2.17 FOR V_{INA} AND/OR V_{INB} HIGH : IF $V_{IN} = 5V$

$$V_{OUT} = V_{OH} = V_{IN} - V_D(ON) = 5 - 0.7 = 4.3V$$

FOR AN ADDITIONAL OR GATE:

$$V_{OUT} = V_{OH} = V_{IN} - 2\ V_D(ON) = 5 - 1.4 = 3.6V$$

2.18 D_A OPEN:

$$I = \frac{V_{CC} - V_{DL} + V_{CC}}{R_1 + R_2} = \frac{4 - 0.7 + 4}{2k} = 3.65mA$$

$$V_P = V_{CC} - IR_1 = 4 - 3.65m(1k) = 0.35V$$

$V_{IN} + V_{DA} = V_P \Rightarrow V_{IN} = V_P - V_{DA} = 0.35 - 0.7 = -0.35V$, D_A ON FOR $V_{IN} \leq -0.35$

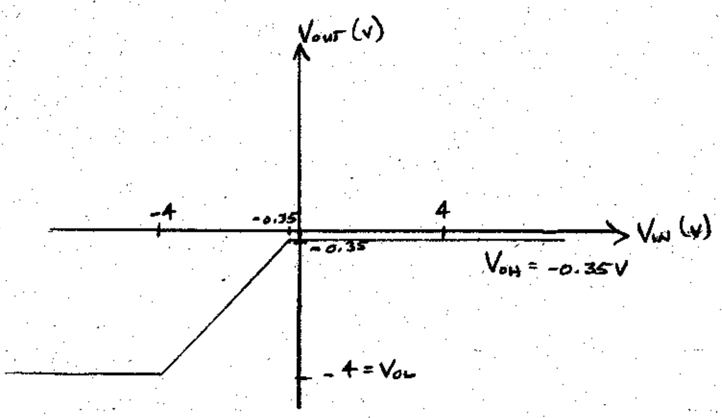
D_L OPEN:

$V_{OUT} = -V_{CC} = -4V$

$V_{IN} \geq -0.35V$

@ $V_{IN} = -4V$

$V_P = -4.3V$ ∴ D_L IS OFF ∴ $V_{OUT} = -4V$



2.19 SEE PROBLEM 2.18:

D_A OPEN:

$I = 3.65 mA$

$V_P = -0.35 mA$

$V_{OUT} = 0.35mA = V_{CC} - IR_1$

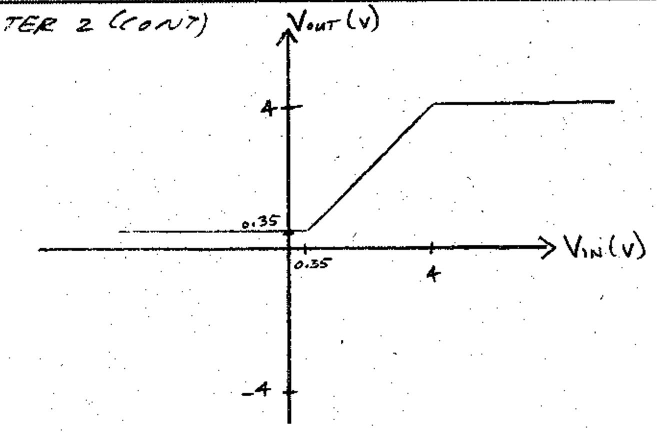
$V_{IN} = V_P + V_D(ON) = -0.35 + 0.7 = 0.35$, D_A IS ON FOR $V_{IN} > 0.35V$

2.19 (CONT'D)

D_B OPEN:

$V_{OUT} = V_{CC} = 4V$

$V_{IN} \leq 0.35V$



2.20 $\underline{V_{INB} = 0}$ FIRST CONSIDER BOTH DIODES OPEN

$$V_P = V_{CC} - R_1\left(\frac{V_{CC} + V_{EE} - V_{D(ON)}}{R_1 + R_2}\right)$$

$$V_P = 5 - 5\left(\frac{10 - 0.7}{105}\right) = 4.56V$$

HOWEVER, FOR $V_P = 4.56V$ AND $V_{INB} = 0$, D_B IS NOT OPEN.
HENCE, D_B SHORTED AND $V_P \neq 4.56V$, INSTEAD

$$V_P = V_{D(ON)} = 0.7V$$

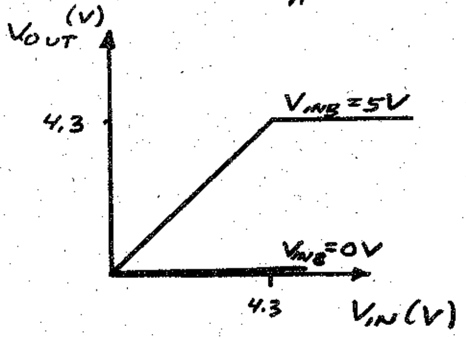
AS V_{INA} INCREASES FROM 0 TO 5V, D_A IS OPEN AND

$$V_{OUT} = V_{INB} = 0V$$

$\underline{V_{INB} = 5V}$ ⇒ D_B OPEN, HOWEVER D_A IS SHORTED AND CURRENT PASSES FROM V_{CC} THROUGH R_1, D_A & D_L. THEN

$$V_{OUT} = V_{INA}$$

UNTIL V_{INA} INCREASES TO 4.3V, THEN D_A OPENS AND $V_P = 5V$ WITH $V_{OUT} = V_{INA} = 4.3V$



6.10 (CONT'D)

(c) $N = I_{OL}/I_{IL} = 61.5m / 1.6m = 38.5 \Rightarrow$ MAX. FAN OUT = 38

(d) $I_{CC}(OH) = I_{IL} = 1.6mA$

$I_{CC}(OL) = 1.25mA + 0.95mA = 2.2mA$

$P_{CC}(AVG) = [(I_{CC}(OH) + I_{CC}(OL))/2]V_{CC} = [(1.6m + 2.2m)/2]4 = 7.65mW$

6.11

SEE PROBLEM 6.10:

(a) $I_{IL} = 0.62 mA$

(b) $I_{OL} = I_{C,O}(SAT) - I_{RL} = 21.2 mA$

$I_{RL} = 3.8mA$

$I_{C,O}(SAT) = 25.0mA$

$I_{B,O} = 0.5 mA$

(c) $N = I_{OL}/I_{IL} = 34.2 \Rightarrow$ MAX. FAN OUT = 34

(d) $I_{CC}(OH) = 0.62mA$ $I_{CC}(OL) = 1.3mA$

$P_{CC}(AVG) = 9.84 mW$

6.12

$V_{OH} = 5V$

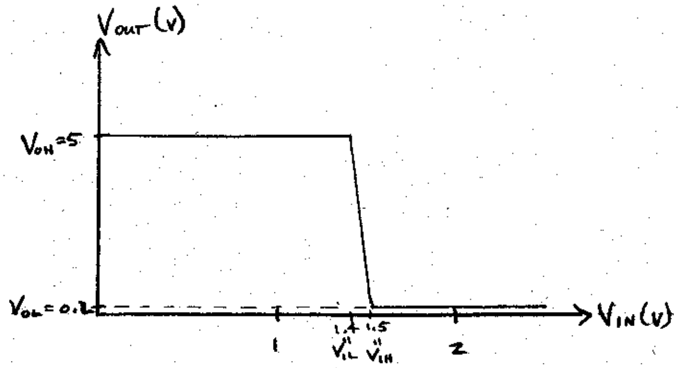
$V_{OL} = 0.2V$

$V_{IL} = V_{BE,O}(FA) + V_{BE,L}(FA) = 0.7 + 0.7 = 1.4V$

$V_{IH} = V_{BE,L}(FA) + V_{BE,O}(SAT) = 0.7 + 0.8 = 1.5V$

$V_{NMH} = 3.5V$

$V_{NML} = 1.2V$



CHAPTER 7 (CONT)

7.13 (a) FOR V_{OH}:

Q_I SAT
Q_S CUTOFF
Q_P FA
Δ_L ON
Q_O CUTOFF

(b) FOR V_{OL}:

Q_I RA
Q_S SAT
Q_P CUTOFF
Δ_L CUTOFF
Q_O SAT

7.14 (a) Q_I, R_B

(b) Q_S, R_C, R_D

(c) Q_P, R_{CP}, R_C

(d) Q_O

7.15 SEE SECTION 7.4, TABLE 7-1.

7.16 FROM CIRCUIT

$$V_{B,P} = V_{BE,O}(SAT) + V_{CE,S}(SAT)$$

WHILE

$$V_{E,P} = V_{CE,O}(SAT) + V_D$$

HENCE

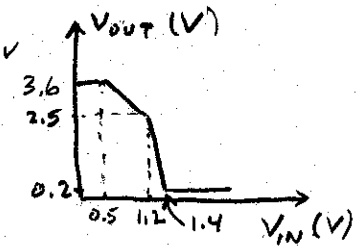
$$V_{BE,P} = V_{B,P} - V_{E,P} = V_{BE,O}(SAT) + V_{CE,O}(SAT) - (V_{CE,O}(SAT) + V_D(ON))$$

$\therefore V_{BE,P} = V_{BE,O}(SAT) - V_D(ON) < V_{BE}(FA)$ AND THEREFORE Q_P OFF.

7.17

PSPICE, JUST DO AS THE PROBLEM SAYS.

7.18



$$V_{OH} = V_{CC} - V_{BE,P}(FA) - V_{BE,PZ}(FA) = 5 - 0.7 - 0.7 = 3.6V$$

$$V_{OL} = V_{CE,O}(SAT) = 0.2V$$

$$V_{IL} = V_{BE,S}(FA) - V_{CE,I}(SAT) = 0.7 - 0.2 = 0.5V$$

$$V_{IH} = V_{BE,O}(SAT) + V_{BE,S}(SAT) - V_{CE,I}(SAT) = 0.8 + 0.8 - 0.2 = 1.4V$$

$$V_{IB} = V_{BE,O}(FA) + V_{BE,S}(FA) - V_{CE,I}(SAT) = 0.7 + 0.7 - 0.2 = 1.2V$$

$$V_{OB} = V_{CC} - I_{RC} R_C - V_{BE,P}(FA) - V_{BE,PZ}(FA)$$

$$= V_{CC} - \left(\frac{R_C}{R_D} + 1\right) V_{BE,P}(FA) - V_{BE,PZ}(FA) = 5 - \left(\frac{760}{470} + 1\right) 0.7 - 0.7 = 2.5V$$

CHAPTER 8 SOLUTIONS

8.1

(a) $V_{BB} - I_1 R_B - V_{BE}(FA) = 0$ $\quad V_{CE} = 0.5V$

$I_{RB} = (V_{BB} - V_{BE}(FA))/R_B = (5.8 - 0.8)/10k = 0.5mA = I_B$

$I_{RC} = (V_{CC} - V_{CE}(HARD))/R_C = (5 - 0.5)/1k = 4.5mA$

$I_B = I_C/\beta = 4.5m/100 = 0.045mA$

$I_{SBD} = I_{RB} - I_B = 500\mu - 45\mu = 455\mu A$

$I_C = I_{RC} + I_{SBD} = 4.5m + 0.455m = 4.955mA \approx 5mA$

(b) FORWARD ACTIVE

(c) $I_B = (V_{BB} - V_{BE}(SAT))/R_B = (5.8 - 0.8)/10k = 0.5mA = I_B$

$I_C = (V_{CC} - V_{CE}(SAT))/R_C = (5 - 0.2)/1k = 4.8mA = I_C$

$V_{CE} = 0.2V$

∴ THE BJT IS SATURATED.

8.2 SEE PROBLEM 8.1:

(a) $I_{RB} = 0.99mA = I_B$, $\quad I_{RC} = 4.5mA$, $I_B = 0.045mA$, $I_{SBD} = 0.95mA$

$I_C = 5.45mA$

(b) FORWARD ACTIVE

(c) $I_B = 0.99mA = I_B$

$I_C = 4.8mA = I_C$

$V_{CE} = 0.2V$

∴ THE BJT IS SATURATED.

8.3 $V_{OH} = V_{CC} = 5V$

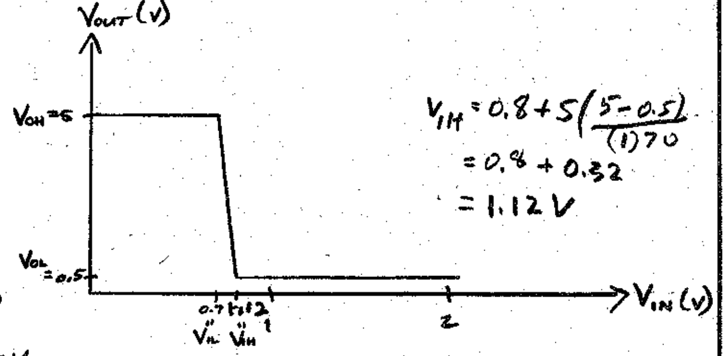
$V_{OL} = V_{CE,0}(HARD) = 0.5V$

$V_{IL} = V_{BE,0}(FA) = 0.7V$

$V_{IH} = V_{BE,0}(HARD) + I_B(EOH) R_B$

$V_{NMH} = V_{OH} - V_{IH} = 5 - 1.12 = 3.88$

$V_{NML} = V_{IL} - V_{OL} = 0.7 - 0.5 = 0.2V$



$V_{IH} = 0.8 + 5\left(\frac{5-0.5}{(1)70}\right)$

$= 0.8 + 0.32$

$= 1.12V$

8.17 SEE SECTION 8.3, TABLE 8.2 :

	V_{OH}	V_{OL}
Q_1	ON HARD	REVERSE
Q_S	CUTOFF	ON-HARD
Q_P	EDGE OF CONDUCTION	FORWARD ACTIVE
Q_{P2}	EDGE OF CONDUCTION	CUTOFF
Q_D	CUTOFF	FORWARD ACTIVE
Q_O	CUTOFF	ON HARD

8.18

$V_{IN_1} = V_{IN_2} = 0 \quad V_{OUT} = 3.6V = V_{OH}$ (FROM #10)

$V_{IN_1} = 0,\ V_{IN_2} = 5V \quad V_{OUT} = 3.6V = V_{OH}$ (FROM #10)

$V_{IN_1} = 5V \quad V_{IN_2} = 0 \quad V_{OUT} = 3.6V = V_{OH}$ (FROM #10)

$V_{IN_1} = V_{IN_2} = 5V \quad V_{OUT} = 0.5V = V_{OL}$ (FROM #10)

∴ THE NAND OPERATION IS SATISFIED.

