

# EE115B-Digital Circuits

## HW1

**Due on Apr. 12, 2024**

1. Number conversion. All numbers below are unsigned. (2 marks each)

$$\begin{aligned}(1) \quad (1010)_2 &= (10)_10 \\(2) \quad (6.75)_{10} &= (10.11)_2 \\(3) \quad (2A)_{16} &= (001010)_2 \\(4) \quad (111010)_2 &= (3A)_{16} \\(5) \quad (128)_{10} &= (200)_8\end{aligned}$$

2. (5 marks each)

- (a) Please write out the sign-magnitude form, 1's and 2's complement of -1.25 and 3.75 respectively.
- (b) Write out the decimal number that the 2's complement 10100110 represents.
- (c) When calculating -28-36 using 2's complement, what's the minimum number of digits required?
- (d) Calculate -28-36 using 2's complement.

$$\begin{array}{lll}(a) \quad -1.25 & 3.75 & (b) -90 \\ \text{s-m: } 11.01 & \text{s-m: } 011.11 & \begin{array}{l} \text{s-m: } 10011100 \\ \text{l's: } 1100011 \\ \text{2's: } 1100100 \end{array} \\ \text{l's: } 10.10 & \text{l's: } 011.11 & \\ \text{2's: } 10.11 & \text{2's: } 011.11 & \end{array}$$

(c) 8 bits

-28: s-m: 10011100  
l's: 11100011  
2's: 11100100

-36: s-m: 10100100  
l's: 11011011  
2's: 11011100

$$\begin{array}{r} 11100100 \\ + 11011100 \\ \hline 111000100 \end{array}$$

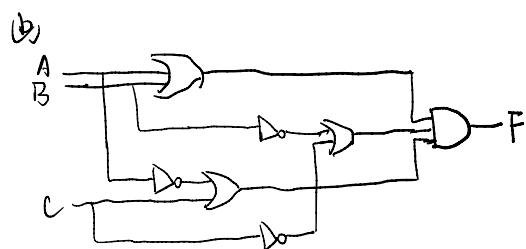
leave out

final result: 11000000

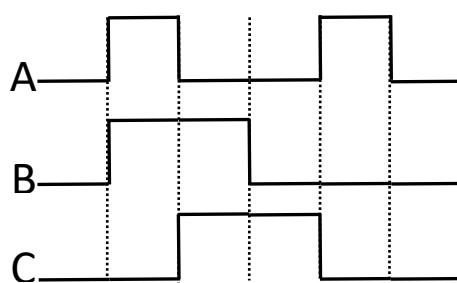
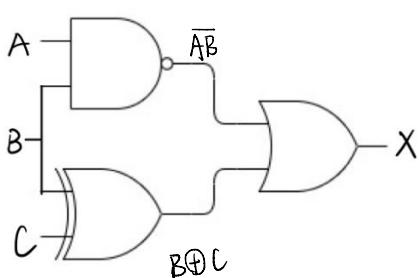
3. Given the Boolean expression  $F = (A + B)(\bar{A} + C)(\bar{B} + \bar{C})$

- (a) Write down its truth table. (5 marks)
- (b) Draw the corresponding logic gate circuit diagram. (5 marks)

Day	A	B	C	$A+B$	$\bar{A}+C$	$\bar{B}+\bar{C}$	F
0	0	0	0	0	1	1	0
0	0	0	1	0	1	1	1
0	1	0	0	1	1	0	0
0	1	1	1	1	0	1	0
1	0	0	0	1	0	1	1
1	0	1	0	1	1	1	1
1	1	0	1	1	0	1	0
1	1	1	1	1	1	0	0



