6.002x CIRCUITS AND ELECTRONICS

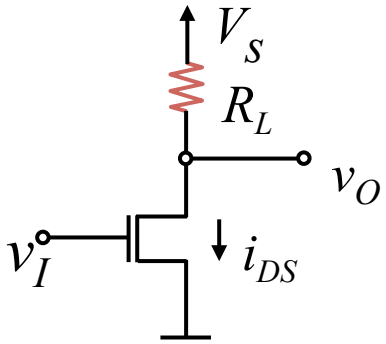
Amplifiers – Revisit Small Signal Trick



Reading: Amplifier small signal model -- Chapter 8 of A&L

Review

- MOSFET amp



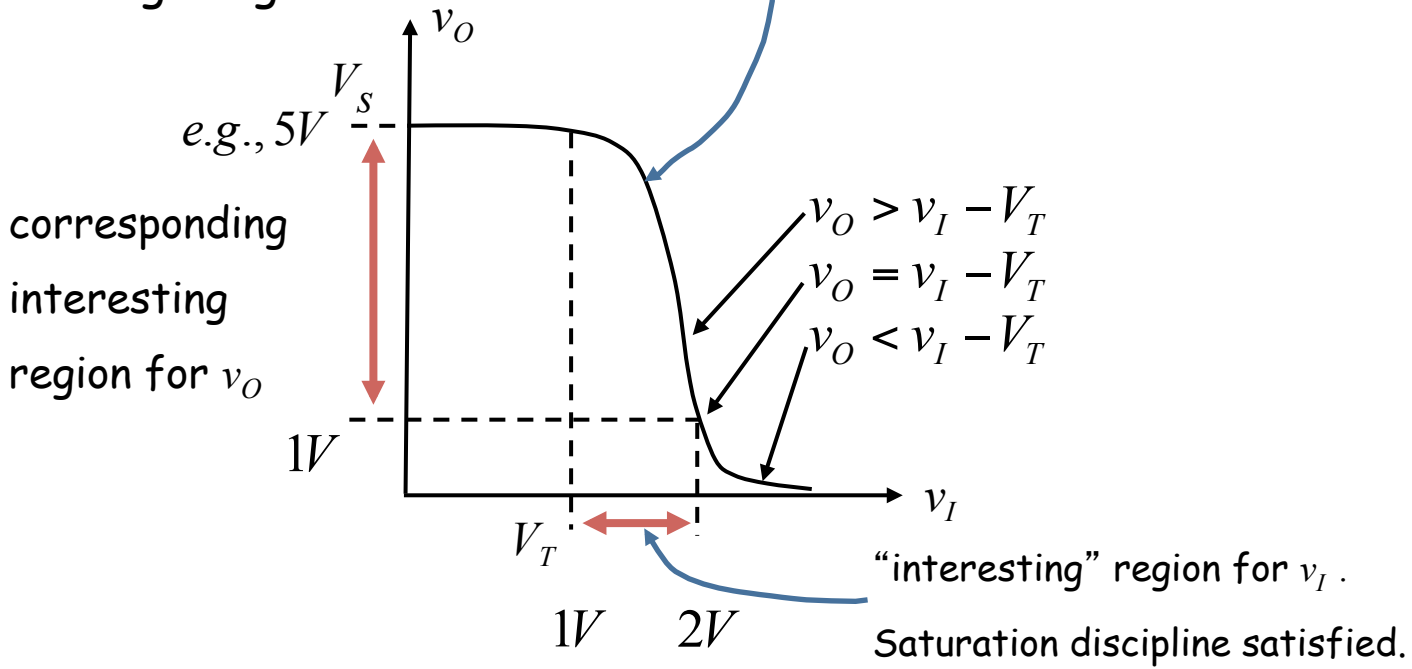
- Saturation discipline — operate MOSFET only in saturation region
- Large signal analysis
  1. Find v_O vs v_I under saturation discipline.
  2. Valid v_I, v_O ranges under saturation discipline.

