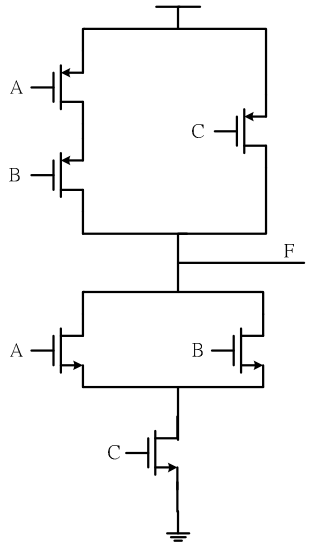
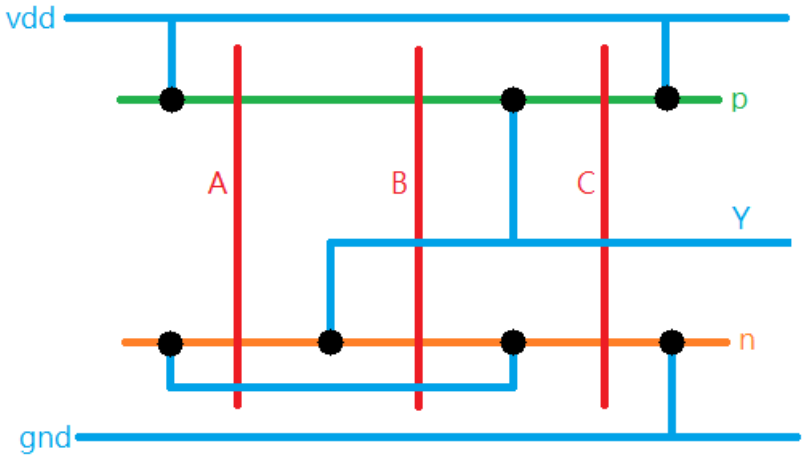
2009 VLSI: Midterm Examination Solution

1.

(a) F=((A+B)*C)'

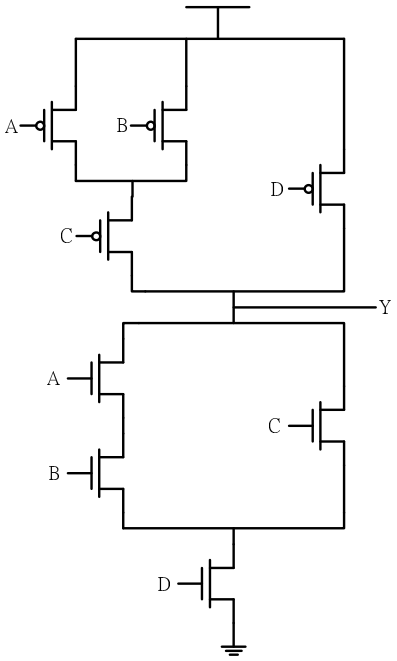


(b)

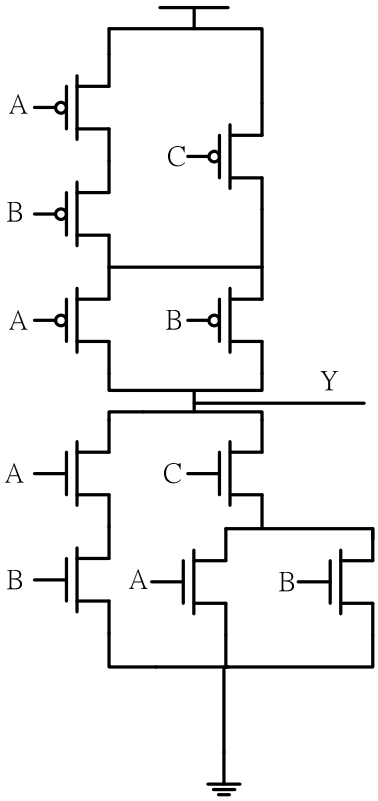


2.

(a) Y=((AB+C)*D)'



(b) Y=(AB+C*(A+B))'


A
C
B
A
B
Y
A
C
B
A
B

3.

(a) Vin=1.5 → 0.3V ; Vout=1 → 0.5V。

(b) Vin=1.5 → 0.9V ; Vout=1 → 0.9V。

4.

(a) β=1 。

(b) $\beta_A > \beta_B > \beta_C$ 。

5.

(a)

$$V_{IL} = 1.0,\ V_{OL} = 0.2, V_{IH} = 1.3, V_{OH} = 1.6$$

(b)

$$NM_L = V_{IL} - V_{OL} = 1 - 0.2 = 0.8(V)$$
$$NM_H = V_{OH} - V_{IH} = 1.6 - 1.3 = 0.3(V)$$

6.

$$I_{ds} = \begin{cases} 0 & V_{gs} < V_t \quad Cutoff \\ \frac{\beta}{2}\left(V_{gs} - V_t - V_{ds}/2\right)V_{ds} & V_{gs} > V_t, V_{ds} < V_{gs} - V_t \quad Linear \\ \frac{\beta}{2}\left(V_{gs} - V_t\right)^2 & V_{gs} > V_t, V_{ds} > V_{gs} - V_t \quad Saturation \end{cases}$$

7.

