

ECE275 Practice problems for Final Spring 2025

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Student Name:

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1 Instructions

- Time allowed is ∞ minutes.
- In order to minimize distraction to your fellow students, you may not leave during the last 10 minutes of the examination.
- The examination is closed-book. One 8×11 in two-sided cheatsheet is allowed.
- Non-programmable calculators are permitted.
- The maximum number of marks is XXX, as indicated; the final examination amounts 10% toward the final grade.
- Please use a pen or heavy pencil to ensure legibility. Colored pens/pencils are recommended for K-map grouping.
- Please show your work; where appropriate, marks will be awarded for proper and well-reasoned explanations.
- If you are behind on grades, you may submit the solutions to this on brightspace before the May 5th exam for (makeup) grades. If you are already ahead, then these grades won't push you beyond hundred in homework+midterm grades.

Problem 1. Use the following 5-variable K-map for $F(B, C, D, E)$, and find a minimal SOP expression for F (15 marks)

DE \ BC	00	01	11	10
	00	01	11	10
00	1			1
01	1	1		1
11		1		
10		1	1	

$A=0$

DE \ BC	00	01	11	10
	00	01	11	10
00		1	1	
01	1	1		1
11		1		
10		1	1	

$A=1$

Problem 2. A sequential circuit has two inputs and two outputs. The inputs (X_1 and X_0) represent a 2-bit binary number, N . If the present value of N is greater than the previous value, then Z_1 is 1. If the present value of N is less than the previous value, then Z_2 is 1. **Otherwise**,

Z_1 and Z_2 are 0. When the first pair of inputs is received, there is no previous value of N , so we cannot determine whether the present N is greater than or less than the previous value; therefore, the “otherwise” category applies.

Find a Mealy state table for the circuit (minimum number of states, including starting state, is five) (30 marks).

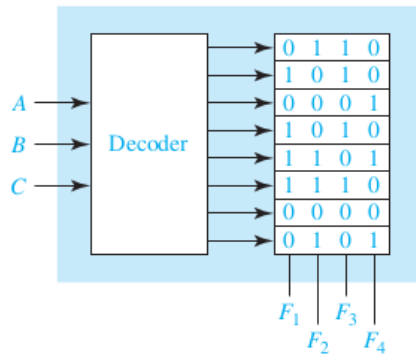
(Hint: The header for Mealy State table will look something like this:)

Present State	Next State				Outputs ($Z_1 Z_2$)			
	Inputs $X_1 X_0 = 00$	01	10	11	$X_1 X_0 = 00$	01	10	11
S_0	S_1	S_2	S_3	S_4	00	00	00	00

Problem 3. A 4:2 priority encoder takes 4 inputs y_0, y_1, y_2, y_3 and has three outputs, w_1, w_0 and IST . Find boolean expressions for w_1 and w_0 using K-maps for the priority encoder. The priority encoder truth table is given for reference (“*” indicates all possible input combinations and “d” indicates don’t care output). (10 marks)

Inputs				Outputs		
y_0	y_1	y_2	y_3	w_1	w_0	IST
0	0	0	0	d	d	0
1	*	*	*	0	0	1
0	1	*	*	0	1	1
0	0	1	*	1	0	1
0	0	0	1	1	1	1

Problem 4. The following diagram shows the pattern of 0’s and 1’s stored in a ROM with eight words and four bits per word. What will be the values of F_1, F_2, F_3 , and F_4 if $A = B = 0$ and $C = 1$? Also give the minterm expansions for F_1 and F_2 (20 marks).



Problem 5. The following prime implicant table is for a four variable function $f(A, B, C, D)$. Give the algebraic expression of each of the essential prime implicants. Find the minimal sum of products expression for f by PI table reduction. (10 marks)

minterms \ PIs:	$\bar{B}D$	$\bar{B}C$	CD	AD
2		×		
3	×	×	×	
7			×	
9	×			×
11	×	×	×	×
13				×

Problem 6. Packages arrive at the stockroom and are delivered on carts to offices and laboratories by student employees. The carts and packages are various sizes and shapes. The students are paid

	C1	C2	C3	C4	C5
P1	x		x		x
P2	x	x	x	x	
P3					x
P4	x				
P5		x	x		
P6		x	x	x	
P7			x	x	

according to the carts used. There are five carts and the pay for their use is

- Cart C1: \$2
- Cart C2: \$1
- Cart C3: \$4
- Cart C4: \$2
- Cart C5: \$2

On a particular day, seven packages arrive, and they can be delivered using the five carts as follows:

- C1 can be used for packages P1, P3, and P4.
- C2 can be used for packages P2, P5, and P6.
- C3 can be used for packages P1, P2, P5, P6, and P7.
- C4 can be used for packages P3, P6, and P7.
- C5 can be used for packages P2 and P4.

