15: Schematic of the *BJT current source* circuit

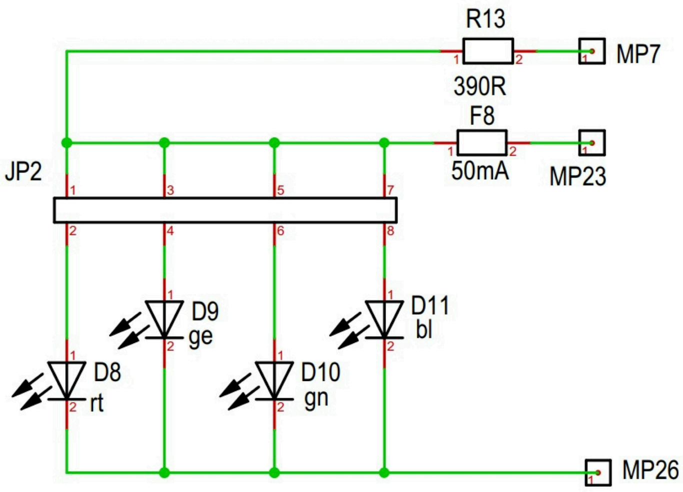

Figure 16: Schematic of the *diode charactieristics* circuit

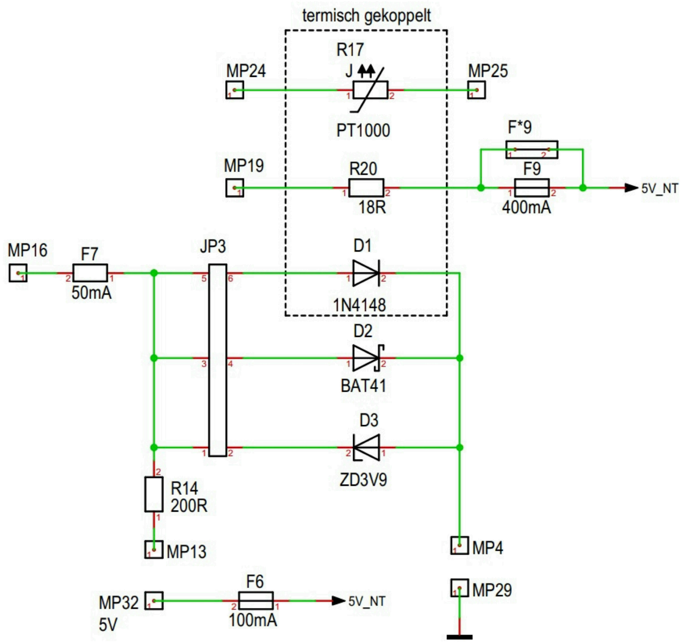

Figure 17: Schematic of the *LED characteristics* circuit

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.

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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