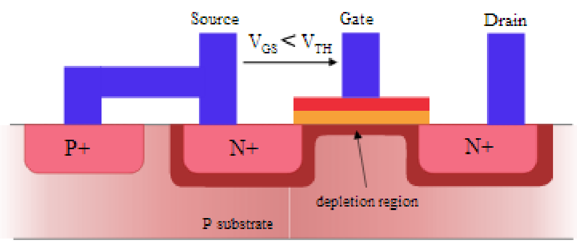
Reference:C:\Users\Bernhard Boser\Documents\Files\Lib\MathCAD\Default\defaults.mcd

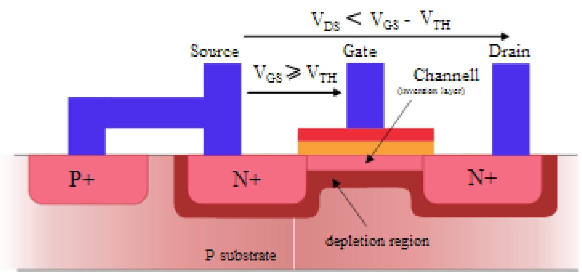
L11: Transconductor

Intro

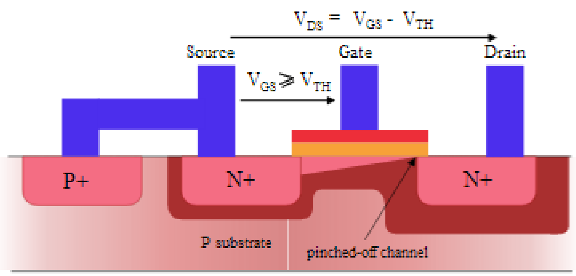
BJT vs MOS

- small-signal
- large signal:
  - MOS: linear/exponential, strong/weak inversion, quadratic
  - BJT: exponential

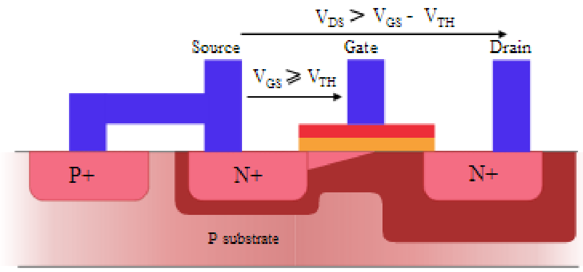




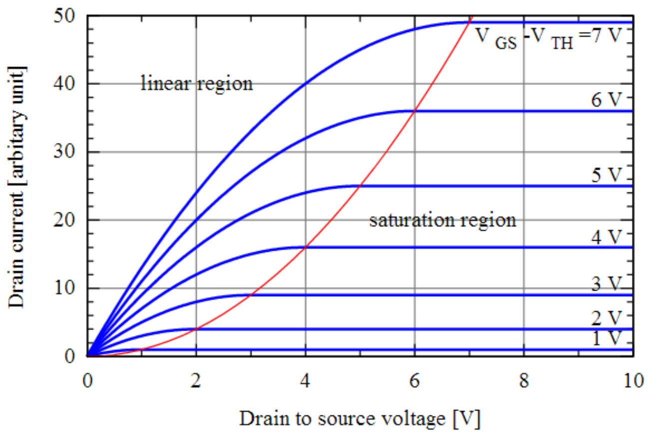
Linear operating region (ohmic mode)