8.19

$V_{OH} = V_{CC} - V_{BE,P}(FA) = 5 - 0.7 = 4.3\,V$

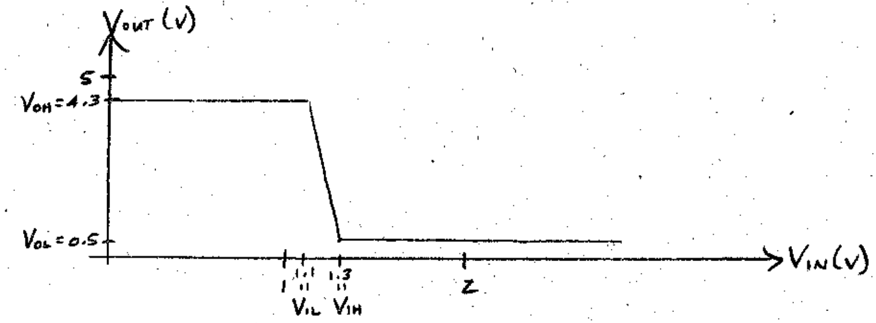
$V_{OL} = V_{CE,O}(HARD) = 0.5V$

$V_{IL} = V_{BE,O}(FA) + V_{BE,S}(FA) - V_{SBD}(ON) = 0.7 + 0.7 - 0.3 = 1.1V$

$V_{IH} = V_{BE,O}(HARD) + V_{BE,S}(HARD) - V_{SBD}(ON) = 0.8 + 0.8 - 0.3 = 1.3V$

$V_{NMH} = V_{OH} - V_{IH} = 4.3 - 1.3 = 3.0V$

$V_{NML} = V_{IL} - V_{OL} = 1.1 - 0.5 = 0.6V$



8.20

(a) $I_{IL} = \left(V_{CC}' - V_{SBD,I}'(ON) - V_{CE,O}(HARD)\right)/R_B' = (5 - 0.3 - 0.5)/20k = 0.21mA$

(b) $I_{OL} = I_{C,O} = \beta_F I_{B,O} = 50(0.533m) = 26.6\ mA$

$I_{B,O} = I_{E,S} - I_{C,O} = 0.633m - 0.1m = 0.533mA$

8.20 (CONT'D)

$I_{C,D} = I_{RCD} = (V_{BE,D}(HARD) - V_{CE,D}(HARD))/R_{CD} = (0.8-0.5)/3k = 0.1mA$

$I_{E,S} = I_{B,S} + I_{C,S} = 0.17m + 0.463m = 0.633mA$

$I_{C,S} = (V_{CC} - V_{CE,S}(HARD) - V_{BE,D}(HARD))/R_C = (5-0.5-0.8)/8k = 0.463mA$

$I_{B,S} = I_{RB} = (V_{CC} - V_{BE,S}(HARD) - V_{BE,D}(HARD))/R_B$

$= (5-0.8-0.8)/20k = 0.17mA$

(c) $N = I_{OL}/I_{IL} = 26.6m/0.21m = 126.67 \Rightarrow$ MAX. FAN OUT = 126

8.21 $I_{CC}(OH) = I_{IL} = 0.21mA$ (FROM 8.20 (a))

$I_{RB}(OL) = 0.17mA$ (FROM 8.20 (b))

$I_{RC}(OL) = 0.463mA$ (FROM 8.20 (b))

$I_{CC}(OL) = I_{RB}(OL) + I_{RL}(OL) = 0.17m + 0.463m = 0.63mA$

$P_{CC}(AVG) = [(I_{CC}(OL) + I_{CC}(OH))/2]V_{CC} = [(0.63m + 0.21m)/2]5 = 2.1mW$

8.22 SEE PROBLEMS 8.20 AND 8.21:

$I_{IL} = 0.11mA$

$I_{OL} = 8.5mA$

$I_{BD} = 0.17mA$, $I_{CD} = 0.1mA$ $I_{ES} = 0.27mA$, $I_{CS} = 0.19mA$, $I_{BS} = 0.09mA$

$N = 80.95 \Rightarrow \therefore$ MAX. FAN OUT = 80

$I_{CC}(OH) = 0.11mA$

$I_{RB}(OL) = 0.09mA$

$I_{RC}(OL) = 0.19mA$

$I_{CC}(OL) = 0.28mA$

$P_{CC}(AVG) = 0.98mW$

8.23
SEE PROBLEMS 8.20 AND 8.21:

$I_{IL} = 1.05mA$

CHAPTER 9 (CONT.)

9.9 $V_{OH} = V_{DD} - V_{BE,IP}(FA) = 5 - 0.7 = 4.3V$

$V_{OL} = V_{CE,O}(HARD) = 0.5V$

$V_{IL} = -V_{BE,IP}(FA) + 3V_{BE}(FA) = 1.4V$

$V_{IH} = -V_{BE,IP}(FA) + 3V_{BE}(HARD) = 1.7V$

WITH NO KNEE

9.10 SAME ANSWER AS 9.2

9.11 SEE TABLE 9.4

9.12

ELEMENT / STATE	Q_{IP}	Q_{S2}	Q_S	Q_D	Q_K	Q_O	Q_P	Q_{OD}	Q_{P2} Q_{P3}
V_{OH}	FA	OFF	← SAME →			OFF	FA	OFF	OFF
V_{OL}	OFF	HARD	← SAME →			HARD	FA	RS	OFF

9.13 POWER DISS FOR 2 INPUT NAND (FIG 9.1a)

$$I_{CC}(0,0) = I_{R_B}(IL) = \frac{5-0.8-0.5}{37k} = 0.1mA$$

$$I_{CC}(0,1) = I_{R_B}(IL) = \frac{5-0.8-0.5}{37k} = 0.1mA = I_{CC}(1,0)$$

$$I_{CC}(1,1) = I_{R_B}(IH) + I_{R_{CS}}(OL) + I_{R_C}(OL) + \overset{0}{\cancel{I_{R_{CP}}}}(OL)$$

Zero drop across R_{EP}

$$= \frac{5-2.4}{37k} + \frac{5-0.5-1.6}{50k} + \frac{5-0.5-0.8}{14}$$

$$= 0.07 + 0.058 + 0.264 = 0.39mA$$

$$P_{CC}(AV) = \frac{(0.1 + 2(0.1) + 0.39)}{4} 5 = \underline{0.8625mW}$$

CHAPTER 9 (CONT)

9.14 POWER DISS FOR 2 INPUT NAND (Fig 9.3a)

$$I_{cc}(0,0) = I_{RB}(1L) = \frac{5-0.3-0.5}{10} = 0.39\,mA$$

$$I_{cc}(0,1) = I_{cc}(1,0) = I_{cc}(0,0) = 0.39\,mA$$

$$I_{cc}(1,1) = I_{RB}(0L) + I_{RCS}(0L) + I_{RC}(0L) + \overset{0}{\cancel{I_{RCP}}}(0L)$$

$$= \frac{5-3(0.8)}{10} + \frac{5-0.5-2(0.8)}{10} + \frac{5-0.5-0.8}{4.1}$$

$$= 0.26 + 0.29 + 0.9 = \underline{1.45\,mA}$$

$$P_{DISS} = I_{cc}V_{cc} = \left(\frac{0.39\times3+1.45}{4}\right)5 = \underline{3.275\,mW}$$

9.15 Power Diss for 2 INPUT NAND (FIG 9.4)

$$I_{cc}(0,0) = I_{RBPI}(0H) + I_{RB}(0H) = \frac{5-0.3+0.7}{30k} + \overset{\boxed{Q_{IP}(FA)}}{\frac{5-0.7-0.5}{10K}} = 0.08+0.38$$

$$= \underline{0.46\,mA}$$

$$I_{cc}(0,1) = I_{cc}(1,0) = I_{cc}(0,0) = 0.46\,mA$$

$$I_{cc}(1,1) = I_{RB}(0L) + I_{RC}(0L) + I_{BPI}(0L) + I_{BOD}(0L) + \overset{0}{\cancel{I_{RCP}}}(0L)$$

NO DROP ACROSS REP

$$I_{RB}(0L) = \frac{5-0.8(3)}{10K} = 0.26\,mA$$

$$I_{RC}(0L) = \frac{5-0.5-0.8}{2K} = 1.85\,mA$$

$$\underset{\boxed{Q_{OD}(RS)}}{I_{RBOD}(0L)} = \frac{5-0.3-0.5}{30k} = 0.14\,mA$$

$$I_{RBPI}(0L) = \text{SAME} = 0.08\,mA$$

$$I_{cc}(1,1) = 0.26 + 1.85 + 0.14 + 0.08 = 2.33\,mA$$

$$P_{cc} = \left(\frac{2.33+0.46(3)}{4}\right)5 = \underline{0.9275\,mA}$$

10.22 (CONT)

$I_{CC}(11) = 2 I_{R_B}(IH) + I_{R_{C_S}}(OH)$

$= 2(0.175) + 0.35 = 0.7 mA$

$P_{CC}(AVG) = 5\left(0.73 + 2(0.73) + 0.7\right)/4 = 3.6 mW$

(b) COMPARE WITH LSTTL NAND OF EX 8.5 → $P_{DISS} = 2.1 mW$

NOTE $3.6 > 2.1$

(c) PROBLEM 10.21 $P_{DISS} = 21.3 mW >> 3.6 mW$

10.23 VTC OF LSTTL OR GATE

$V_{OH} = V_{CC} - V_{BE,P}(FA) = 5 - 0.7 = 4.3 V$

$V_{OL} = V_{CE,O}(HARD) = 0.5 V$

$V_{IL} = -V_{SBD,I}(ON) + V_{BE,S_2}(FA) + V_D(ON) = -0.3 + 0.7 + 0.7 = 1.1 V$

$V_{IH} = -V_{SBD,I}(ON) + V_{BE,S_2}(HARD) + V_D(ON) = -0.3 + 0.8 + 0.7 = 1.2 V$

10.24

(a) CRITICAL VOLTAGES

$V_{OH} = V_{CC} - V_{BE,P}(FA) = 5 - 0.7 = 4.3 V$

$V_{OL} = V_{CE}(SAT) = 0.2 V$

$V_{IL} = -V_{CE,I} - V_{BE,S}(FA) = -0.2 + 0.7 = 0.5 V$

$V_{IH} = -0.2 + 1.6 = 1.4 V$

<u>Breakpoint at</u>

$V_{IB} = 1.2 V$

$V_{OB} = 5 - 20\left(\frac{0.7}{12}\right) - 0.7$

$\cong 3.12 V$ and sketch curve

b) AVG POWER DISSIPATION

$$P_{CC} = V_{CC}\left(I_{CC}(00) + I_{CC}(01) + I_{CC}(10) + I_{CC}(11)\right)$$

$$I_{CC}(00) = 2 I_{R_B}(IL) = 2\left(\frac{V_{CC} - V_{BE,I}(SAT) - V_{IL}}{R_B}\right)$$

$$= 2\left(\frac{5 - 0.8 - 0.2}{40}\right) = 2(0.1) = 0.2 mA$$

10.24 (CONT)

$$I_{CC}(01) = I_{R_B}(IL) + I_{R_B}(IH) + I_{R_C}(OL)$$

$(= I_{CC}(10))$

$$= 0.1 + \frac{V_{CC} - V_{BC,I}(RA) - 2V_{BE,S}(SAT)}{R_B} + \frac{V_{CC} - V_{CE,S}(SAT) - V_{BE,O}(SAT)}{R_C}$$

$$= 0.1 + \frac{5 - 0.7 - (0.8)2}{40} + \frac{5 - 0.2 - 0.8}{20}$$

$$= 0.1 + 0.07 + 0.2 = 0.39 \text{ mA}$$

$$I_{CC}(11) = 2 I_{R_B}(IH) + I_{R_C}(OL)$$

$$= 2(0.07) + 0.2 = 0.34 \text{ mA}$$

$$P_{CC}(AVG) = 5\left(\frac{0.2 + 2(0.39) + 0.34}{4}\right) = 1.6 \text{ mW}$$

(c) COMPARE WITH EXAMPLE 10.2 → 17.88 mW

∴ POWER DISS MUCH LESS FOR LTTL GATE

10.25

a) VTC

$$V_{OH} = V_{CC} - 2V_{BE}(FA) = 5 - 2(0.7) = 3.6V$$

$$V_{OL} = V_{CE,O}(SAT) = 0.2V$$

$\underline{V_{IL}}$ FOR THE AND GATE, WHEN $V_{IN} = V_{IL}$, $V_{OUT} = V_{OL}$. THUS WHEN V_{AND} BEGINS TO INCREASE FROM V_{OL}, WE HAVE

$$V_{C_{S_2}} = V_{BE,O}(SAT) + V_{BE,S}(SAT) + V_{D_S}(ON) = 2(0.8) + 0.7 = 2.3V$$

$$\therefore I_{R_{C_S}} = \frac{V_{CC} - V_{C_{S_2}}}{R_{C_S}} = \frac{5 - 2.3}{1} = 2.7 \text{ mA} \Rightarrow \text{ALL THRU } D_S, \text{ SINCE } Q_{S_2}, Q_{SD} \text{ CUTOFF}$$

WHEN $V_{C_{S_2}}$ BEGINS TO REDUCE FROM 2.3V, Q_{S_2} BEGINS TO CONDUCT. THIS OCCURS FOR

$$V_{IN} = V_{BE,S_2} - V_{CE_I}(SAT) = 0.7 - 0.2 = 0.5V = V_{IL}$$

FURTHERMORE, WHEN $V_{C_{S_2}} = 3(.7) = 2.1V$, Q_0 BECOMES CUTOFF AND

$$I_{R_{C_S}} = \frac{V_{CC} - V_{C_{S_2}}}{R_{C_S}} = \frac{5 - 2.1}{1} = 2.9 \text{mA} = I_{E_{S_2}}$$

THIS CURRENT IS SUFFICIENT TO SATURATE Q_{SD} SINCE $I_{R_{SD}} = 0.8/0.4 = 2\text{mA}$ PRODUCES $V_{BE,S_D}(SAT) \cong 0.8V$

HENCE, $I_{B_{SD}} = 0.9\text{mA}$ AND

$$\underline{V_{IH}} = V_{BE,S_D}(SAT) + V_{BE,S_2}(SAT) - V_{CE,I}(SAT) = 0.8 + 0.8 - 0.2 = 1.4V$$

CHAPTER 11 (CONT)

11.13 V_{NOR}

$$V_{OH} = -V_{BE,N}(ECL) = -0.7V$$

$$V_{IL} = -1.175 - 0.05 = -1.225V$$

$$V_{IH} = -1.175 + 0.05 = -1.125V$$

$$V_{OL} = -I_E R_{C_I} - V_{BE_N}(ECL)$$

$$= -\left(\frac{V_{IH} - V_{BE}(ECL) + V_{EE}}{R_E}\right) R_{C_I} - V_{BE}(ECL)$$

$$= -\left(\frac{-1.125 - 0.75 + 5.2}{1.18}\right)(0.29) - 0.75$$

$$V_{OL} = -1.57V$$

11.14 $V_{OH} = V_{NOR} = -I_{B,BN} R_{C,I} - V_{BE,BN}(ECL) = -\overbrace{(27.69\mu A)}^{= \frac{-0.75+5}{0.5+3(51)}}(500) - 0.75 = -0.76V$

$$I_{B,BN} = (V_{EE} - V_{BE,BN}(ECL)) / (R_{C,I} + (1+\beta)R_{BN}) = (5-0.75)/500 + 51(3k) = 27.69\mu A$$

$$V_{IL} = V_{BB} - 0.05 = -1.175 - 0.05 = -1.225V$$

$$V_{IH} = V_{BB} + 0.05 + -1.175 + 0.05 = -1.125V$$

$$V_{OL} = -I_C R_C - V_{BE}(ECL) = -(1.845m)(300) - 0.75 = -1.3V = V_{NOR}$$

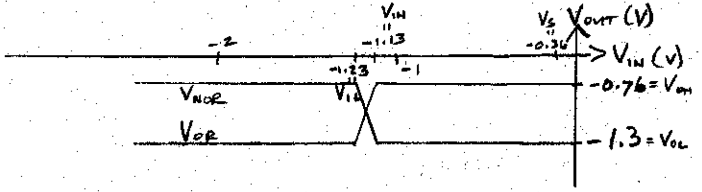
$$I_{C,I} \approx I_{E,I} = (V_{IN} - V_{BE,I}(ECL) + V_{EE})/R_E = (V_{OH} - V_{BE,I}(ECL) + V_{EE})/R_E$$

$$= (-0.76 - 0.75 + 5)/2k = 1.845\,mA$$

$$V_S = \left[V_{BC}(SAT) + \frac{R_{C1}}{R_E}(V_{BE}(SAT) - V_{EE})\right] / \left(1 + \frac{R_{C1}}{R_E}\right) = \left[0.6 + \frac{500}{2k}(0.8-5)\right] / \left(1 + \frac{500}{2k}\right) = -0.36V$$

