

# Electronics Laboratory

Winter semester 2025

## Lab 4 – Op Amps

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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 4 - MOSFETs

11. Januar 2025

### 4.2 Non-inverting amplifier

#### 4.2.1 Simulation

##### Introduction

In this section, we simulated a non-inverting amplifier circuit shown in [Figure 5](#). We ran two simulations, one with  $R_1 = 2 \text{ k}\Omega$  connected to the feedback loop and the other with it disconnected, effectively setting its value to infinity. For both setups we ran an ac frequency sweep from 5 kHz to 5 MHz with 500 points per decade and plotted both results in [Figure 2](#).

##### Circuit Diagrams:

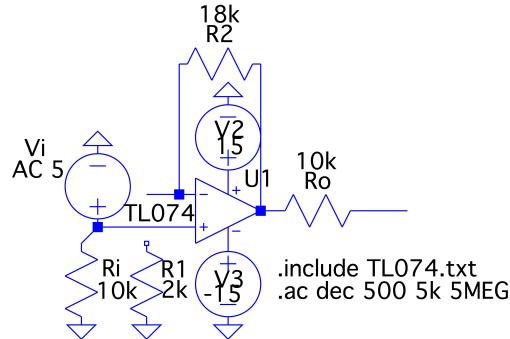


Figure 1: LTSpice *non-inverting amplifier* circuit diagram<sup>1</sup>

##### Plots:

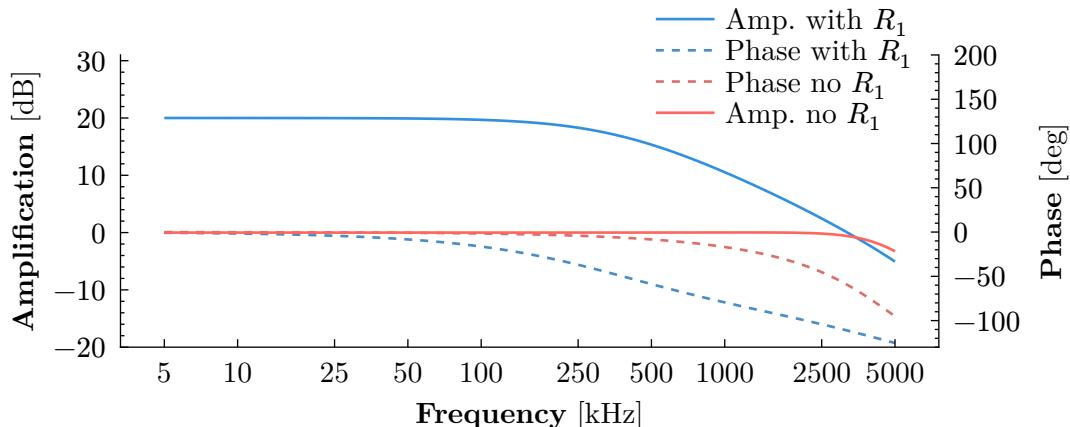


Figure 2: Simulated phase and amplification of the non-inverting amplifier for a frequency of 5kHz-5MHz on a logarithmic scale.  $R_1 = 2 \text{ k}\Omega$

<sup>1</sup>We changed AC 5 to AC 1 (we originally tried to do 15 mV as in the real measurement, but with 1 V we got very similar values to 15 mV so we decided on that.)

### Text Questions:

With  $R_1$  in the circuit, it reaches 0 dB amplification at  $f \approx 3184$  kHz, so the gain-bandwidth is  $3184$  kHz  $\cdot \left(1 + \frac{R_f}{R_1}\right) = 3184$  kHz  $\cdot \left(1 + \frac{18\text{ k}\Omega}{2\text{ k}\Omega}\right) = 31840$  kHz.

Without  $R_1$  it crosses 0 dB at 103.03 kHz, so it has a gain-bandwidth of  $1 \cdot 103.03$  kHz = 103.03 kHz

### Conclusion:

We successfully simulated the non-inverting amplifier. With  $R_1$  connected, we got amplification values of approx 20 dB for frequencies under 150 kHz. We got a gain-bandwidth of 31840 kHz. The phase shift is  $0^\circ$  at the beginning but linearly decreases to  $\approx -120^\circ$  at the end.