Review Large Signal Analysis Review

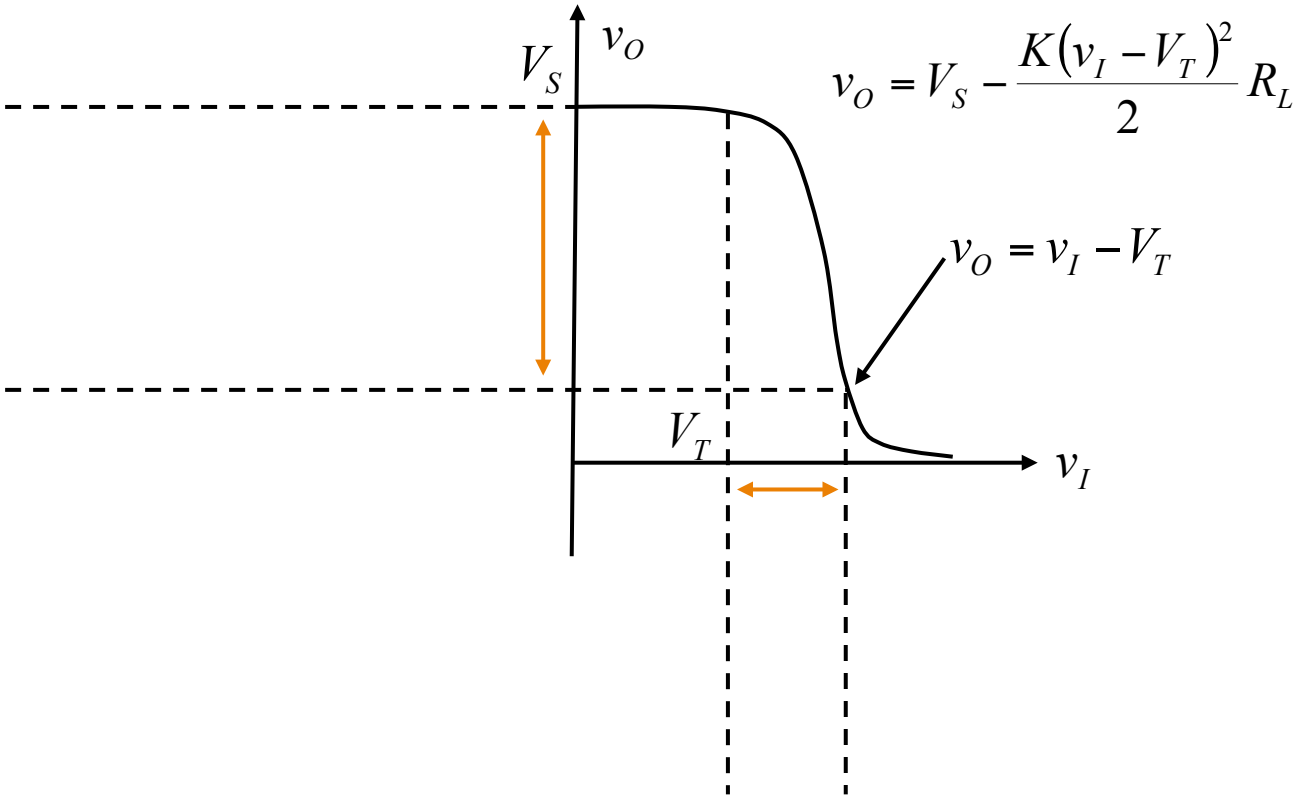
1. v_O vs v_I

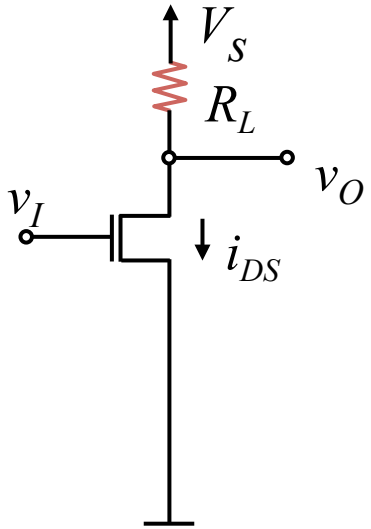
$$v_O = V_S - \frac{K(v_I - V_T)^2}{2} R_L$$

