1.0 Objective

In Exps. 6 and 7, we investigated the small signal properties of single stage amplifiers (e.g., common source, common drain, etc.). Now we will see how these single stage amplifiers perform together. By cascading the stages, new amplifiers with enhanced performance can be realized. We will also study the effects of loading of one stage on the other.

To show your understanding of the lab, your write-up should contain:

- A discussion on how single stages interact together
- A discussion on interstage loading based on 2-port models

2.0 Prelab

- H & S: Chapter 9
- For the cascode circuit in Fig. 1, hand-calculate the gain, input resistance and output resistance for a supply current of $I_{SUP} = 1$ mA.

(SPICE Models: ‘Lab Chip Schematics’ manual)
3.0 Procedure

3.1 The Cascode

The cascode amplifier is nothing more than a common source - common gate cascade. Figure 1 above shows a simplified cascode with a current source load.

The 2 port model for the cascode is shown below.

![FIGURE 1. Cascode Amplifier with Current Source Bias](image1)

![FIGURE 2. 2-Port Representation of Cascode](image2)
In your lab, the cascode circuit will include extra biasing circuits as shown in Fig. 3. These circuits make use of DC feedback (coupled through the external low-pass filter), in order to stabilize this high-gain circuit. After simplification, Fig. 3 reduces to the basic cascode amplifier in Fig. 1 for the frequencies we will be concerned with.

1. Set up the circuit from Lab Chip 5 as shown in Fig. 3. Let $R_{Bias}$ be 10 k$\Omega$ and $C_{in}$ be 10 $\mu$F. Let $V_{CC}$ be set at 3.5 V. Note: The user just needs to furnish the external elements in the box. (the elements in the dashed “boxes” in Fig. 3).

2. Determine the bias current and DC voltage at $V_{OUT}$. Using Fig. 3, what are the maximum and minimum DC voltages that $V_{OUT}$ can swing to while keeping all the devices in the saturation. Compare with measurements of output clipping levels.

3. Using the oscilloscope, find the gain $v_{out}/v_{in}$. Use a 5 kHz sine wave with an amplitude of 65 mV. If the signal at the output is clipped, decrease the input amplitude until no clipping occurs.

4. Calculate the input resistance and output resistance for the cascode. Using the calculated value of the input resistance, you can calculate how much of the input voltage is attenuated. Determine the gain of the cascode $v_{out}/v_{in}$. How does the cascode compare to the Common Source in terms of input resistance, output resistance and voltage gain? Optional: measure the input and the output resistances.

**FIGURE 3.** MOS Cascode with DC Feedback Biasing (Lab Chip 5)
Procedure

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**Lab Tip**

Find the DC voltage at $v_{OUT}$ (PIN 5) and make sure that $M_3$ and $M_4$ are saturated. If they are not, get a new chip. The circuit takes about 10 - 20 seconds to stabilize. Be patient.

5. Perform a SPICE analysis on the cascode in Fig. 1 (the circuit in Fig. 3 is extra credit) and compare your results with simulation.

3.2 Cascading Stages

1. *While leaving the cascode intact*, build the common source as shown in Fig. 4; do not include the coupling capacitor yet. Find the bias current through $R_{BAS}$. Does the DC voltage at $V_{OUT}$ confirm the fact that $I_D = I_{BAS}$? Find the gain of the common source.

2. Now cascade the two stages together with the use of the 10 μF coupling capacitor. What is its function? (Hint: look at the DC voltage at both sides of the capacitor) What would happen if the capacitor were not present? Change the amplitude of the sinusoid to 50 mV.

3. Find the gain for the cascade. Measure the gain $v_{out1} / v_{in}$. Why is it reduced?

4. Draw the 2 port models for the cascaded amplifier in Fig. 4. Comment on the overall gain and the loading between stages.
FIGURE 4. Cascode - Common Source Cascade

Lab Chip 5

Lab Chip 1

PIN 28

$V_{DD} = 3.5 \text{ V}$

$V_{IN}$

$V_{IN}$

$V_{BIAS}$

$Q_1$

$Q_2$

$M3501$

$M3501$

$R_C = 10k\Omega$

$RC$

$10 \mu F$

$V_{OUT1}$

$V_{OUT2}$

$V_{DD} = 5\text{ V}$

$PIN 28$

$PIN 10$

$PIN 9$

$PIN 11$

Ground = PIN 14

$vin$

$v_{OUT1}$

$V_{OUT2}$

$vin$

$_+$

$-+$

$-+$

$+-$

$+-$

$+-$

$+-$

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