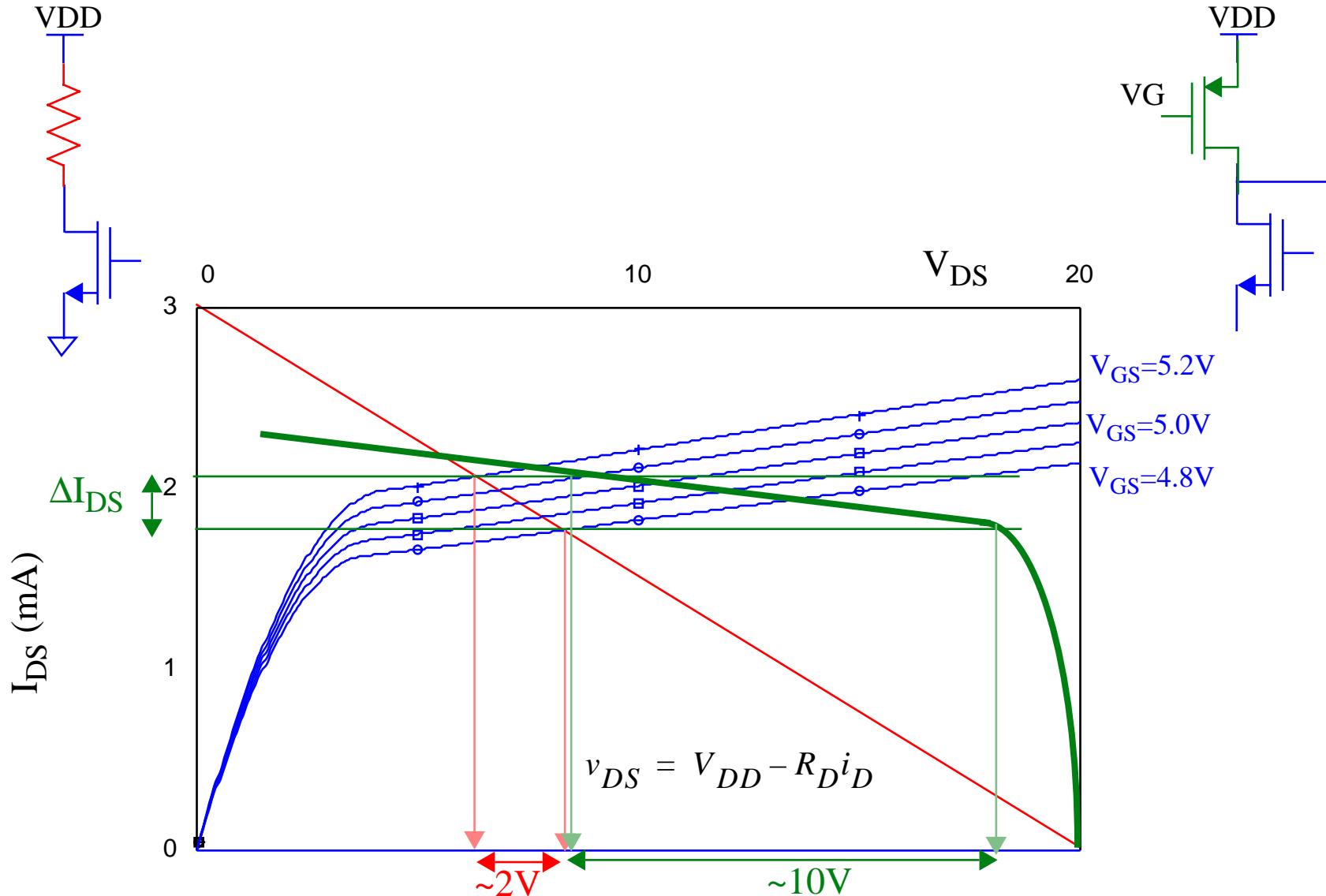


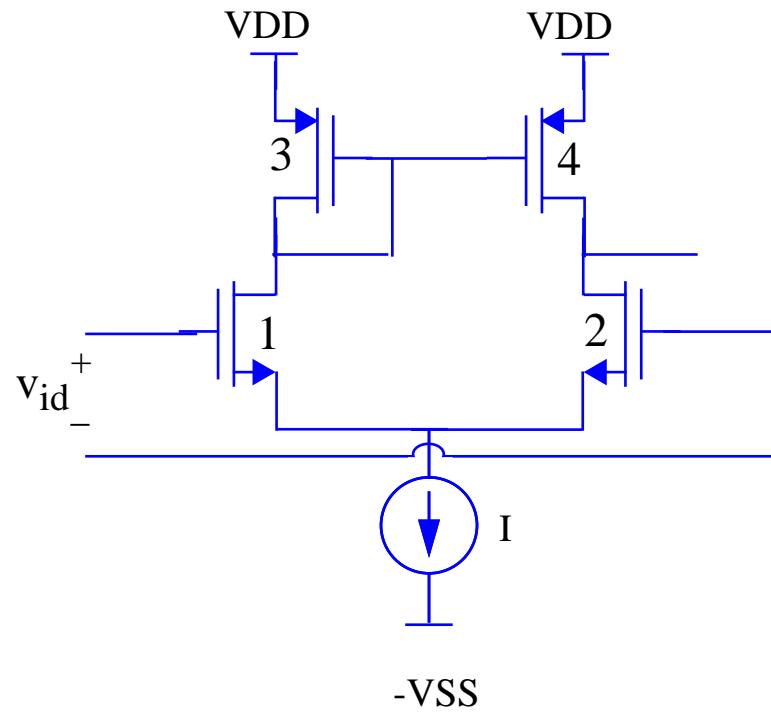
## Passive Loads vs Active Loads

- MOS diff amp loads are generally transistors on ICs