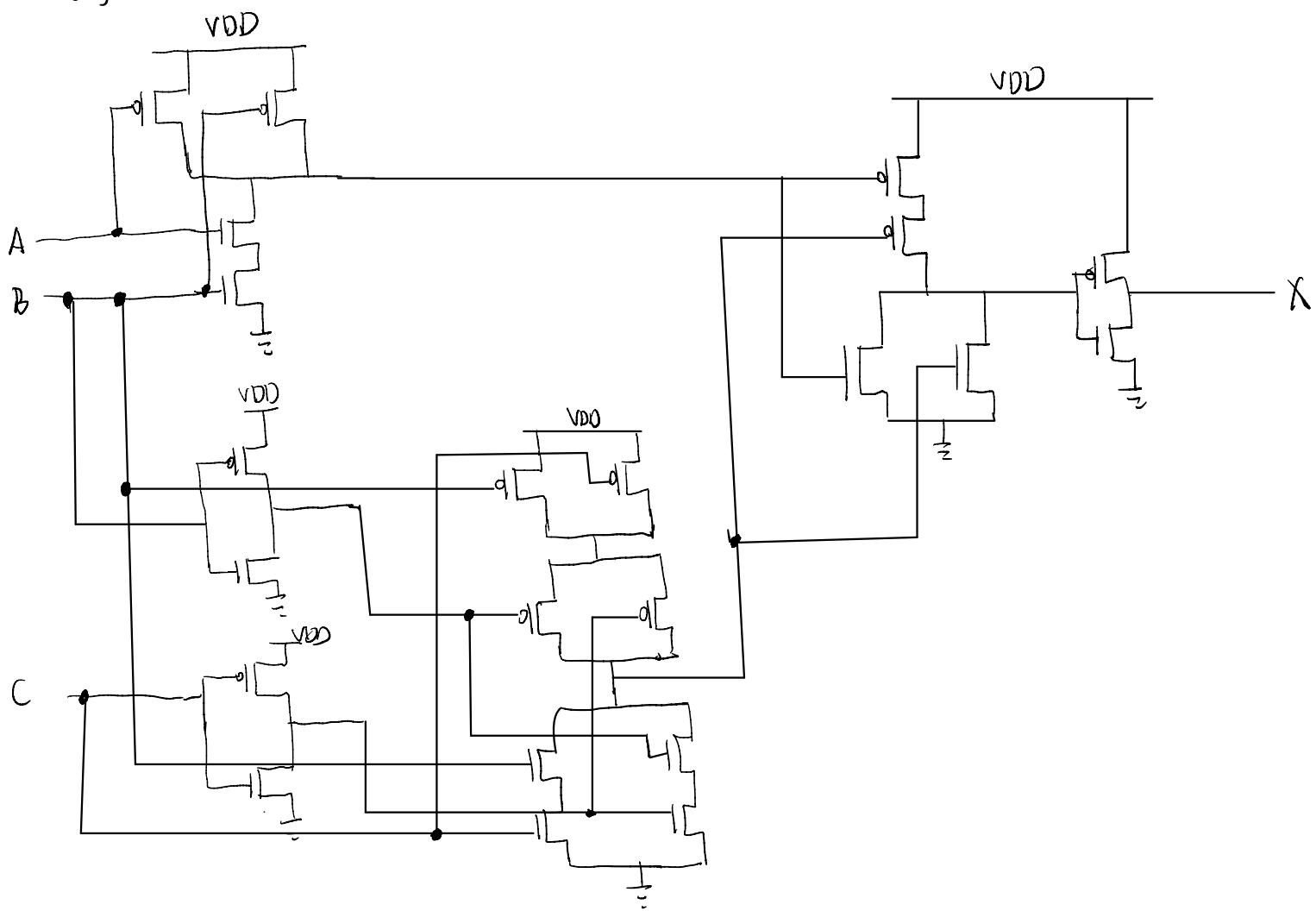
4. (a) Plot the output (X) waveform. (5 marks)  
 (b) Plot the circuit using MOSFET. (5 marks)



(a)



(b)

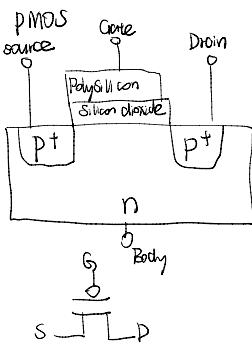
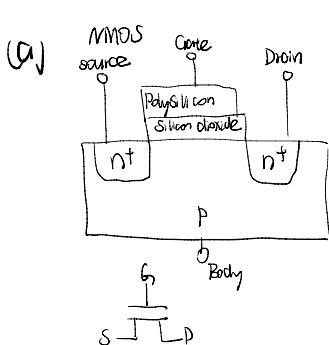


5. Describe the behavior of electrons and holes at the PN junction under zero bias. (5marks)

the initial diffusion of electrons and holes leads to the formation of a depletion region and a built-in electric field. This field balances the further diffusion of charge carriers, resulting in no net current flow across the junction.

6. (5 marks each)

