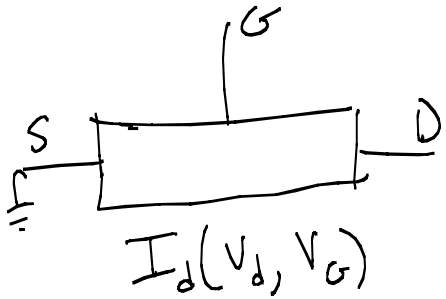
Plan: Junction FETs (today)

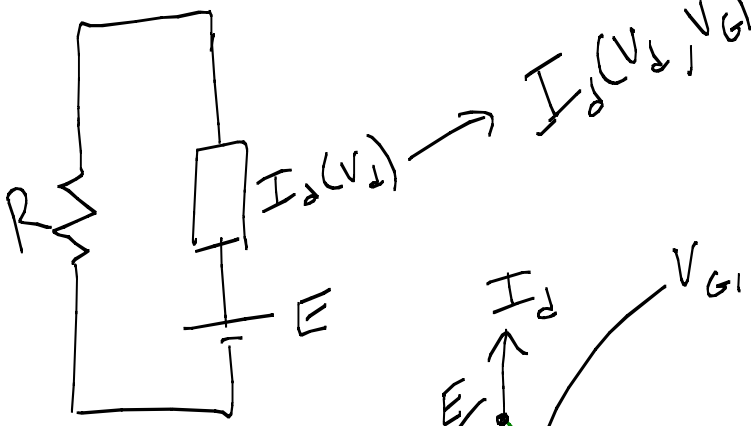
Metal-Oxide-Semiconductor FETs (11/27)

Bipolar Transistors (11/29)

Quiz 4 (12/4)

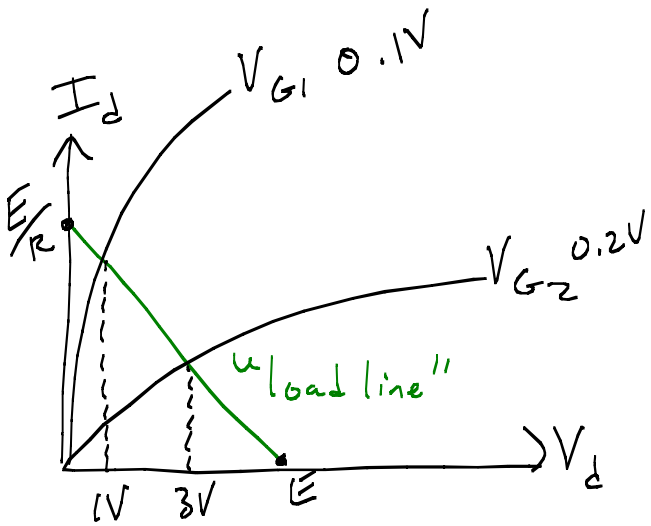
Transistors, amplification, "Load line"



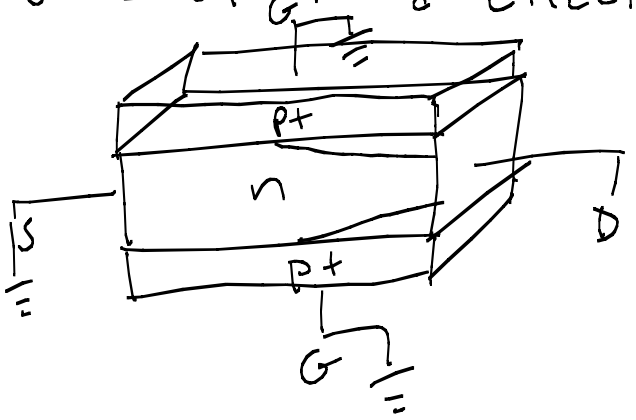


$$E = I_d R + V_d$$

$$I_d = \frac{E}{R} - \frac{V_d}{R}$$

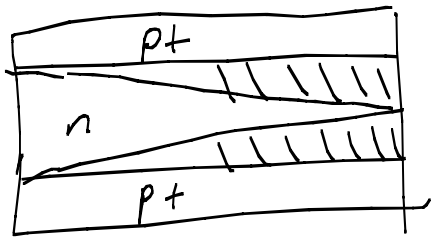


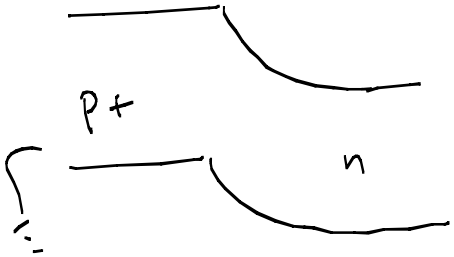
Junction field-effect transistor (JFET)

