

0 Cutoff region - Point B

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

$$I_D = 0$$

0 Edge of saturation - Point B

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

$$V_{OS} = V_{GS} - V_t$$

$$V_{GS} = V_t + \sqrt{\frac{1 + 2((R_D)(k'n)(w/L)(V_{DD}) - 1)}{(R_D)(k'n)(w/L)}}$$

0 Cutoff: $V_{GS} < V_t$
 $i_D = 0$
 $V_{OS} = V_{DD}$

0 Saturation: $V_{GS} \geq V_{GS} - V_t$
 $i_D = \frac{1}{2} k'n \frac{w}{L} (V_{GS} - V_t)^2$
 $i_D = \frac{V_{DD} - V_{OS}}{R_D}$
 $\frac{V_{DD} - V_{OS}}{R_D} = \frac{1}{2} k'n \frac{w}{L} (V_{GS} - V_t)^2$
 $V_{OS} = V_{DD} - \frac{1}{2} k'n \frac{w}{L} (V_{GS} - V_t)^2 R_D$
 $V_{OS} \propto V_{GS}^2$ [not linear!]

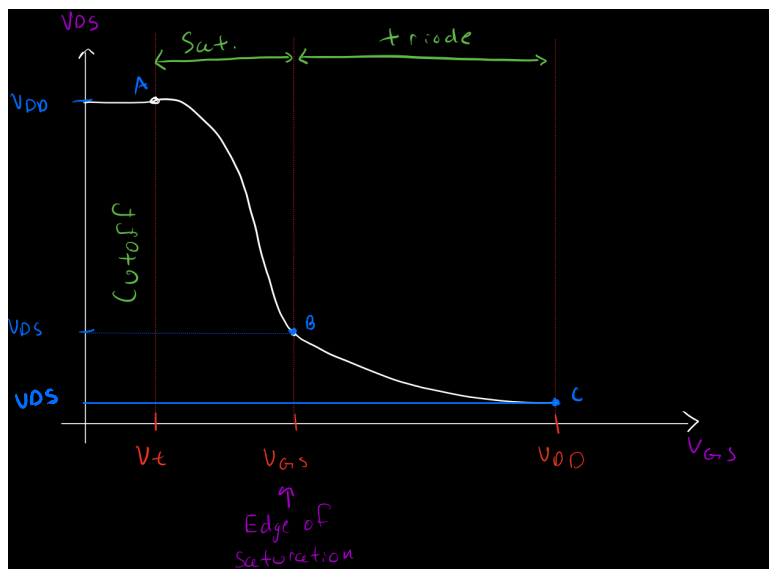
0 Triode: $V_{GS} < V_{GS} - V_t$
 $i_D = k'n \frac{w}{L} \left[(V_{GS} - V_t) V_{OS} - \frac{1}{2} V_{OS}^2 \right]$
 $i_D = k'n \frac{w}{L} (V_{GS} - V_t) V_{OS}$ [neglect since very small]
 $i_D = \frac{V_{DD} - V_{OS}}{R_D}$
 $V_{OS} = \frac{V_{DD} - V_{OS}}{1 + R_D k'n \frac{w}{L} (V_{GS} - V_t)}$
 $\frac{V_{DD} - V_{OS}}{R_D} = k'n \frac{w}{L} (V_{GS} - V_t) V_{OS}$
 $V_{OS} = \frac{V_{GS}}{1 + R_D k'n \frac{w}{L} (V_{GS} - V_t)}$

↑
see module 6 notes!

0 Triode Region - Point C

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

$$V_{OS} = V_O = \frac{V_{GS}}{1 + R_D k'n \frac{w}{L} (V_{GS} - V_t)}$$



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

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

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

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



$$R_{in} = \infty$$

$$g_m = k'_n \frac{W}{L} (V_{GSQ} - V_t) = (4)(10)(7.16 - 4)$$

$$g_m = 1.264 \text{ mA/V}$$

$$r_o = \frac{V_A}{I_{DQ}} = \frac{10}{0.25} = 50 \text{ k}\Omega$$

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

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

$$= -1.264(5.52)$$

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

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

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

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