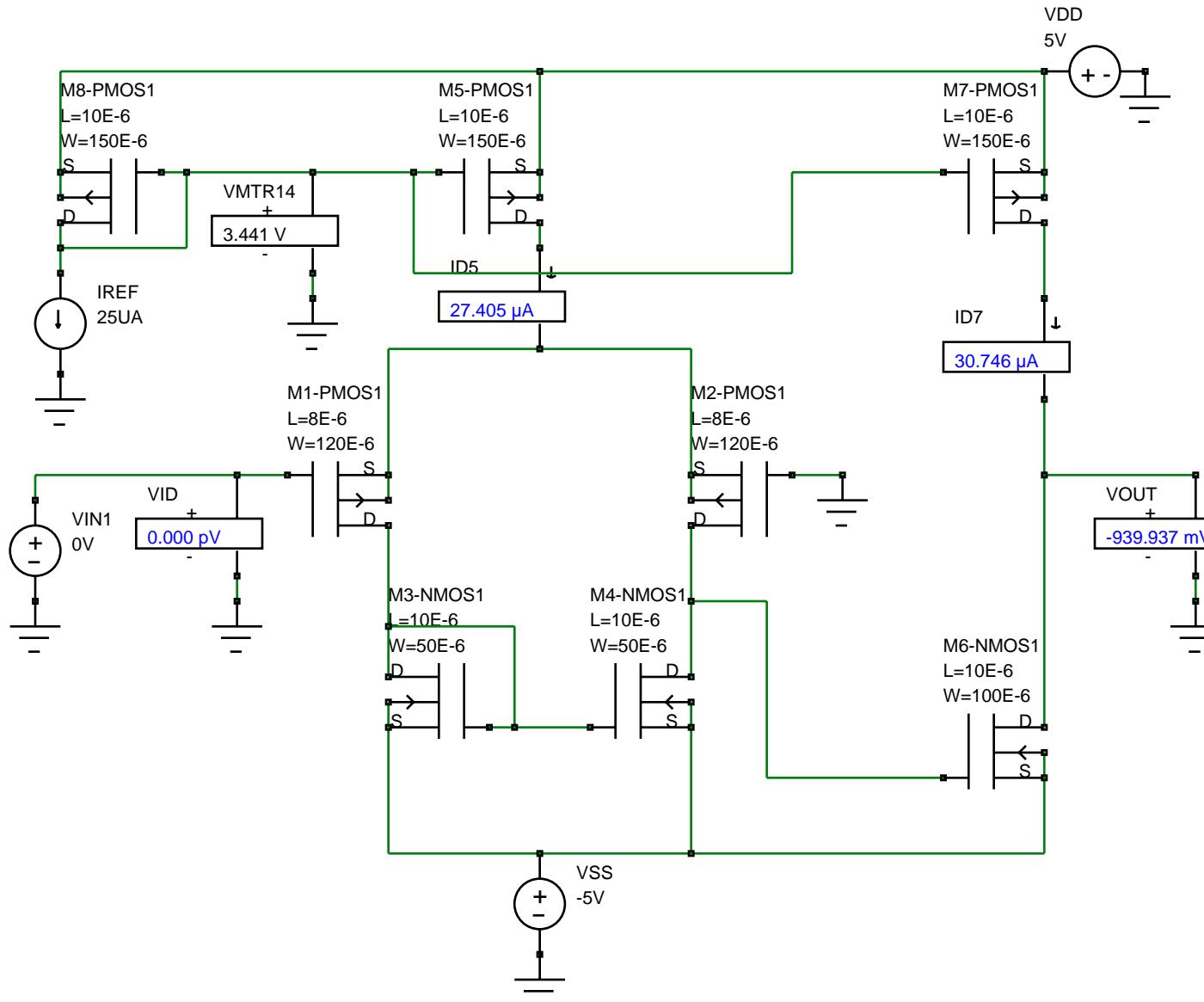


# Active Loads

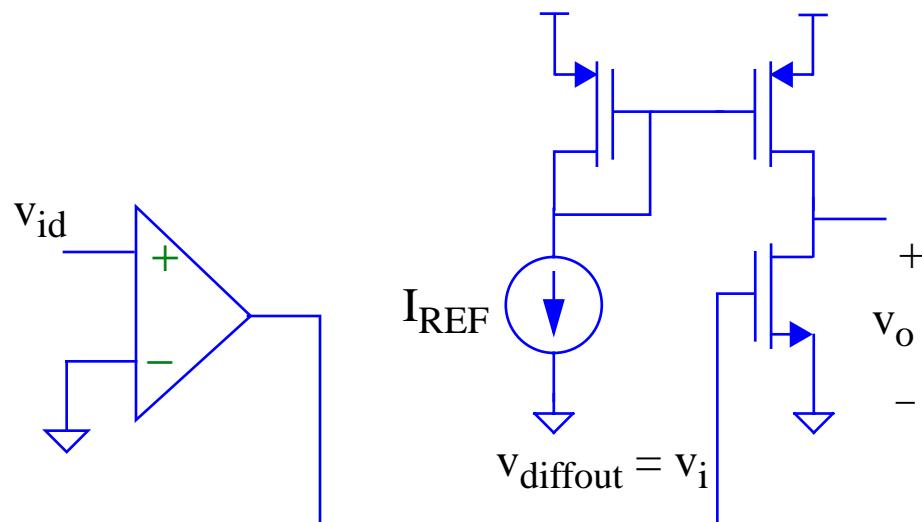
- MOS diff amp loads are generally transistors in ICs



