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April 03, 2023

Mosfet Amplifier Design & Analysis

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III. Objectives:

In this experiment, the objective is to explore the design and analysis of MOSFET amplifiers, with a focus on constructing constant-current sources, active loads, and amplifiers using only enhancement-mode MOSFETs. By working with static-sensitive devices, students will learn the proper procedures for handling these components to prevent damage from electrostatic discharge. Furthermore, the experiment aims to teach students how to scale parameter values from data sheet conditions to circuit conditions, enabling them to apply this knowledge in designing complex low-voltage, low-power analog and digital integrated circuits using MOSFETs. By conducting this experiment, students will gain hands-on experience and a deeper understanding of the fundamental principles of MOSFET amplifier design and analysis.

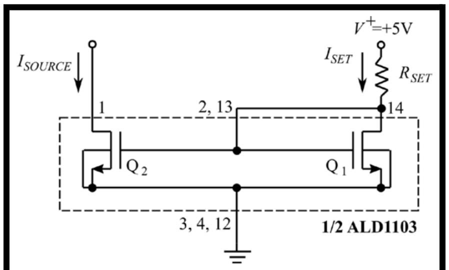
IV. Equipment Used:

- Breadboard
- Various Electronic Components

- Power supply
- Function generator
- Oscilloscope
- Multi-Meter

V. Preliminary Calculations:

A. In the preliminary calculations, we determined the value of RSET needed to obtain a constant current of approximately 10 mA. We used the formula provided in **Figure 1** to perform the calculations. After carrying out the calculations, we found the required RSET value to be 400 Ω. For a detailed explanation of the math and the calculations performed, please refer to **Appendix 1** at the end of the report.



$$I_{SOURCE} = I_{SET} = \frac{V^+ - Vt}{R_{SET}} \equiv \frac{V^+ - 1.0}{R_{SET}} \equiv \frac{4}{R_{SET}}$$

Figure 1: Preliminary Formula

VI. Procedure/Result/Analysis:

01. Procedure:

a. Prepare the workspace by gathering all parts, leads, and probes before starting the experiment.
b. Assemble the breadboard for the first circuit, following the provided schematics in the lab manual.
c. Carefully insert the IC(s) into the breadboard, ensuring correct pin connections, and have a lab partner check the circuit connections.
d. Always ensure the power is OFF before connecting or disconnecting the MOSFETs.
e. Construct the basic current mirror constant-current source (Figure 1) and measure the output current as you vary the load resistance using a decade box.
f. Build the cascode current source (Figure 2) with two NMOS pairs, and repeat the output current measurement as you vary the load resistance.
g. Perform the post-experiment calculations and comparisons using the equations provided in the lab manual and textbook.

02. Experiment:

a. In our experiment, we began by constructing the basic current mirror constant-current source as shown in **Figure 1**. We selected the nearest standard value for RSET that we had available. After setting up the circuit, we placed a decade box with an initial value of 0 ohms in series with the multimeter in the mA position between VDD and the output of the current source (the drain of Q2). We then turned on the power and observed the current. It wasn't close to 10 mA, so we turned off the power and adjusted RSET to achieve a current within 2 mA of 10 mA. We were able to accomplish this by using a 300-ohm RSET, which resulted in a current of 10 mA. Next, we varied the resistance of the decade box from 0 ohms to 2 k and recorded the current for each resistive load value (every 100 Ω). By analyzing this data, we aimed to determine an approximation for the output resistance to be around 314 Ω from **Figure 2** found below. Comparing this to the value within the datasheet, we determined that these values were significantly off considering the data sheet states $r_o = 5000\ \Omega$. It was then determined that the range for the resistance using linear regression found below in **Figure 2,** to be 0-2600 ohms before the current would become zero. We then measured the gate-to-source voltage (VGS) for both transistors, Q1 and Q2. We found that VGSQ2 was 2.33 V, while VGSQ1 was 2.49 V. To do this, we first turned off the power and removed the multimeter from the circuit. Then, we changed the test leads on the meter to measure DC voltage. After turning the power back on, we measured the VGS values of the transistors.

