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Exercise:
Gain Stage

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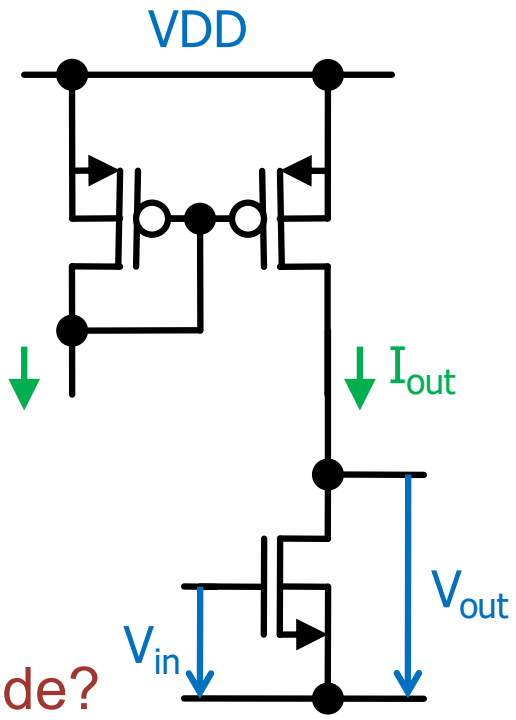
1. Basic Gain Stage

- Implement a NMOS gain stage.
  - Use real transistor models ('nmos','pmos')
  - Use a NMOS with W/L = 1µ/0.5µ
  - Use a PMOS of W/L = 1µ/1µ
  - Bias the PMOS with a *mirror* to 10µA
  - Operate at VDD = 1.8 V
- Sweep V_{in} and observe V_{out}
- What is the largest gain (derivative!) ?
- Why is the 'upper' part of the curves so wide?
- Change
  - the bias current
  - W, L of the input transistor

  and observe what happens. Explain!
  Why can't you increase gain more with W,L changes?
- Can you operate at 100µA?



2. Operation point

- Use the trick explained in the lecture to set the operation point
  - Use for instance C=1uF, R=100MΩ
- Make an AC sweep

3. Bandwidth

- Load the gain stage with a capacitor (1 pF)
- Observe the bandwidth
  - best use the ‘automatic’ operation point
- Modify the load capacitor
  - Is bandwidth inversely proportional to C_L?
- Modify I_D
  - Make a Parametric Sweep with 2-3 values (0.1µA, 1µA, 10µA)
  - Do you find what you expect?

4. PMOS Amplifier

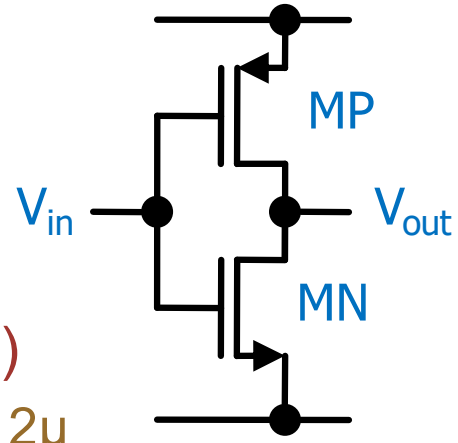
- Design a PMOS gain stage (with a NMOS current mirror load)

5. Cascoded Gain stage

- Set up a cascoded gain stage
  - Use W/L = 5µ / 0.4µ for all 4 MOS
  - Use I_{bias} = 10 uA
  - **Use a stacked mirror on the PMOS side** (different from demo in lecture!)
  - Use a ‘safe’ cascode voltage for the NMOS
- Simulate
  - Make a DC sweep. What is the gain ?
  - Try different Cascode voltages
  - Check that $v_{out} = v_{in}$ is a good operation point for AC analysis
- Make an AC sweep with a load of C_{load} = 100fF
  - What is the gain?
  - Simulate a non-cascoded gain stage in parallel an compare

6. The Inverter

- The PMOS 'load' in the gain stage supplies a more or less constant current
- In the CMOS Inverter shown, the PMOS is switched with the input signal, it acts as the NMOS



- Simulate the DC transfer function $V_{out}(V_{in})$
  - For instance $L_N = L_N = 0.5\mu$, $W_N = 1\mu$, $W_P = 2\mu$
  - What is different from the normal gain stage ?
  - What is the maximum gain ?
- Use a small signal analysis to find the gain