## Two Stage OpAmp

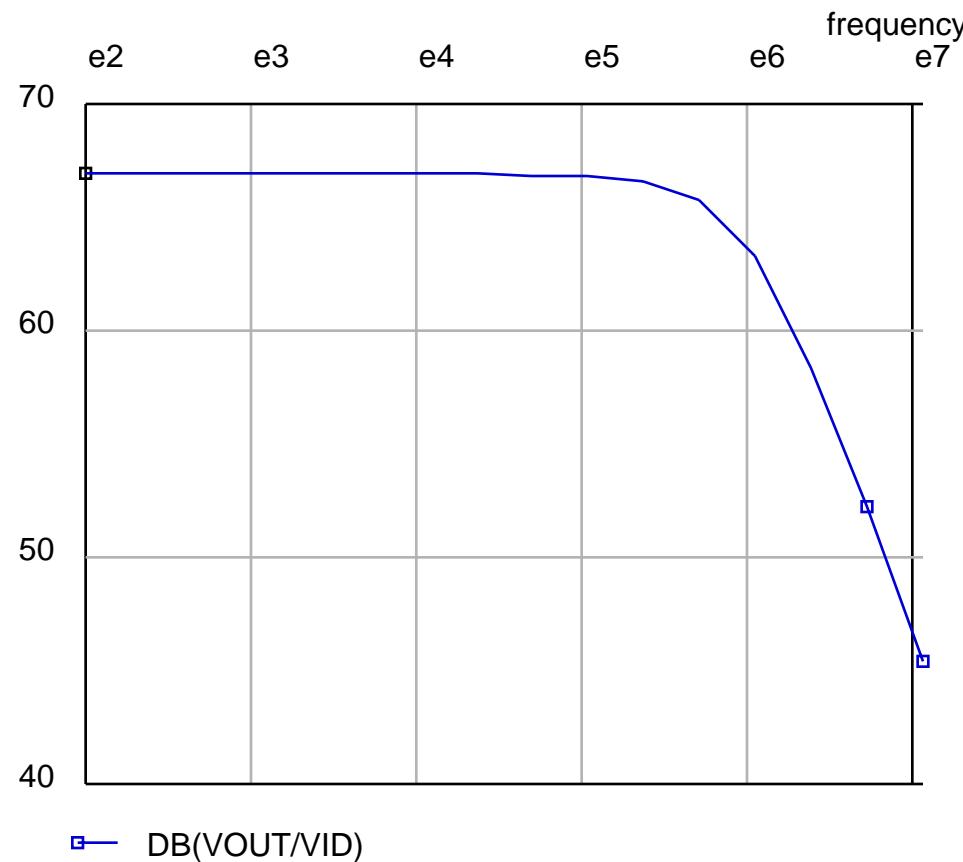


## Two Gain Stages

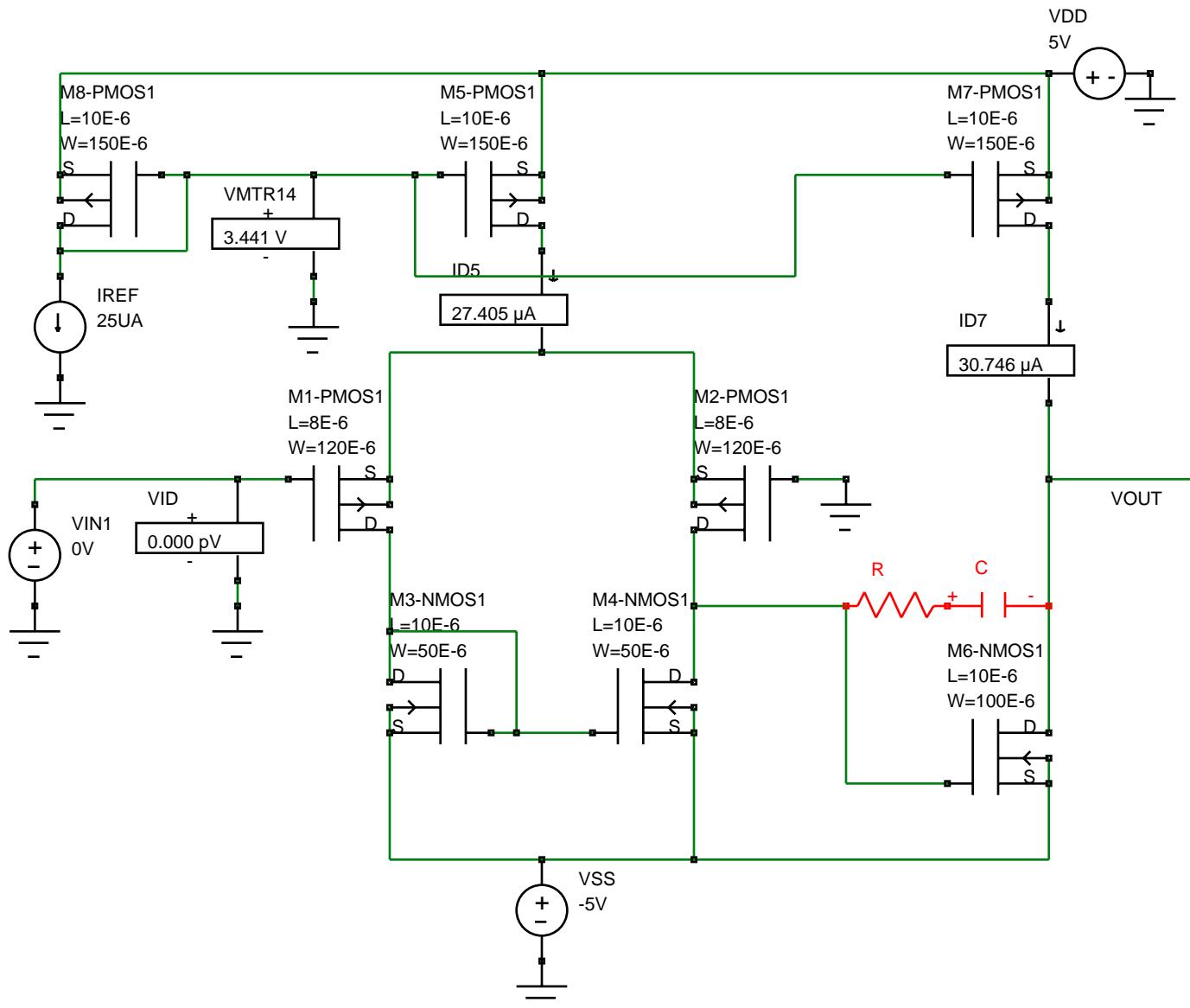


## Two Stage OpAmp

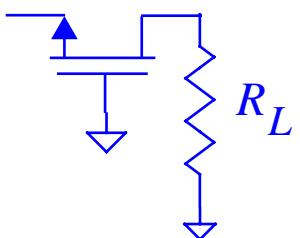
- The overall gain is the product of the two stage gains



