HW#4

5.14	5.27
5.17	5.29
5.18	5.44 (a) & (b)
5.19	

EXAM 1 GRADES

A	8
B	13
C	8
D	2
F	4

AVG ≈ 78

EXAM 1 REVIEW

① 10 kΩ & 100 kΩ, INV. AMP.

a) $A_{CL} = -\frac{R_2}{R_1} = -\frac{10}{100} = \boxed{-0.1}$

$= -\frac{100}{10} = \boxed{-10}$

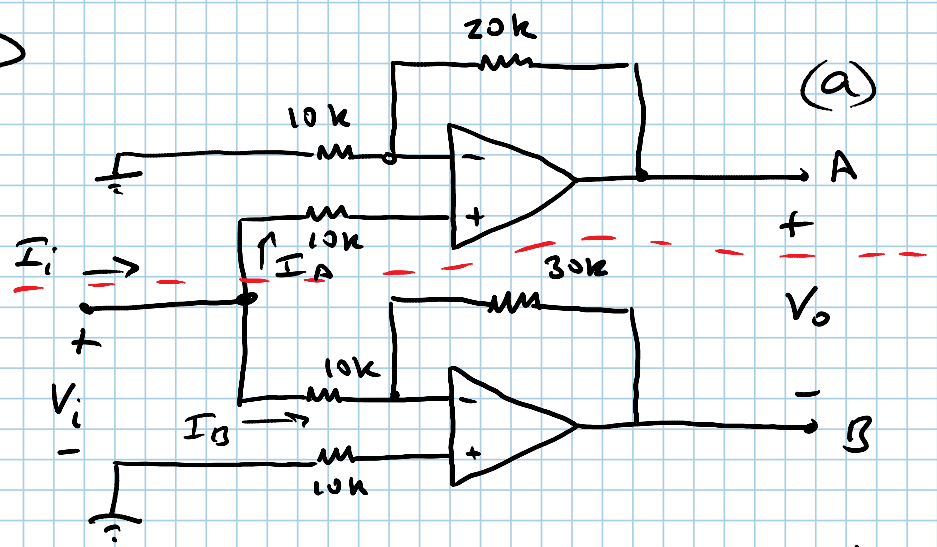
b) $A_{OL} = 100\left(\frac{V}{V}\right)$ $\quad A_{CL} = ?$

$$A_{CL} = -\frac{R_2}{R_1 + \frac{R_1 + R_2}{A_{OL}}} = \frac{10}{100 + \left(\frac{100+10}{100}\right)} = \boxed{-0.0989}$$

$$= \frac{100}{10 + \left(\frac{100+10}{100}\right)} = \boxed{-9.01}$$

EXAM 1 REVIEW (CONT.)

②



(a) $I_A = \emptyset A$

$\therefore I_i = I_B$

$V_o = V_A - V_B$

$V_A = \left(1 + \frac{20k}{10k}\right) V_i = 3V_i$

$V_B = -\left(\frac{30k}{10k}\right) V_i = -3V_i$

$V_o = 3V_i - (-3V_i) = 6V_i$

$A_{cl} = \frac{V_o}{V_i} = \boxed{6}$

b) FIND $R_i = \frac{V_i}{I_i}$, $I_i = I_B = \frac{V_i - 0}{10k} = \frac{V_i}{10k}$ ✓

$R_i = \frac{V_i}{V_i/10k} = \boxed{10k\Omega}$

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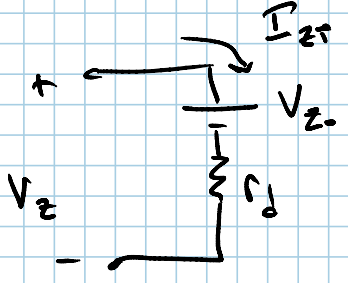
③