The stockroom manager wants the packages delivered at minimum cost. Using minimization techniques described in this class, present a systematic procedure for finding the minimum cost solution. (20 marks)

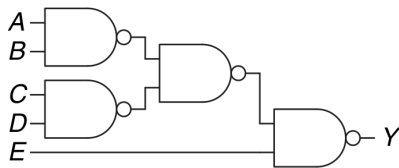
Problem 7. (a) For $V_{IH} = 4$ V, $V_{OH} = 4.5$ V, $V_{IL} = 1$ V, $V_{OL} = 0.3$ V, and $V_{DD} = 5$ V, calculate the noise margins NM_H and NM_L (5 marks).

(b) Draw an eight-input NAND gate built using NMOS technology and pull-up resistor (5 marks).

(c) In the above circuit, if the voltage drop across each transistor is 0.1 V, what is V_{OL} ? What is the corresponding NM_L using the other parameters from part (a) (10 marks).

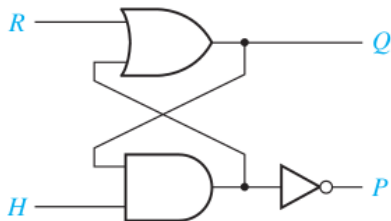
Problem 8. What is the difference between positive logic and negative logic? Design a CMOS complex gate for $f = x_1\bar{x}_2 + \bar{x}_1x_2$ under negative logic (10 marks).

Problem 9. Find the propagation delay and contamination delay of the following circuit (5 marks):



Problem 10. Describe how tri-state and open-collector outputs are different from totem-pole outputs using NMOS NOR gate as an example (10 marks).

Problem 11. A latch can be constructed from an OR gate, an AND gate, and an inverter connected as follows:



- What restriction must be placed on R and H so that P will always equal Q (under steady-state conditions) (10 marks)?
- Construct a characteristic (next-state) table and derive the corresponding characteristic equation for the latch (5 marks).

Define boolean variables

$$C_i = \begin{cases} 1 & \text{if cart } C_i \text{ is used} \\ 0 & \text{if cart } C_i \text{ is not used} \end{cases}$$

for $i = \{1, 2, 3, 4, 5\}$

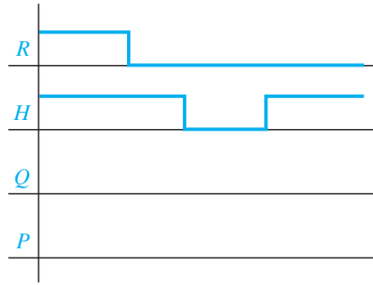
All packages are delivered

$$\begin{aligned} & \text{if} \\ & = \underbrace{(C_1 + C_3)}_{\text{Package 1}} \cdot \underbrace{(C_2 + C_5)}_{P2} \cdot (C_1 + C_4) \end{aligned}$$

$$\begin{aligned} & \cdot (C_1 + C_5) \cdot (C_2 + C_3) \cdot (C_2 + C_5 + C_4) \\ & \cdot (C_3 + C_4) \end{aligned}$$

$$\begin{aligned} & = \underbrace{C_3 \cdot C_4 \cdot C_5}_{\text{cost} = 8} \\ & + \underbrace{C_1 \cdot C_2 \cdot C_4}_{\text{cost} = 5} \checkmark \\ & + \dots \end{aligned}$$

3. Complete the following timing diagram for the latch (10 marks)



Problem 12. Figure 1 shows the notation for a BCD to 7-segment display and Table 1 shows the corresponding truth table. The inputs corresponding to the missing rows in the truth table should be considered as don't care.