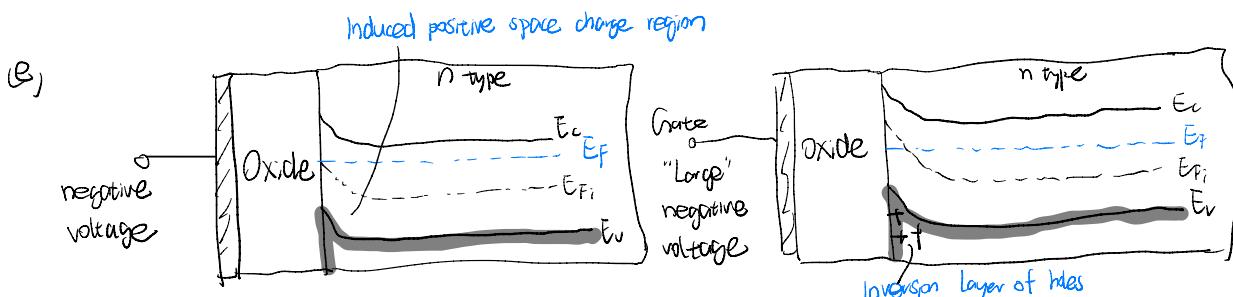
- Plot the structure of NMOS and PMOS and provide their symbol representations.
- Describe how to connect the terminals of NMOS and PMOS to enable them.
- Explain the working principle of a CMOS inverter briefly.
- Given an NMOS transistor operating with the following parameters:  $V_{GS} = 6V$ ,  $V_{DS} = 3V$ ,  $V_T = 0.7V$ ,  $\mu_n = 400\text{cm}^2/\text{V}\cdot\text{s}$ ,  $C_{ox} = 2 \times 10^{-7}\text{F/cm}^2$ ,  $W = 50\mu\text{m}$ ,  $L = 2\mu\text{m}$ .
- Plot energy diagram of PMOS under  $V_g < 0$ .



for NMOS: apply positive voltage to gate  
PMOS: apply negative voltage to gate  
(both are relative to source)

(e) If input is high NMOS is on. PMOS is off connecting the output to ground  
If input is low, NMOS is off. PMOS is on connecting the output to VDD.

(d)  $I_D = \mu_n C_{ox} \left( \frac{W}{L} \right) [V_{GS} - V_T] V_{DS} - \frac{V_{DS}^2}{2} = 0.0228A$



7. Simplify the following expressions using the rules of Boolean algebra. (5 marks each)

$$(a) AD + A\bar{D} + AB + \bar{A}C + BD + A\bar{B}EF + \bar{B}EF \quad \overline{\overline{BC} \cdot \bar{D}}$$

$$(b) A + \overline{A}\overline{B}\overline{C}(\bar{A} + \overline{\bar{B}\bar{C}} + D) + BC$$

$$\begin{aligned} (a) & A(D + \bar{D}) + AB + \bar{A}C + BD + \bar{B}EF(A + \bar{A}) \\ & = A + AB + \bar{A}C + BD + \bar{B}EF \\ & = A + \bar{A}C + BD + \bar{B}EF \\ & = A + C + BD + \bar{B}EF \end{aligned}$$

$$\begin{aligned} (b) & A + (A + BC)(\bar{A} + B + \bar{C} + \bar{D}) + BC \\ & = A + A\bar{A} + A\bar{D}CB + AC + \bar{A}BC + B\bar{C}\bar{D} + B\bar{C} + BC \\ & = A + A(\bar{B}\bar{D} + \bar{C}\bar{D}) + \bar{A}BC + B\bar{C}\bar{D} + BC \\ & = A + \bar{A}BC + BC + B\bar{C}\bar{D} \\ & = A + BC\bar{D} + BC \\ & = A + BC \end{aligned}$$

8. Transform  $L(A, B, C) = (\bar{A}B + BC)(AB + \bar{A}\bar{B} + \bar{C})$  into the standard SOP form. (5 marks)

$$\begin{aligned} L &= \bar{A}B\bar{A}B + \bar{A}B\bar{A}\bar{B} + \bar{A}B\bar{C} + ABC + \bar{A}\bar{B}BC + BC\bar{C} \\ &= \bar{A}B\bar{C} + ABC \end{aligned}$$

9. Draw the following function using karnaugh map and minimize it. (5 marks)

$$L(A, B, C, D) = (\bar{A} + \bar{B} + \bar{C} + \bar{D})(B + C + D)(\bar{A} + B + \bar{C} + D)(\bar{A} + \bar{B} + C + D)(A + \bar{B} + C + D)$$

$$L = (\bar{A} + \bar{B} + \bar{C} + \bar{D})(A + B + C + D)(\bar{A} + B + C + D)(\bar{A} + B + \bar{C} + D)(\bar{A} + \bar{B} + C + D)(A + \bar{B} + C + D)$$

1	1	1	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	0	0
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

		CD	00	01	11	10
		AB	00	01	11	10
A	B	00	0			
		01	0			
A	B	11	0	0	0	
		10	0			0

$$L = (C + D)(\bar{A} + \bar{B} + \bar{C} + \bar{D})(\bar{A} + B + D)$$

(a)	R	A	G	Y
0	0	0	0	0
0	0	0	1	0
0	1	0	0	0
0	1	1	1	1
1	0	0	0	0
1	0	1	1	1
1	1	0	1	0
1	1	1	0	0

$$\text{Lb, } Y = \bar{R}AG + R\bar{A}G + RAG$$