# Compensation



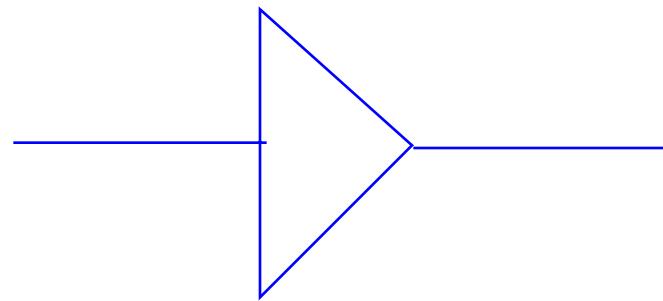
## Common Gate Configuration

$$r_{in} = \frac{V_g - V_{gs}}{I_g}$$


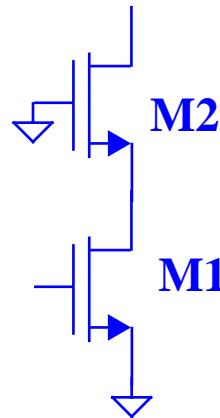
The diagram shows a common gate configuration. It consists of a vertical line representing the drain, with a zigzag symbol indicating it is connected to a load resistor  $R_L$ . A horizontal line representing the source is connected to the drain at its bottom. A third line, representing the gate, is connected to the source line. Arrows indicate the direction of current flow: up through the drain, down through the source, and up through the gate. The input voltage  $V_g$  is applied across the gate and source terminals.

## Common Gate Configuration

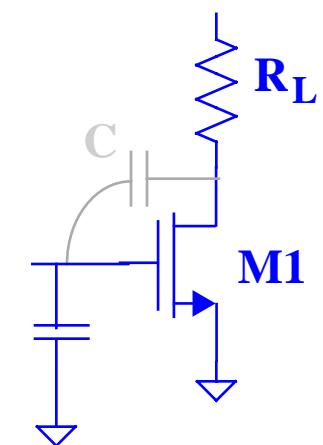
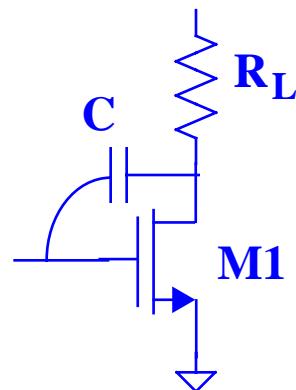
- Common gate configuration acts as a current buffer (just like common base)



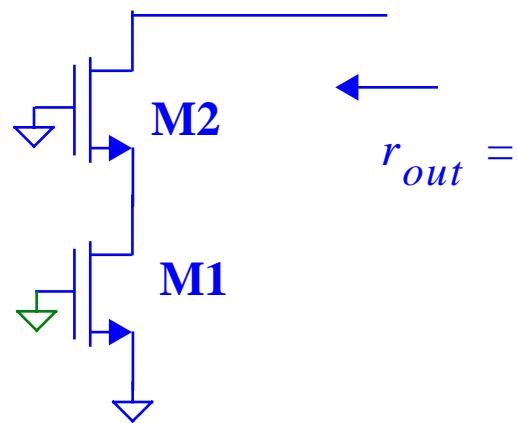
# Cascode



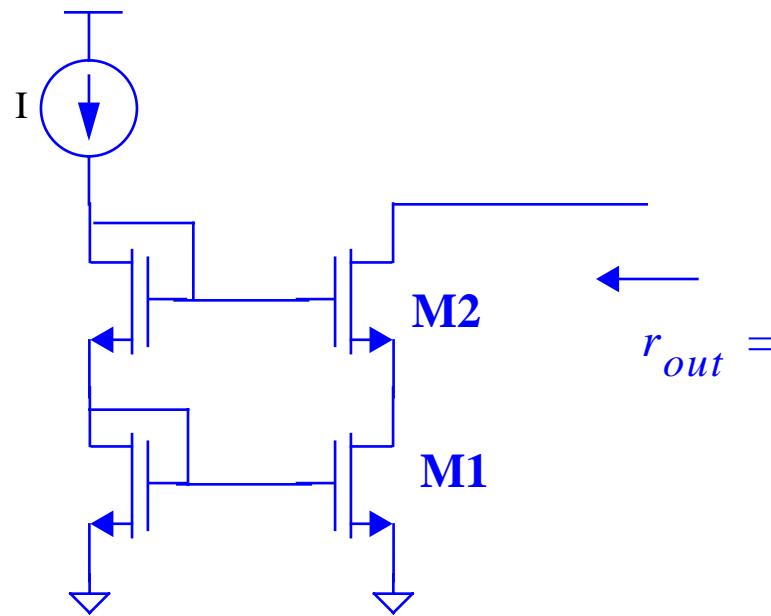
- Cascade of common source and common gate stages.
- Broader frequency band than common source
- Higher output impedance than common source



