

# 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.*

## 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  $\beta$  (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:

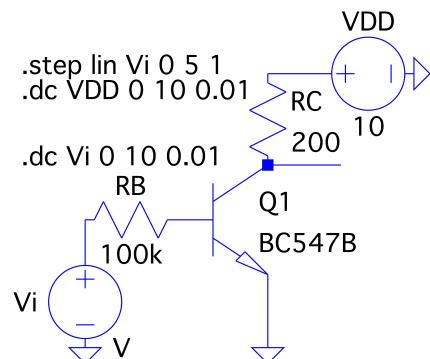


Figure 1: LTSpice circuit diagram with instructions for both the first (bottom) and second (top) task

##### Plots:

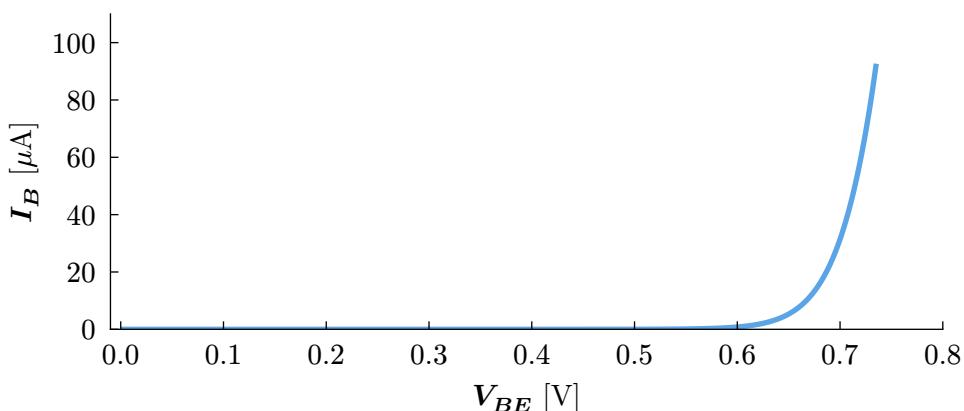


Figure 2: Simulated base current over base-emitter voltage

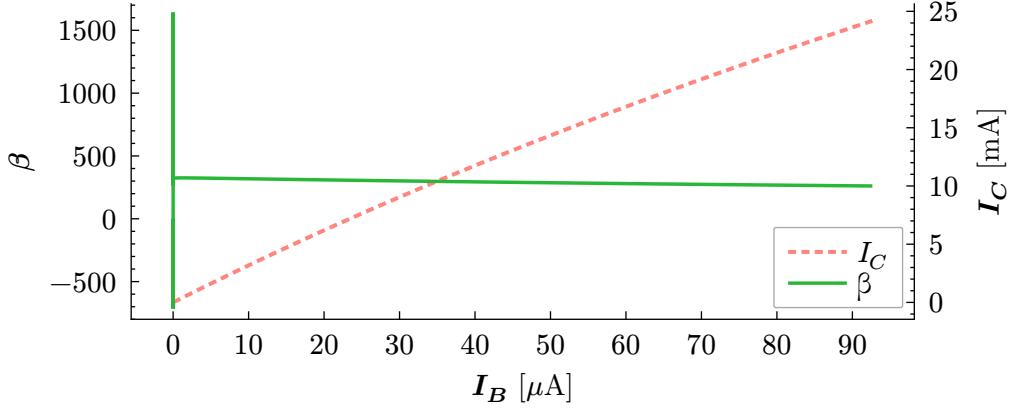


Figure 3: Simulated  $\beta$  and  $I_C$  over  $I_B$

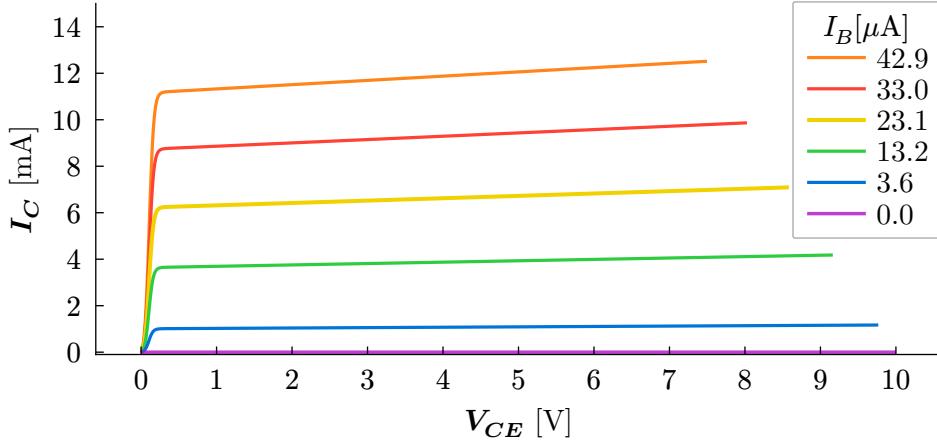


Figure 4: Simulated current through  $R_C$  plotted over collector-emitter voltage

### Text Questions:

At currents  $I_B \lesssim 0.15 \mu\text{A}$ ,  $\beta$  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  $I_B > 0.15 \mu\text{A}$ , the value for  $\beta \approx 325$ .

As seen in Figure 3,  $\beta$  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.

$I_B[\mu\text{A}]$	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

### Conclusion:

Table 1: Early Voltages

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  $\beta$  as well as the early voltages at different base currents.

