o Cutoff region — Point B

$$\boxed{\begin{aligned} V_I &= V_t \\ V_O &= V_{DD} \end{aligned}}$$

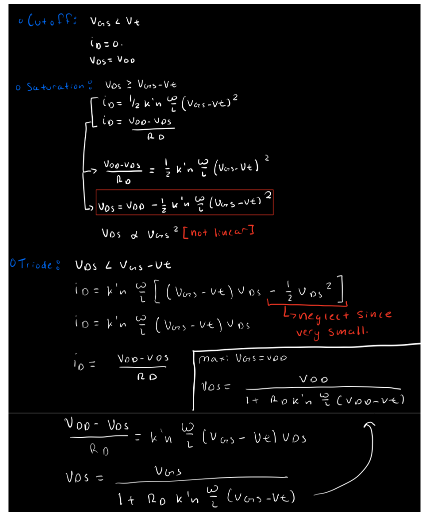
$I_D = 0$

o Edge of saturation — Point B

$$\boxed{\begin{aligned} &V_O = V_I - V_t \\ &\uparrow \qquad\ \uparrow \\ &V_{DS} \quad V_{GS} \end{aligned}}$$

$$\boxed{V_{DS} = V_{GS} - V_t}$$

$$\boxed{V_{GS} = V_t + \frac{\sqrt{1 + 2\left((R_D)(k'_n)(W/L)(V_{DD})\right)} - 1}{(R_D)(k'_n)(W/L)}}$$



o Cutoff: $V_{GS} < V_t$

$i_D = 0$.

$V_{DS} = V_{DD}$

o Saturation: $V_{DS} \geq V_{GS} - V_t$

$i_D = \frac{1}{2} k'_n \frac{W}{L} (V_{GS} - V_t)^2$

$i_D = \frac{V_{DD} - V_{DS}}{R_D}$

$\rightarrow \frac{V_{DD} - V_{DS}}{R_D} = \frac{1}{2} k'_n \frac{W}{L} (V_{GS} - V_t)^2$

$\rightarrow \boxed{V_{DS} = V_{DD} - \frac{1}{2} k'_n \frac{W}{L} (V_{GS} - V_t)^2}$

$V_{DS} \propto V_{GS}^2$ [not linear]

o Triode: $V_{DS} < V_{GS} - V_t$

$i_D = k'_n \frac{W}{L} \left[(V_{GS} - V_t) V_{DS} - \underbrace{\tfrac{1}{2} V_{DS}^2}_{} \right]$

↳ neglect since very small.

$i_D = k'_n \frac{W}{L} (V_{GS} - V_t) V_{DS}$

$i_D = \frac{V_{DD} - V_{DS}}{R_D}$

max: $V_{GS} = V_{DD}$

$V_{DS} = \frac{V_{DD}}{1 + R_D k'_n \frac{W}{L} (V_{DD} - V_t)}$

$\frac{V_{DD} - V_{DS}}{R_D} = k'_n \frac{W}{L} (V_{GS} - V_t) V_{DS}$

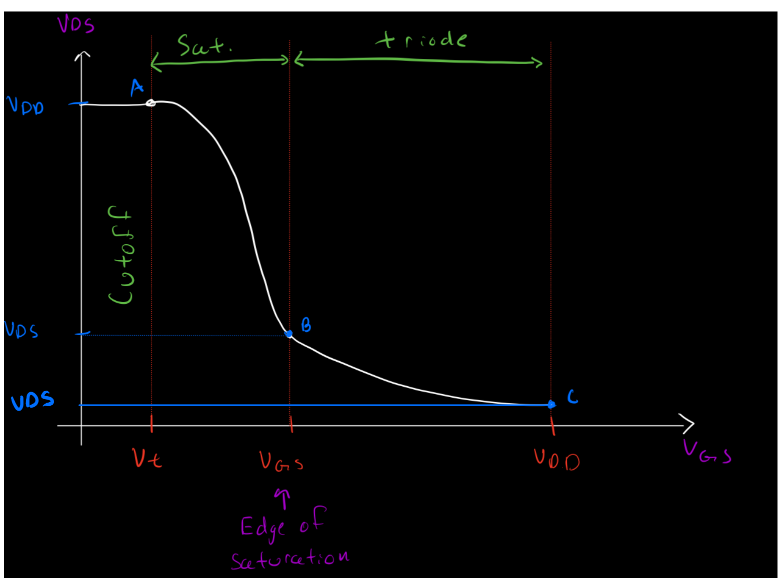
$V_{DS} = \frac{V_{GS}}{1 + R_D k'_n \frac{W}{L} (V_{GS} - V_t)}$

↑ see module 6 notes ?

o Triode Region — Point C

$$\boxed{V_{GS} = V_I = V_{DD}}$$

$$\boxed{V_{DS} = V_O = \frac{V_{GS}}{1 + R_D k'_n \frac{W}{L} (V_{GS} - V_t)}}$$

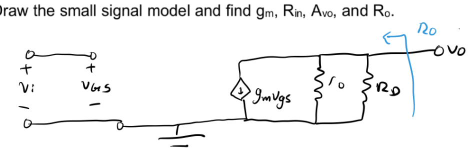


$$A_{vo} = \frac{v_o}{v_i} = -g_m R_D = -\left(k'_n \frac{W}{L} (V_{IQ} - V_t)\right) R_D$$

$$I_{DQ} = \frac{1}{2} k'_n \frac{W}{L} (V_{GSQ} - V_t)^2$$

$$g_m = k'_n \frac{W}{L} (V_{GSQ} - V_t)$$

b. Draw the small signal model and find g_m, R_{in}, A_{vo}, and R_o.



$R_{in} = \infty$

$g_m = k'_n \frac{W}{L} (V_{GSQ} - V_t) = (.4)(10)(.716 - .4)$

$g_m = 1.264\ mA/V$

$r_o = \frac{V_A}{I_{DQ}} = \frac{10}{.2E-3} = 50k\Omega$

$R_o = r_o \parallel R_D = 50 \parallel 6.2 = 5.52\ k\Omega$

$A_{vo} = \frac{v_o}{v_i} = -g_m (r_o \parallel R_D)$

$= -1.264(5.52)$

$A_{vo} = -6.98\ V/V$

$$R_o = \frac{1}{g_m}$$

$$G_v = \frac{R_L}{R_L + 1/g_m}$$

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots \frac{1}{R_n}$$