## Cascode - increased output impedance



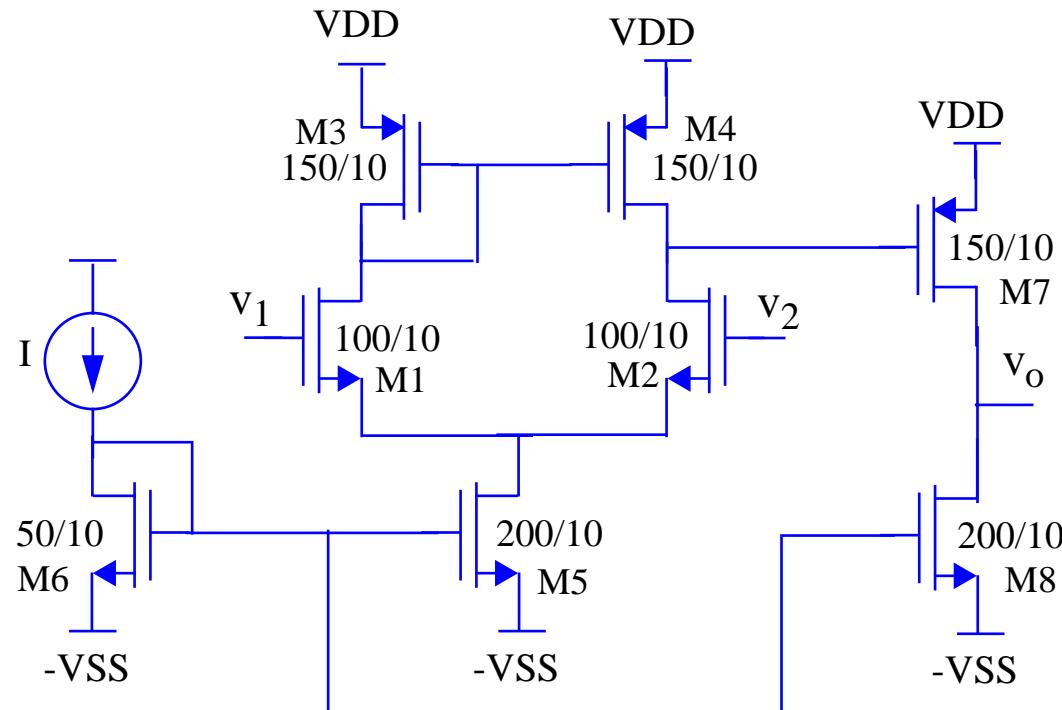
## Cascode current source - increased output impedance



## Problem from previous year's exam#3

Calculate the midband gain ( $v_o/(v_1-v_2)$ ) as a function of I (the reference current) for the two-stage CMOS opamp shown below. Assume that all of the biasing is working properly. Show all of your work!

$$\begin{aligned}\lambda_p &= 0.02 \\ \lambda_n &= 0.01 \\ \mu_p C_{ox} &= 20 \mu A/V^2 \\ \mu_n C_{ox} &= 20 \mu A/V^2\end{aligned}$$



## 1. Calculate currents of M5 and M8

Calculate the midband gain ( $v_o/(v_1-v_2)$ ) as a function of I (the reference current) for the two-stage CMOS opamp shown below.

