UM-SJTU Joint Institute

VE311

Laboratory Report

Excercise 5

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[rev4.1]

1 Objective

1. Get familiar with the Differential Amplifier
2. Understand Current Mirror

2 Differential Amplifier

2.1

In Proteus, we build the circuit and plot $V_{out1}, V_{out2}, V_{out1} - V_{out2}$, vs t.

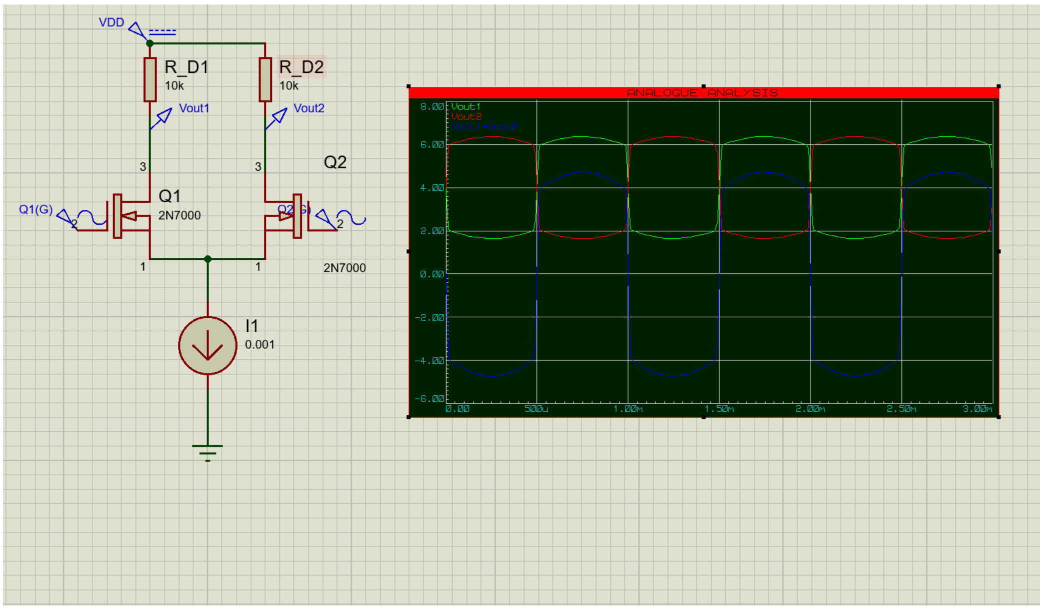

Figure 1: Simulation Result

2.2

In Proteus, we build the circuit and plot V_{out1}vsV_{in}, Here, V_{out} always equals $4V$

2.3

In the lab, we get the following result.

$$A_{dm} = \frac{1070}{20} = 53.5$$

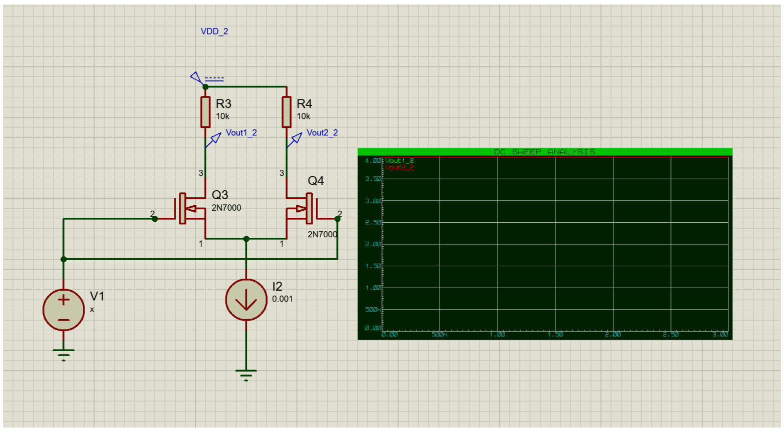

Figure 2: Simulation Result

2.4

In the lab, we get the following result.

$$A_{cm} = \frac{25}{10} = 2.5$$

which is in align with the result we have got in b.