$V_Z = V_{Z0} + I_{ZT} r_d \Rightarrow \left(V_{Z0} = V_Z - I_{ZT} r_d\right)$

$10V = V_{Z0} + (10mA)(0.05k\Omega) \Rightarrow \boxed{V_{Z0} = 9.5\,V}$ (C)



a) IF $I_{ZT} = 5mA$ $V_Z = ?$

$V_Z = V_{Z0} + I_{ZT} r_d$

$= 9.5V + (5mA)(0.05k\Omega)$

$\boxed{V_Z = 9.75\,V}$

b) IF $I_{ZT} = 20mA$, $V_Z = ?$

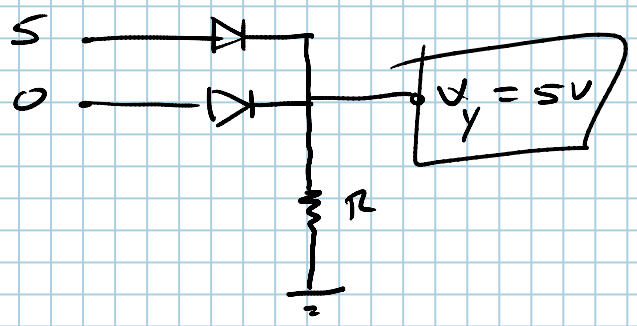
$V_Z = V_{Z0} + I_{ZT} r_d = 9.5\,V + (20mA)(0.05k\Omega)$

$\boxed{V_Z = 10.5\,V}$

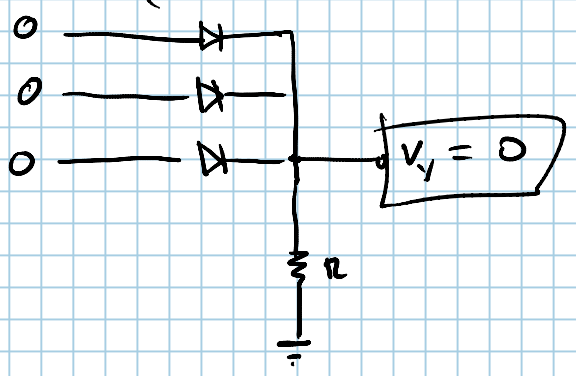
EXAM 1 REVIEW (CONT.)

④

(a)

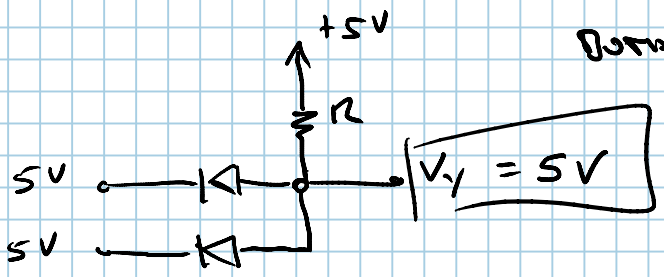


(b)



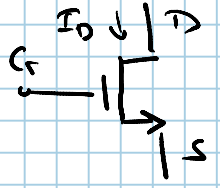
(c)

BOTH DIODES = R.B.



EXAM 2 : 16 JULY 2015

NMOS

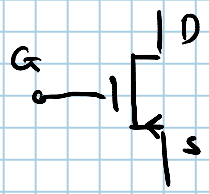


TRIODE OPERATION: $I_D = k_n'\left(\frac{W}{L}\right)\left[(V_{GS}-V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$

SATURATION OPERATION: $I_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)(V_{GS}-V_t)^2$

$V_{DS} \geq V_{GS} - V_t$

PMOS



TRIODE OPERATION: $I_D = k_p'\left(\frac{W}{L}\right)\left[(V_{GS}-V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$

SATURATION OPERATION: $I_D = \frac{1}{2}k_p'\left(\frac{W}{L}\right)(V_{GS}-V_t)^2$

	V_t	V_{GS}	TRIODE	SATURATION
NMOS	>0	$\geq V_t$	$V_{DS} < V_{GS}-V_t$	$V_{DS} \geq V_{GS}-V_t$
PMOS	<0	$\leq V_t$	$V_{DS} > V_{GS}-V_t$	$V_{DS} \leq V_{GS}-V_t$

3 REGIONS OF OPERATION: CUT-OFF ($i_D = 0$)

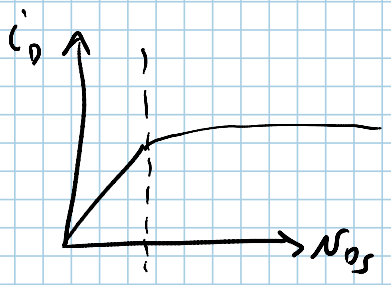
TRIODE

SATURATION

(NMOS)