## Circuit Diagrams:

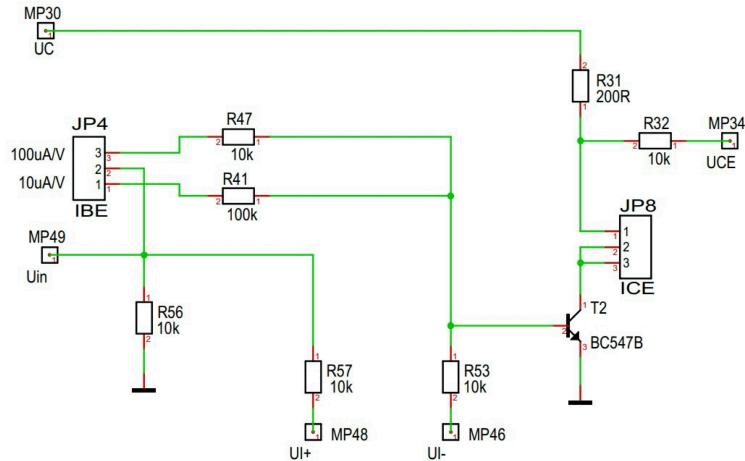


Figure 5: Schematic of the *BJT characteristics* circuit

## Plots:

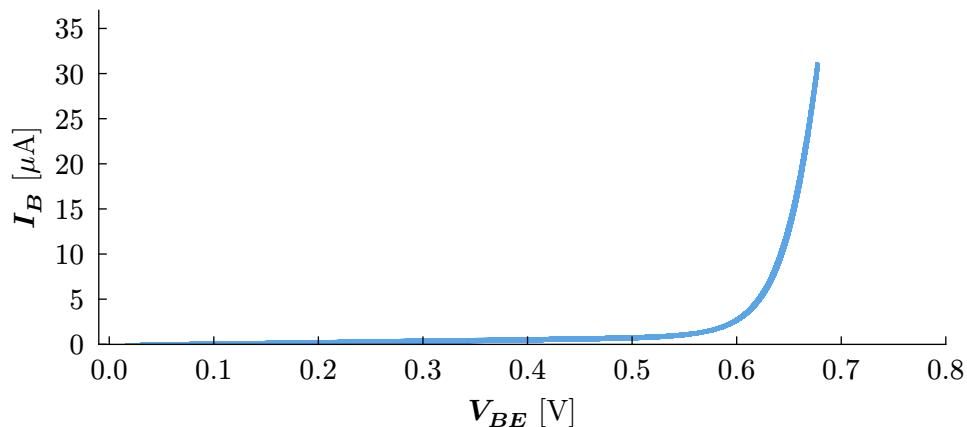
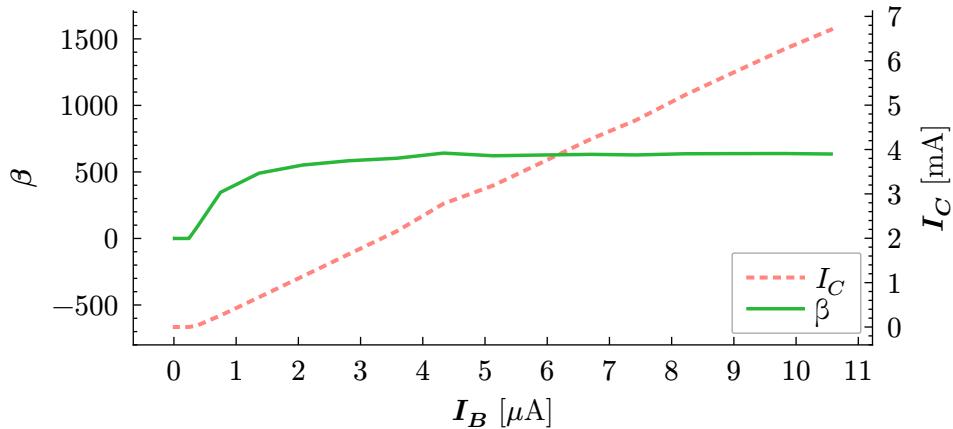
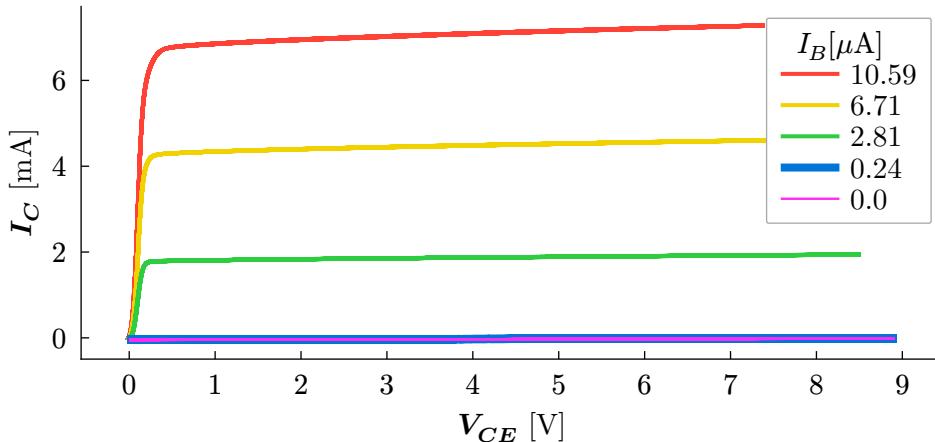


Figure 6: Measured base current over base-emitter voltage

Figure 7: Measured  $\beta$  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.

$\beta$  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  $I_B \approx 0.0 \mu\text{A}$  and  $I_B \approx 0.24 \mu\text{A}$  are not realistic, because  $I_C$  is close to 0 A.

$I_B[\mu\text{A}]$	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:

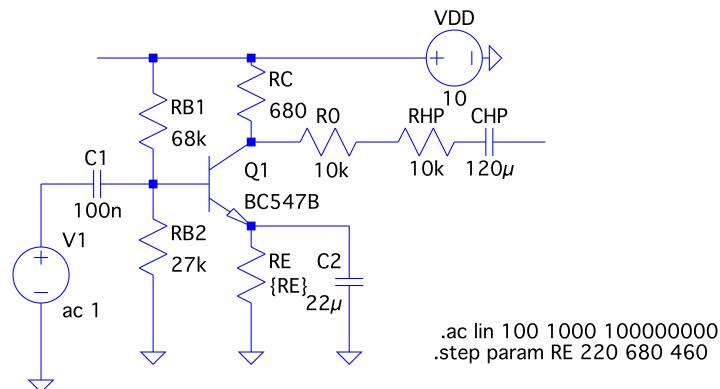


Figure 9: LTSpice circuit diagram for the common emitter amplifier

#### Plots:

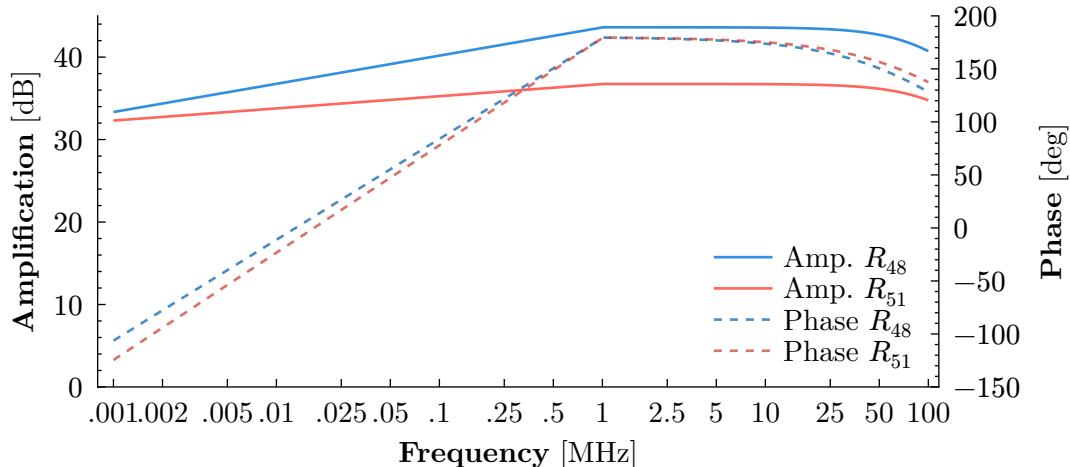


Figure 10: Simulated phase and amplification of the common emitter amplifier for a frequency of 1kHz-100MHz on a  $\log_2$  scale.  $R_{48} = 220 \Omega$  and  $R_{51} = 680 \Omega$