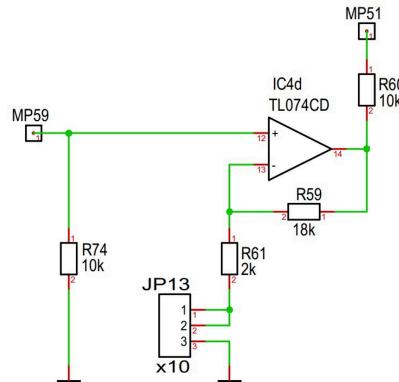
Without  $R_1$ , the amplification was  $\approx 0$  dB under 3 MHz with a peak going over 0 dB at 100 kHz and little phase shift of  $\varphi < 25^\circ$  for frequencies under 1 MHz.

### 4.2.2. Measurement

#### Introduction

In this section, we measured the *non-inverting amplifier* shown in [Figure 3](#). As in the simulation, we measured twice, first with the Resistor  $R_{61} = 2\text{ k}\Omega$  connected through the Jumper JP13, the other with it not connected. For both, we measured an AC input from 5 kHz to 5 MHz with 500 points per decade. The feedback resistor  $R_f = 18\text{ k}\Omega$

#### Circuit Diagrams:



[Figure 3](#): Schematic of the *non-inverting amplifier* circuit

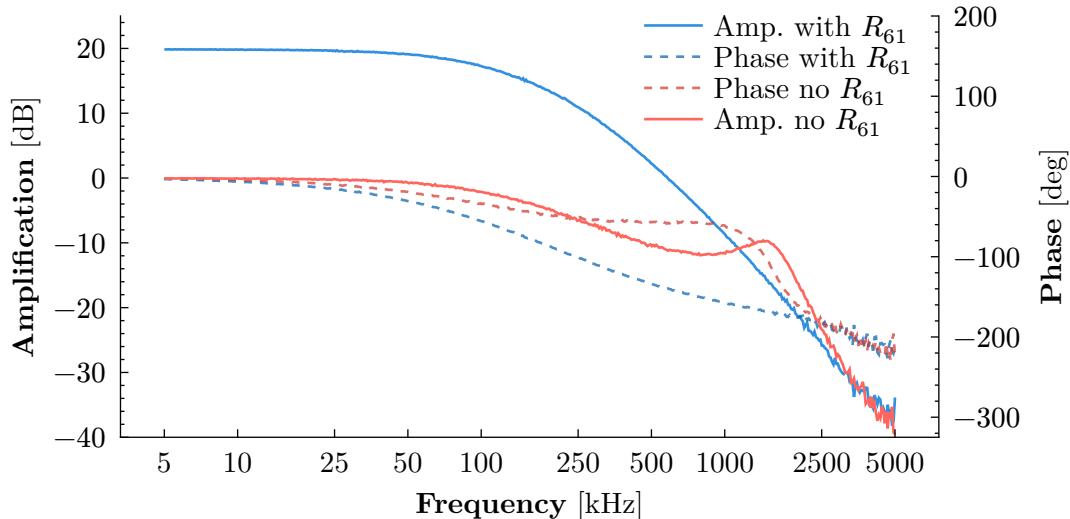
**Plots:**

Figure 4: Simulated phase and amplification of the non-inverting amplifier for a frequency of 5 kHz - 5 MHz on a logarithmic scale.  $R_1 = 2 \text{ k}\Omega$

**Text Questions:**

With  $R_{61} : 584.93 \text{ kHz}$  which corresponds to a gain-bandwidth of  $584.93 \text{ kHz} \cdot \left(1 + \frac{R_f}{R_1}\right) = 584.93 \text{ kHz} \cdot \left(1 + \frac{18 \text{ k}\Omega}{2 \text{ k}\Omega}\right) = 5849.3 \text{ kHz}$ .

Without  $R_{61}$ , the gain crosses 0dB at 7.78 kHz, so it has a gain-bandwidth of 7.78 kHz.