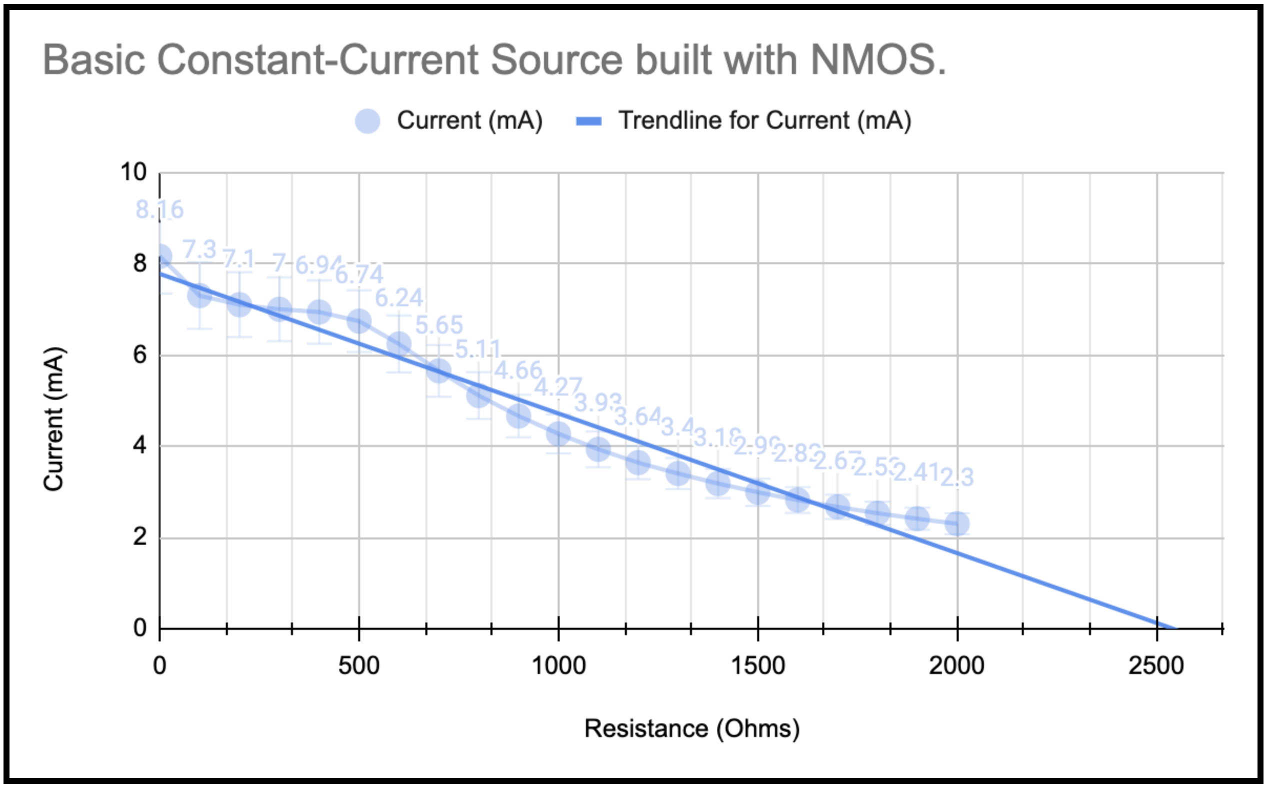


Figure 2: Basic Constant-Current Source built with NMOS

b. After completing the initial experiment, we proceeded to construct the cascode current source as shown in **Figure 3**, using two NMOS pairs. Our aim was to analyze the performance of the cascode configuration in comparison to the basic current mirror constant-current source. We repeated the output current measurement while varying the load resistance, just as we did in the previous experiment. Once we had gathered the data for the cascode current source, we plotted the output current as a function of the load resistance in **Figure 4**. The apparent output resistance of the cascode current source appears to be significantly higher than that of the simple current source. This is evident from the data we collected, where the output current remains relatively constant as the load resistance increases for the cascode current source, whereas it varies more for the simple current source. This higher output resistance leads to better performance as a constant-current source. By using the given equation and the calculated parameters from the transistor datasheet, we determined the output resistance of the cascode current source to be around 187,500 ohms; these calculations can be observed within **Appendix 2**. Comparing the two output resistances, the cascode current source shows a significant improvement over the simple current source. This higher output resistance suggests better stability and performance in many applications, making the cascode configuration a preferable choice in certain situations.