TRIODE OPERATION: $v_{GS} \geq V_t$ (INDUCED CHANNEL)

AND KEEP v_{DS} SMALL ENOUGH FOR A CONTINUOUS CHANNEL.



$$v_{DS} < v_{GS} - V_t$$

$$v_{DS} - v_{GS} < -V_t$$

$$v_D - v_S - (v_G - v_S) < -V_t$$

$$v_D - v_G < -V_t$$

$$v_G - v_D > V_t \Rightarrow \boxed{v_{GD} > V_t}$$ (INDUCED, CONTINUOUS CHANNEL, TRIODE)

$$i_D = k_n' \left(\frac{W}{L}\right)\left[(v_{GS} - V_t)v_{DS} - \tfrac{1}{2}v_{DS}^2\right], \quad k_n' = \mu_n C_{ox}$$

IF v_{DS} ≡ VERY SMALL $\Rightarrow$ $\boxed{i_D \approx k_n'\left(\frac{W}{L}\right)(V_{GS} - V_t)v_{DS}}$

$$r_{DS} = \frac{v_{DS}}{i_D} = \left[k_n'\left(\frac{W}{L}\right)(V_{GS} - V_t)\right]^{-1} \quad (v_{DS} \equiv \text{SMALL},\ v_{GS} = V_{GS})$$

SATURATION OPERATION (NMOS):

$v_{GS} \geq V_t$ (INDUCED CHANNEL)

$v_{DS} \geq v_{GS} - V_t$

$v_{DS} - v_{GS} \geq -V_t$

$v_D - v_S - (v_G - v_S) \geq -V_t$

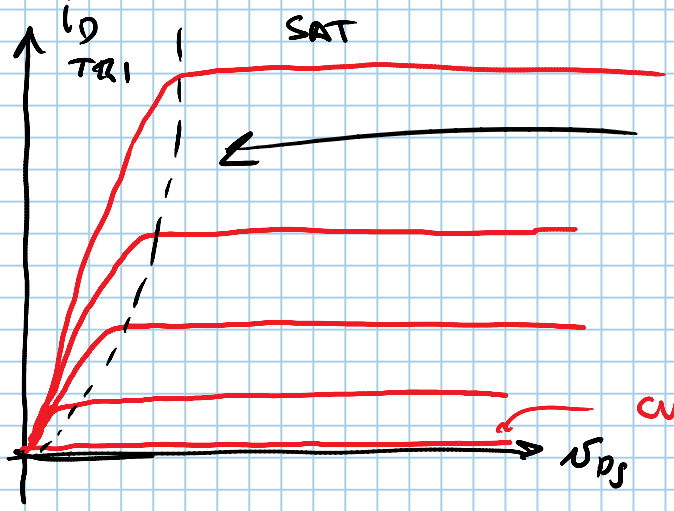
$v_D - v_G \geq -V_t$

$v_G - v_D \leq V_t$

$v_{GD} \leq V_t \Rightarrow$ PINCHED-OFF CHANNEL SATURATION

@ THE TRIODE - PINCH-OFF BOUNDARY $v_{DS} = v_{GS} - V_t$

$\therefore \quad i_D = \frac{1}{2} k_n' \left(\frac{W}{L}\right) (v_{GS} - V_t)^2$