**Conclusion**

We successfully measured the *non-inverting amplifier* and saw really similar measurements to what we simulated earlier, when we used  $V_i = 1 \text{ V}$  in the simulation and  $V_i = 15 \text{ mV}$  in the measurement. In the measurement the phase shift is higher than in the simulation and reaches  $\varphi \approx -200^\circ$ . The amplification falls to  $\approx -35 \text{ dB}$  for high frequencies in both cases, which is significantly lower than in the simulation, where it drops to  $\approx -5 \text{ dB}$ .

**4.3 Voltage-to-current converter****4.3.1 Simulation****Introduction**

In this section we took a look at the voltage to current converter with an integrated LED.

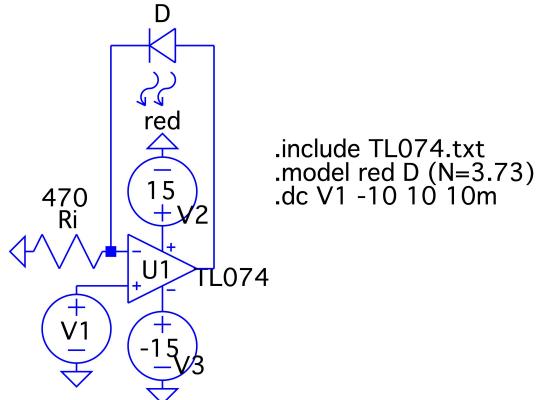
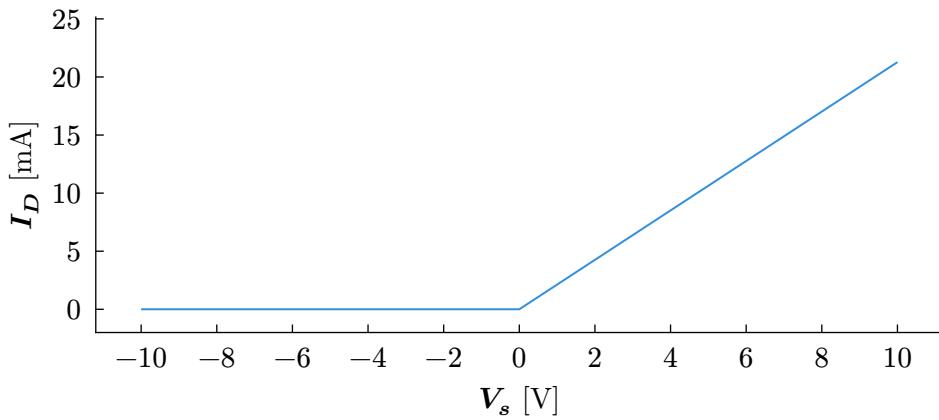
**Circuit Diagrams:**Figure 5: LTSpice *voltage-to-current converter* circuit diagram**Plots:**

Figure 6: Simulated LED current

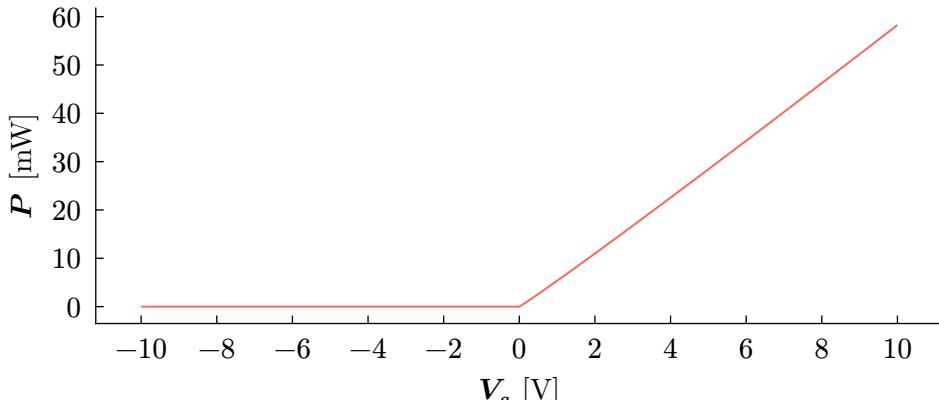


Figure 7: Simulated LED power

**Text Questions:**

As the power dissipated by the LED is  $P = V * I$  the graph of the LED power (Figure 7) is very similar to the graph of the current (Figure 6), just multiplied with the voltage. The characteristics show the typical curve of a LED with no current flowing through whilst  $V_s$  is below the forward voltage of the LED. The current rises in relation to the Voltage. All power dissipated by the LED is in the form of either light or heat. LED do not emit much heat, instead dissipating the power mainly by emitting light. Because the power rises with rising voltage, the LED emits more light with increasing voltage  $V_s$ .