3 Current Mirror

3.1

In this figure, we calculate the corresponding A_v

3.2

In this part, we built the following circuit. However, we cannot measure the resuly due to the proteus problem.

3.3

In the lab, we get the following result, and plot the corresponding figure

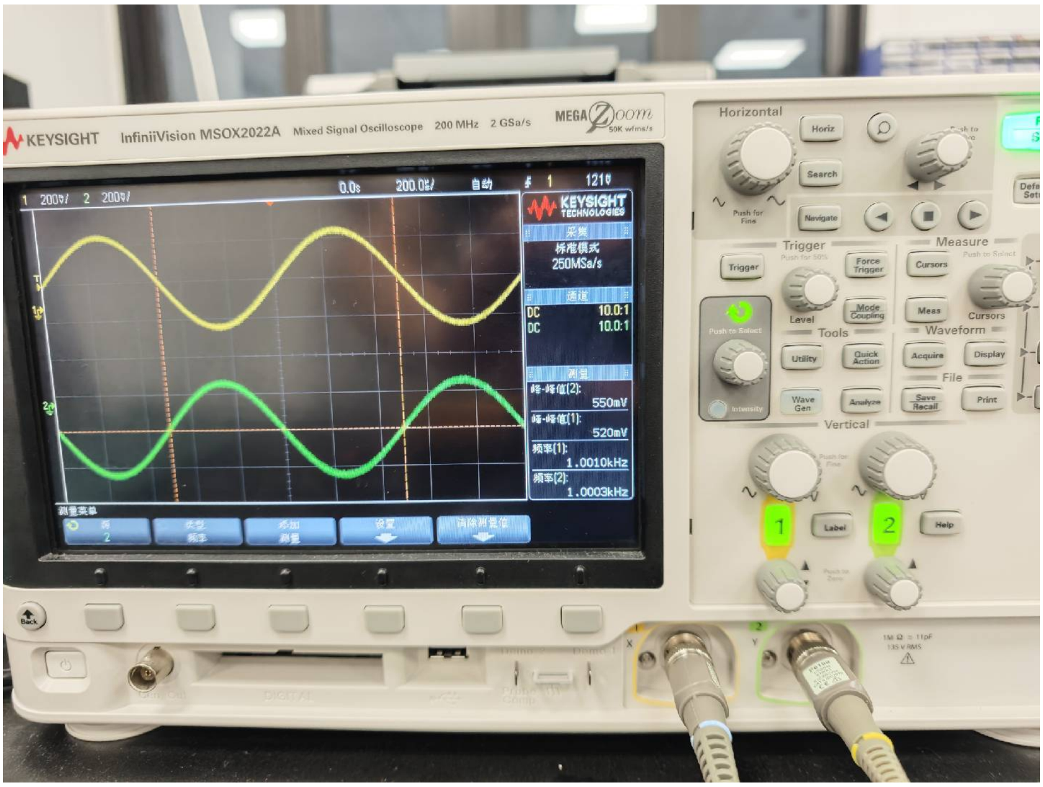

Figure 3: Lab Result

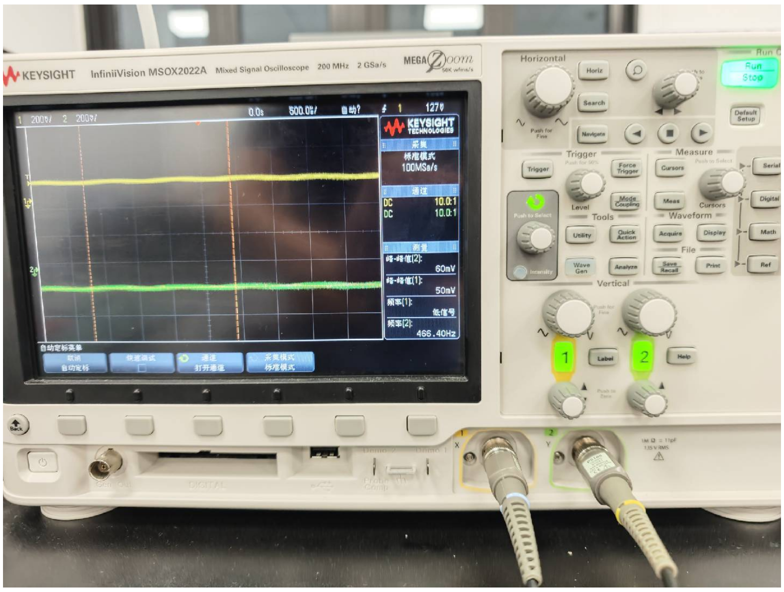

Figure 4: Lab Result

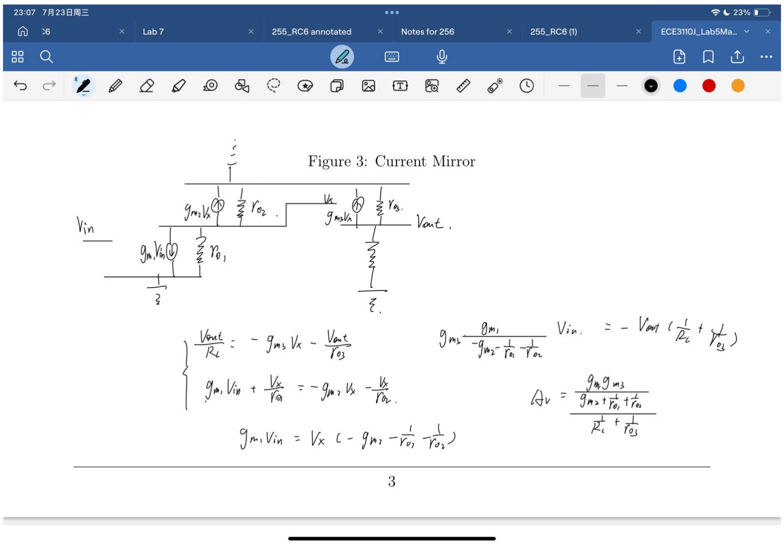

Figure 5: Calculation Result

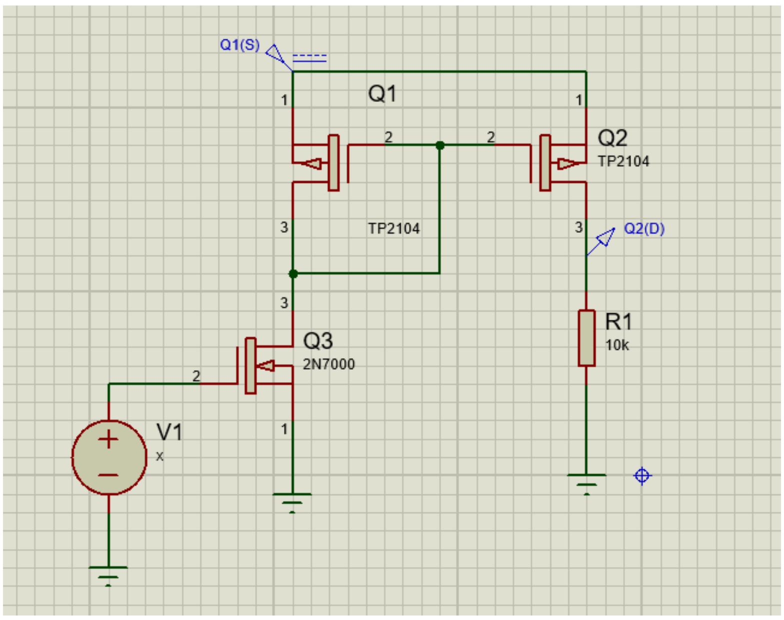

Figure 6: Simulation Circuit

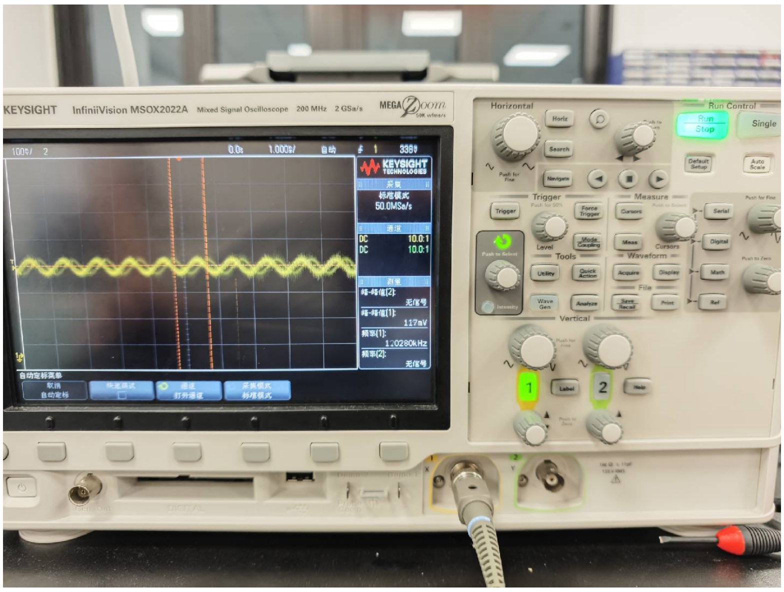

Figure 7: 1.5V

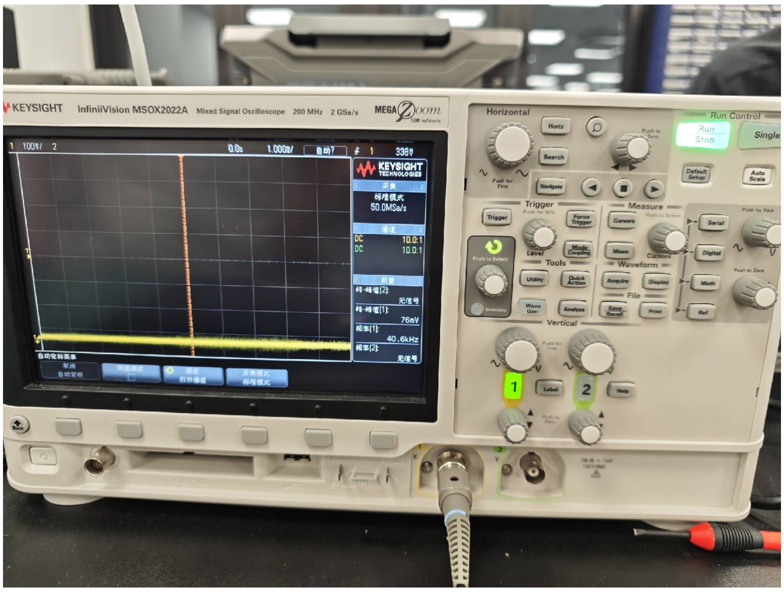

Figure 8: 1V

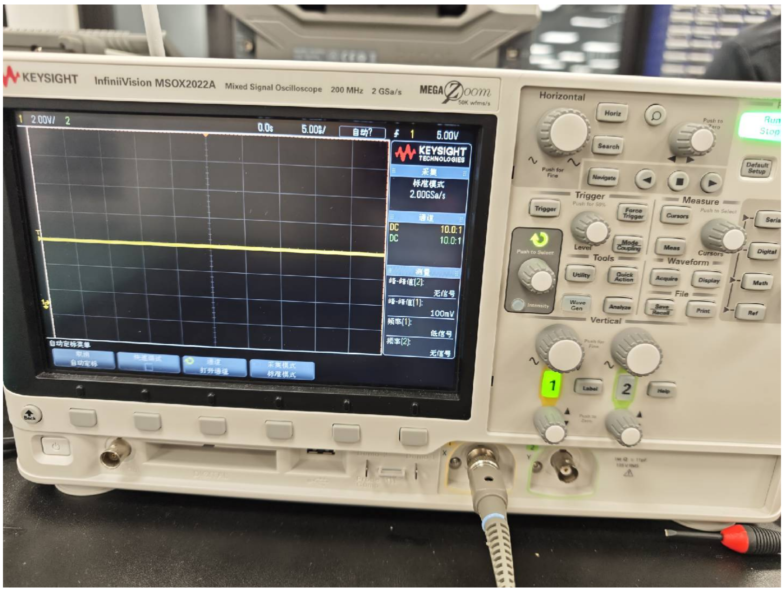

Figure 9: 2.5V

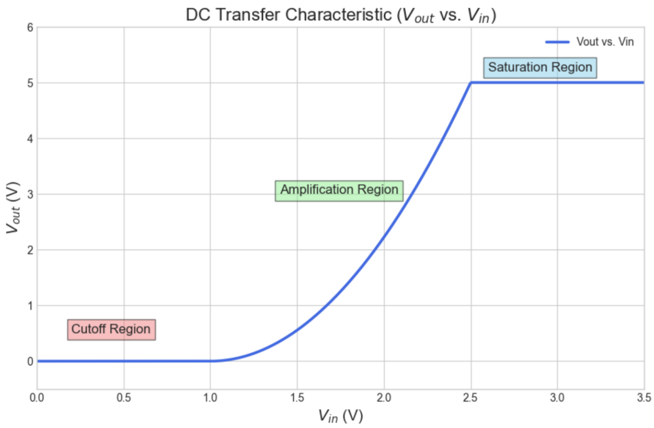

Figure 10: V_{out} vs V_{in}

4 Error Analysis

4.1 Errors from Component Mismatches and Circuit Construction