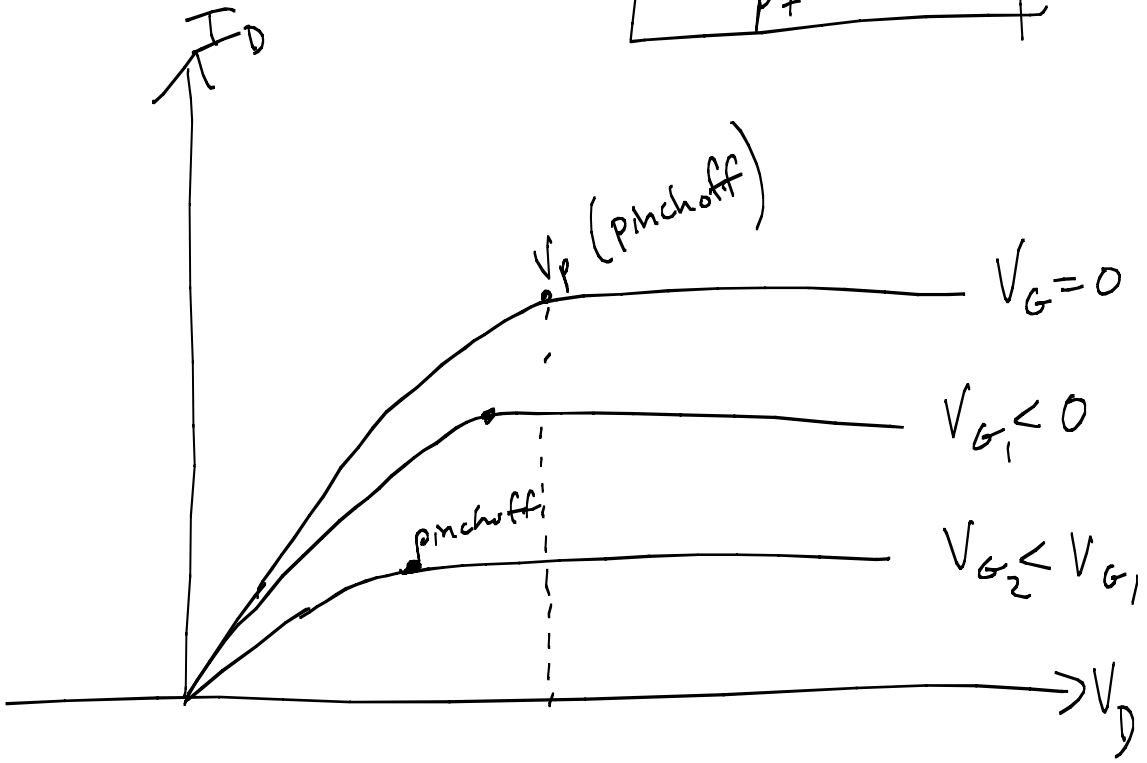


$$R = \frac{\rho L}{A}$$

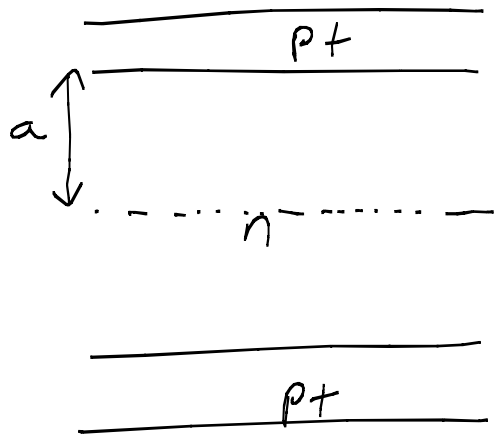
Pinchoff:







Pinchoff



pinchoff when $x_{n_0} = a$

$$\left(\frac{2\varepsilon (V_0 - V) N_a}{q N_d (N_a + N_d)} \right)^{1/2} = a$$

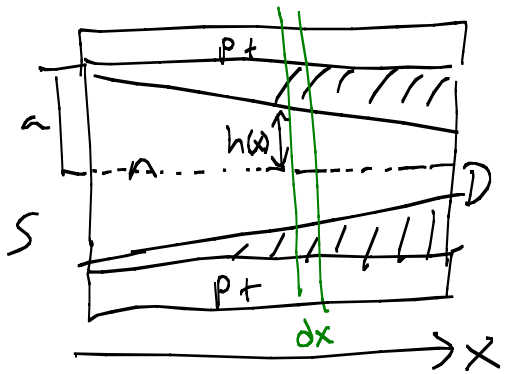
$N_a \gg N_d \quad V_0 - V \rightarrow V_p$

$$\left(\frac{2\varepsilon V_p}{q N_d} \right)^{1/2} = a$$

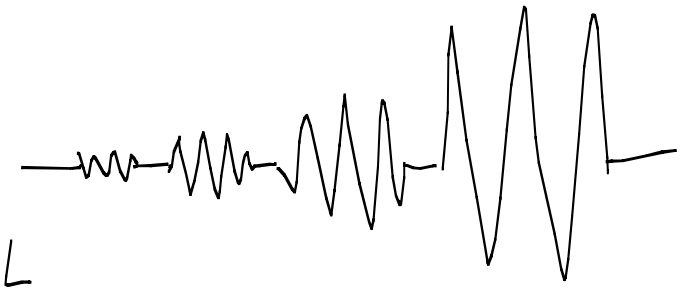
$$V_p = \frac{a^2 q N_d}{2\varepsilon} \qquad V_G = 0$$

Drain current (as a function of drain and gate voltage)

$I_D(V_D, V_G) = ?$

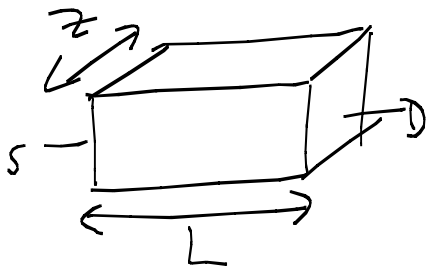


$\Longrightarrow$



$$R = \frac{\rho L}{A}$$

$$dR = \frac{\rho dx}{2hz}$$



$$I = \frac{dV}{dR} = \frac{2hz\,dV}{\rho\,dx}$$

$$\int_0^L I\,dx = \int_0^{V_D} \frac{2z}{\rho} h\,dV = \frac{2z}{\rho}\int_0^{V_D} h\,dV$$

$$IL = \frac{2z}{\rho}\int_0^{V_D} h\,dV \Longrightarrow I = \frac{2z}{\rho L}\int_0^{V_D} h\,dV$$

Evaluation of integral

$$\int_0^{V_D} h\, dV \qquad N_a \gg N_d$$

$$h(x) = a - \left(\frac{2\varepsilon V}{qN_d}\right)^{1/2} \Rightarrow a - \left(\frac{a^2 V}{V_p}\right)^{1/2} = a\left(1 - \left(\frac{V}{V_p}\right)^{1/2}\right)$$

$$\left(V_p = \frac{qN_d a^2}{2\varepsilon}\right)$$

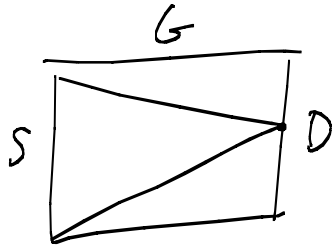
$$V \to V(x) - V_G$$

$$\int_0^{V_D} a\left(1 - \left(\frac{V(x) - V_G}{V_p}\right)^{1/2}\right) dV = a\left[V - \frac{2}{3}V_p\left(\frac{V - V_G}{V_p}\right)^{3/2}\right]\Bigg|_0^{V_D}$$

$$= a\left[V_D - \frac{2}{3}V_p\left(\frac{V_D - V_G}{V_p}\right)^{3/2} + \frac{2}{3}V_p\left(-\frac{V_G}{V_p}\right)^{3/2}\right]$$

$$I = \underbrace{\frac{2Za}{\rho L}}_{G_0} V_p\left[\frac{V_D}{V_p} - \frac{2}{3}\left(\frac{V_D - V_G}{V_p}\right)^{3/2} + \frac{2}{3}\left(-\frac{V_G}{V_p}\right)^{3/2}\right]$$