**Conclusion:**

The voltage to current converter takes a known voltage and has a calculable current as output.

**4.3.2. Measurement****Introduction**

In this section the goal was to measure the voltage to current converter and compare with the simulation.

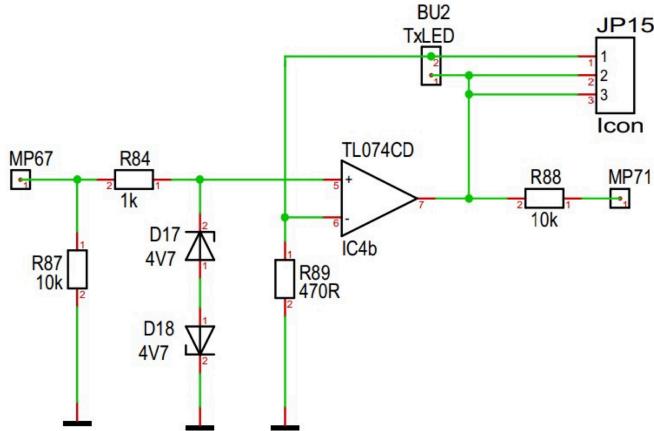
**Circuit Diagrams:**

Figure 8: Schematic of the *voltage-to-current converter* circuit

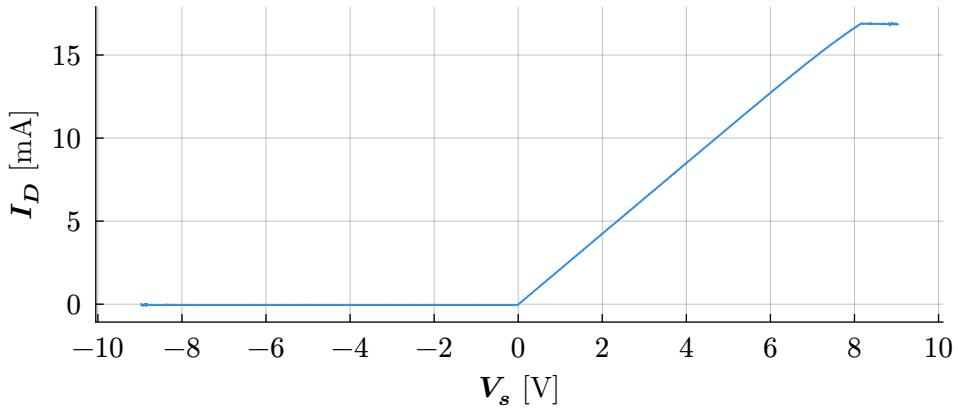
**Plots:**

Figure 9: Measured LED current

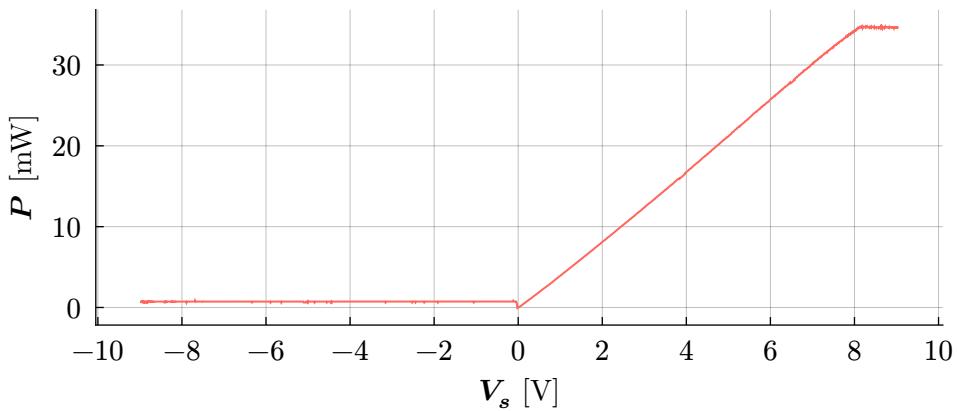


Figure 10: Measured LED power

**Text Questions:**

The current through the LED was measured as the voltage drop over  $R_{89} = 470\Omega$  at Pin1 of JP15 and calculated by  $I_D = \frac{V_{Pin1}}{R_{89}}$ .