From next page $I_B = 27.69\mu A$

THE <u>OR</u> CASE IS IDENTICAL TO THE <u>NOR</u> CASE, EXCEPT INVERTEA,



11.14 (CONT'D)

$$I_{B,BO} = (V_{ER} - V_{BE,BO}(ECL)) / (R_{C,R} + (1+\beta) R_{DO}) = (5-0.75)/(500+51(3k)) = 27.69\mu A$$

$$\therefore I_{B,BO}(OH) = I_{B,BN}(OH)$$

11.15

$$V_{OH} = V_{OR} = -I_{B,BO} R_{CR} - V_{BE,BO}(ECL) = -43.5\mu(245) - 0.75 = -0.76V$$

$$I_{B,BO} = (V_{EE} - V_{BE,BO}) / (R_{C,R} + (1+\beta_F) R_{DO}) = (5.2-0.75)/(245+51(2k)) = 43.5\mu A$$

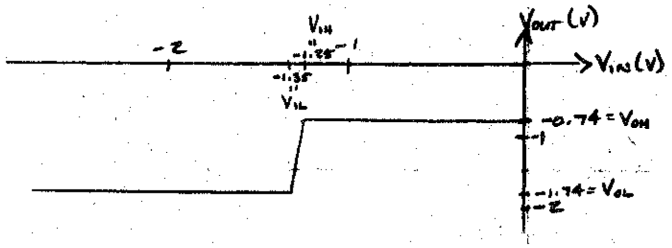
$$V_{OL} = -I_{RCR} R_{CR} - V_{BE,BO}(ECL) = -4.04m(245) - 0.75 = -1.74V$$

$$I_{RCR} \approx I_E = (V_{BB} - V_{BE,R}(ECL) + V_{EE}) / R_E = (-1.3-0.75+5.2)/0.78k = 4.04mA$$

11.16

$$V_{IL} = V_{BB} - 0.05 = -1.3 - 0.05 = -1.35V$$

$$V_{IH} = V_{BB} + 0.05 = -1.3 + 0.05 = -1.25$$



11.17

$V_{IH} = -1.1V$

$V_{NMH} = V_{OH} - V_{IH} = 0.2V$, $\therefore V_{OH} = 0.2 - 1.1 = -0.9V = V_{MIN}$ FOR MAX FAN-OUT

$$I'_{IH} = \frac{I'_{E_1}}{\beta_F+1} = \frac{V_{OH} - V'_{BE}(FA) + V'_{EE}}{(\beta_F+1) R_E} = \frac{-0.9 - 0.75 + 5.2}{51(0.78)} = 0.089mA$$

$$I_{OH} = I_{E_{BO}} - I_{RDO}$$

$$I_{E_{BO}} = (1+\beta_F) I_{B_{BO}} = (1+\beta_F)\left(\frac{-[V_{BE}(FA) + V_{OH}]}{R_{CR}}\right) = 51\left(\frac{-0.75+0.9}{0.245}\right) = 31.2mA$$

$$I_{R_{DO}} = \frac{V_{OH} + V_{BE}}{R_{EF}} = \frac{-0.9+5.2}{2} = 2.15mA \quad \therefore I_{OH} = 31.2 - 2.15 = 29.05mA$$

$$N = \frac{29.05}{0.089} = 326.4 \text{ or } 326$$

11.18

$\underline{V_I = V_{IH} = -0.7V}$; $Q_I(FA)$, $Q_R(OFF)$, $Q_O(SAT)$

$$I_{B,O} = \frac{5-0.8}{3} = 1.4mA$$

$I_C = 50(1.4)mA$ – too large

$\therefore V_{OUT} = V_{CE}(SAT) = 0.2V = V_{OL}$

$\underline{V_I = V_{IL} = -2V}$; $Q_I(OFF)$, $Q_R(FA)$

AND $Q_O(OFF)$ SINCE

$$V_{B,O} = 5 - \left(\frac{5.2-1.3-0.75}{0.78}\right)3$$

$$V_{B,O} = 5 - 12.09 = -7V$$

$\therefore V_{OUT} = V_{CC} = 5V = V_{OH}$

CHAPTER 12 (CONT)

12.10 $I_{EE}(NOH)$:

$$I_{R_E}(NOH) = \frac{V_{BB} - V_{BE}(ECL) + V_{EE}}{R_E} = \frac{-1.175 - 0.75 + 5.2}{1.18} = 2.78mA$$

$$I_{R_{DN}}(NOH) = \frac{V_{OH} + V_{EE}}{R_{DN}} = \frac{-0.75 + 5.2}{1.5} = 2.97mA$$ ✓

$$I_{R_{D0}}(NOH) = \frac{V_{OL} + V_{EE}}{R_{D0}} = \frac{-1.58 + 5.2}{1.5} = 2.41mA$$ ✓

$$I_{R_{BL}} = \frac{V_{EE} - 2V_{\gamma}(m)}{R_{BH} + R_{BL}} = \frac{5.2 - 1.5}{2.3 + 0.3} = 1.42mA$$

$$I_{R_{BE}} = \frac{V_{EE} - I_{RBH}R_{BL} - V_{BE}(ECL)}{R_{BE}} = \frac{5.2 - \frac{5.2 - 1.5}{2.6}(0.3) - 0.75}{2} = 2.015\ mA$$

$$I_{EE}(NOH) = 2.78 + 2.97 + 2.41 + 1.42 + 2.015 = 11.6mA$$ ✓

$I_{EE}(NOL)$:

$$I_{R_E}(NOL) = \frac{V_{OH} - V_{BE}(ECL) + V_{EE}}{R_E} = \frac{-0.75 - 0.75 + 5.2}{1.18} = 3.7mA$$

$$I_{R_{DN}}(NOL) = \frac{V_{OL} + V_{EE}}{R_{DN}} = 2.41mA$$ ✓

$$I_{R_{D0}}(NOL) = \frac{V_{OH} + V_{EE}}{R_{D0}} = 2.97\ mA$$ ✓

$I_{R_{BL}} = 1.42mA$ ✓

$I_{R_{BE}} = 2.015mA$ ✓

$$\therefore I_{EE}(NOL) = 3.7 + 2.41 + 2.97 + 1.42 + 2.015 = 12.5\ mA$$ ✓

$$P_{EE}(AV) = \left(\frac{11.6 + 12.5}{2}\right)5 = \underline{60.3mW}$$ ✓

(NEXT PAGE)

12.11 FROM 12.10 Substituting $R_{DN} = R_{D0} = 3k \rightarrow P_{EE} = \underline{47.2mW}$

12.12 FROM 12.10 substituting $R_E = 3k \rightarrow P_{EE} = \underline{51.8mW}$

13.6

$$V_{BB} = -I_{R_{BH}}R_{BH} - V_{BE}(ECL)$$

$$= -\left(\frac{V_{EE} - 2V_D(ON)}{R_{BH}+R_{BL}}\right)R_{BH} - V_{BE}(ECL) = -\left(\frac{5.2-2(0.75)}{0.907+4.98}\right)(0.907) - 0.75$$

$$= -1.32 V$$

13.7 FOR THE OR OUTPUT

$$V_{OH} = -V_{BE,BO}(ECL) = -0.75 V$$

$$V_{OL} = -I_{R_{CR}}R_{CR} - V_{BE,BO}(ECL) = -\left(\frac{V_{BB} - V_{BE,R}(ECL) + V_{EE}}{RE}\right)R_{CR} - V_{BE}(ECL)$$

$$= -\left(\frac{-1.32 - 0.75 + 5.2}{0.777}\right)(0.245) - 0.75 = -1.74 V$$

$$V_{IH} = V_{BB} + 0.05 = -1.315 V$$

$$V_{IL} = V_{BB} - 0.05 = -1.325 V$$

$$V_S = \frac{0.6 + \frac{217}{777}(0.75-5.2)}{1+\frac{217}{777}} = \frac{-0.643}{1.279} = -0.5V \text{ (FOR NOR)}$$

13.8 DOUBLING R_E CHANGES V_{OL} AND V_S ONLY. THE NEW VALUES ARE

$$V_{OL} = -\left(\frac{-1.38 - 0.75 + 5.2}{2(0.777)}\right)(0.245) - 0.75 = -1.234 V$$

$$V_S = \frac{0.6 + \frac{217}{2(777)}(0.75-5.2)}{1+\frac{217}{2(777)}} = \frac{-0.02}{1.14} = -0.018V$$

13.9 DOUBLING R_C CHANGES V_{OL} AND V_S ONLY. THE NEW VALUES ARE

$$V_{OL} = -\frac{(-1.38-0.75+5.2)}{0.777}(2)(0.245) - 0.75 = -2.69V$$

$$V_S = \frac{0.6 + \frac{2(217)}{777}(0.75-5.2)}{1+2(217)/777} = \frac{-1.886}{1.559} = -1.21 V$$

13.10 V_{OH} REDUCES BY 0.1 V. THEREFORE $V_{OH} = -0.75 - 0.1$

$$V_{OH} = -0.85 \quad , \quad V_E' = -0.85 - 0.75 = -1.6V$$

$$I_{R_E}' = \frac{-1.6+5.2}{.365} = 9.86 mA$$

$$I_B' = \frac{9.86}{49+1} = 0.197 mA$$

$$I_{R_P}' = \frac{-0.85+5.2}{50} = 0.087 mA$$

13.10 (CONT)

$$I'_{IH} = 0.087 + 0.197 = 0.284$$

$$I_{R_{C_2}} = \frac{(-0.75)-(-0.85)}{0.1} = 1\ mA$$

$$I_{OH} = (49+1)(1) = 50\ mA$$

$$N = \frac{50\ mA}{0.284\ mA} = 176.05 \longrightarrow N = 176$$

13.11 ALLOWABLE $V_{OH} = -0.75 - 0.1 = -0.85$

$$I'_{R_E} = \frac{V'_E + 5.2}{R_E} = \frac{-0.85-0.75+5.2}{0.777} = 4.63\ mA$$

$$I'_B = \frac{I'_E}{\beta_F + 1} = \frac{4.63}{50} = 0.093\ mA$$

$$I'_{R_P} = \frac{-0.85+5.2}{50} = 0.087\ mA$$

$$I'_{IH} = 0.087 + 0.093 = 0.18\ mA$$

$$I_{R_{C_2}} = -\frac{-0.75-(-0.85)}{0.217} = 0.46\ mA$$

$$I_{OH} = (49+1)(0.46) = 23.04$$

$$N = \frac{23.04}{0.18} = 128.01 \longrightarrow N = 128$$

13.12 BIAS NETWORK POWER DISS

$$I_{R_{B_L}} = \frac{5.2 - 2(0.75)}{0.350 + 1.950} = 1.6\ mA$$

$$I_{R_{B_2}} = \frac{5.2 - 1.6(0.35) - 0.75}{2} = 1.95\ mA$$

THUS, FOR BIAS NETWORK

$$P_{DISS} = V_{EE}(I_{R_{B_L}} + I_{R_{B_2}}) = 5.2(1.6+1.95)$$

$$= 18.46\ mW$$

CHAPTER 14 SOLUTIONS

14.1

$$V_{BB} = -I_R R - V_{BE,B_1}(ECL) = -I_{C_{S_2}} R - V_{BE}(ECL)$$

$$= -\left(\frac{V_{D(on)} - V_{BE}(ECL)}{R_{E_2}}\right) R - V_{BB}(ECL)$$

$$V_{BB} = -\left(\frac{0.8 - 0.75}{0.1}\right)(0.9) - 0.75 = -1,2\ V$$

$$V_{BB}' = -V_{EE} + V_{BE}(ECL) + I_R R = -4.5 + 0.75 + 0.45 = -3.3 V$$

14.2 $R = 500\Omega$

$$V_{BB} = -\left(\frac{0.8 - 0.75}{0.1}\right)(0.5) - 0.75 = -1 V$$

$$V_{BB}' = -4.5 + 0.75 + 0.25 = -3.5 V$$

14.3 AS EXPLAINED IN TEXT

14.4 $V_{EE} = 5,2V$

V_{BB} UNCHANGED $= -1,2V$

$$V_{BB}' = -5,2 + 0.75 + 0.25 = -4.2V$$

14.5 $R_E' = 0.5k\Omega$

$$I_E = \frac{V_{BB}' - V_{BE,E}(ECL) + V_{EE}}{R_E'} = \frac{-3,2 - 0.75 + 4.5}{0.5}$$

$$I_E = 1.1 mA$$

14.6 CRITICAL VOLTAGES

$$V_{OH}^{(NOH)} = -V_{BE}(ECL) - I_{R_C}(NOH) R_{C_I}$$

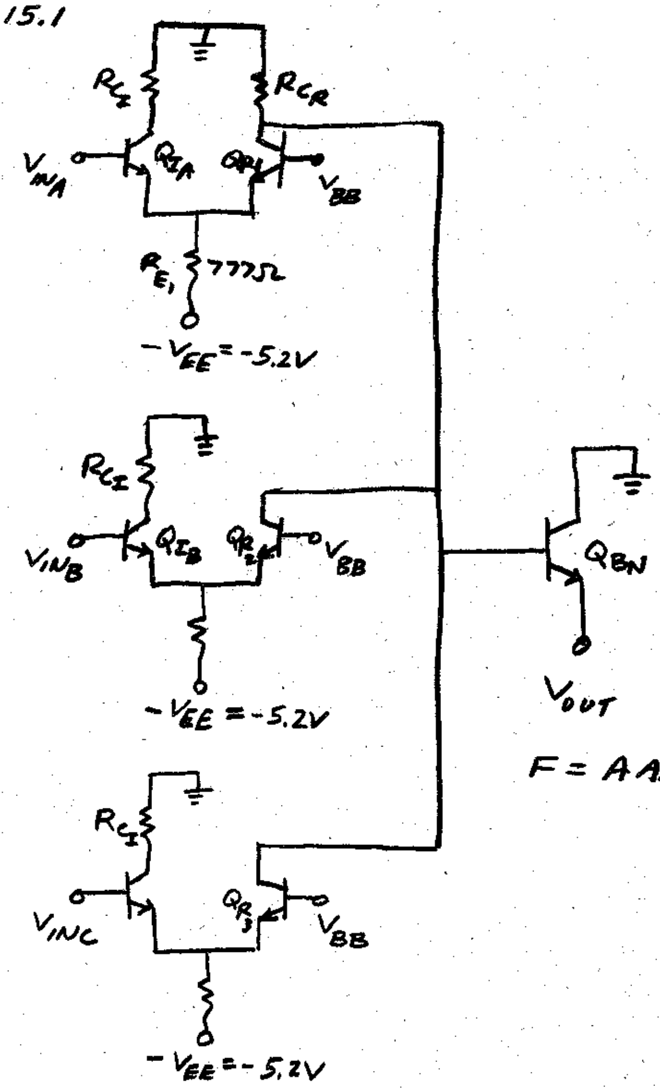
$$= -V_{BE}(ECL) - I_1 R_{C_I}$$

$$= -0.75 + \left(\frac{V_{B,O} + V_{D_{L_1}}(ON)}{2R}\right) R$$

$$= -0.75 + \frac{-0.85 + 0.75}{2} = -0.8 V$$

CHAPTER 15 SOLUTIONS

15.1



F = A AND B AND C

15.2

$$V_{OH} = -I_{R_{CR}} R_{CR} - V_{BE,BN}(ECL)$$

$$V_{OH} = 0 - 0.75 = -0.75V$$

$$V_{OL} = -I_{R_{E_1}} R_{CR} - V_{BE,BN}(ECL)$$

$$V_{OL} = -\left(\frac{V_{BB} - V_{BE,R}(ECL) + V_{EE}}{R_E}\right) R_{CR} - V_{BE,BN}(ECL)$$

$$V_{OL} = -\left(\frac{-1.32 - 0.75 + 5.2}{777}\right)(245) - 0.75$$

$$\therefore V_{OL} = -0.99 - 0.75 = -1.74V$$

$$V_{IL} = V_{BB} - 0.05 = -1.32 - 0.05 = -1.37V$$

$$V_{IH} = V_{BB} + 0.05 = -1.32 + 0.05 = -1.27V$$

V_S = IS NONEXISTANT SINCE Q_R DOES NOT SATURATE

CHAPTER 16 (CONT)