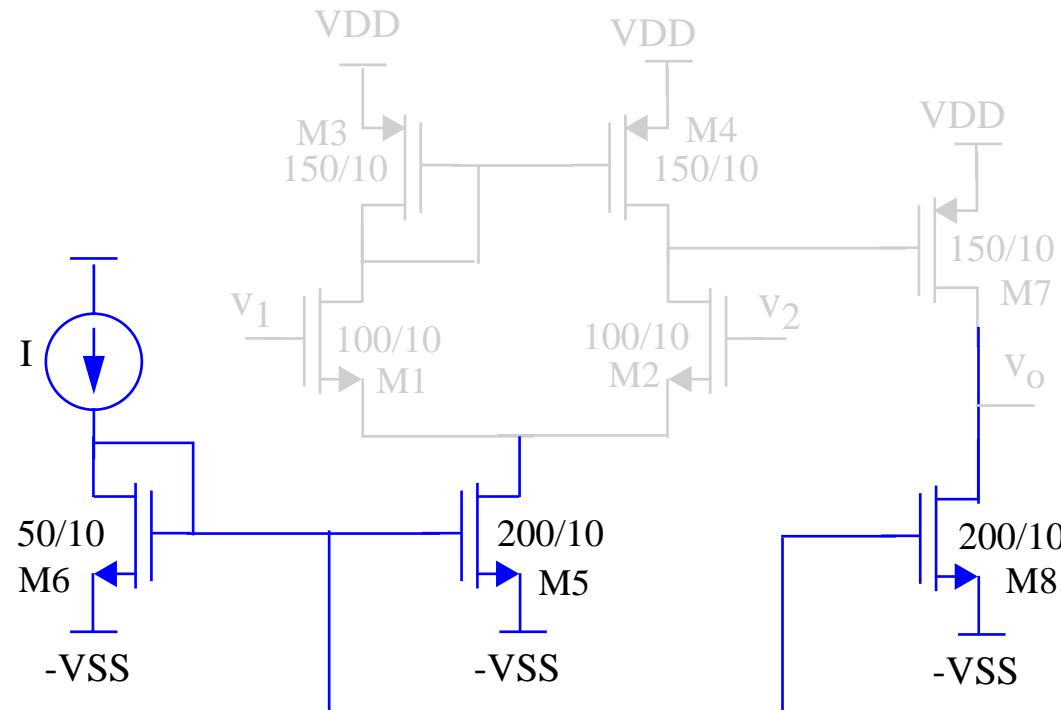
Assume that all of the biasing is working properly. Show all of your work!

$$\lambda_p = 0.02$$

$$\lambda_n = 0.01$$

$$\mu_p C_{ox} = 20 \mu A/V^2$$

$$\mu_n C_{ox} = 20 \mu A/V^2$$



## 2. Calculate gain $A_{\text{diff}}$ of the differential stage M5-M1-M2-M3--M4

Calculate the midband gain ( $v_o/(v_1-v_2)$ ) as a function of I (the reference current) for the two-stage CMOS opamp shown below. Assume that all of the biasing is working properly. Show all of your work!