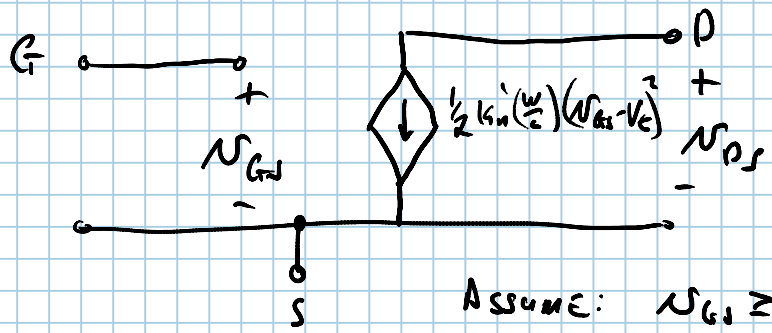


EQUATION OF BOUNDARY

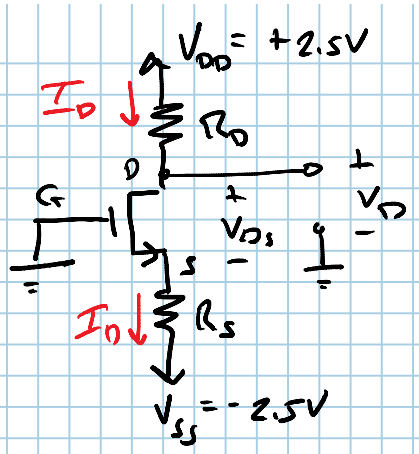
$i_D = \frac{1}{2} k_n' \left(\frac{W}{L}\right) v_{DS}^2$

CUT-OFF, $v_{GS} \leq V_t$

NMOS MODEL FOR SATURATION (LARGE-SIGNAL MODEL)



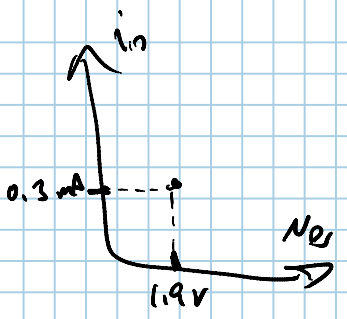
ASSUME: $v_{GS} \geq V_t$, $v_{DS} \geq v_{GS} - V_t$



$V_t = 1V$

$\mu_n C_{ox} = 60\ \frac{\mu A}{V^2}$

$\frac{W}{L} = \frac{120\ \mu m}{3\ \mu m}$



Find R_D & R_S if $I_D = 0.3\ mA$
$= 300\ \mu A$

$V_D = 0.4V$

$$R_D = \frac{V_{DD} - V_D}{I_D} = \frac{(2.5 - 0.4)V}{0.3\ mA} = \boxed{7\ k\Omega}$$

$v_{GD} > V_t$

$v_{DS} (=, <)\ v_{GS} - V_t$? $\Rightarrow$ TRIODE, SAT

$v_{GD} \leq V_t$

$$v_{GD} = v_G - v_D = 0\ V - 0.4 = \boxed{-0.4V = v_{GD}}$$

$v_{GD} \leq V_t \Rightarrow$ SATURATION

$$I_D = \frac{1}{2} k_n' \left(\frac{W}{L}\right) (V_{GS} - V_t)^2$$

$$300\mu A = \frac{1}{2} \left(60\ \frac{\mu A}{V^2}\right) \left(\frac{120}{3}\right) (V_{GS} - 1)^2$$

$$(V_{GS} - 1)^2 = 0.25$$

$$V_{GS} - 1 = \pm 0.5$$

$V_{GS} = 1 \pm 0.5 = 1.5V, 0.5V$ REMEMBER, $V_{GS} \geq V_t$

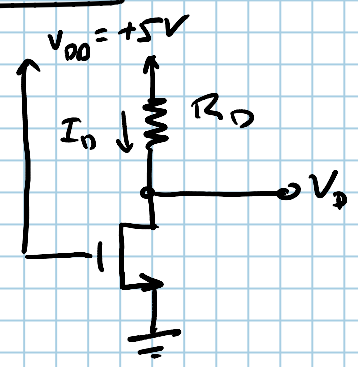
$V_{GS} = 1.5V = v_G^{0} - v_S \Rightarrow -v_S = 1.5\ V$

$\boxed{V_S = -1.5V}$

$$R_S = \frac{V_S - V_{SS}}{I_D} = \frac{-1.5V - (-2.5V)}{0.3mA} = \boxed{3.33k\Omega}$$

