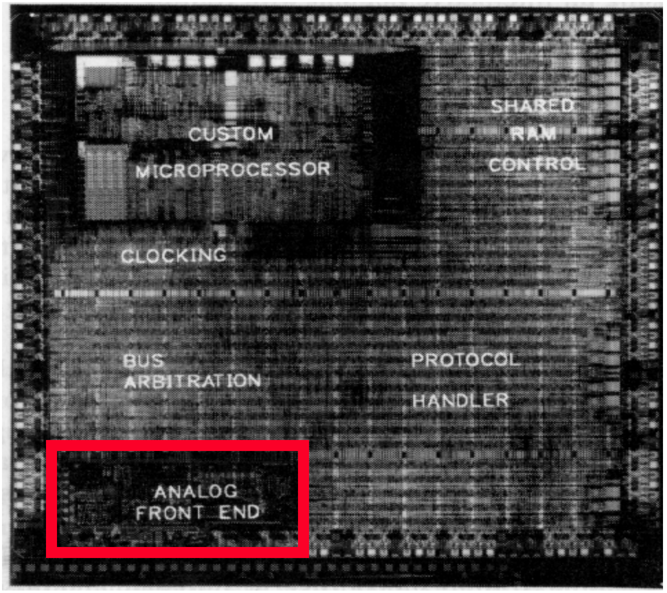
MOS IC Amplifiers

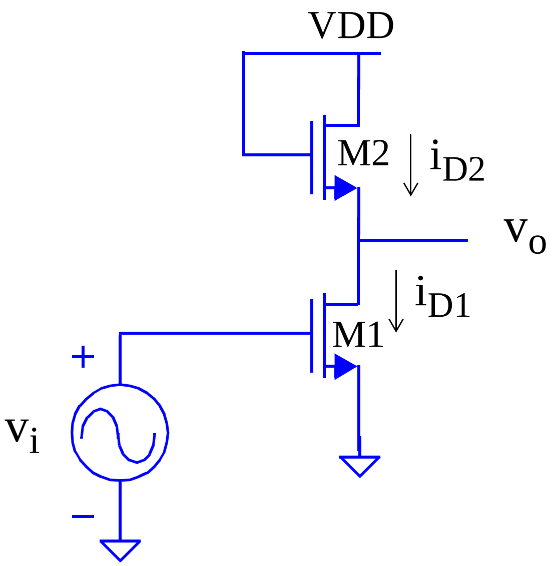
- MOSFETs are inferior to BJTs for analog design in terms of quality per silicon area
- But MOS is the technology of choice for digital applications
- Therefore, most analog portions of mixed-signal designs are MOS
- Most MOS amplifiers will be IC amplifiers with “active” loads
- Resistors and decoupling capacitors are too expensive on ICs