Saturation current @ pinchoff



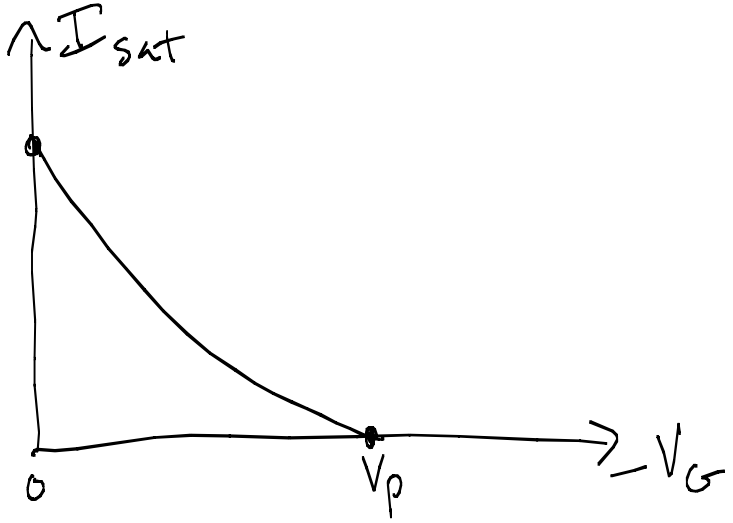
$$V_D - V_G = V_p$$

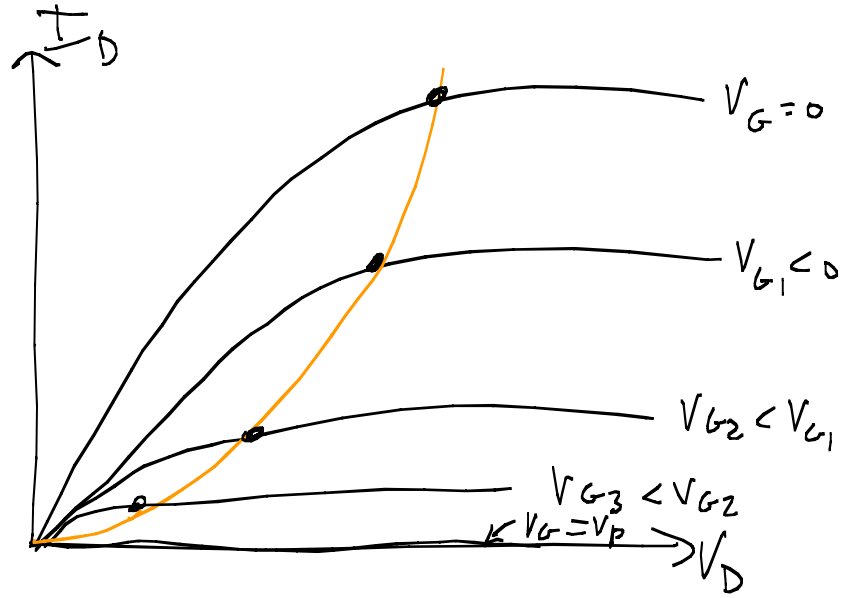
$$\frac{V_D}{V_p} - \frac{V_G}{V_p} = 1$$

$$\frac{V_D}{V_p} = 1 + \frac{V_G}{V_p}$$

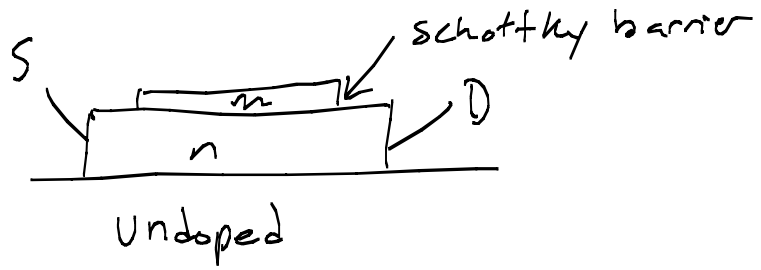
$$I_{sat} = G_0 V_p \left[1 + \frac{V_G}{V_p} - \frac{2}{3}\left(\frac{V_p}{V_p}\right)^{3/2} + \frac{2}{3}\left(-\frac{V_G}{V_p}\right)^{3/2} \right]$$

$$= G_0 V_p \left[\frac{1}{3} + \frac{V_G}{V_p} + \frac{2}{3}\left(-\frac{V_G}{V_p}\right)^{3/2} \right]$$





MESFET



HEMT

2DEG channel