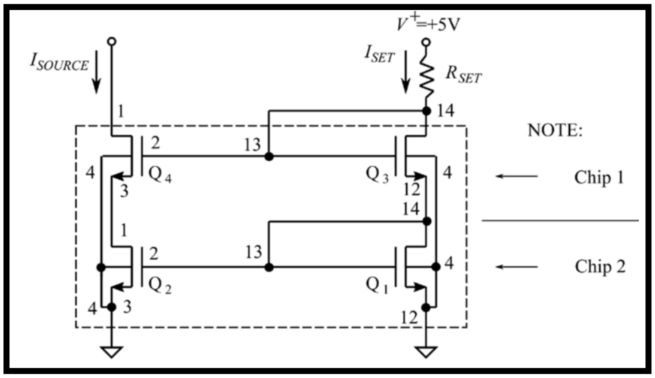


Figure 3: A Cascode Current Source built with NMOS transistors

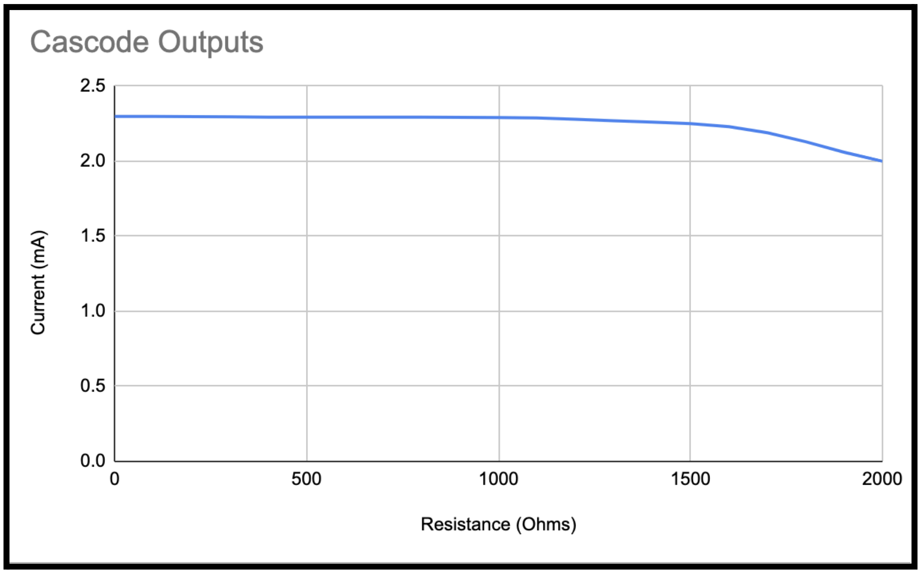


Figure 4: A Cascode Output

VII. Conclusion:

In conclusion, this experiment allowed us to explore the characteristics and performance of two different current source configurations: the simple current source and the cascode current source. By conducting measurements and analyzing the data, we were able to determine the output resistance of both configurations. Our findings revealed that the cascode current source exhibited a significantly higher output resistance compared to the simple current source, implying better stability and performance in various applications.

VIII. References:

Not applicable

IX. Appendix:

Appendix 1:

$$I_{Source} = I_{Set} = \frac{V^{+} - Vt}{R_{Set}}$$

$$R_{Set} = \frac{V^{+} - Vt}{I_{Set}} = \frac{5\,V - 1\,V}{10mA} = 400\Omega$$

Appendix 2:

$$R_{o} = \frac{V_{x}}{I_{x}} = r_{o4} + r_{o2}(1 + g_{m} r_{o4}) =$$

$$5000 + (5000(1 + 0.0075 * 5000)) = 187,500$$