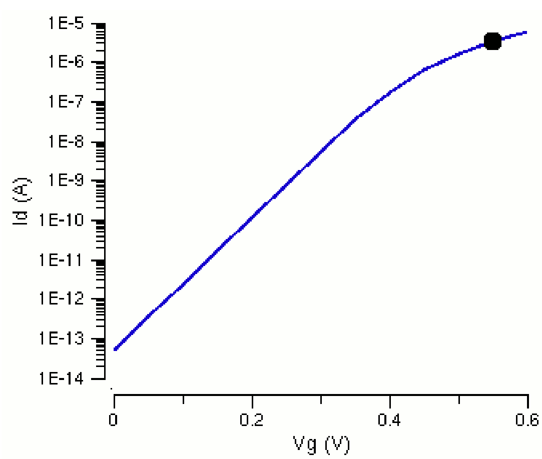


Saturation mode at point of pinch-off



Saturation mode





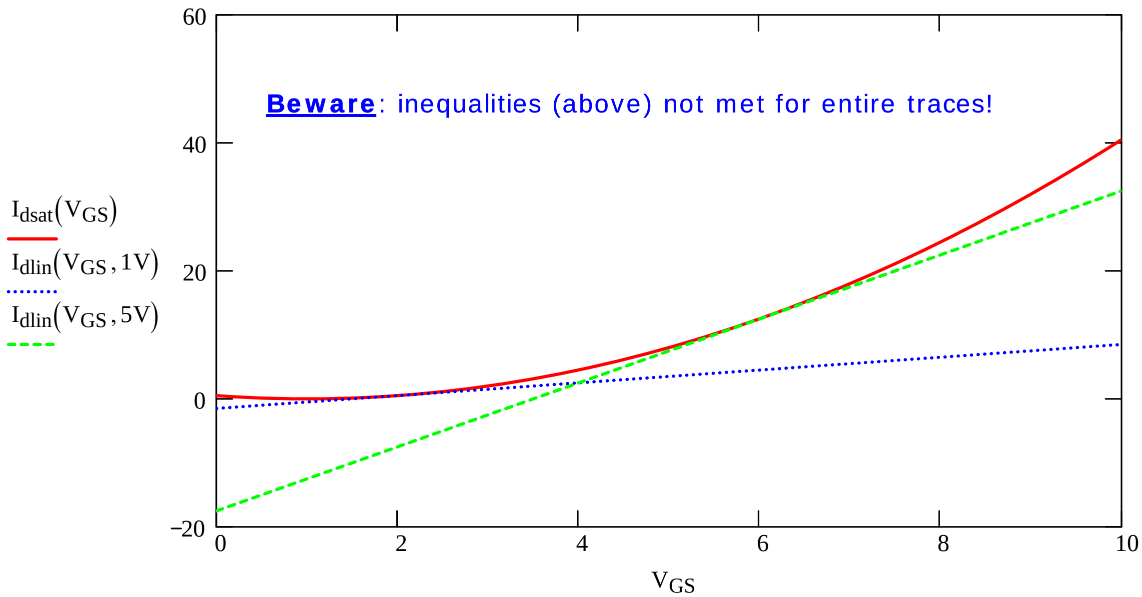
$k_p := 1$ $V_{TH} := 1V$

$$I_{dlin}(V_{GS}, V_{DS}) := k_p \cdot \left(V_{GS} - V_{TH} - \frac{V_{DS}}{2}\right) \cdot V_{DS}$$ for $V_{GS}>V_{TH}$ and $V_{DS} < V_{GS}-V_{TH}$

$$I_{dsat}(V_{GS}) := \frac{k_p}{2} \cdot (V_{GS} - V_{TH})^2$$ for $V_{GS}>V_{TH}$ and $V_{DS} > V_{GS}-V_{TH}$

$$I_{dweak}(V_{GS}) := e^{\frac{V_{GS}}{V_t}}$$

for $V_{GS} < V_{TH}$ and $V_{DS} > V_{GS} - V_{TH}$



Transconductor

$$I_o = G_m \cdot V_i$$

MOS Linear:
$$I_d = \mu \cdot C_{ox} \cdot \frac{W}{L} \cdot \left(V_{GS} - V_{TH} - \frac{V_{DS}}{2}\right) \cdot V_{DS}$$

Transconductance:
$$\frac{d}{dV_{GS}} \mu \cdot C_{ox.} \cdot \frac{W}{L} \cdot \left(V_{GS} - V_{TH} - \frac{V_{DS}}{2}\right) \cdot V_{DS} \text{ simplify } \rightarrow \mu \cdot C_{ox.} \cdot \frac{W}{L} \cdot V_{DS}$$

$$G_m = \frac{dI_d}{dV_{GS}} = \mu \cdot C_{ox.} \cdot \frac{W}{L} \cdot V_{DS}$$

depends on V_{DS}

BTW:
$$\frac{d}{dV_{DS}} \mu \cdot C_{ox.} \cdot \frac{W}{L} \cdot \left(V_{GS} - V_{TH} - \frac{V_{DS}}{2}\right) \cdot V_{DS} \text{ simplify } \rightarrow -\mu \cdot C_{ox.} \cdot W \cdot \frac{(V_{DS} - V_{GS} + \text{volt})}{L}$$

Eliminating V_{DS} dependence

Small Ri --> CG or CB. Which is preferable?

- BJT: lower Ri = 1/gm
- rpi in parallel with Rlin --> offset resistance
- Needs BiCMOS process

$$r_o = \frac{1}{g_o} = \frac{V_A}{I_C} \qquad \left(\frac{25\mu A}{100V}\right)^{-1} = 4\,M\Omega$$

Example: high gain amplifier with current source load