Token Ring LAN
JSSC 12/89

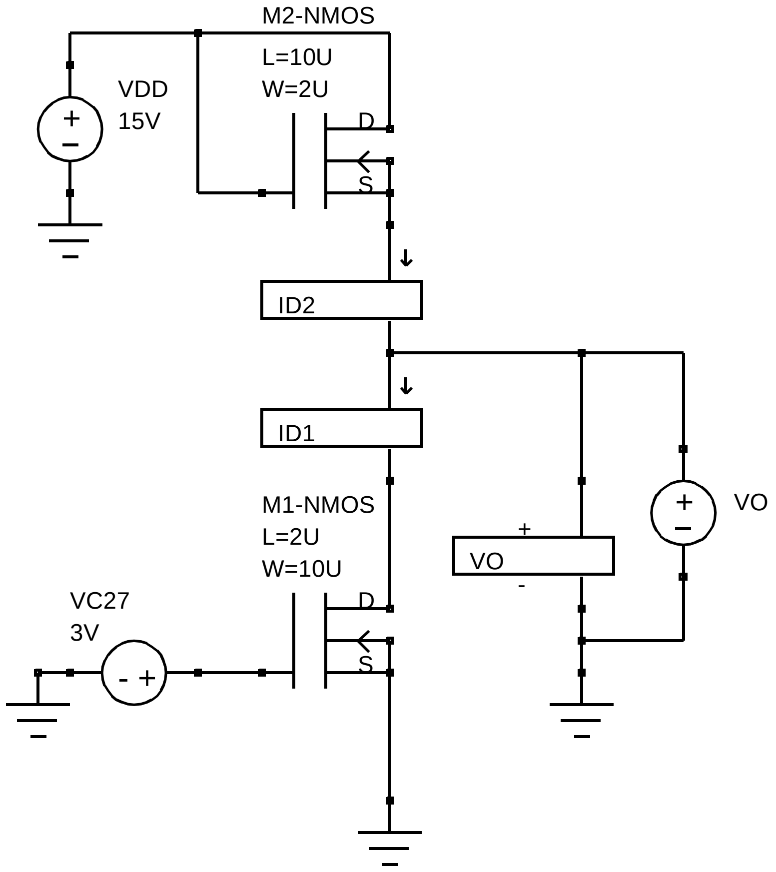
NMOS Amplifier --- Active Load

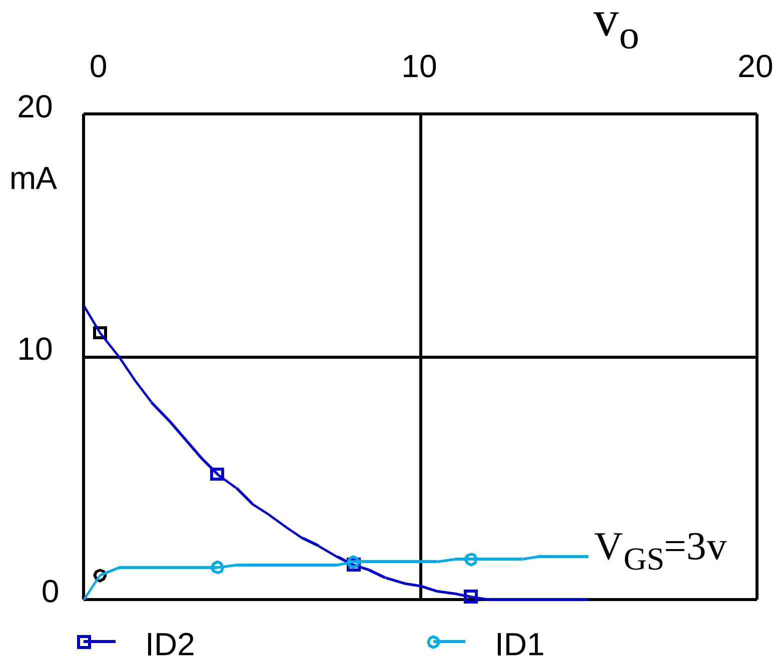
- Natural extension of amplifier with resistor pull-up
- Size M2 and bias M1 so that M1 is in saturation
- This is a digital NMOS logic gate when large input signals are applied