#### 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:

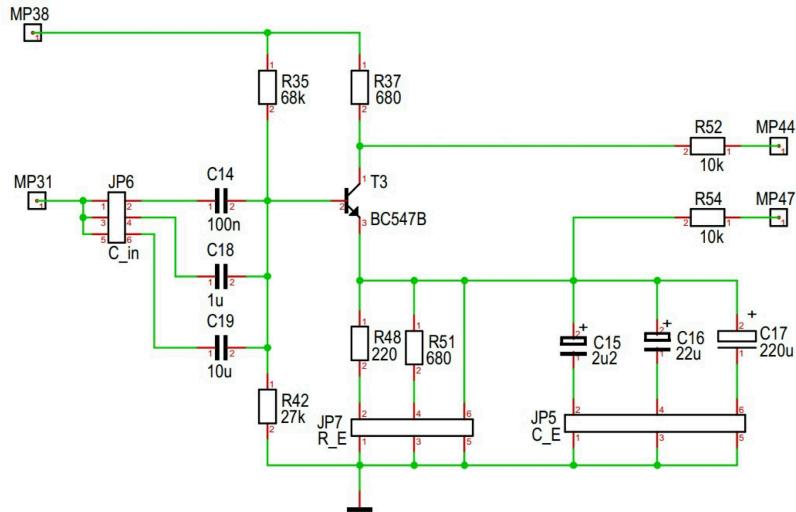


Figure 11: Schematic of the *BJT Amplifier* circuit

#### Plots:

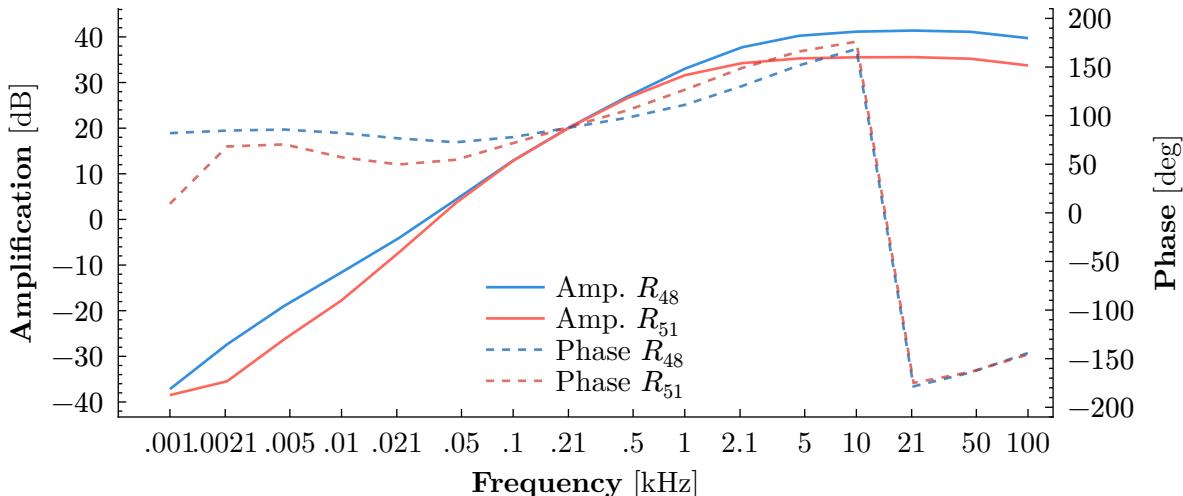


Figure 12: Phase and amplification of the common emitter amplifier for 1Hz-100kHz on a  $\log_2$  scale.  $R_{48} = 220 \Omega$  and  $R_{51} = 680 \Omega$

#### Text Questions:

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

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:

$$R_{48}: 41.15 \text{ dB and } 168.48^\circ$$

$$R_{51}: 35.53 \text{ dB and } 176.11^\circ$$

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