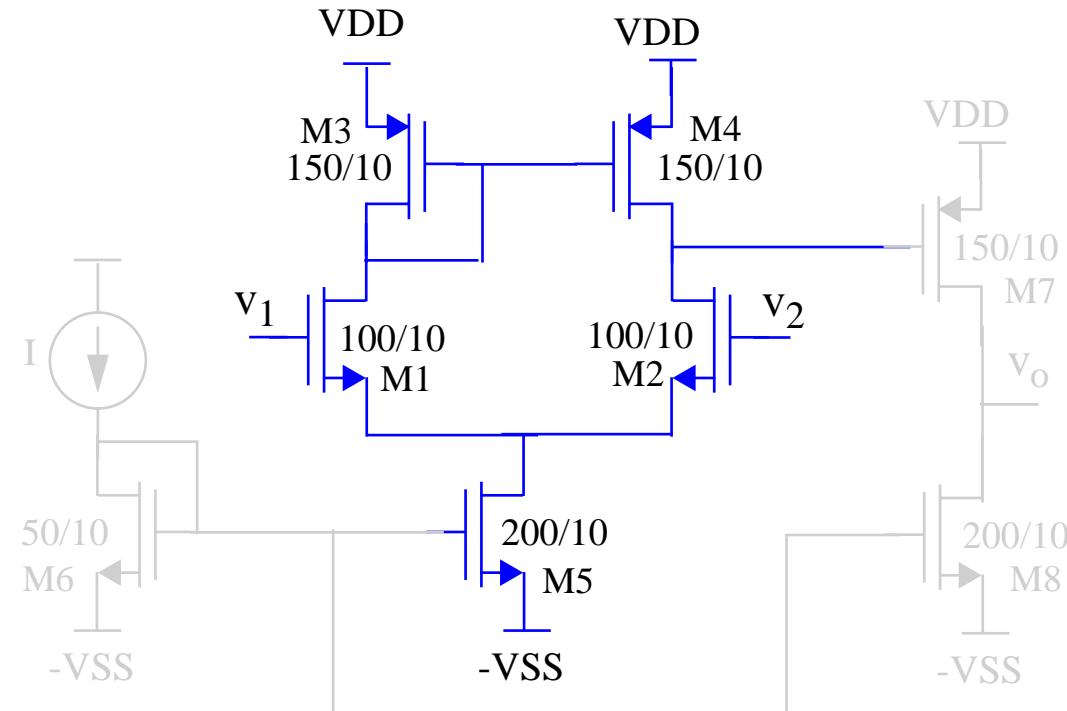
$$\lambda_p = 0.02$$

$$\lambda_n = 0.01$$

$$\mu_p C_{ox} = 20 \mu A/V^2$$

$$\mu_n C_{ox} = 20 \mu A/V^2$$

$$g_m = \sqrt{2\mu_n C_{ox}} \sqrt{\frac{W}{L}} \sqrt{I_D}$$



### 3. Calculate gain of the second stage

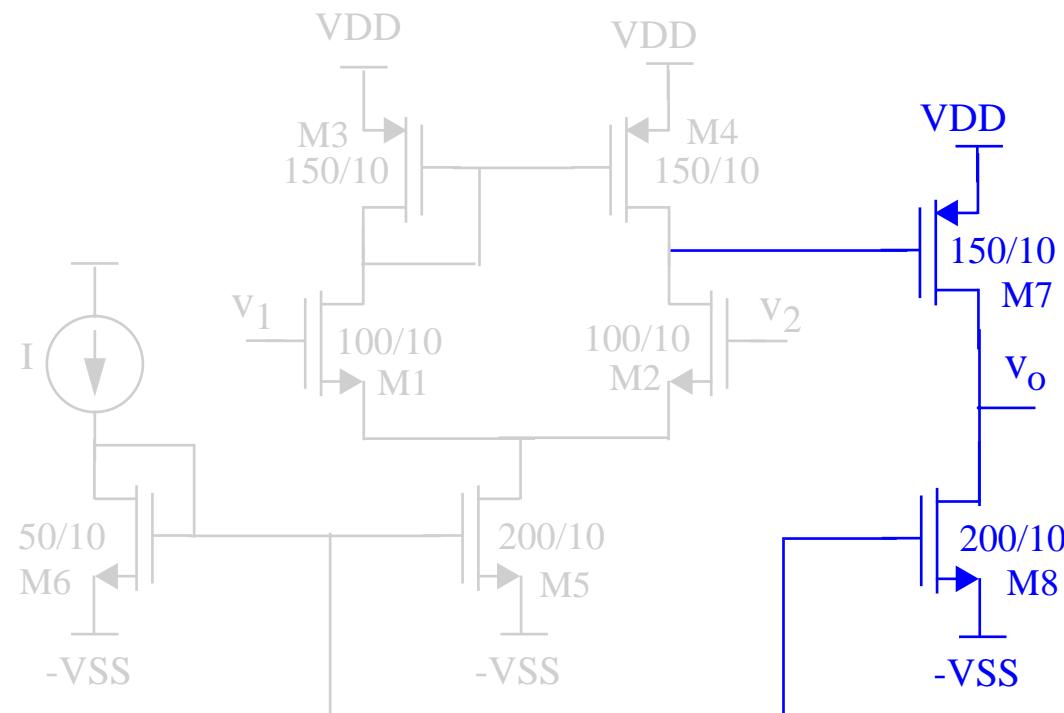
Calculate the midband gain ( $v_o/(v_1-v_2)$ ) as a function of I (the reference current) for the two-stage CMOS opamp shown below. Assume that all of the biasing is working properly. Show all of your work!

$$\lambda_p = 0.02$$

$$\lambda_n = 0.01$$

$$\mu_p C_{ox} = 20 \mu A/V^2$$

$$\mu_n C_{ox} = 20 \mu A/V^2$$



#### 4. Combine gain of both stages

Calculate the midband gain ( $v_o/(v_1-v_2)$ ) as a function of I (the reference current) for the two-stage CMOS opamp shown below. Assume that all of the biasing is working properly. Show all of your work!

$$\lambda_p = 0.02$$

$$\lambda_n = 0.01$$

$$\mu_p C_{ox} = 20 \mu A/V^2$$

$$\mu_n C_{ox} = 20 \mu A/V^2$$