2. Valid operating ranges

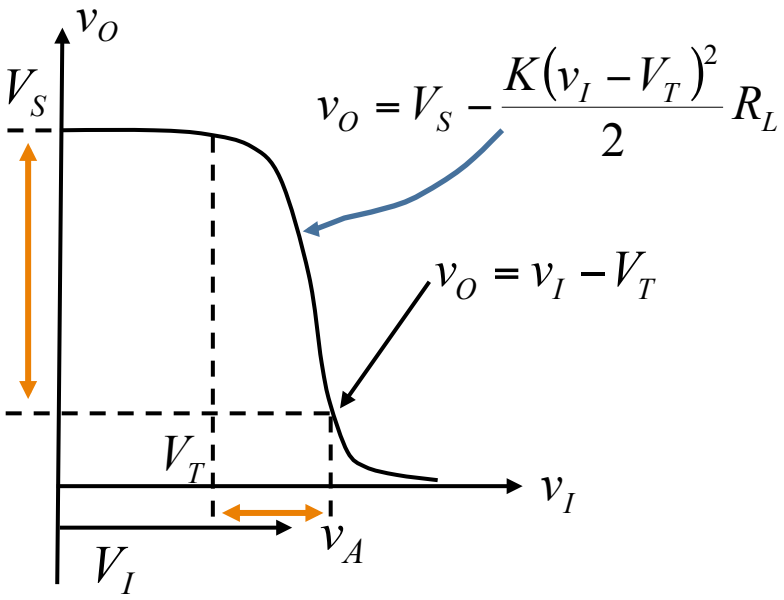


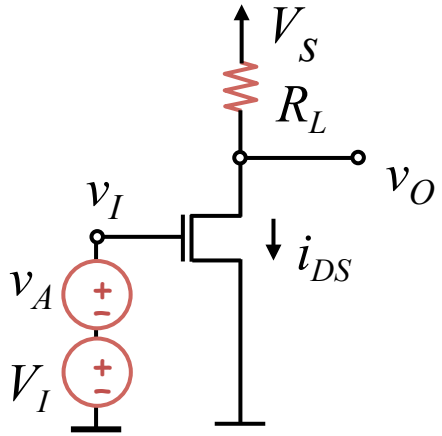
Operating in the saturation region





But…



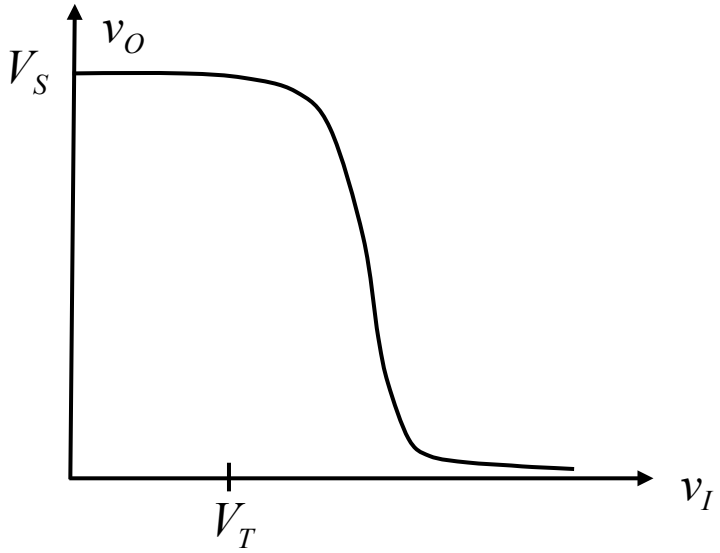


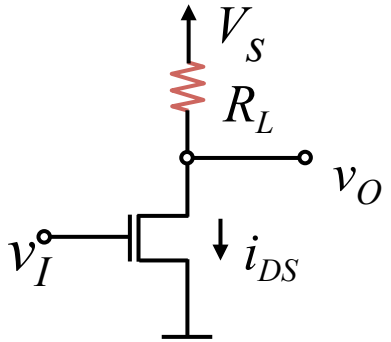
Demo

Amp is nonlinear … ☹

How do we get a linear amplifier?

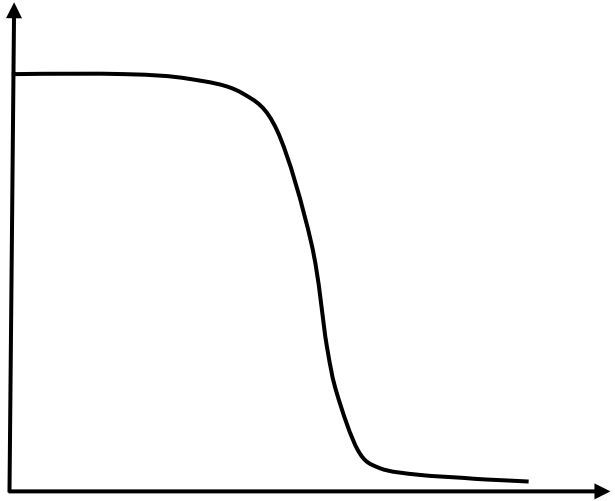
Small Signal Trick

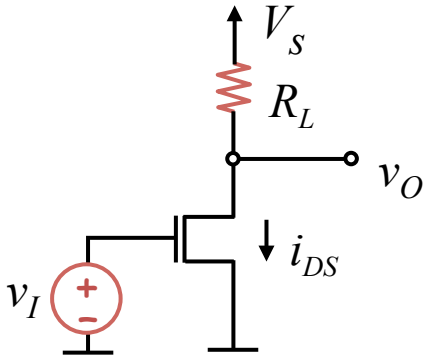




Small Signal Trick

Remember
"Boost and Shrink"