Load Line View

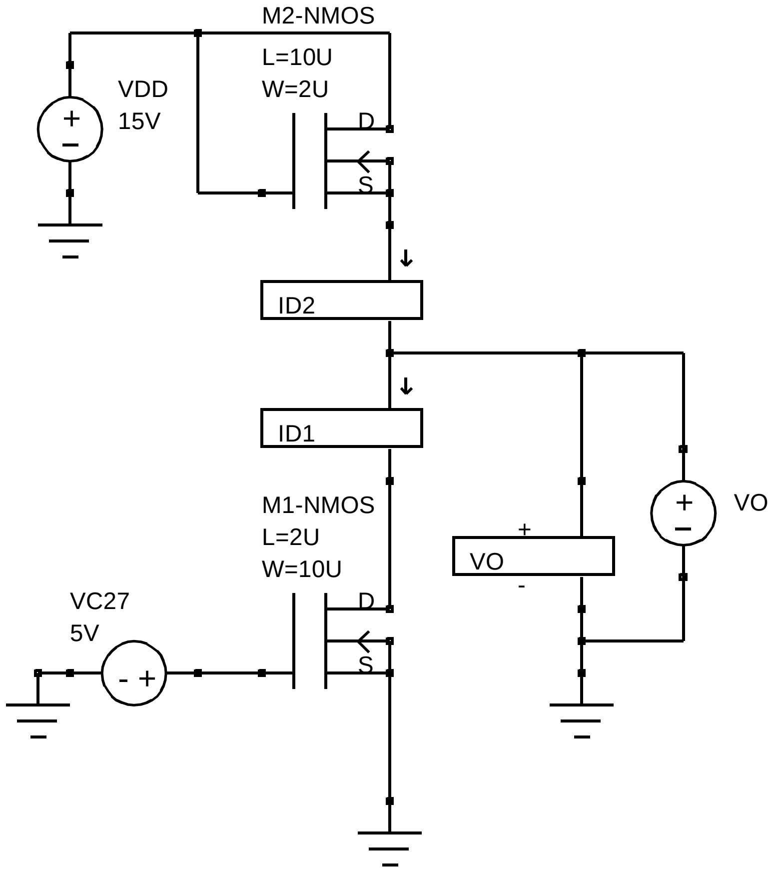
- “Load line” is nonlinear

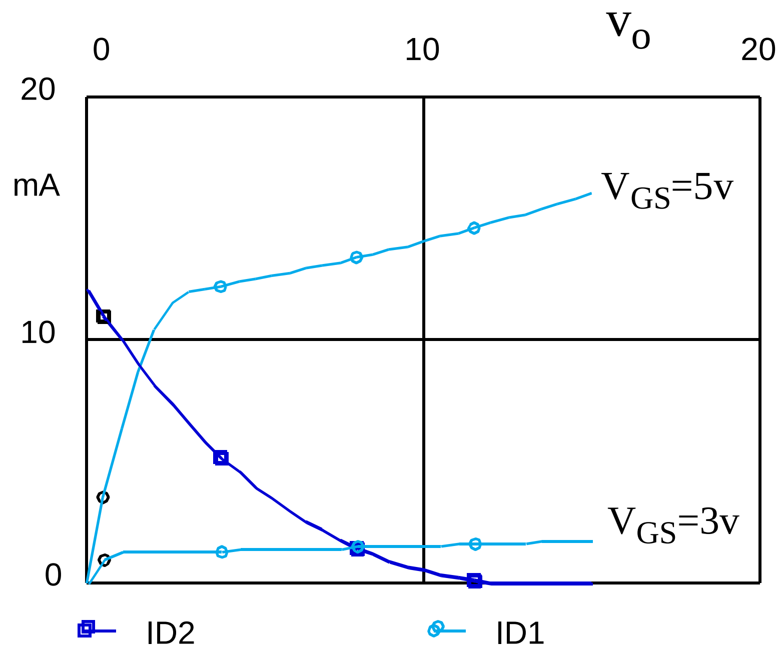




NMOS Amplifier Example

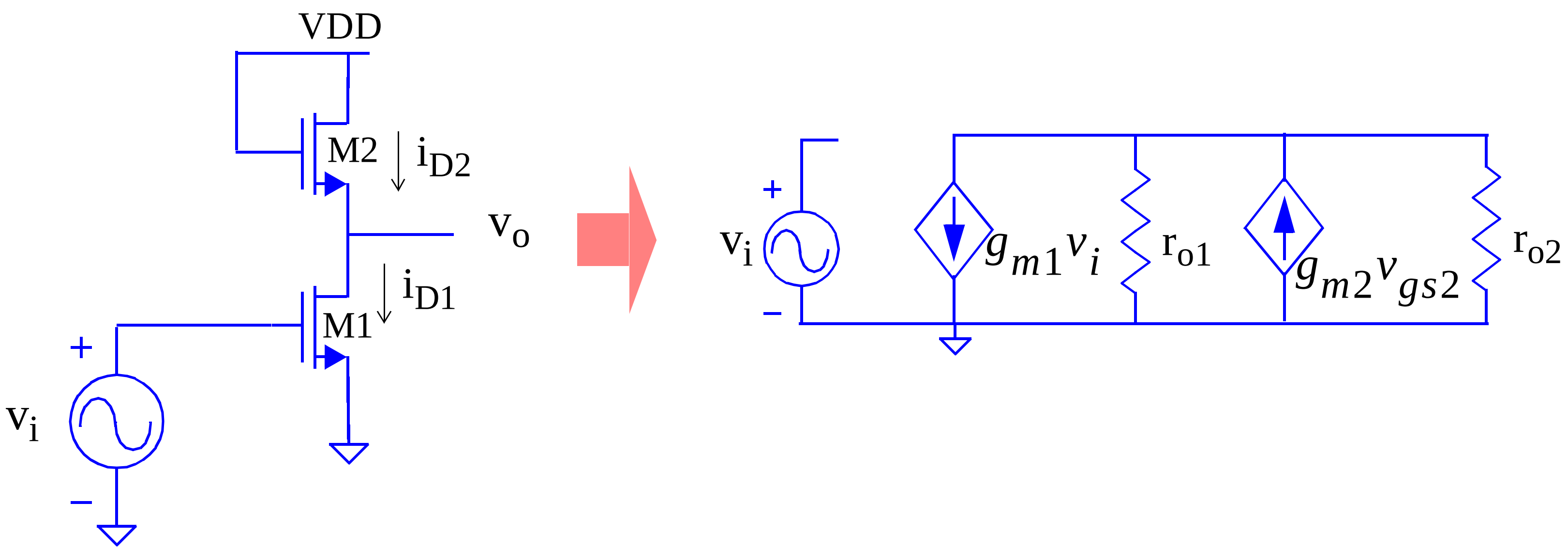
- For a larger dc input bias voltage M1 is no longer in saturation



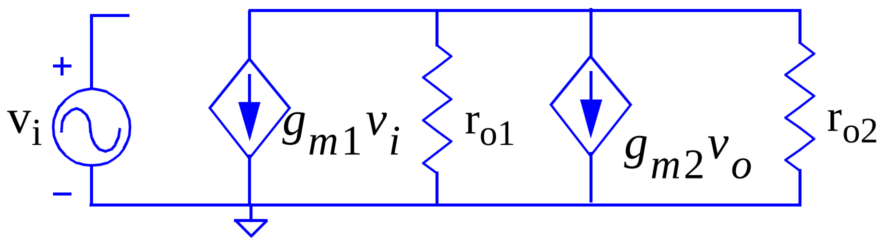


Small Signal Model

- M2 behaves like a resistor in the small signal model
- Why?