The voltage drop of the LED was calculated by taking the difference of the voltage between Pin1 and Pin2

The measured curves show a stop of the linear relation between the current  $I_D$  and the voltage  $V_S$  (Figure 9). At the point  $V_{s(max)}$  the curve becomes flat instead of continuing linearly. This is because the operational Amplifier reaches saturation and stops increasing the output voltage.

$$V_{s(max)} \approx 8.1 \text{ V}$$

**Conclusion**

The measured data shows some difference to the simulated one, the Op Amp behaves differently and real world physics have to be taken into account when calculating the data.

**4.4 Transimpedance Amplifier****4.4.1 Simulation****Introduction**

In this section the goal is to simulate a transimpedance amplifier, but used a current source in place of a photodiode.

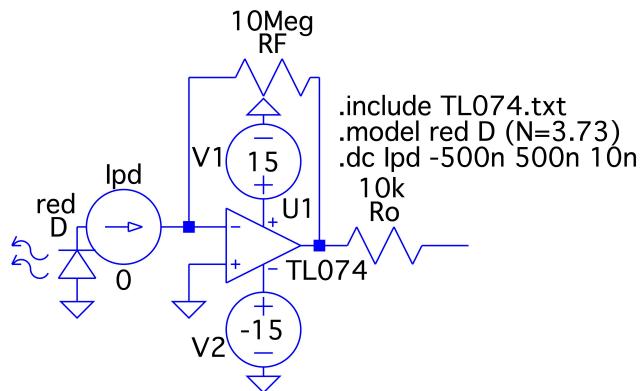
**Circuit Diagrams:**

Figure 11: LTSpice *transimpedance amplifier* circuit diagram

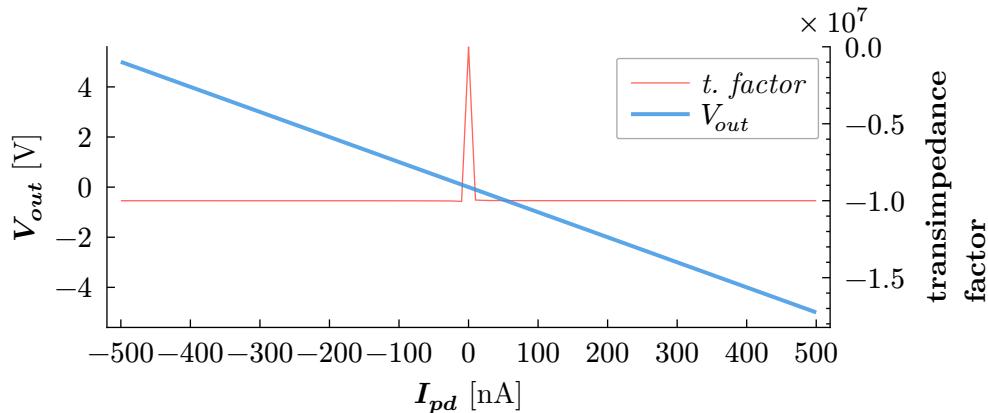
**Plots:**

Figure 12: Simulated transimpedance amplifier

**Text Questions:**

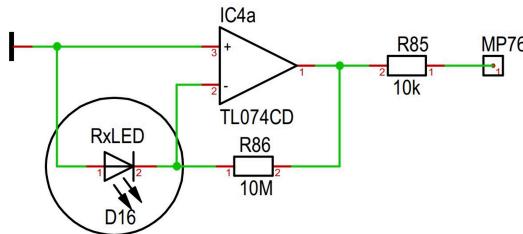
Figure 12 shows the relation of  $V_{out}$  and  $I_{pd}$ . They are linearly dependant. As the transimpedance factor is  $\frac{V_{out}}{I_{pd}}$  the transimpedance factor is roughly  $-1 * 10^7$ . The factor is mainly determined by the resist  $R_f$ .