16.5 NPN LAYERS S/D — SUBSTRATE — SUBSTRATE
N^+ P N

PNP LAYERS S/D - SUBSTRATE — SUBSTRATE
P^+ N P

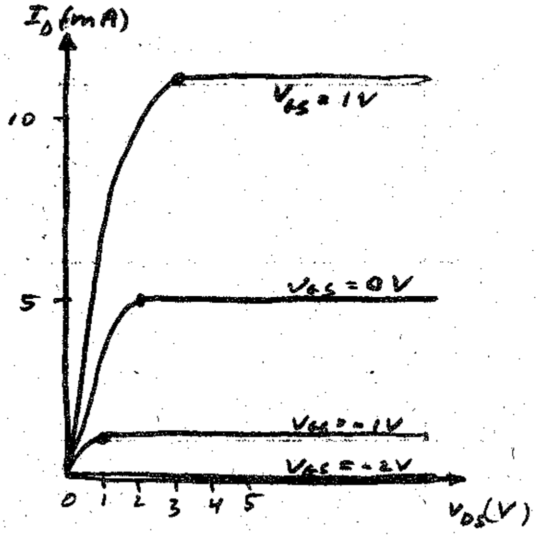
16.6 BEGIN BY REARRANGING $I_D(SAT)$ AS

$$I_D(SAT) = \frac{5}{4}\left(2 + V_{GS}\right)^2$$

THUS, $V_T = -2V$

AND

$$\frac{R}{2} = 5/4 = 1.25\,mA/V^2$$



SAT CALCULATIONS

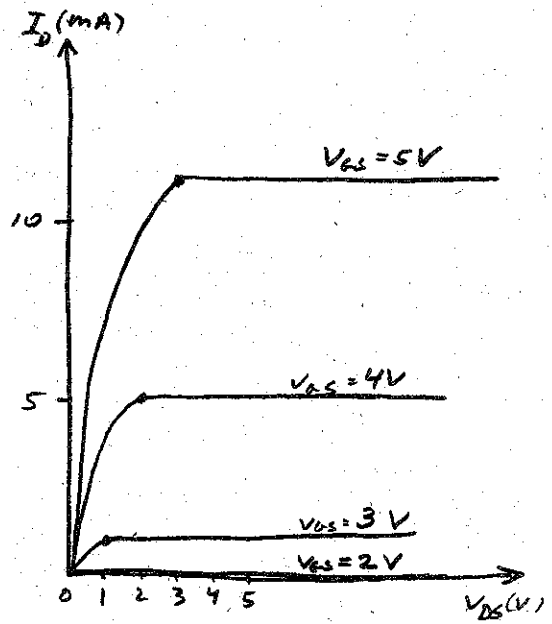
V_{GS}(V)	$I_D(SAT)$(mA)
-2	0
-1	5/4 = 1.25 mA
0	5 = 5 mA
1	9(5/4) = 11.25 mA

16.7 REARRANGE $I_D(SAT)$

$$I_D(SAT) = \frac{5}{4}\left(V_{GS} - 2\right)^2$$

THUS,
$V_T = 2V$

AND $\frac{R}{2} = \frac{5}{4} = 1.25\,mA/V^2$



SAT CALCULATIONS

V_{GS}(V)	$I_D(SAT)$ (mA)
2	0
3	1.25
4	5
5	9(5/4) = 11.25

CHAPTER 17 SOLUTIONS

17.1 SEE SOLUTION FOR PROBLEM 16.6.

17.2 " " " " 16.7

17.3 " " " " 16.8

17.4 CONVERT $I_D(LIN)$ to $I_D(SAT)$

WHERE (BY INSPECTION) $V_T = 1V$, $k = 5 mA/V^2$

$$\therefore I_D(SAT) = \frac{5}{2}(V_{GS} - 1)^2$$

AND THIS IS TWICE THE CURRENT OF PROB 17.1

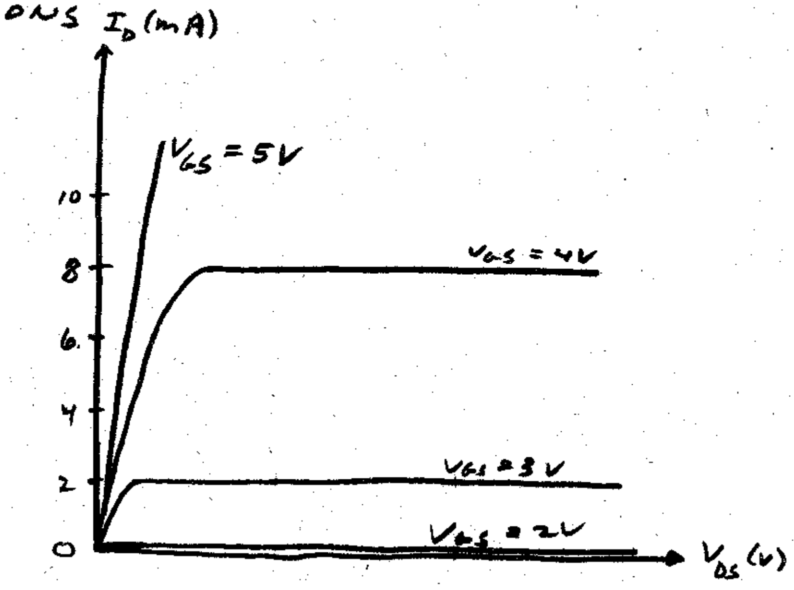
17.5 CONVERT $I_D(LIN)$ to $I_D(SAT)$

WHERE (BY INSPECTION) $V_T = -2V$, $k = 4mA/V^2$

$$\therefore I_D(SAT) = 2(V_{GS} - 2)^2$$

SAT CALCULATIONS

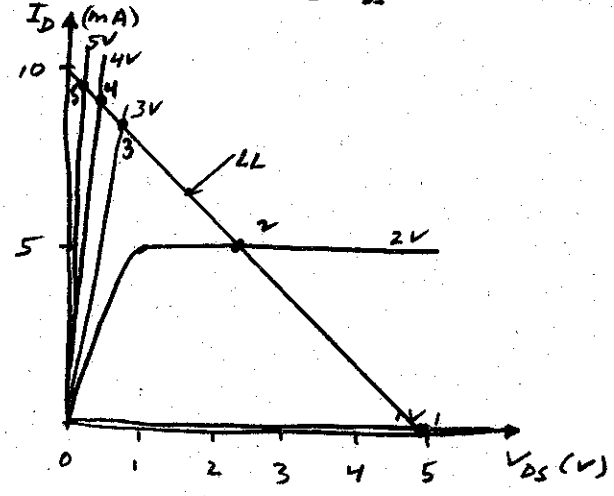
$V_{GS}(V)$	$I_D(mA)$
2	0
3	2
4	8
5	18

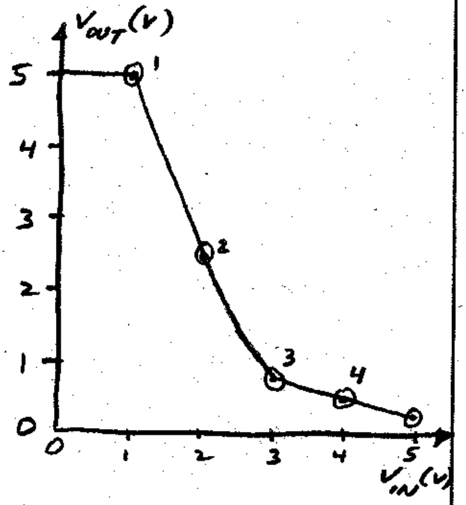


17.6 THIS I_D vs V_{DS} AND V_{GS} CORRESPONDS TO PROBLEM 17.3

17.9

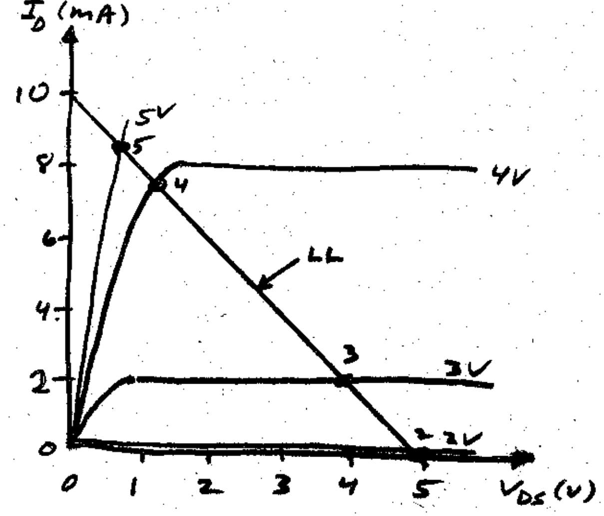
REDRAWING $I_D - V_{DS}$ CHARACTERISTICS

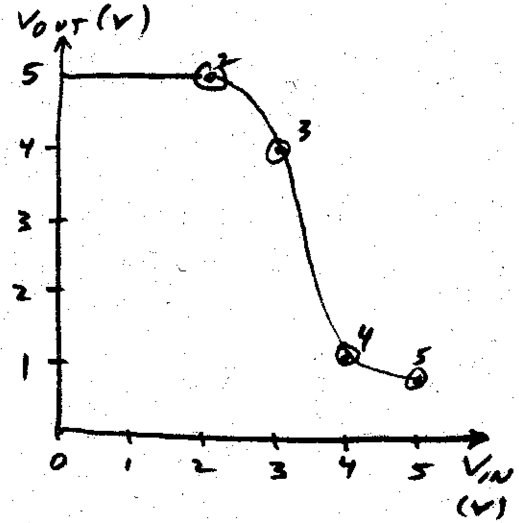




17.10 SAME SOLUTION AS PROBLEM 17.7

17.11 REDRAWING I_D CHARACTERISTICS FROM 17.5 AND LL WITH $R_L = 0.5 k\Omega$, $V_{DD} = 5V$





17.12 SAME SOLUTION AS PROBLEM 17.9.

17.13 AVG STATIC POWER DISSIPATION

$V_{DD} = 5V$, $I_{DD}(OH) = 0$, $I_{DD}(OL) = 0.3 mA$

$P_{DD}(AV) = 5\left(\frac{0+0.3}{2}\right) = 0.75 mW$

CHAPTER 18 SOLUTIONS

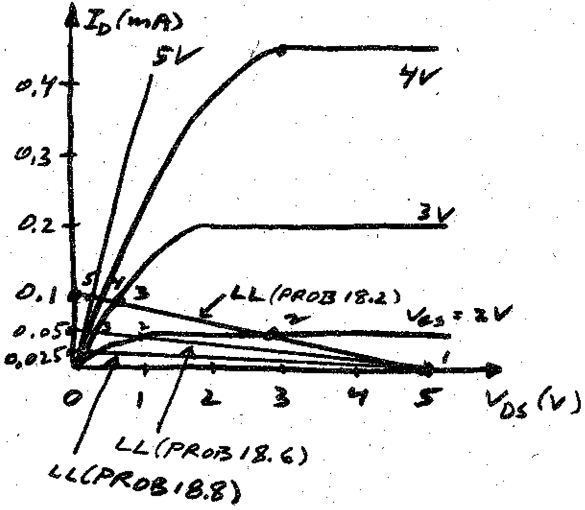
18.1

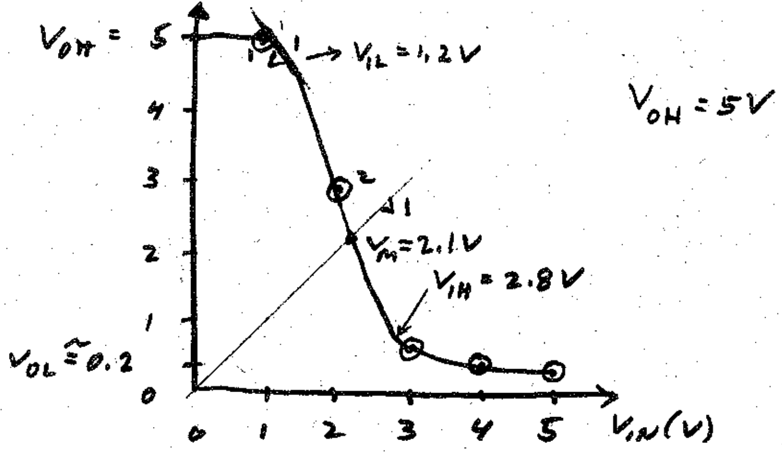
CRITICAL VOLTAGE	V_{OH}	V_{OL}	V_{IL}	V_{IH}	V_M
BJT STATE	OFF	LIN	SAT	LIN	SAT

18.2 $V_T = 1V$, $k = 0.1 mA/V^2$

$$I_D(SAT) = \frac{k}{2}(V_{GS} - V_T)^2 = \frac{0.1}{2}(V_{GS} - 1)^2$$

V_{GS}	I_D(SAT)(mA)
1	0
2	0.05
3	0.20
4	0.45
5	0.8





$V_{OH} = 5V$

18.3 $V_{IN} < 1V$, NO CUTOFF AND $V_{OH} = 5V$

$$V_{IL} = V_T + \frac{1}{kR_L} = 1 + \frac{1}{0.1(50)} = 1.2V, \quad V_{OL} = \frac{V_{DD}}{kR_L(V_{DD} - V_T) + 1} = 0.238V$$