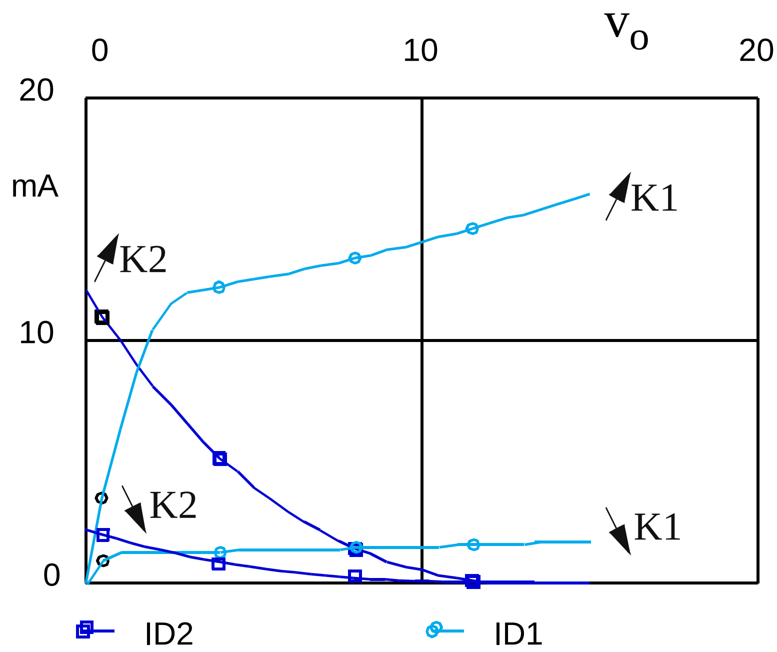


Small Signal Model



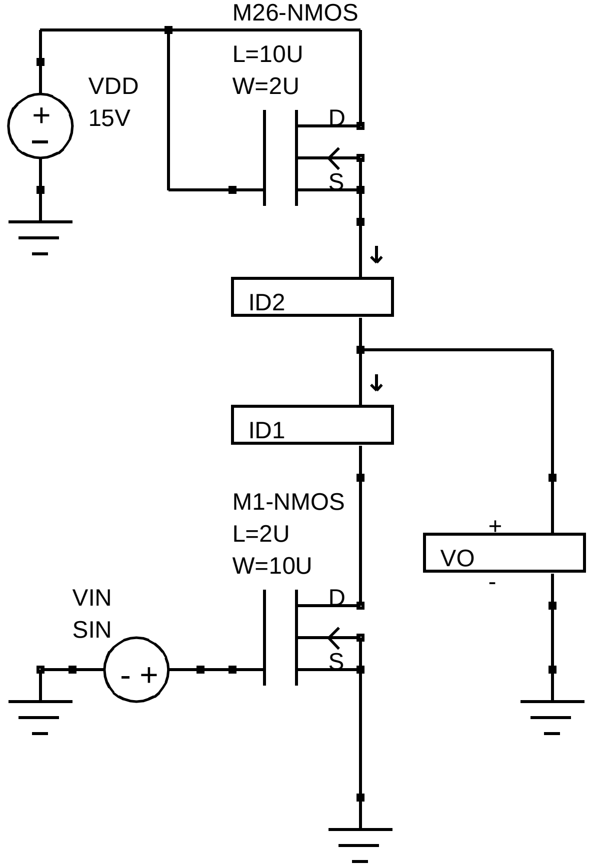
NMOS Amplifier Example

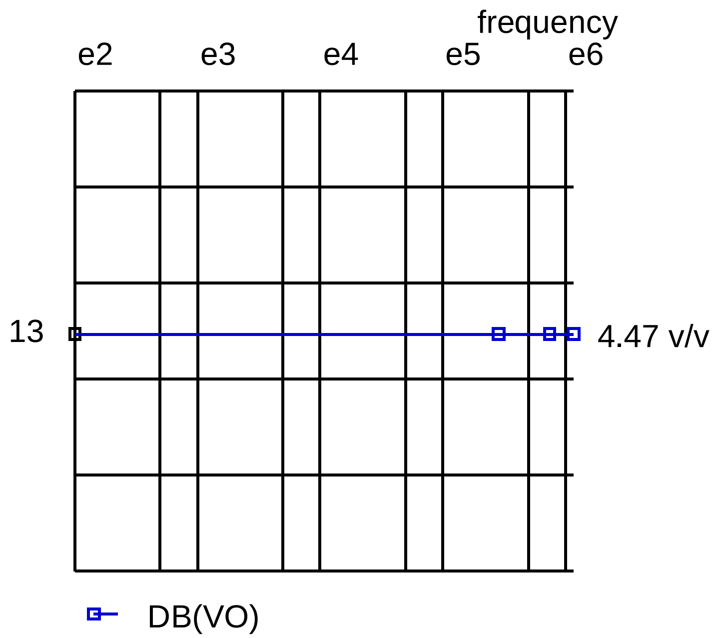
- We would tend to lower the “resistance” of the pull-up transistor (increase K2), or decrease the current levels of the amplifier transistor (decrease K1) to keep M1 in saturation
- But these changes tend to lower the gain



NMOS Amplifier Example

- Design objective is to make K1 as large as possible, and K2 as small as possible, to get a reasonable gain



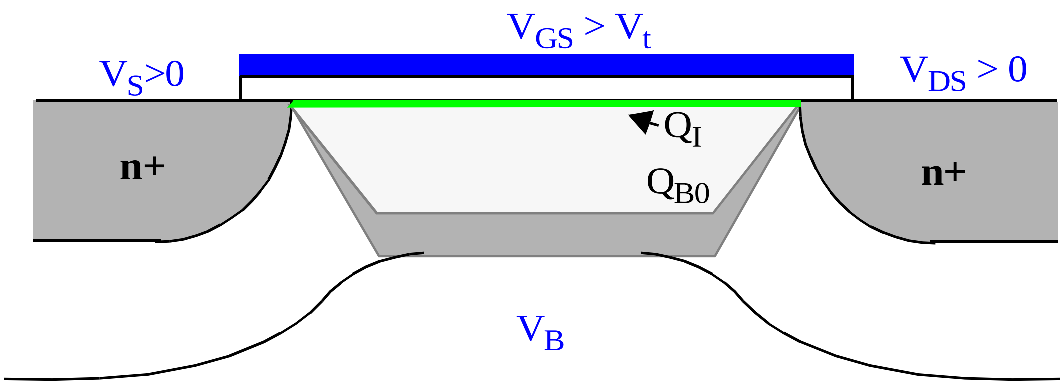


- Why the deviation from ideal gain?