### Conclusion

We calculated the amplification of the common emitter amplifier with  $R_{48} \approx 41 \text{ dB}$  and with  $R_{51} \approx 35 \text{ dB}$ . 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 a bipolar-based current source.

#### Circuit Diagrams:

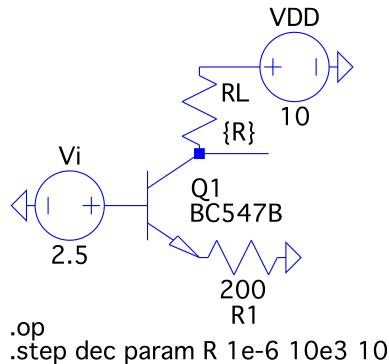


Figure 13: LTSpice circuit diagram with  $R_E = 200\Omega$  and  $V_i = 2.5V$

#### Plots:

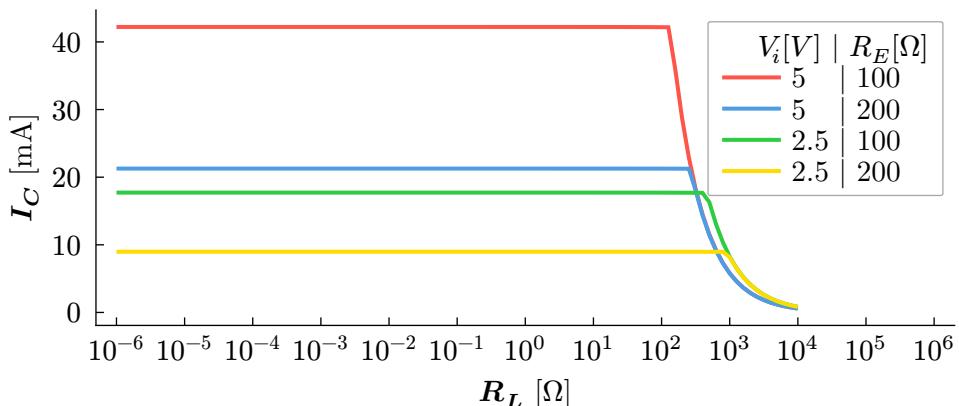


Figure 14: Current through  $R_L$  with different values for  $R_L$

**Text Questions:**

(g)

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

(h)

$V_i$ [V]	$R_E$ [ $\Omega$ ]	$I_{C(\max)}$ [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 based current source, which we used to power light-emitting diodes.