1. implement segment "a" using an 8:1 mux and no other logic gate, (10 marks)
2. implement segment "a" using a 4:1 mux and one other gate, (10 marks)
3. implement segment "f" with 4:1 mux and no other logic gate. Assume inputs are available in both uncomplemented and complemented form. (Hint: There are ${}^4C_2 = 6$ possible pairs of control inputs: (w_3, w_2) , (w_2, w_1) , (w_1, w_0) , (w_0, w_3) , (w_0, w_2) , (w_1, w_3) . There are 6 don't care conditions. With two control inputs of the multiplexer and one input, you can represent an expression with up to 4-SOP-terms of size three-literals or less. You might arrive at the answer sooner, if you try to write the minimal SOP expression first and find the two inputs that occur most often in all the terms. Those two inputs are most likely to be the chosen pair of control inputs.) (10 marks)

Row	w_3	w_2	w_1	w_0	a	b	c	d	e	f	g
0	0	0	0	0	1	1	1	1	1	1	0
1	0	0	0	1	0	1	1	0	0	0	0
2	0	0	1	0	1	1	0	1	1	0	1
3	0	0	1	1	1	1	1	1	0	0	1
4	0	1	0	0	0	1	1	0	0	1	1
5	0	1	0	1	1	0	1	1	0	1	1
6	0	1	1	0	1	0	1	1	1	1	1
7	0	1	1	1	1	1	1	0	0	0	0
8	1	0	0	0	1	1	1	1	1	1	1
9	1	0	0	1	1	1	1	1	0	1	1

Table 1: Truth table for BCD to seven-segment display as shown in Figure 1. The missing combinations of inputs should be considered as don't care.

Problem 13. Design a 3-bit modulo 8 counter that counts from 000, to 111 and then loops back to 000. (A modulo N counter counts from 0 to $N - 1$) (20 marks).

1. Draw its state transition table
2. Design the circuit using a D flip-flop.

Problem 14. Draw Mealy state transition diagram which investigates an input sequence X and will produce an output of $Z = 1$ for any input sequence ending in 0011 or 110.

Example:

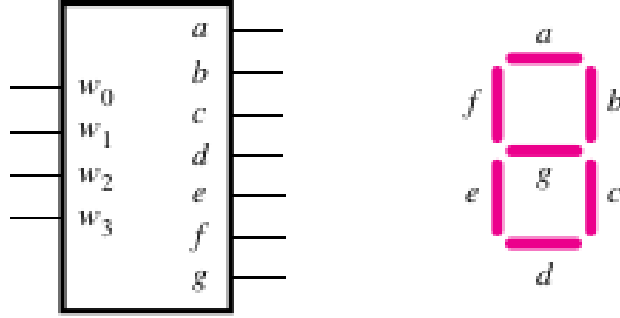


Figure 1: Seven segment display and BCD-to-7-segment display converter. When $a = 1$ the corresponding segment of the display lights up. To display the number 8, you will turn on all the seven segments, while to display 1, you will turn on $b = 1, c = 1$ and turn off $= 0$ the rest. The full truth-table for the seven-segment display is shown in Table 1.

$$\begin{array}{l}
 X = \quad 1 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0 \quad 1 \\
 Z = \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 1 \quad 1 \quad 0 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0 \quad 1 \quad 0
 \end{array}$$

Notice that the circuit does not reset to the start state when an output of $Z = 1$ occurs. A minimum solution requires six states. Assign 000 to the start state. (20 marks).

Problem 15. Find the expression for J_0 and K_0 assuming that J_0 and K_0 are inputs to the J-K flip flop that capture the state of the second most significant bit Q_0 of the following state encoded table. The state encoding table given with state encoding denoted as $Q_2Q_1Q_0$. (20 marks).

Present State $Q_2Q_1Q_0$	Next State		Output	
	$X = 0$ $Q_2^+Q_1^+Q_0^+$	$X = 1$ $Q_2^+Q_1^+Q_0^+$	$X = 0$ Z	$X = 1$ Z
000	100	101	1	0
001	100	101	0	1
010	000	000	1	0
011	000	000	0	1
100	111	110	1	0
101	110	110	0	1
110	011	010	1	0
111	011	011	0	1