Body Effect

- For discrete FETs there is no body effect since the source is tied to the body
- For ICs, all of the NFET body nodes are tied to the lowest potential in the ckt

- The source of our load transistor is not at the same potential as the substrate
- Source voltage partially modulates the channel --- back gate effect

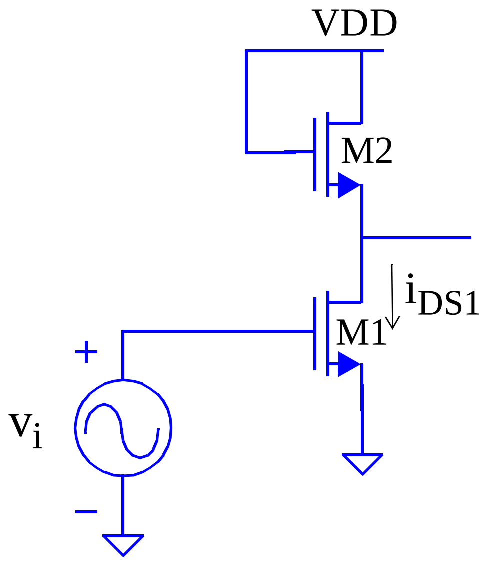


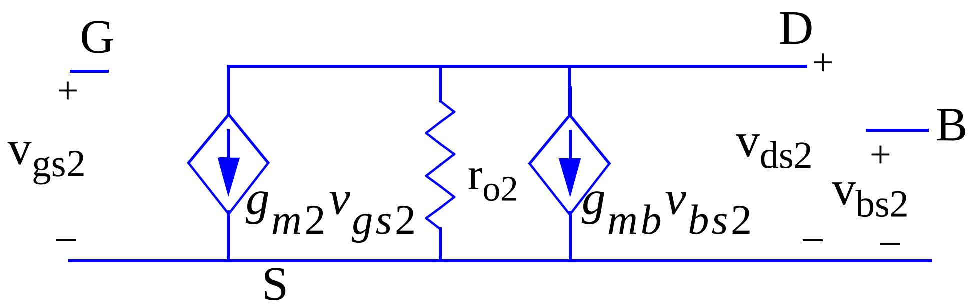
- For large signal behavior this is captured by the change in V_t based on the parameter, gamma

$$V_t = V_{t0} + \gamma(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f})$$

Body Effect

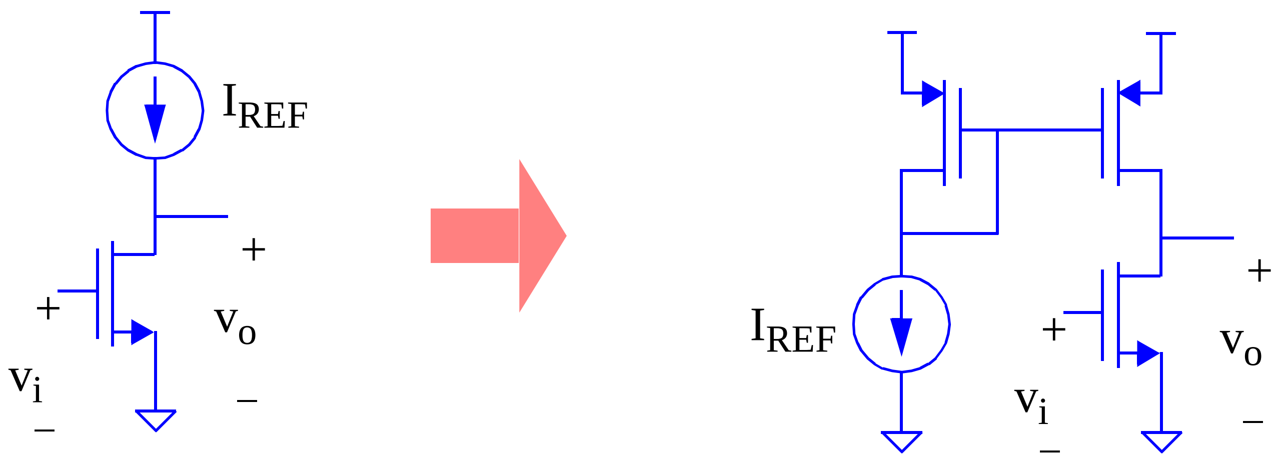
- The impact on the small signal model is a function of same parameters
- The change in v_o (which is the source voltage) modulates the back gate





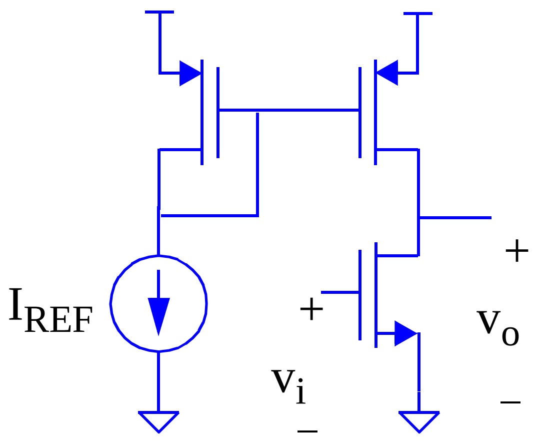
Common Source CMOS Amplifier --- Active Load

- Body effect is not as significant a problem for CMOS
- Current sources are used as pull-ups instead of resistors or load-transistors
- Having complementary types of transistors simplifies the implementation
- Is the body effect a factor for this amplifier?