The most significant errors in this lab likely stem from the non-ideal nature of the components and their assembly on a breadboard. The in-lab differential amplifier required setting a 1 mA tail current by manually adjusting a rheostat, replacing the ideal current source used in the simulation[cite: 28, 31]. Accurately setting this current is difficult, and any deviation would directly alter the amplifier's DC operating point and gains. Furthermore, the performance of both the differential amplifier and the current mirror critically depends on perfectly matched transistors. For the differential amplifier, any variation in the parameters between transistors M_1 and M_2 would unbalance the circuit, degrading its common-mode rejection[cite: 9, 20]. Similarly, the current mirror's accuracy relies on M_2 and M_3 being identical to ensure the current is copied precisely. The drain resistors (R_{D1}, R_{D2}) also have a manufacturing tolerance; if their actual resistances are not equal, the differential amplifier will be further unbalanced[cite: 9, 16, 17]. Finally, the use of a breadboard can introduce parasitic capacitance from long wires and unreliable contact resistance, leading to intermittent connections and fluctuating measurements.

4.2 Errors from Measuring Instruments and Environmental Factors

The equipment used for measurement and the lab environment also introduce potential errors. The internal resistance of the current meter, used to set the 1 mA tail current, adds to the total resistance of that branch and can alter the very current it is meant to measure. Additionally, oscilloscope probes have intrinsic capacitance, which can load the output nodes (V_{out1}, V_{out2}) and affect the measured AC waveforms. As the transistors operate, they generate heat, which can alter their characteristics and cause the circuit's DC bias points to drift during the experiment, leading to inconsistent readings. Lastly, noise from power lines and other ambient electromagnetic sources can be picked up by the circuit, appearing as small fluctuations on the oscilloscope and interfering with precise voltage measurements.

4.3 Conclusion

In this lab, the fundamental principles of the differential amplifier and the current mirror were successfully demonstrated. The differential amplifier was constructed and tested, confirming its ability to amplify differential input signals while rejecting common-mode signals. A key part of the experiment involved comparing the ideal simulated circuit, which used a perfect current source, with the practical in-lab version that used a rheostat to set the tail current.

The second part of the lab focused on the current mirror, where experiments showed how an input voltage could be used to set a current that was then effectively copied through a load resistor. By measuring the input and output voltages, the circuit's transfer characteristics and voltage gain were determined. Overall, this lab provided valuable hands-on experience with the design and behavior of these essential analog circuit building blocks.