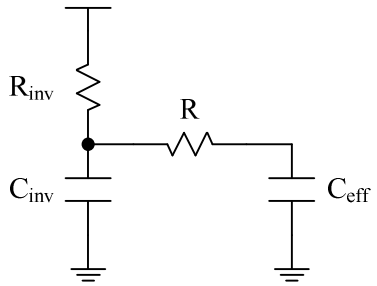
(a)	T	(f)	T
(b)	F	(g)	F
(c)	F	(h)	T
(d)	F	(i)	F
(e)	T	(j)	T

8.

(a)	F	(f)	F
(b)	T	(g)	F
(c)	T	(h)	T
(d)	F	(i)	T
(e)	T	(j)	F

9.

$$C_{gnd} = 0.2f\,{}^{F}\!/_{\mu m} \times 2000\mu m = 0.4pF$$
$$C_{adj} = 0.1f\,{}^{F}\!/_{\mu m} \times 2000\mu m = 0.2pF$$
$$R = 0.1\,{}^{\Omega}\!/_{\mu m} \times 2000\mu m = 200\Omega$$



$t_{cd} \Rightarrow C_{eff} = C_{gnd}$,
$t_{cd} = R_{inv}C_{inv} + (R_{inv} + R)C_{eff} = 1k \times 5f + 1.2k \times 0.4p = 485ps$
$t_{pd} \Rightarrow C_{eff} = C_{gnd} + 2C_{adj}$,
$t_{pd} = R_{inv}C_{inv} + (R_{inv} + R)C_{eff} = 1k \times 5f + 1.2k \times 0.8p = 965ps$

10.

$$The\ path\ effort = 14 \times 5 \times 8 = 560$$
$$\hat{f} = \sqrt[N]{560},\ D_F = N \times \hat{f} = N \times \sqrt[N]{560}$$

(a)

$N = 4$
$N = 5$
$N = 6$

(b)

$$N = 4, \quad D_F = 4 \times \hat{f} = 4 \times \sqrt[4]{560} = 19.4584$$

$$N = 5, \quad D_F = 5 \times \hat{f} = 5 \times \sqrt[5]{560} = 17.7259$$

$$N = 6, \quad D_F = 6 \times \hat{f} = 6 \times \sqrt[6]{560} = 17.2259$$

11.

(a)

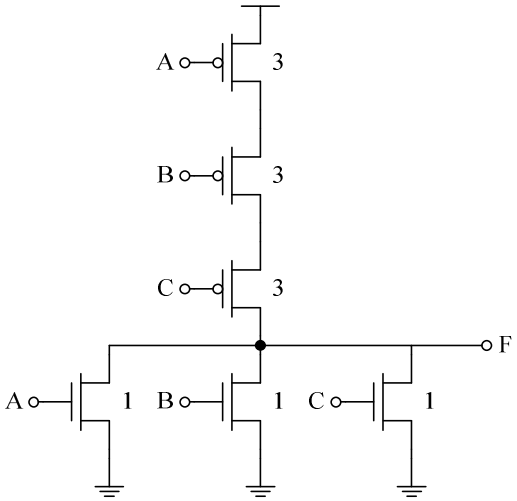
$$F = GBH = 1 \times 1 \times \frac{10p}{20f} = 500$$
$$N = \log_4 F = \log_4 500 = 4.4829$$
$let\ N = 4$
OR
$Find\ \min\ of\ N\sqrt[N]{500}$
$N = 5\ or\ 6$

(b)

$$N = 4,\ D_F = 4\sqrt[4]{F} = 4\sqrt[4]{500} = 18.9148 = 3.78 \times FO4\ inverter\ delay$$
$$N = 5,\ D_F = 5\sqrt[5]{F} = 5\sqrt[5]{500} = 17.3286 = 3.47 \times FO4\ inverter\ delay$$
$$N = 6,\ D_F = 6\sqrt[6]{F} = 6\sqrt[6]{500} = 16.9036 = 3.38 \times FO4\ inverter\ delay$$

12.

(a)



(b)

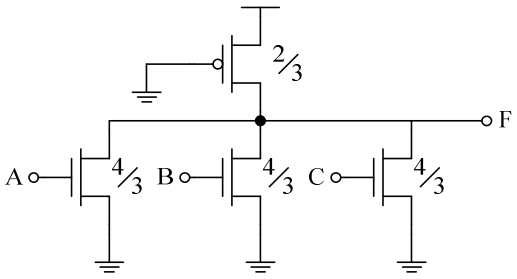
$$g_u = \frac{3+1}{1+0.5} = \frac{8}{3}$$

$$g_d = \frac{3+1}{2+1} = \frac{4}{3}$$

$$g_{avg} = 2$$

13.