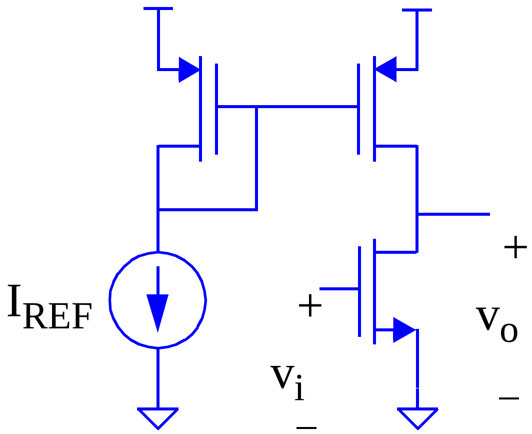


Common Source Small Signal Model

- Load line is now nearly a constant current --- huge gain
- What does the small signal model look like?



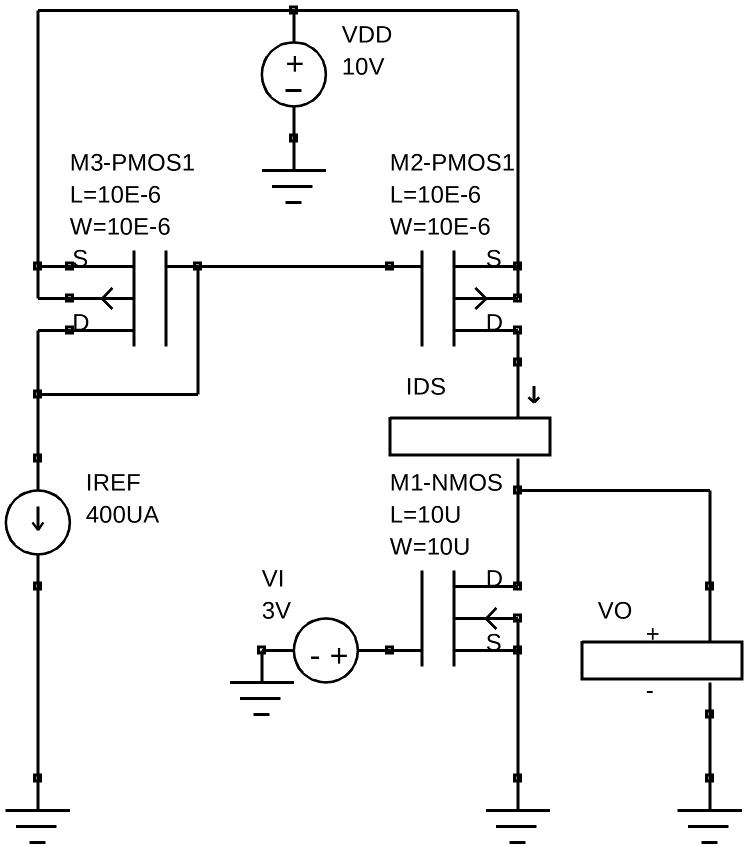
Common Source Small Signal Model

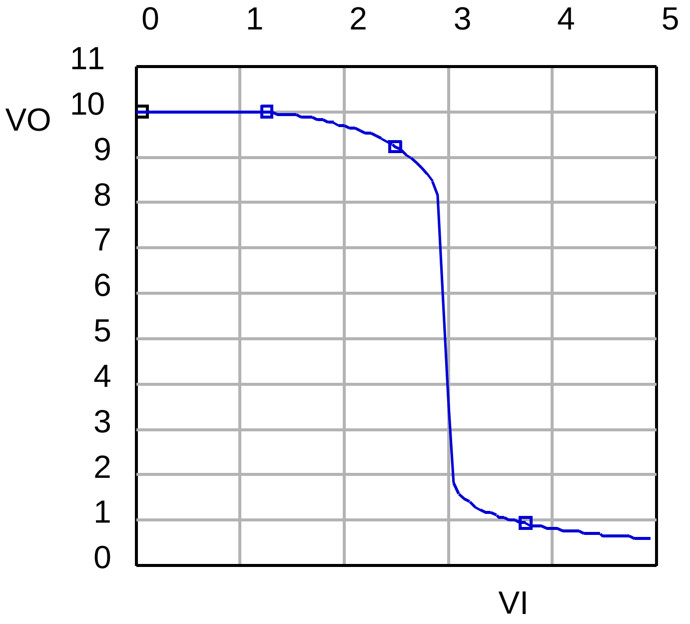


CMOS High Gain Region

- Input-output relation is very similar to a CMOS inverter

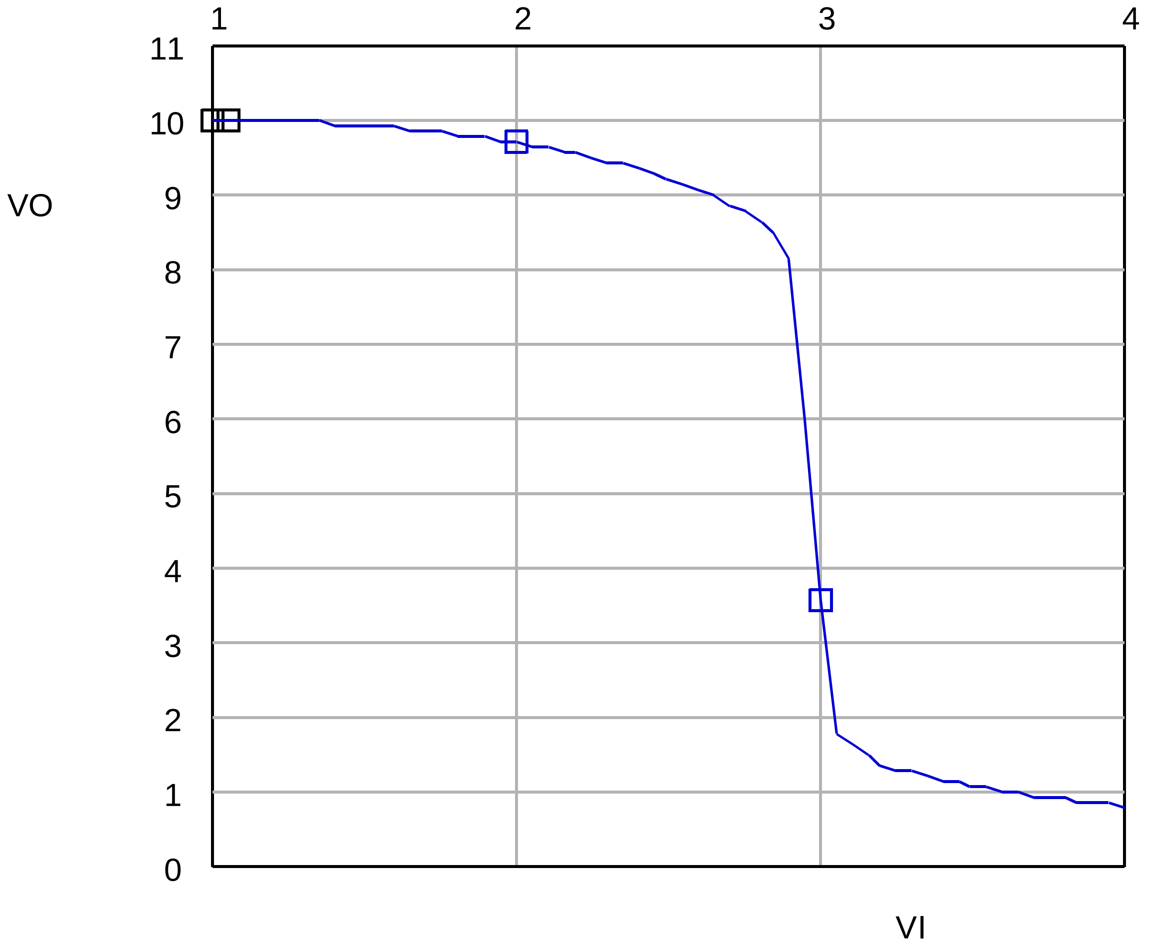
V_t = 1v   K=100μA/V^2 lamda=0.01





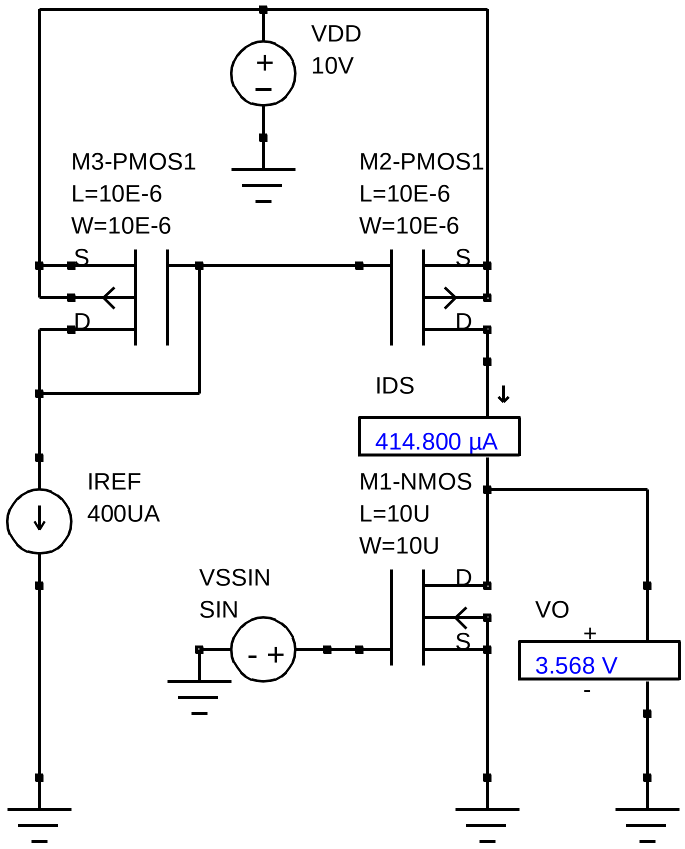