**Conclusion:**

The transimpedance amplifier can be used to transform a current into a voltage source with a factor determined by the resist in the feedback loop.

**4.4.2. Measurement****Introduction**

In this section we use a transimpedance amplifier to calculate the current generated by a photodiode by means of output voltage.

**Circuit Diagrams:**Figure 13: Schematic of the *transimpedance amplifier* circuit

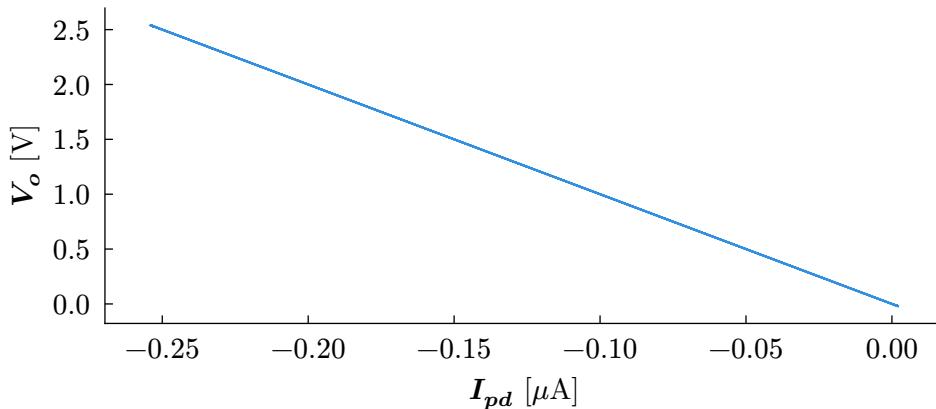
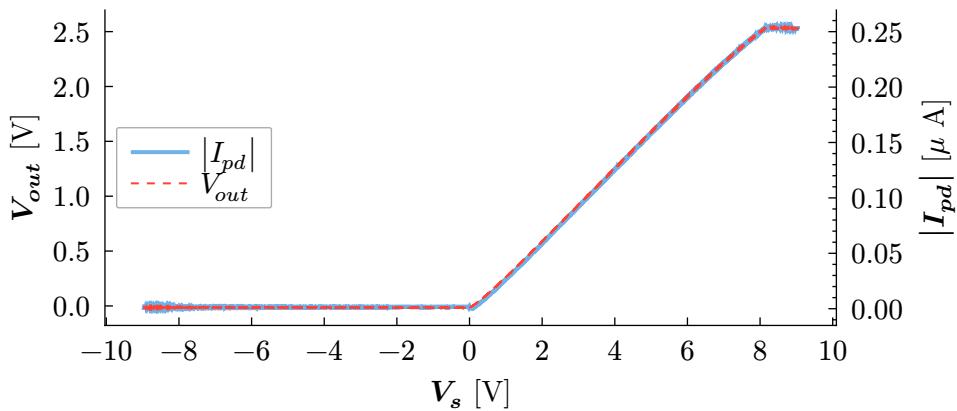
**Plots:**

Figure 14: Measured transimpedance amplifier

Figure 15: Measured transimpedance amplifier over  $V_s$ **Text Questions:**

- (c) to estimate the current over D16, we use the relation  $U = -R * I$  where R is R88 as it is inside the feedback loop of the amplifier circuit. This leads to  $I = -\frac{U}{R}$
- (d) The current flows in the opposite direction of the input current, because the photodiode is in the same direction as the red LED but used to generate the current.
- (f) The output voltage of the transimpedance amplifier is the input voltage  $\frac{V_s}{1} * 10^6$  because the resist R88 is  $1\text{M}\Omega$ . this is shown in the data, as  $V_o$  is the same as  $I_{pd}$  just different by a factor of 1M. The data for  $V_s > 0$  is explained by the means of current generation. As the current is generated via a photodiode, which in turn is powered by a LED. The LED only turns on for currents greater than the forward voltage of the diode. This leads to the circuit of the transimpedance amplifier only being powered while the LED is on making measurement below  $V_{fwd}$  pointless.

**Conclusion**

The measurement data showed the characteristics of the transimpedance amplifier to transform current into voltage. It also showcased the direct relation of the two, as well as the ability of a LED to function as a photodiode.