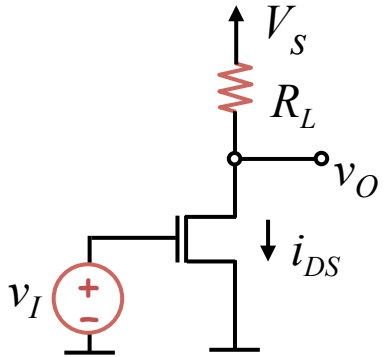




- Operate amp at V_I, V_O → DC "bias"
  (possible choice: midpoint of valid input operating range)
- Superimpose small signal of interest on top of V_I
- Response to small signal seems to be approximately linear

Boost – Use DC Bias

We use a DC bias V_I to "boost" interesting input signal above V_T (and in fact, well above V_T)



Let's look at this in more detail —

I graphically

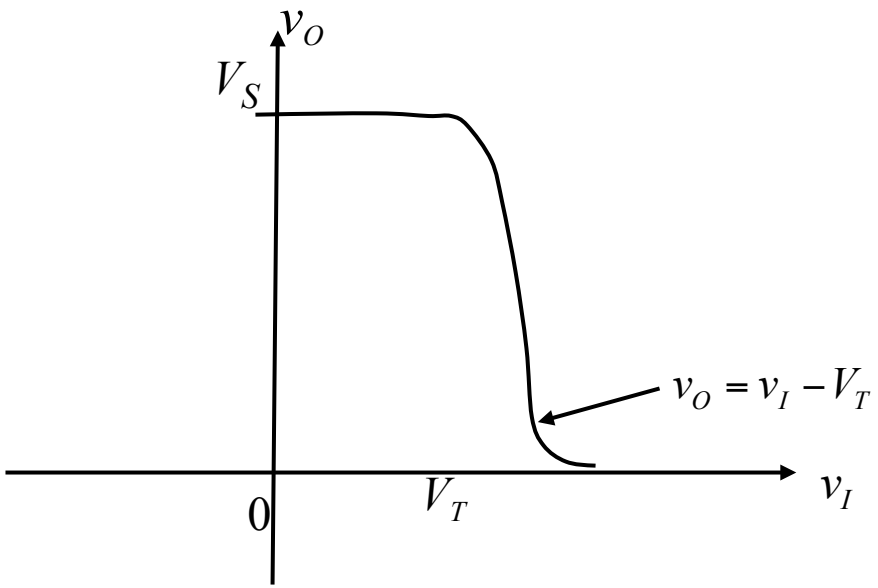
II mathematically

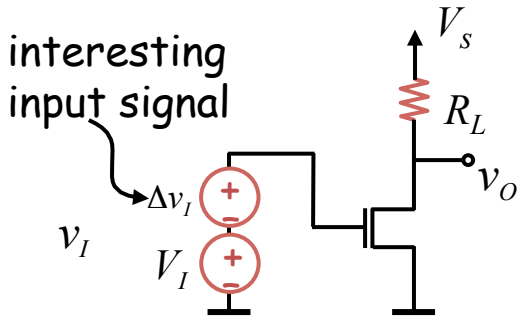
III from a circuit viewpoint



In the next sequence

I Graphically





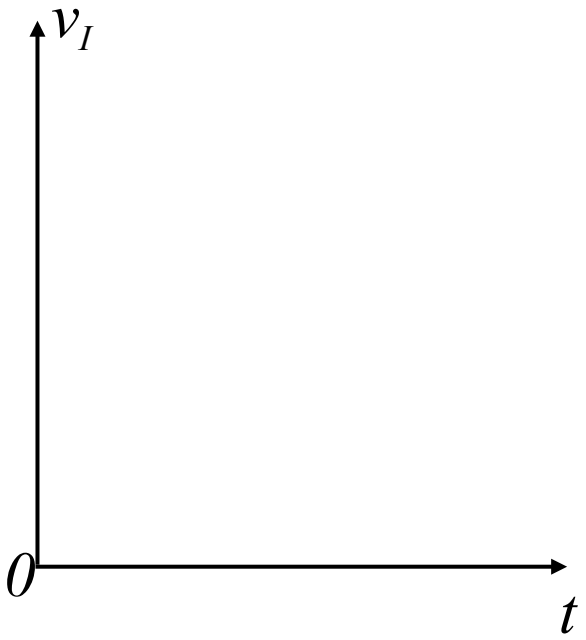
Recall Small Signal Model Notation

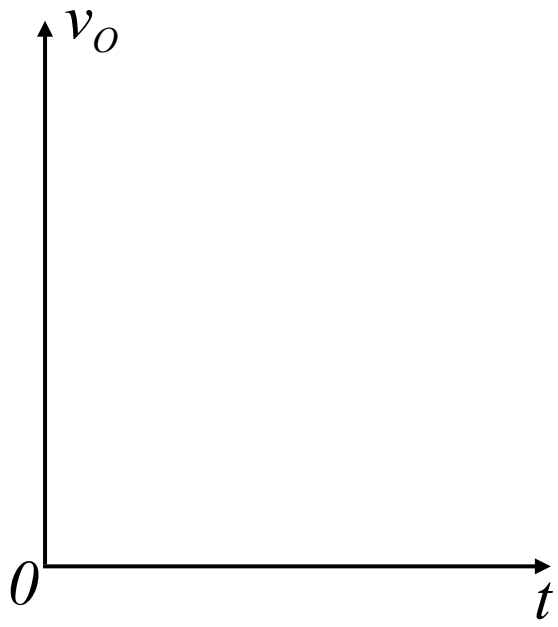
aka incremental model
aka linearized model

Small Signal Model