V_{IH}: $$\frac{3k}{8}(V_{IH} - V_T)^2 + \frac{1}{2R_H}(V_{IH} - V_T) - \frac{V_{DD}}{R_L} = 0$$

$$V_{IH} - V_T = \frac{-\frac{1}{2R_L} \pm \sqrt{\frac{1}{4R_L^2} + \frac{3kV_{DD}}{2R_L}}}{3k/4} = \frac{-0.01 \pm \sqrt{0.0001 + 0.015}}{0.075}$$

$$V_{IH} - V_T = 1.505V \longrightarrow V_{IH} = 2.505V$$

CHAPTER 19 SOLUTIONS

19.1

CRITICAL POINT	V_{OH}	V_{OL}	V_{IL}	V_{IH}	V_M
N_O	CUTOFF	LIN	EOS	LIN	SAT
N_L	SAT	SAT	SAT	SAT	SAT

19.2

$$k_o = k'\left(\frac{W}{L}\right)_O = 20\mu \frac{20\mu}{2\mu} = 200\mu A/V^2$$

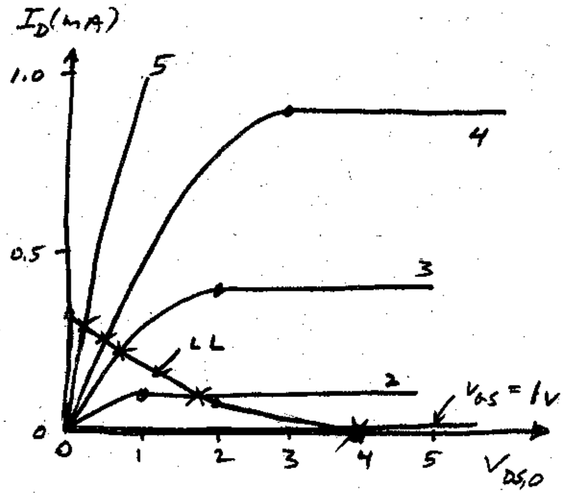
$$k_L = k'\left(\frac{W}{L}\right)_L = 20\mu \frac{10\mu}{5\mu} = 40\mu A/V^2$$

I-V EXPRESSION FOR N_L:

$$I_{D,L}(SAT) = \frac{k_L}{2}\left(V_{DS,L} - V_{T,L}\right)^2 = \frac{k_L}{2}\left([V_{DD} - V_{DS,O}] - V_{T,L}\right)^2 = \frac{40\mu}{2}\left((5-1) - V_{DS,O}\right)^2$$

$$I_{D,L}(SAT) = 20\mu\left(4 - V_{DS,O}\right)^2$$

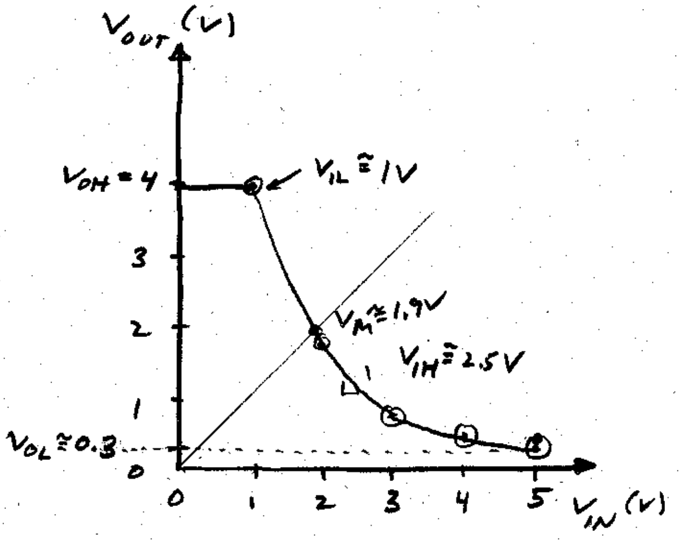
$I_{D,L}$(mA)	V_{DS}(V)
0	4
0.08	2
0.32	0



I-V SAT EXPRESSION FOR N_O:

$$I_{D,O}(SAT) = \frac{k_O}{2}\left(V_{GS} - V_T\right)^2 = 100\mu\left(V_{GS} - 1\right)^2$$

V_{GS}(V)	$I_{D,O}$(SAT) mA
1	0
2	0.1
3	0.4
4	0.9



CHAPTER 20 SOLUTIONS

20.1

OPERATING STATES AT CRITICAL POINTS
E-ONLY LOAD

CRITICAL POINT	OUTPUT N_O	LOAD N_L
V_{OH}	CUTOFF	LIN
V_{IL}	SAT	LIN
V_M	SAT	LIN
V_{IH}	LIN	LIN
V_{OL}	LIN	LIN

20.2

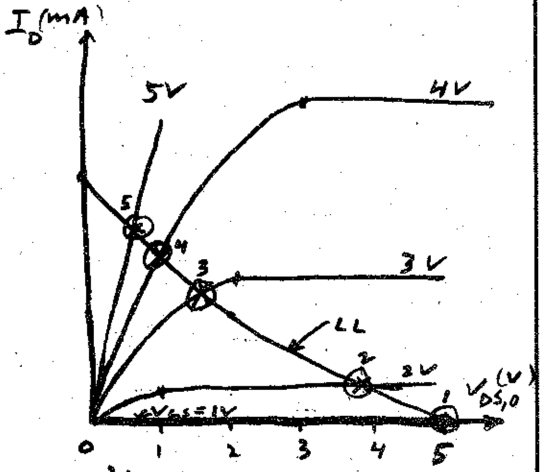
$$k_0 = k'(W/L)_0 = 20\mu\left(\frac{20\mu}{2\mu}\right) = 200\mu A/V^2, \quad V_T = 1V$$

$$k_L = k'(W/L)_L = 20\mu\left(\frac{10\mu}{5\mu}\right) = 40\mu A/V^2$$

$$N_0 : I_{D,0}(SAT) = \frac{k_0}{2}(V_{GS} - V_T)^2$$

$$I_{D0}^{(SAT)} = 100\mu(V_{GS} - 1)^2$$

V_{GS}	I_D (mA)
1	0
2	0.1
3	0.4
4	0.9
5	1.6



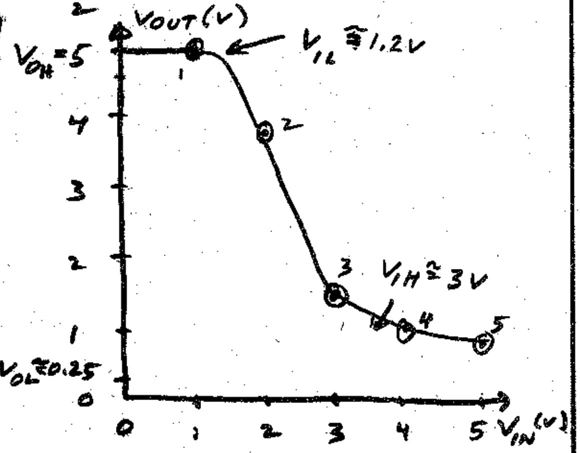
$$N_L : I_{D,L}(LIN) = k_L\left((V_{GS,L} - V_T)V_{DS,L} - V_{DS,L}^2/2\right)$$

$$I_{D,L}(LIN) = k_L\left((V_{GG} - V_{DS,0} - V_{T,L})(V_{DD} - V_{DS,0}) - \frac{(V_{DD} - V_{DS_0})^2}{2}\right)$$

$$= 40\mu\left[(7 - 1 - V_{DS,0})(5 - V_{DS,0}) - \left(\frac{5 - V_{DS0}}{2}\right)^2\right]$$

$$= 40\mu\left[(6 - V_{DS,0})(5 - V_{DS,0}) - \frac{(5 - V_{DS})^2}{2}\right]$$

$V_{DS,0}$	$I_{D,L}$ (mA)
5	0
0	$40\left[30 - \frac{25}{2}\right] = 0.7$
2	$0.04\left(4(3) - \frac{9}{2}\right) = 0.3$



CHAPTER 21 SOLUTIONS

21.1

STATES OF THE MOSFETS N_O AND N_L

CRITICAL POINT	OUTPUT N_O	LOAD N_L
V_{OH}	CUTOFF	LINEAR
V_{IL}	SAT	LIN
V_M	SAT	SAT
V_{IH}	LIN	SAT
V_{OL}	LIN	SAT

21.2 GRAPHICAL DETERMINATION OF CRITICAL POINTS

$$k_o = k'\left(\frac{W}{L}\right)_o = 20\mu\left(\frac{20\mu}{5\mu}\right) = 80\mu A/V^2$$

$$k_L = k'\left(\frac{W}{L}\right)_L = 20\mu\left(\frac{10\mu}{5\mu}\right) = 40\mu A/V^2$$

N_O:

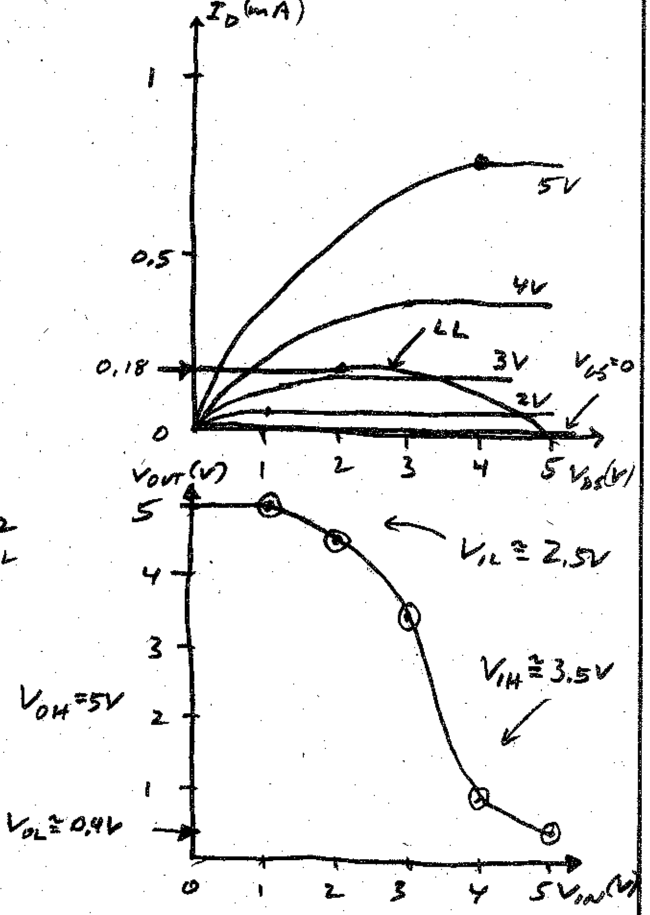
$$I_{D,O}(SAT) = \frac{80\mu}{2}(V_{GS}-1)^2$$

$V_{GS}(V)$	$I_{D,O}(mA)$
1	0
2	.040
3	.160
4	.360
5	0.64

N_L:

$$I_{D,L} = \frac{k_L}{2}(V_{GS,L}-V_{T,L})^2 = \frac{k_L}{2}V_{T,L}^2$$

$$= \frac{0.04}{2}(-3)^2 = 0.18mA$$

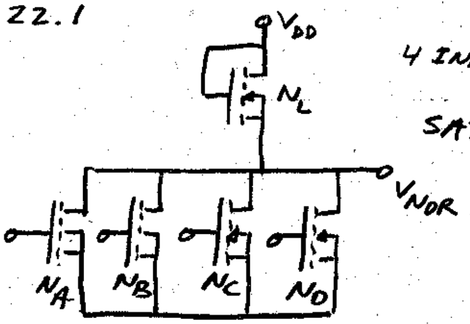


$V_{NMH} = 5 - 3.5 = 1.5V$

$V_{NML} = 2.5 - 0.4 = 2.1V$

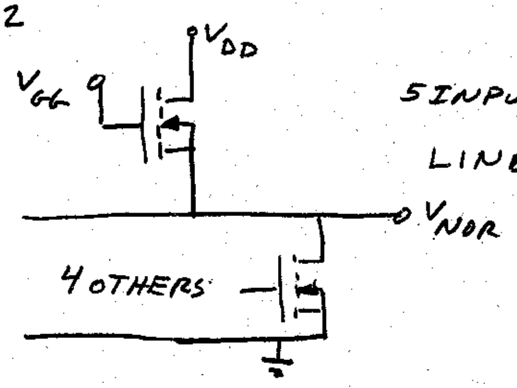
CHAPTER 22 SOLUTIONS

22.1



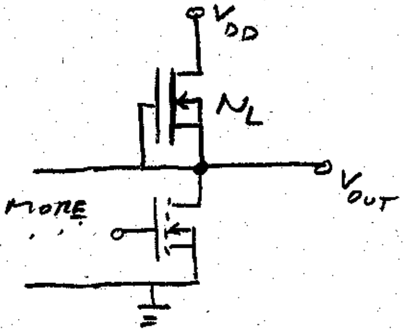
4 INPUT NMOS NOR GATE
WITH
SATURATED E-O LOAD

22.2



5 INPUT NOR GATE
WITH
LINEAR E-O LOAD

22.3 3 INPUT NOR GATE
WITH E-D LOAD



FOR ONE INPUT HIGH

$$V_{OL}(\text{E-D LOADED}) = \frac{k_L V_{TL}^2}{2k_0(V_{DD}-V_{T0})}$$

$$V_{OL} = \frac{k'(W/L)_L V_{TL}^2}{2k'\left(\frac{W}{L}\right)_0(V_{DD}-V_{T0})}$$

$$0.08 = \frac{(W/L)_L(-1)^2}{2\left(\frac{W}{L}\right)_0(5-1)}$$

$$\therefore \frac{(W/L)_L}{(W/L)_0} = (0.08)(8) = 0.64$$

LET $\underline{L = 2\mu M}$, THEN $\frac{W_L}{W_0} = 0.64$

THEN LET $W_0 = 10\mu$ AND $W_L = 6.4\mu$

22.37

$\overline{A \oplus B + C}$

22.38

C IS AN ENABLE TERMINAL

FOR C = 0, $V_{OUT} = \overline{A+B}$

FOR C = 1, $\underline{V_{OUT} = 1}$

22.39

$F = \overline{A\cdot(B+C) + (D+E)F}$

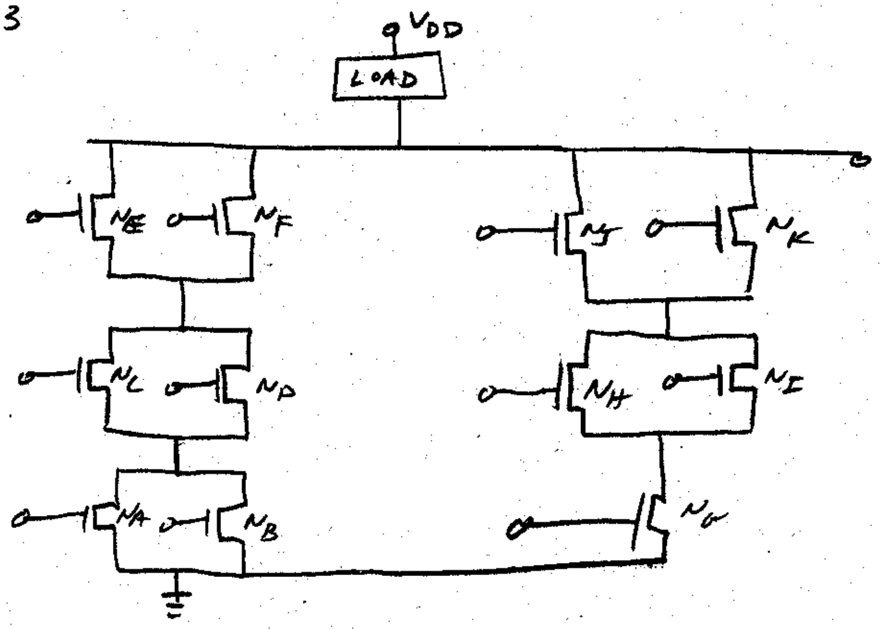
22.40

$F = \overline{(A+B)(C+D+E) + FG}$

22.41 SIMPLY REDRAW CIRCUIT

22.42 SIMPLY REDRAW CIRCUIT

22.43



23.3 (CONT)

$$3\underline{V_{IH}^2} - 6V_{IH} - 3V_{IH} + \overset{\checkmark}{6} - 2\left(\underline{\frac{9}{16}V_{IH}^2} - \frac{9}{4}V_{IH} + \overset{\checkmark}{\frac{9}{4}}\right) = 16 - 8V_{IH} + V_{IH}^2$$

$$V_{IH}^2\left(3 - \frac{9}{8} - 1\right) + V_{IH}\left(-6 - 3 + \frac{9}{2} + 8\right) + \left(6 - \frac{9}{2} - 16\right) = 0$$

$$V_{IH}^2(0.875) + V_{IH}(3.5) - 14.5 = 0$$

$$V_{IH}^2 + 4\,V_{IH} - 16.6 = 0$$

$$\therefore V_{IH} = -\frac{4}{2} + \frac{\sqrt{(4)^2 + 4(16.6)}}{2} = -2 + 4.54 = 2.54V$$