(a)



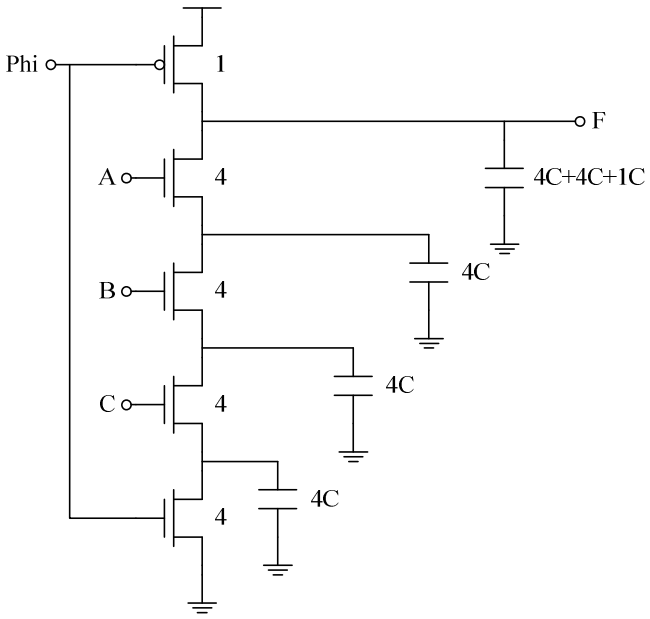
(b)

$$g_u = \frac{4/3}{2/3 + 1/3} = \frac{4}{3}$$

$$g_d = \frac{4/3}{2+1} = \frac{4}{9}$$

$$g_{avg} = \frac{8}{3}$$

14.



Let V_X be the voltage at node F which is suffered from charge sharing.

The worst charge sharing occurs when:

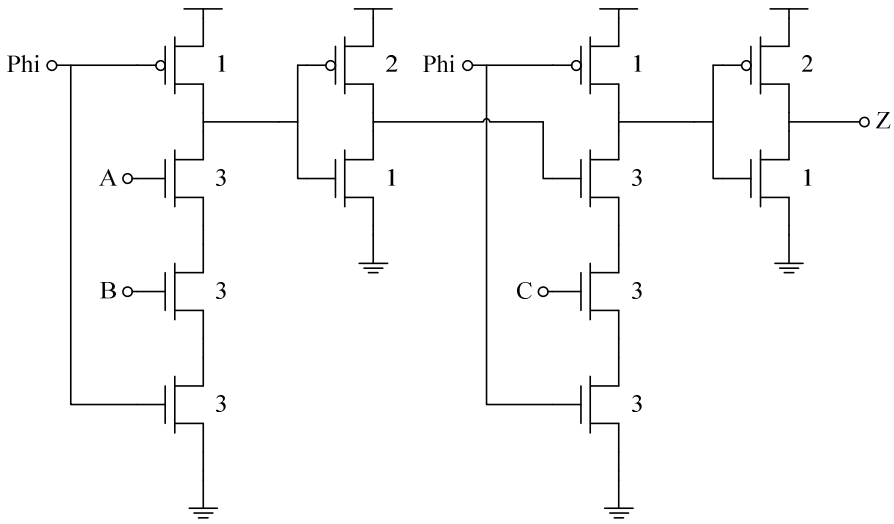
Pre-charge: A=B=C=0 → Evaluation: A=B=1, C=0.

$$Q = 9C \times V_{DD} = (9C + 4C + 4C) \times V_x$$

$$\Rightarrow V_x = \frac{9}{17} V_{DD}$$

15.

(a)



(b)

$$Loading\ at\ Z: 3 \div 10 \times 160 = 48$$

$$D_F = \sum f_i = g_1 h_1 + g_2 h_2 + g_3 h_3 + g_4 h_4$$

$$D_F = {}^{3}\!/_{3} \times {}^{3}\!/_{3} + 1 \times {}^{3}\!/_{3} + {}^{3}\!/_{3} \times {}^{3}\!/_{3} + 1 \times {}^{48}\!/_{3}$$

$$= 1 + 1 + 1 + 16 = 19$$

16.

(a)

$$G = {}^{4}\!/_{3} \times {}^{5}\!/_{3} \times {}^{5}\!/_{3} = \frac{100}{27}$$

$$B = 3 \times 2 = 6$$

$$H = \frac{60}{10} = 6$$

$$F = GBH = \frac{400}{3}$$

$$\hat{f} = \sqrt[3]{F} = 5.1087$$

$$P = 2 + 3 + 2 = 7$$

$$D = 3\hat{f} + P = 22.3262$$

(b)

$$y = \frac{60 \times 5/3}{\sqrt[3]{400/3}} = 19.5743$$

$$x = \frac{19.5743 \times 2 \times 5/3}{\sqrt[3]{400/3}} = 12.7718$$

$$Size\ of\ PMOS\ of\ NOR2 : 19.5743 \times 4/5 = 15.6595$$

$$Size\ of\ NMOS\ of\ NOR2 : 19.5743 \times 1/5 = 3.9149$$

$$Size\ of\ PMOS\ of\ NAND3 : 12.7718 \times 2/5 = 5.1087$$

$$Size\ of\ NMOS\ of\ NAND3 : 12.7718 \times 3/5 = 7.6631$$

17.

(a)	T	(f)	F
(b)	T	(g)	T
(c)	F	(h)	F
(d)	F	(i)	F
(e)	F	(j)	T