Input: $v_I = V_I + v_i$

Output: $v_O = V_O + v_o$





II Mathematically

$$v_O = V_S - \frac{R_L K}{2}\left(v_I - V_T\right)^2$$

… watch my fingers!

II Mathematically

$$v_O = V_S - \frac{R_L K}{2}\left(v_I - V_T\right)^2$$

… watch my fingers!

We will see why this is called transconductance in the next sequence

Transconductance related to MOSFET parameters and V_I

Mathematically

$$v_o = -R_L \underbrace{K\left(V_I - V_T\right)}_{g_m} v_i$$

g_m related to V_I

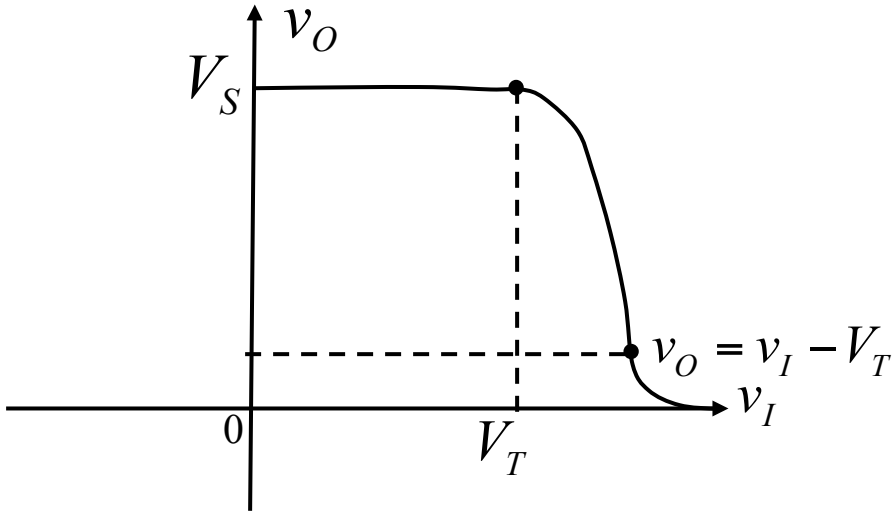
In other words, our circuit behaves like a linear amplifier for small signals

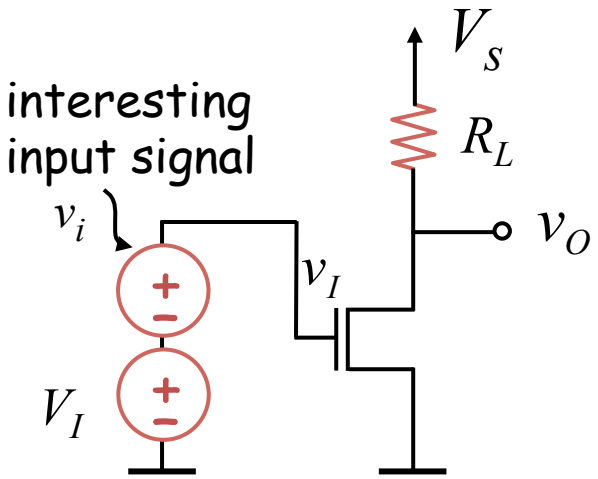
Another way

$$v_O = V_S - \frac{R_L K}{2}\left(v_I - V_T\right)^2$$

Also, see Figure 8.9 in the text for a graphical interpretation of this result

Small Signal Demo





Demo