V_M:

$$V_M = \left[V_{DD} + V_{TP} + V_{TN}\sqrt{\frac{k_N}{k_P}}\right] / \left[1 + \sqrt{\frac{k_N}{k_P}}\right]$$

$$= \left[5 + (-1) + 1\sqrt{\frac{100}{50}}\right] / \left[1 + \sqrt{\frac{100}{50}}\right] = \frac{5.4142}{2.416}$$

$$= 2.24V$$

$$V_{NMH} = V_{OH} - V_{IH} = 5 - 2.54 \approx 2.46V$$

$$V_{NML} = V_{IL} - V_{OL} = 1.79 - 0 = 1.79V$$

23.4 GRAPHICAL DETERMINATION OF CRITICAL VOLTAGES

$V_{DD} = 10V$

$I_{D,N}(SAT) = 50\mu(V_{IN} - 1)^2$ UNCHANGED FROM PROBLEM 23.2

$$I_{D,P}(SAT) = \frac{50}{2}(V_{GS,P} + V_T)^2 = 25\mu(10 - V_{IN} - 1)^2$$

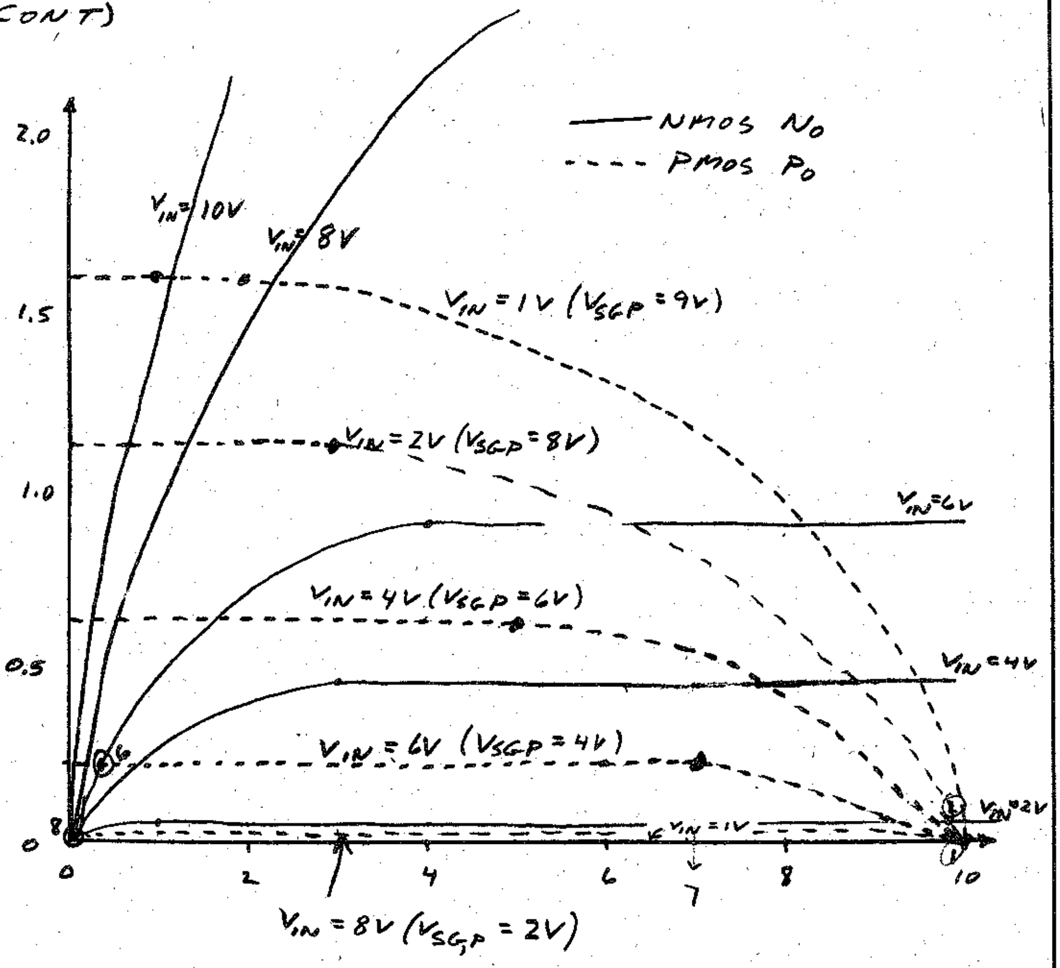
$$I_{D,P}(SAT) = 25\mu(9 - V_{IN})^2$$

V_{IN}	$I_{D_N}^{(SAT)}$
1	0
2	0.05
4	0.45
6	0.8
8	2.45
10	4.05

V_{IN}	$I_{D,P}(SAT)$ mA	$V_{SGP}=(10-V_{IN})$
1	1.6	9
2	1.225	8
4	0.625	6
6	0.225	4
8	0.025	2
9	0	1 ← V_T

IV CHARACTERISTICS ON NEXT PAGE

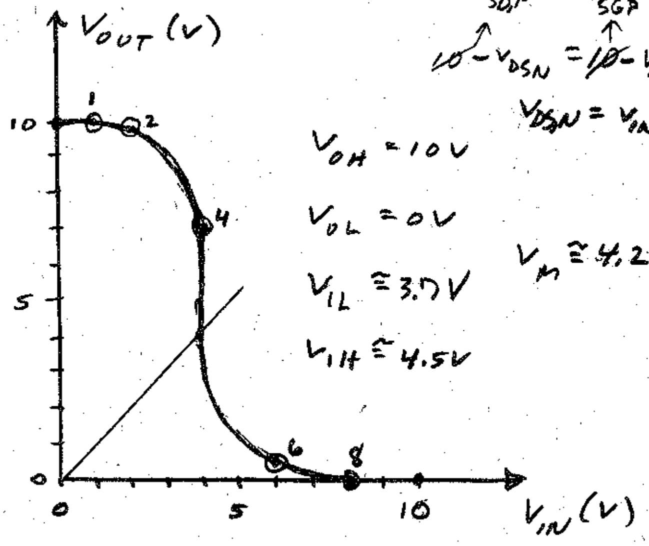
23.4 (CONT)



$V_{SD,P} = V_{SGP} + V_{TP} = V_{SGP} - 1$

$\cancel{10} - V_{DSN} = \cancel{10} - V_{IN} + V_{T,P}$

$V_{DSN} = V_{IN} - V_{T,P}$



$V_{OH} = 10V$

$V_{OL} = 0V$

$V_{IL} \cong 3.7V$

$V_{IH} \cong 4.5V$

$V_M \cong 4.2V$

24.11 BY INSPECTION OF THE CIRCUIT

$$F = \overline{A\overline{B} + \overline{A}B} = (\overline{A}+B)(A+\overline{B}) = \overline{A}\,\overline{B} + AB \quad \text{XNOR}$$

24.12 XOR

24.13 THE RELATION FOR W/L RATIOS FOR CMOS NAND GATES WITH m INPUTS IS

$$2.5\left(\frac{W}{mL}\right)_N = \left(\frac{W}{L}\right)_P$$

THUS, FOR A 2 INPUT NAND gate

$$\frac{2.5}{2}\left(\frac{W}{L}\right)_N = \left(\frac{W}{L}\right)_P$$

CASE A: CHOOSE MINIMUM SIZE NMOSFETs

$$\left(\frac{W}{L}\right)_N = \frac{4\mu m}{2\mu m}$$

AND THUS

$$\left(\frac{W}{L}\right)_P = \left(\frac{4\mu}{2\mu}\right)\left(\frac{2.5}{2}\right) = \frac{5\mu}{2\mu}$$

FOR THIS CASE THE CHIP AREA FOR THE 4 TRANSISTORS IS

$$AREA = 2\left(A_N + A_P\right) = 2\left(4\times 2 + 5\times 2\right) = 36\,\mu m^2$$

CASE B CHOOSE MINIMUM SIZE PMOSFETS

$$\left(\frac{W}{L}\right)_P = \frac{4\mu}{2\mu}$$

THUS,

$$\left(\frac{W}{L}\right)_N = \left(\frac{4}{2}\right)\left(\frac{2}{2.5}\right) = \frac{4\mu}{2.5\mu} = \frac{3.2\mu}{2\mu}$$

AND

$$AREA = 2\left(4\times 2 + 3.2\times 2\right) = 28.8\,\mu m^2$$

25.6)

	V_{IN}	N_o	P_o	PULL-UP PATH	PULL-DOWN PATH	V_{OUT}
1.	LOW	OFF	ON	YES	NO	HIGH
2	HIGH	ON	OFF	NO	YES	LOW
3	Z	?	?	NO	NO	Z
4	X	?	?	YES	YES	X

25.7) EQUATE THE LINEAR DRAIN CURRENTS FOR THE N- AND P- CHANNEL MOSFETS:

$$I_{D,N} \text{ (LIN)} = I_{D,P} \text{ (LIN)}$$

$$k_N \left[(V_{GS,N} - V_{TN}) V_{DS,N} - \frac{V_{DS,N}^2}{2} \right] = k_P \left[(V_{SG,P} + V_{T,P}) V_{SD,P} - \frac{V_{SD,P}^2}{2} \right]$$

SUBSTITUTE:

$$V_{GS,N} = V_{INA} = V_{OH} = 5V$$

$$V_{SG,P} = V_{DD} - V_{INB} = V_{DD} - V_{OL} = 5V$$

$$V_{DS,N} = V_{OUT}$$

$$V_{SD,P} = V_{DD} - V_{OUT}$$

$$80\mu\left[(5-1)V_{OUT} - \frac{V_{OUT}^2}{2}\right] = 80\mu\left[(5+(-1))(5-V_{OUT}) - \frac{(5-V_{OUT})^2}{2}\right]$$

$$\underline{4V_{OUT}} - \cancel{\frac{V_{OUT}^2}{2}} = 20 - 4V_{OUT} - \frac{25}{2} + \underline{5V_{OUT}} - \cancel{\frac{V_{OUT}^2}{2}} \longrightarrow 3V_{OUT} = 20 - \frac{25}{2} = 7.5$$

COLLECT LIKE TERMS AND SOLVE FOR V_{OUT}:

$$V_{OUT} = 2.5V = V_X$$

25.8

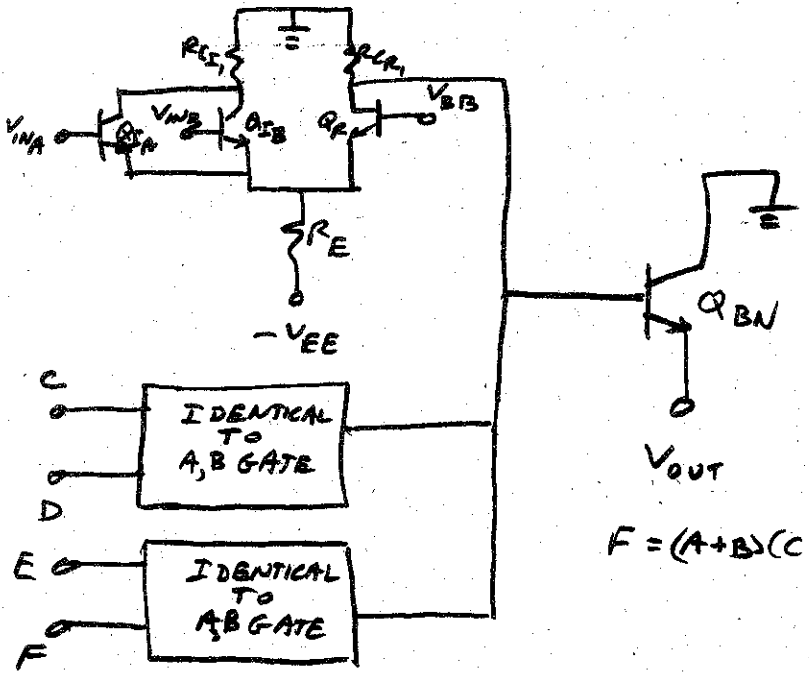
V_A	$V_B = V_C$	V_{OUT}
Low	Low	V_{DD}
Low	Hi	Low
Hi	Low	Low
Hi	Hi	Low

25.9

V_{IN}	$\overline{V_{PEN}}$	V_{NEN}	V_{TINV}
Low	Low	Low	Hi
Low	Low	Hi	Hi
Low	Hi	Low	X
Low	Hi	Hi	X
Hi	Low	Low	X
Hi	Low	Hi	Low
Hi	Hi	Low	X
Hi	Hi	Hi	Low

CHAPTER 15 (CONT)

15.11 REALIZE THE LOGIC FUNCTION $F = (A+B)(C+D)(E+F)$



$F = (A+B)(C+D)(E+F)$

15.12 TO OBTAIN THE INVERSE OF F, FROM PROBLEM 15.11, $\bar{F} = \overline{(A+B)(C+D)(E+F)}$
USE SAME CIRCUIT AS PROBLEM 15.11
EXCEPT COLLECTOR DOTTINF OF INPUT
TRANSISTOR COLLECTORS WITH OUTPUT
BUFFER BJT QBINV.