$V_{DS} = V_D - V_S = 0.4 - (-1.5) = 1.9V$

EXAMPLE



$V_t = 1V$

$k_n'\left(\frac{W}{L}\right) = 1 \frac{mA}{V^2}$

a) FIND R_D & $V_D = 0.1V$

b) FIND r_{DS}

$V_{GS} = 5 - 0 = +5V$

$V_{DS} = 0.1 - 0 = 0.1\ V$

$V_{GS} - V_t = 5 - 1 = 4V$

$V_{DS} < V_{GS} - V_t$

$0.1V < 4V \Rightarrow$ TRIODE REGION

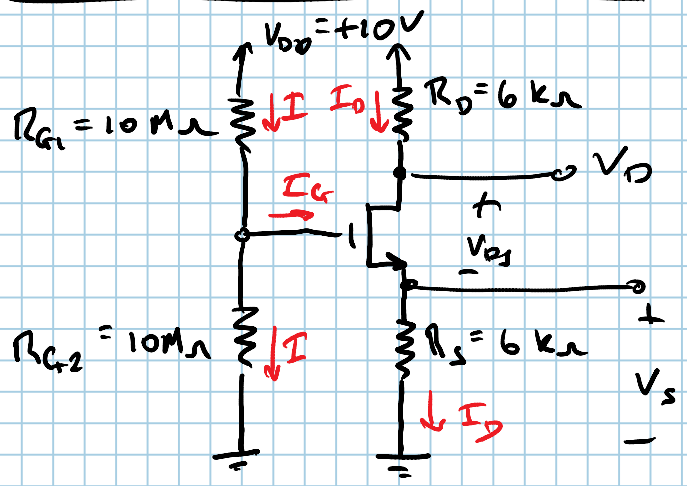
$$I_D = k_n'\left(\frac{W}{L}\right)\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

$$I_D = \left(1 \frac{mA}{V^2}\right)\left[(5-1)(0.1) - \frac{1}{2}(0.1V)^2\right] = \boxed{0.395\,mA = I_D}$$

$$R_D = \frac{(5-0.1)V}{0.395\,mA} = \frac{4.9V}{0.395mA} = \boxed{12.4\,k\Omega}\ (a)$$

$$r_{DS} = \frac{V_{DS}}{I_D} = \frac{0.1V}{0.395\,mA} = \boxed{253\,\Omega}\ (b)$$

EXAMPLE 5.6, pg 263



FIND ALL NODE VOLTAGES AND ALL BRANCH CURRENTS.

$V_t = 1V$, $k_n'\left(\frac{W}{L}\right) = 1\ mA/V^2$

$$V_G = \left(\frac{10}{10+10}\right)(10V) = \boxed{5V}$$

- ASSUME A REGION OF OPERATION
- SOLVE PROBLEM
- CHECK ASSUMPTION

$$I = \frac{10V}{(10+10)M\Omega} = \frac{10V}{20M\Omega} = \boxed{0.5mA}$$

- ASSUME SATURATION

$$I_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)(V_{GS}-V_t)^2 \quad , \quad \left.\begin{aligned} V_G &= +5V \\ V_S &= I_D R_S = 6I_D \end{aligned}\right\} V_{GS} = 5 - 6I_D$$

$$I_D = \frac{1}{2}\,1\left(\frac{mA}{V^2}\right)(5-6I_D-1)^2$$

$$2I_D = (4-6I_D)^2 = 16 - 48I_D + 36I_D^2 \Rightarrow 36I_D^2 - 50I_D + 16 = 0$$

$$I_D = 0.5mA,\ 0.889\ mA \quad \text{(WHICH ONE?)}$$

IF $I_D = 0.889mA$, $V_S = 6I_D = 6(0.889mA) = 5.334V \Rightarrow V_{GS} = -0.334V < V_t$ (CUT-OFF)

IF $I_D = 0.5mA$ $(I_S = I_D)$, $V_S = 6(5mA) = \boxed{3V = V_S}$

$V_{GS} = 5 - 3 = 2V > V_t$ ✓

KVL: $V_{DD} - I_D R_D - V_D = 0$

$$V_D = V_{DD} - I_D R_D = 10V - (0.5mA)(6k\Omega) = \boxed{7V = V_D}$$

$$V_{DS} = V_D - V_S = 7 - 3 = \boxed{4V = V_{DS}} \geq V_{GS} - V_t \quad (2-1=1)$$

(IN SATURATION)