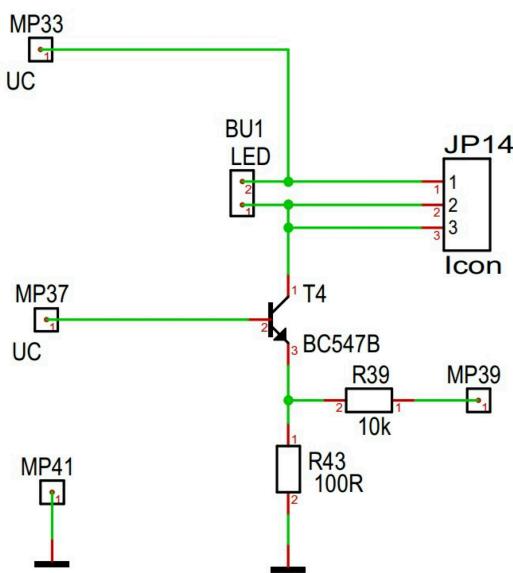
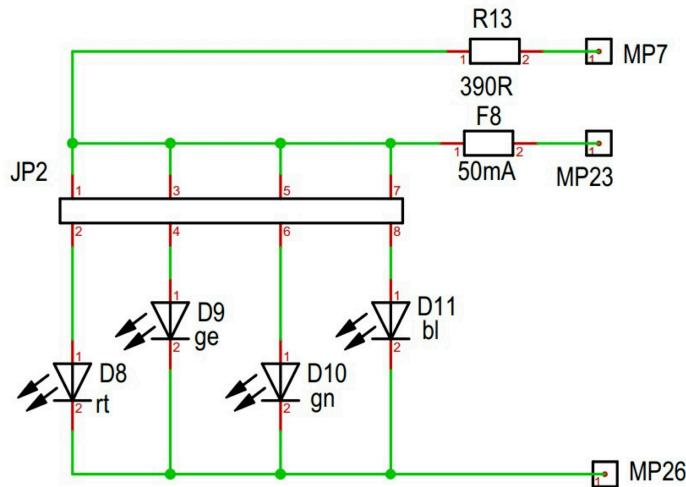
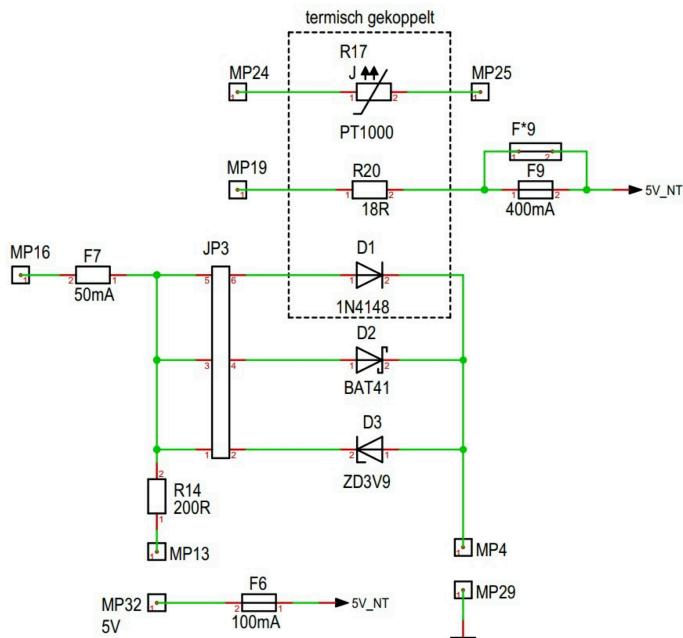
**Circuit Diagrams:**

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

Figure 16: Schematic of the *diode charactieristics* circuitFigure 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 unpleasantly 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 unpleasantly 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.