15.13

A	B	XOR
0	0	0
0	1	1
1	0	1
1	1	0

15.14

A	B	XNOR
0	0	1
0	1	0
1	0	0
1	1	1

26.10 TWICE THE DRIVE STRENGTH IMPLIES THAT THE W/L RATIOS OF THE DEVICES IN THE STACK SHOULD BE DOUBLED THUS,

$$\frac{W_{N0}}{L_{N0}} = \frac{W_{NI}}{L_{NI}} = 2\left(\frac{8\mu m}{2\mu m}\right) = 8$$

AND

$$\frac{W_{P0}}{L_{P0}} = \frac{W_{PI}}{L_{PI}} = 2\left(\frac{20\mu m}{2\mu m}\right) = 20$$

HENCE

$$k_{NI} = k_{N0} = k'_{NI}\frac{W_{NI}}{L_{NI}} = 40\mu(8) = 320\mu A/V^2$$

$$k_{PI} = k_{P0} = k'_{PI}\frac{W_{PI}}{L_{PI}} = 16\mu(20) = 320\mu A/V^2$$

ALSO

$$\frac{W_{NF}}{L_{NF}} = \left[\frac{V_{ID}-V_{TN}}{V_{DD}-V_{ID}}\right]^2\frac{W_{NI}}{L_{NI}} = \left[\frac{4-1}{5-4}\right]^2 8 = 72$$

$$\frac{W_{PF}}{L_{PF}} = \left[\frac{V_{DD}+V_{TP}-V_{IU}}{V_{IU}}\right]^2\frac{W_{PI}}{L_{PI}} = \left[\frac{5-1-1}{1}\right]^2 20 = 180$$

26.11 USING THE EQS OF THE PREVIOUS PROBLEM (26.10)

$$\frac{W_{N0}}{L_{N0}} = \frac{W_{NI}}{L_{NI}} = 2\ \frac{8\mu m}{2\mu m} = 8 \text{ AND } \frac{W_{P0}}{L_{P0}} = \frac{W_{PI}}{L_{PI}} = 2\ \frac{20\mu m}{2\mu m} = 20$$

$$\frac{W_{NF}}{L_{NF}} = \left[\frac{4-1}{7-4}\right]^2 8 = 8$$

$$\frac{W_{PF}}{L_{PF}} = \left[\frac{7-1-1}{1}\right]^2 20 = 25(20) = 500$$

26.12 USING THE EQS OF THE PREVIOUS PROBLEMS

SAME RESULTS FOR N_0, P_0, N_I, P_I. THEN

$$\frac{W_{NF}}{L_{NF}} = \left[\frac{4-1}{10-4}\right]^2 8 = \left[\frac{1}{4}\right] 8 = 2$$

$$\frac{W_{PF}}{L_{PF}} = \left[\frac{10-1-1}{1}\right]^2 20 = 64(20) = 1280$$

27.4 (CONT)

For the third stage:

$$k_{N_3} = k_{P_3} = k_N'(W/L)_{N_3} = 40\mu(120/2) = 2.4\,mA/V^2$$

$$C_{L3} = [(WL)_{N_4} + (WL)_{P_4}]C_{ox} = [1750\times2 + 700\times2]\,690a$$

$$= (3500 + 1400)\,690 = 3.38pF$$

$$\tau_{P_3} = AC_{L3}/k_{P3} = \frac{0.322\times 3.38p}{2.4m} = 0.45ns$$

For the Fourth stage:

$$k_{N_4} = k_{P_4} = (40\mu)(700/2) = 14mA/V^2$$

$$C_{L4} = C_L = 5pF$$

$$\tau_{P4} = \frac{0.322\,(5p)}{14m} = 0.115ns$$

$$\tau_{P_{TOTAL}} = 0.39+0.47+0.45+0.115 = 1.425nS$$

27.5 ALL k_N and $k_P \times \frac{1000}{690}$ and ALL $C_{IN} \times \frac{1000}{690}$

∴ ALL τ unchanged except τ_4

27.6 Transconductance Parameters doubled

From Problem 27.4:

$$A = B = 0.322/V,\ k_{P_1} = 160\mu A/V^2,\ C_{L_1} = 96.6fF$$

$$\tau_{P_1} = \frac{0.322\,(96.6f)}{160\mu} = \frac{0.39}{2} = 0.195ns$$

For the second stage

$$\tau_{P_2} = AC_{L2}/k_{P_2} = 0.47/2 = 0.235ns$$

For the 3rd stage

$$\tau_{P_3} = AC_{L3}/k_{P3} = 0.45/2 = 0.225nS$$

For the 4th stage $\tau_{P4} = \frac{0.115}{2} = 0.0575nS$

∴ $\tau_{TOTAL} = 0.7125nS$

PRODUCED DUE TO THE LARGE GATE CURRENT, THE FANOUT AND RELIABILITY OF THE GATE ALSO BECOME UNACCEPTABLE.

34.6 $a = 0.1\ \mu m$ $\quad$ $\beta' =$ PROCESS TRANSCONDUCTANCE

$W = 0.6\ \mu m$ $\quad$ $\beta =$ DEVICE TRANSCONDUCTANCE

$L = 3.0\ \mu m$

$$\beta' = \frac{\mu_N \epsilon_{GaAs}}{2a} = \frac{8600\ \frac{cm^2}{V\text{-}s} \times 1.16 \times 10^{-12}\ F/cm}{2 \times 10^{-5}\ cm}$$

$$\therefore \boxed{\beta' = 498.8\ \mu A/V^2} \boxed{\doteq 500\ \mu A/V^2}$$

$$\beta = \beta' \cdot W/L = 498.8 \times \frac{0.6}{3.0} = 99.76\ \mu A/V^2$$

$$\therefore \boxed{\beta = 99.76\ \mu A/V^2} \boxed{\cong 100\ \mu A/V^2}$$

34.7

$$V_P = \frac{qN_D a^2}{2\epsilon_{GaAs}} \qquad N_D = 10^{17}/cm^3$$

$$= \frac{1.6 \times 10^{-19} \times 10^{17} \times 10^{-5}}{2 \times 1.16 \times 10^{-12}}$$

$$\boxed{V_P = 0.69\ V}$$

$$V_T = V_{bi} - V_P$$
$$= 0.8 - 0.69$$
$$= 0.11\ V$$

$$\boxed{V_T = 0.11\ V}$$

35.7

a) $V_{OH} = V_{SBD,GaAs}(ON) = 0.8\text{ V}$

$$\boxed{V_{OH} = 0.8\text{ V}}$$

$$V_{IL} = V_{T,0} + |V_{T,L}| \left[\frac{\beta_L [1 + \lambda_L (V_{DD} - V_{SBD,GaAs})] \tanh \alpha_L (V_{DD} - V_{SBD,GaAs})}{\beta_0 (1 + \lambda_0 V_{SBD,GaAs}) \tanh \alpha_0 V_{SBD,GaAs}} \right]^{1/2}$$

$$= 0.2 + |-1| \left[\frac{1}{10} \frac{\tanh 2(0.2)}{\tanh 2(0.8} \right]^{1/2} = 0.2 + 0.2$$

$$\boxed{V_{IL} = 0.4\text{ V}}$$

$$V_{OL} = \frac{1}{\alpha_0} \cdot \frac{\beta_L}{\beta_0} \frac{V_{T,L}^2}{(V_{OH} - V_{T,0})^2} \cdot (1 + \lambda_L \cdot V_{DD}) = \frac{1}{2} \frac{1}{10} \frac{(-1)^2}{(0.8 - 0.2)^2}$$

$$\boxed{V_{OL} = 0.139\text{ V}} \boxed{= 0.14\text{V}}$$

FOR DETERMINATION OF VIH, NUMERICAL SOLUTION OF TWO EQUATIONS, AS IN PROBLEM 35.2, IS REQUIRED. STARTING WITH A GUESS VALUE FOR EACH OF VIN i.e. VIH AND VOUT, SOLUTION CAN BE WORKED OUT ON MATHCAD.

$V_{OUT} = 0.22\text{ V}$

$\boxed{V_{IH} = 0.69\text{ V}}$ SEE NEXT PAGE FOR DETAILS

$$V_{NMH} = V_{OH} - V_{IH} = \boxed{0.11\text{ V}}$$

$$V_{NML} = V_{IL} - V_{OL} = \boxed{0.26\text{ V}}$$

b) DIRECT SUBSTITUTION IN TO THE EXPRESSIONS AS IN 35.5 GIVES

$$I_{DD}(OH) = \underline{88.535\ \mu A} \leftarrow \begin{matrix} \beta_L V_{T,L}^2 (1 + \lambda_L (V_{DD} - V_{OH})) \tanh \alpha_L (V_{DD} - V_{OH}) \\ 100 (-1)^2 (1 + 0 (0.7)) \tanh 2 (0.7) \end{matrix}$$

$$I_{DD}(OL) = 99.14\ \mu A \leftarrow 100 (-1)^2 \tanh 2 (1.5 - 0.14)$$

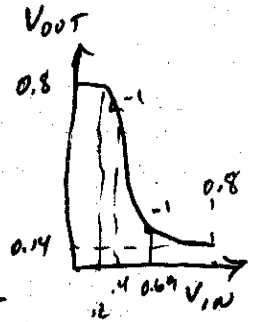
$$P_{DD} = \frac{(88.535 + 99.14)}{2} \cdot (1.5)$$

$$\boxed{P_{DD} = 140.8\ \mu W}$$

CHAPTER 35 (CONT)

35.7

Determination of V_{IH}



(1) $V_{IH} = 0.2 + \frac{1}{\sqrt{10 \tanh 2V_{out}}}$

(2) $V_{IH} = 0.2 + \cosh^2 2V_{out} \tanh 2V_{out}$

Equate

$0.316 = \frac{1}{\sqrt{10}} = \cosh^2 2V_{out} \tanh^{3/2} 2V_{out}$

Choose $2V_{out}$	Calculate $\cosh^2(2V_{out})(\tanh^{3/2}(2V_{out})) =$
0.22	(1.0492) (1.007) = 0.1
0.4	(1.169) (0.234) = 0.274
0.38	(1.151) (0.218) = 0.25
0.5	(1.271) (0.314) = 0.4
0.45	(1.217) (0.274) = 0.33
0.44	(1.21) (.266) = 0.32

$\therefore \underline{2V_{OUT} \cong 0.44\,V} \rightarrow V_{OUT} = 0.22$

$V_{IH} = 0.2 + \cosh^2(0.44) \tanh (0.44)$

$= 0.2 + \underbrace{(1.206)(0.41)}_{0.49} = \underline{0.69\ V}$

as a check

$V_{IH} = 0.2 + \frac{1}{\sqrt{10 \tanh 0.44}} = 0.2 + .49 = 0.69$

c) MAXIMUM FANOUT

MAXIMUM FANOUT IS OBTAINED FOR $V_{OUT} = V_{IH}$

$$I_{D,L} = \beta_L V_{T,L}^2 \cdot \tanh(\alpha_L (V_{DD} - V_{IH}))(1 + \lambda_L (V_{DD} - V_{IH}))$$

$$= 92.34 \ \mu A$$

$$I'_{G,0}(IH) = I_{SBD} \cdot \exp\left[\frac{V_{IH}}{0.026}\right] = (10^{-12} \mu A)\left(\exp\left[\frac{0.69}{0.026}\right]\right)$$

$$= 0.335 \ \mu A$$

$$N = \frac{I_{D,L}}{I'_{G,0}(IH)} = 275.64$$

$$\boxed{N_{MAX} = 275}$$

FANOUT FOR $NM_H = 0.1 \text{ V}$

$$V_{OUT} = \overset{0.69}{V_{IH}} + \overset{+0.1}{NM_H}$$

$$V_{OUT} = 0.79$$

$$I_{D,L\,(V_{OUT} = 0.79)} = \beta_L \cdot V_{T,L}^2 \cdot \tanh[\alpha_L (V_{DD} - V_{OUT})\left(1 + \lambda_L (V_{DD} - V_{OUT})\right)$$

$$= 88.809 \ \mu A$$

$$I'_{G0\,(V_{OUT} = 0.794)} = (I_{SBD}) . \exp\left(\overset{.79}{V_{OUT}}/0.026\right)$$

$$= 15.6 \ \mu A$$

$$N = I_{D,L} / I'_{G0}$$

$$= 5.69$$

$$\boxed{N = 5}$$

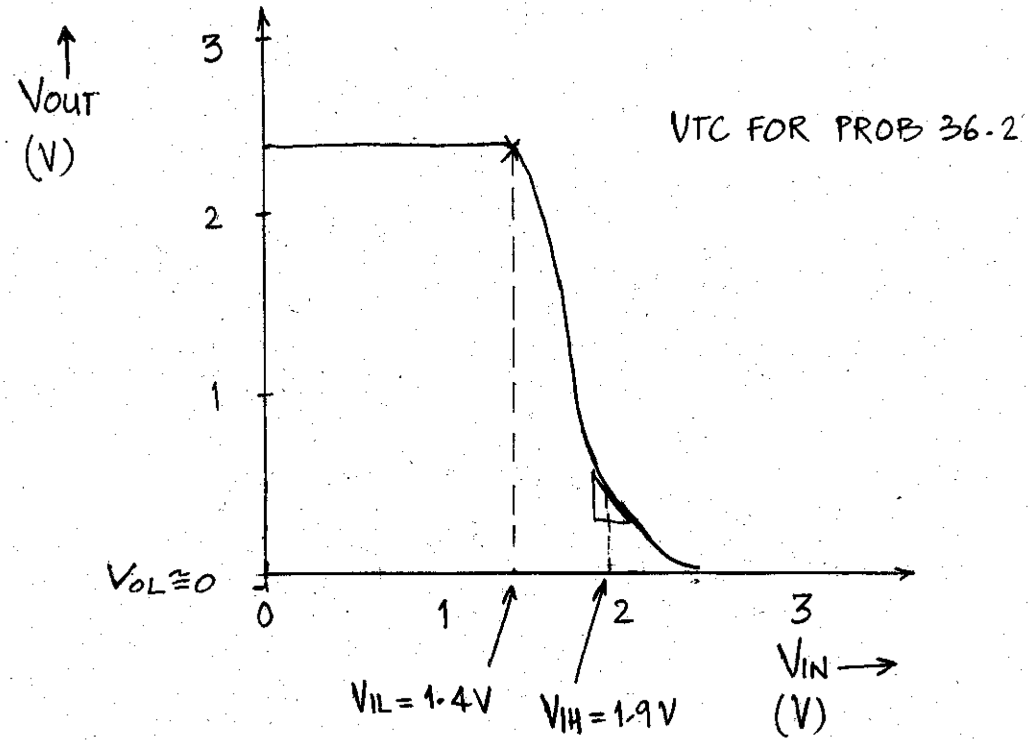
$$V_{IH} = 1.4 + (0.32)\tanh^{-1/2}(0.426)$$

$$= 1.4 + 0.5$$

$$\boxed{V_{IH} = 1.9\ V}$$

$$V_{NML} = V_{IL} - V_{OL} = 1.4 - 0.05 = 1.35\ V$$

$$V_{NMH} = V_{OH} - V_{IH} = 2.4 - 1.9 = 0.5\ V$$



36.3

AVERAGE POWER DISSIPATION

$$P_{DISS} = I_{DD} \cdot V_{DD} + I_{SS} \cdot V_{SS}$$

WHERE $I_{DD} = \dfrac{I_{DD}(OH) + I_{DD}(OL)}{2}$

$I_{SS} = \dfrac{I_{SS}(OH) + I_{SS}(OL)}{2}$

CHAPTER 36 (CONT)

36.3 (CONT)

$$I_{DD}(OL) = I_{D,L}(OL) = \beta_L V_{T,L}^2 (1+\lambda_L(V_{DD}-V_{OL}))$$

$$= \left(\frac{100}{10}\right)(-1)^2(1+0.2(3-0.05))$$

$$= 10\ (1+0.59) = \underline{15.9\mu A}$$

$$I_{DD}(OH) = \beta_L V_{T,L}^2(1+\lambda_L V_{DS,L})\tanh \alpha_L V_{DS,L}$$

$$= \left(\frac{100}{10}\right)(-1)^2(1+0.2(3-2.4))\underbrace{\tanh \overbrace{2(3-2.4)}^{1.2}}_{0.83}$$

$$= 10\ (1+0.12)(0.83)$$

$$= \underline{9.3\mu A}$$

$$I_{SS}(OL) = \beta_D V_{T,D}^2\left(1+\lambda_D\left(V_{OH}-3V_{SBD\,GaAs}(ON)+V_{SS}\right)\right)$$

$$= 100(-1)^2(1+0.2(2.4-2.4-(-3)))$$

$$= 100\ (1+0.6) = \underline{160\mu A}$$

$$I_{SS}(OH) = \beta_D V_{T,L}^2(1+\lambda_D(V_{OL}-3V_{SBD\,GaAs}(ON)+V_{SS}))\tanh \alpha_D V_{DS,L}$$

$$= 100(-1)^2(1+0.2(0.05-2.4+3))\tanh 2(0.65)$$

$$= 100\ (1+0.2(0.65))(0.86) = \underline{97.2\mu A}$$

$$P_{DISS}(AV) = V_{DD}I_{DD} + V_{SS}I_{SS} = 3\left(\frac{15.9+9.3}{2}\right)+3\left(\frac{160+97.2}{2}\right)$$

$$= 37.8 + 386 = 423.8\mu W$$

$$= 0.42\ mW$$

37.4

a) $V_{OH} = V_{DD} - 3V_{SBD,GaAs(ON)} = \boxed{0.6V}$

$V_{IL} = V_{T,0} = \boxed{-1.5V}$

$V_{OL} = -3V_{SBD,GaAs(ON)} = \boxed{-2.4V}$

THE FOLLOWING EXPRESSIONS ARE NUMERICALLY SOLVED FOR V_{IH}

$$\beta_L \cdot V_{T,L}^2 \tanh\alpha_L \cdot V_{DS,L} \cong \beta_0 (V_{IN} - V_{T,0})^2 \cdot \tanh\alpha_0 V_{DS,0} + \beta_C \cdot V_{T,C}^2 - \beta_F (V_{GS,F} - V_{T,0})^2$$