CMOS High Gain Region

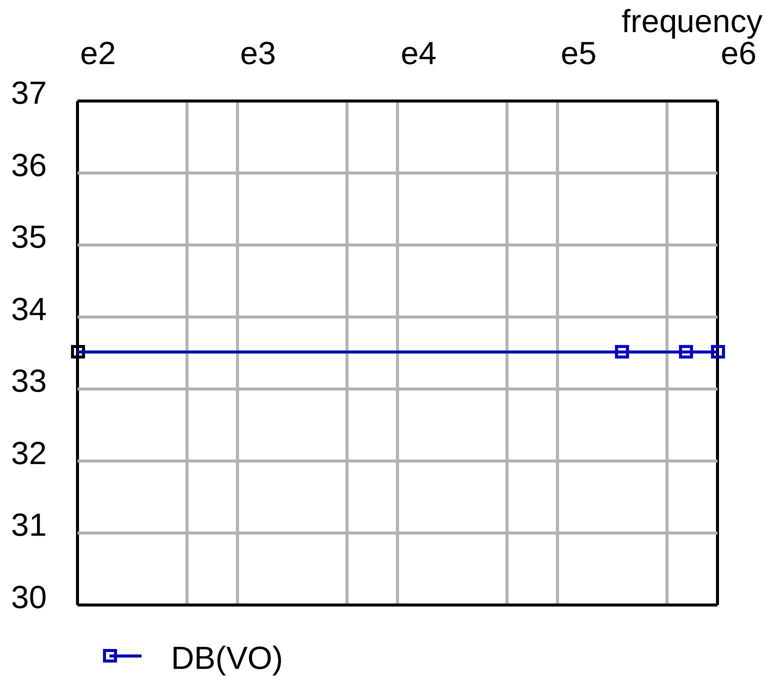
- What is the allowable range for v_o and v_i ?



ac Response

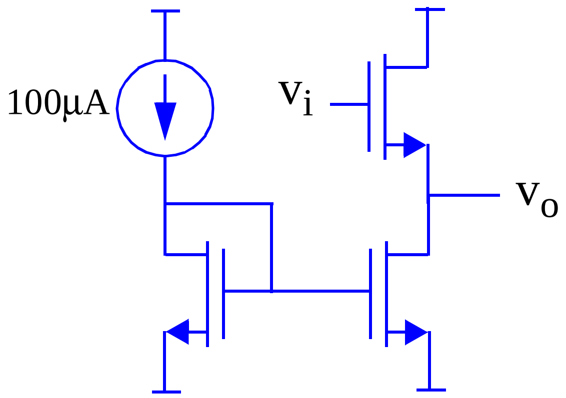
- Using an ac input with a 3 volt offset: $V_t = 1v$ $K=100\mu A/V^2$ lamda=0.01



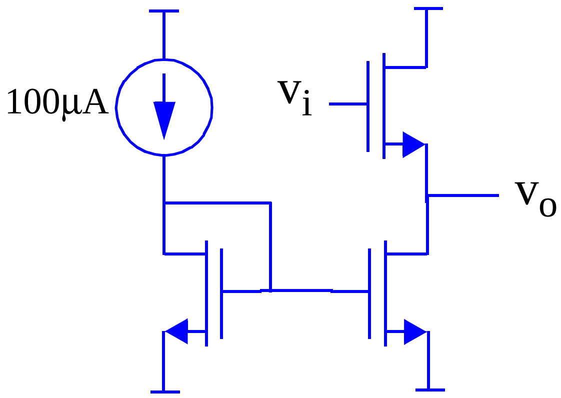


Common Drain (Source Follower) Amplifier

- Source Followers are used for output stages
- Gain less than unity, but provides low output resistance to drive loads



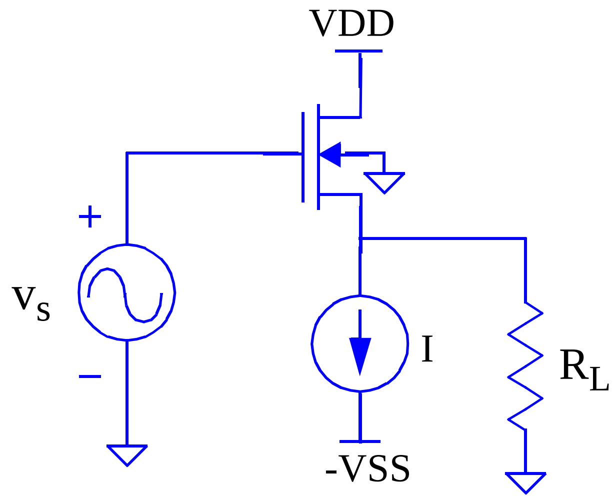
Common Drain (Source Follower) Amplifier



Common Drain (Source Follower) Amplifier

Source Follower

- For an emitter follower, the gain is the voltage division of input resistance and emitter resistance
- But the source follower is somewhat different from an impedance reflection standpoint



- Small signal impedance looking into the gate appears as an infinite resistor, while that from the perspective of the source is finite

Small Signal Model

- Assuming that R_L is infinite?