AND

$$\frac{\alpha_L \cdot V_{T,L}^2}{\cosh^2\alpha_L \cdot V_{DS,L}} + \frac{(\beta_0/\beta_L)\alpha_L \cdot (V_{IN} - V_{T,0})^2}{\cosh^2\alpha_0 \cdot V_{DS,0}} = 2\frac{\beta_0}{\beta_L}(V_{IN} - V_{T,0})\tanh\alpha_0 \cdot V_{DS,0}$$

WHERE $V_{DS,L} = V_{DD} - [V_{OUT} + 3V_{SBD,GaAs(ON)}]$

$V_{DS,0} = V_{OUT} + 3V_{SBD,GaAs(ON)}$

WE GET,

$V_{OUT} = -1.95V$ AND $\boxed{V_{IH} = -0.05V}$ SEE NEXT PAGE

AND,

$V_{NMH} = V_{OH} - V_{IH}$ AND $V_{NML} = V_{IL} - V_{OL}$

$V_{NMH} = 0.65V$ $V_{NML} = -1.5 + 2.4 = 0.9V$

b) $$I_{SS(OL)} = \overset{(100)}{\beta_C} \cdot \overset{(1.5)^2}{V_{T,C}^2} [1 + \overset{(0)}{\lambda_C}(V_{OL} + V_{SS})] \cdot \tanh [\underset{2\,(-2.4+3)}{\alpha_C (V_{OL} + V_{SS})}]$$

$= 187.6\mu A$

$$I_{SS}(OH) = \underset{(100)}{\beta_C} \cdot \underset{(1.5)^2}{V_{T,C}^2} [1 + \overset{0}{\lambda_C}(V_{OH} + V_{SS})] \cdot \overset{1}{\tanh} [\underset{2\,(0.6+3)}{\alpha_C (V_{OH} + V_{SS})}]$$

$= 225\mu A$

$I_{SS} = (I_{SS(OL)} + I_{SS(OH)})/2 = 206.3\mu A$

$$I_{DD(OL)} = I_{D,L(OL)} + I_{D,F(OL)}$$
$$= \underset{50}{\beta_L} \cdot \underset{(1.5)^2}{V_{T,L}^2}(1 + \lambda_L \cdot V_{DD}) \cdot \overset{1}{\tanh}\alpha_L \cdot V_{DD} + \underset{50}{\beta_F} \overset{(0.8+1.5)^2}{(V_{GS,F} - V_{T,F})^2} \cdot \{1 + \lambda_F \cdot V_1\} \cdot \underset{1}{\tanh}\alpha_F \cdot V_1$$

WHERE $V_1 = V_{DD} + V_{SBD,GaAs(ON)}$

$= 377\mu A$

$I_{DD(OH)} = I_{SS}(OH) = 225\mu A$

$I_{DD} = (I_{DD(OL)} + I_{DD(OH)})/2 = 301\mu A$

$P_{DISS} = V_{DD} \cdot I_{DD} + V_{SS} \cdot I_{SS} = \boxed{1.522mW}$

37.4 (CONT)

V_{IH}: 2 EQUATIONS

$$(1)\quad \cancel{50}(-1.5)^2 \cancelto{1}{\tanh}\, 2(0.6-V_{OUT}) = \cancelto{2}{100}(V_{IN}+1.5)^2 \cancelto{\#1}{\tanh}\, 2(V_{out}+2.4)$$
$$+\cancelto{2}{100}(1.5)^2 - \cancel{50}(0.8+1.5)^2$$

$$(-1.5)^2 = 2(V_{IN}+1.5)^2 \tanh \underbrace{2(V_{out}+2.4)}_{x} + 2(2.25) - (2.3)^2$$

$$2.25 - 4.5 + 5.25 = 2(V_{IN}+1.5)^2 \tanh(x)$$

$$3 = 2(V_{IN}+1.5)^2 \tanh(x)$$

$$(1)\quad V_{IN}+1.5 = \sqrt{\frac{3}{2}\frac{1}{\tanh(x)}} = \frac{1.225}{\tanh^{1/2}(x)}$$

$$(2)\quad \cancel{\frac{2(-1.5)^2(\quad)}{\cosh^2 2\underset{(0.6-V_{out})}{(large>1)}}}\ + \cancel{\left(\frac{100}{50}\right)}\frac{2(V_{IN}+1.5)^{\cancel{2}}}{\cosh^2 \underbrace{2(V_{OUT}+2.4)}_{x}} = 2\cancel{\left(\frac{100}{50}\right)}\cancel{(V_{IN}+1.5)}\tanh(x)$$

$$\downarrow$$
$$\cong 0$$

$$(2)\quad V_{IN}+1.5 = \cosh^2 x \tanh x$$

where $x = 2(V_{OUT}+2.4)$

Equate (1) & (2) $\quad \dfrac{1.225}{\tanh^{1/2} x} = \cosh^2 x \tanh x$

or $\quad 1.225 = \cosh^2 x \tanh^{3/2} x$

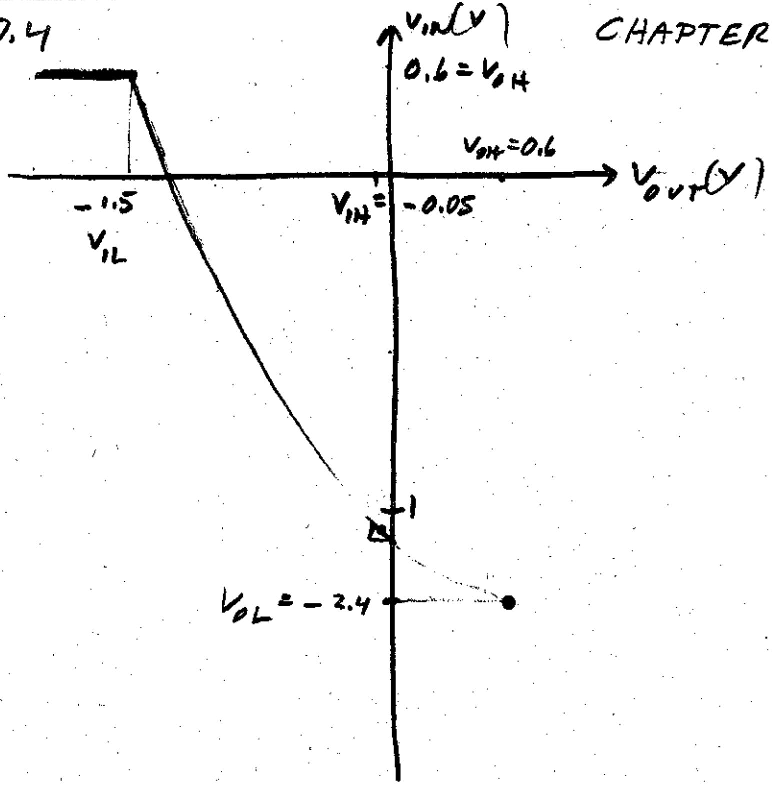
choose x	Calculate $\cosh^2 x \tanh^{3/2} x$
1	$2.381 \times 0.665 = 1.58$
0.85	$1.914 \times 0.574 = 1.1$
0.9	$2.054 \times 0.6 = 1.25$ close enough

$\therefore x = 0.9 = 2(V_{out}+2.4) \rightarrow V_{OUT} = -1.95V$

Back substitution

$V_{IN}+1.5 = \dfrac{1.225}{\tanh^{1/2}(0.9)} \longrightarrow V_{IN} = -1.5+1.45 = -0.05V$

37.4



37.5 $V_{OH} = V_{DD} - 3V_{SBD,GaAs}(ON) = 0.6\,V$

$V_{IL} = V_{T,0} = -1.5V$

$V_{OL} = -3V_{SBD,GaAs}(ON) = -2.4V$

THE EQS TO SOLVE ARE:

$$\beta_L V_{T,L}^2 \tanh \alpha_L V_{DS,L} \cong \beta_0 (V_{IN} - V_{T,0})^2 \tanh \alpha_0 V_{DS,0} + \beta_C V_{T,C}^2 - \beta_F (V_{GS,F} - V_{T,0})^2$$

and

$$\frac{\alpha_L V_{T,L}^2}{\cosh^2 \alpha_L V_{DS,L}} + \frac{\frac{\beta_0}{\beta_L} \alpha_L (V_{IN} - V_{T,0})^2}{\cosh^2 \alpha_0 V_{DS,0}} = 2\frac{\beta_0}{\beta_L}(V_{IN} - V_{T,0}) \tanh \alpha_0 V_{DS,0}$$

where $V_{DS,L} = V_{DD} - (V_{OUT} + 3V_{SBD,GaAs}(ON))$

and $V_{DS,0} = V_{OUT} + 3V_{SBD,GaAs}(ON)$

Substituting into the EQS YIELDS

$$500(1.5)^2(1) = 1000(V_{IN}+1.5)^2 \tanh \alpha_0 V_{DS_0} + 100(1.5)^2 - 100(0.8+1.5)^2 \quad (1)$$

and

$$\frac{1000}{500}\frac{2(V_{IN}+1.5)^2}{\cosh^2 2(V_{OUT}+2.4)} = 2\left(\frac{1000}{500}\right)(V_{IN}+1.5)\tanh 2(V_{OUT}+2.4) \quad (2)$$

CHAPTER 39 (SOLUTIONS)

39.1 ANALYZE THE CIRCUIT TO SEE THAT

V_{OUT} = HIGH FOR V_{INA} = HIGH OR V_{INB} = HIGH

ALSO, When $V_{INA} = V_{INB}$ = HIGH, V_{OUT} = High

and V_{OUT} = LOW FOR $V_{INA} = V_{INB}$ = LOW

THIS GATE PERFORMS XOR

39.2 BY INSPECTION OF THE FIGURE, THE LOGIC OUTPUT IS $\overline{(A+C)(B+D}$

$V_{OH} = V_{DD}$, $V_{OL} = 2V_{OL}$(ONE MESFET)

Yes, Fig 39.9

39.3 BY INSPECTION OF THE FIGURE, THE LOGIC OUTPUT IS $\overline{AB+CD}$

$V_{OH} \cong V_{DD} - 3V_{SBD}(ON)$

$V_{OL} = 2V_{OL}$(ONE MESFET)

39.4

OUTPUT IS $\overline{A+B}$

39.5 OUTPUT IS $\overline{A \cdot B}$

30.4 a) STATIC POWER DISSIPATION

$P_{DISS} = I_{DD} V_{DD}$

OUTPUT HIGH STATE : N_0 (OFF) $\Longrightarrow I_{DD}(OH) = 0$

OUTPUT LOW STATE : P_0 (OFF) $\Longrightarrow I_{DD}(OL) = 0$

$\therefore \; I_{DD} = \frac{I_{DD}(OH) + I_{DD}(OL)}{2} = 0$

$P_{DISS} = 0$

b) DYNAMIC POWER DISSIPATION

$P_{DD} = C_L \nu V_{DD}^2 = 0.08 \times 10^{-12} \times 50 \times 10^{6} \times 5^{2}$

$P_{DD} = 100 \mu W$, Total Power Diss = $100 \mu W$

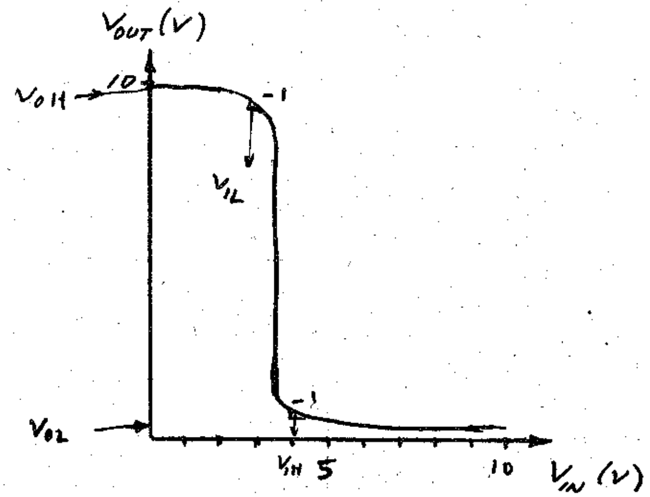
30.5 V_{IN}(LOW); N_1(OFF), P_1(ON), Q_N(OFF), Q_P(SAT)

$V_{OUT} = V_{DD} - V_{CE,P}(SAT) = V_{OH} = 10 - 0.2 = 9.8V$

V_{IN}(HIGH); N_1(ON), P_1(OFF), Q_P(OFF), Q_N(SAT)

$V_{OUT} = V_{CE,N}(SAT) = V_{OL} = 0.2V$

TO FIND V_{IL} & V_{IH} USE TEXT PROCEDURE



30.6 a) STATIC POWER DISSIPATION

$$P_{DISS} = I_{DD} V_{DD}$$

$$I_{DD} = \frac{I_{DD}(OH) + I_{DD}(OL)}{2} = \frac{0+0}{2} = 0$$

$P_{DISS} = 0$ REGARDLESS OF V_{DD} VALUE

b) DYNAMIC POWER DISSIPATION

$$P_{DD} = C_L \nu V_{DD}^2 = 0.05 \times 10^{-12} \times 25 \times 10^6 \times 10^2$$

$$P_{DD} = 125 \mu W$$

Total Power Diss $= 125 \mu W$

30.7 $\underline{V_{IN}(LOW)}$; $N_I(OFF)$, $P_I(ON)$, $Q_N(ON)$, $Q_P(OFF)$

Q_N GIVES LARGE CURRENT INITIALLY

$V_{OUT} = V_{DD} - V_{BE,N}(FA) = V_{OH} = 5 - 0.7 = 4.3V$

$\underline{V_{IN}(HIGH)}$; $P_1(OFF)$, $N_I(ON)$, $Q_N(OFF)$, $Q_P(ON)$ - PROVIDES PULL-DOWN

$V_{OUT} = V_{BE,P}(FA) = V_{OL} = 0.7V$

LOGIC SWING $= V_{DD} - 2V_{BE}(FA) = 5 - 2(0.7) = 3.6V$

30.8 STATIC POWER DISSIPATION $= I_{DD} V_{DD} = 0(V_{DD}) = 0$

30.9 V_{OH} IS $V_{DD} - V_{BE,N_2}(FA) = 5 - 0.7 = 4.3V$ (N_3 and P_I ON)

V_{OL} IS $V_{BE,N_1}(FA) = 0.7V$ (N_1 IS ON & N_2 OFF)

30.10 STATIC POWER DISSIPATION $= 0$

30.11 $V_{OH} = V_{DD}$, $V_{OL} = 0$

30.12 STATIC POWER DISSIPATION $= 0$