Textbook problems

1. Problem 1-16

Design a combinational circuit with three inputs x, y, z and three outputs A, B, C. When the binary input is 0, 1, 2,or 3, the binary output is one greater than the input. When the binary input is4, 5, 6,or 7, the binary output is one less than the input.

x	y	z	A	B	C
0	0	0	0	0	1
0	0	1	0	1	0
0	1	0	0	1	1
0	1	1	1	0	0
1	0	0	0	1	1
1	0	1	1	0	0
1	1	0	1	0	1
1	1	1	1	1	0

Output A = x'y + xz

x\yz	00	01	11	10
0	0	0	1	1
1	0	1	1	0

Output B = xy'z' + x'z + x'y + yz

x\yz	00	01	11	10
0	0	1	1	1
1	1	0	1	0

Output C

x\yz	00	01	11	10
0	1	0	0	1
1	1	0	0	1

2. Problem 1-19

A sequential circuit has two D'Flip-flops A and B, two inputs x and y, and one output z. The flip-flop input equations and the circuit output are as follows:

Da= x'y+xA

Db = x'B + xA

z = B

a. Draw the logic diagram of the circuit.

b. Tabulate the state table.

A	B	x	y	Da	Db	z
0	0	0	0	0	0	0
0	0	0	1	1	0	0
0	0	1	0	0	0	0
0	0	1	1	1	0	0
0	1	0	0	0	1	1
0	1	0	1	1	1	1
0	1	1	0	0	0	1
0	1	1	1	0	0	1
1	0	0	0	0	0	0
1	0	0	1	1	0	0
1	0	1	0	1	1	0
1	0	1	1	1	1	0
1	1	0	0	0	1	1
1	1	0	1	1	1	1
1	1	1	0	1	1	1
1	1	1	1	1	1	1

3. Problem 1-20

Design a 2-bit count-down counter. This is a sequential circuit with two flip-flops and one input x. When x = 0 ,the state of the flip-flops does not change. When x = 1, the state sequence is 11, 10, 01, 00, 11 and repeat.

A	B	x	A	B	Da	Db
0	0	0	0	0	0	0
0	0	1	1	1	1	1
0	1	0	0	1	0	1
0	1	1	0	0	0	0
1	0	0	1	0	1	0
1	0	1	0	1	0	1
1	1	0	1	1	1	1
1	1	1	1	0	1	0

Da = Ax’ + A’B’x + AB

A\Bx	00	01	11	10
0	0	1	0	0
1	1	0	1	1

Db = B’x + Bx’

A\Bx	00	01	11	10
0	0	1	0	1
1	0	1	0	1

4. Problem 1-21

Combinational Circuit Problems:

Design sequential circuit with two JK flip-flops A B and two inputs E and x. If E = 0, the circuit remains in the same state regardless of the value of x. When E = 1 and x = 1, the circuit goes through the state transitions from 00 to 01 to 10 to 11 back to 00, and repeats. When E = 1 and x = 0, the circuit goes through the state transitions from 00 to 11 to 10 to 01 back to 00, and repeats.

A	B	E	x	A	B	Ja	Ka	Jb	Kb
0	0	0	0	0	0	0	X	0	X
0	0	0	1	0	0	0	X	0	X
0	0	1	0	1	1	1	X	1	X
0	0	1	1	0	1	0	X	1	X
0	1	0	0	0	1	0	X	X	0
0	1	0	1	0	1	0	X	X	0
0	1	1	0	0	0	0	X	X	1
0	1	1	1	1	0	1	X	X	1
1	0	0	0	1	0	X	0	0	X
1	0	0	1	1	0	X	0	0	X
1	0	1	0	0	1	X	1	1	X
1	0	1	1	1	1	X	0	1	X
1	1	0	0	1	1	X	0	X	0
1	1	0	1	1	1	X	0	X	0
1	1	1	0	1	0	X	0	X	1
1	1	1	1	0	0	X	1	X	1

Ja = BEx + B’Ex’

AB\Ex	00	01	11	10
00				1
01			1	
11	X	X	X	X
10	X	X	X	X

Ka = BEx + B’Ex’

AB\Ex	00	01	11	10
00	X	X	X	X
01	X	X	X	X
11			1	
10				1

Jb = E

AB\Ex	00	01	11	10
00			1	1
01	X	X	X	X
11	X	X	X	X
10			1	1

Kb = E

AB\Ex	00	01	11	10
00	X	X	X	X
01			1	1
11			1	1
10	X	X	X	X

5. A burglar alarm for a bank is designed so that it senses four input signal lines from different equipment/sensors. Line A is from the secret control switch, line B is from a pressure sensor under a steel safe in a locked closet, line C is from a battery-powered clock, and line D is connected to a switch on the locked closet door. The following conditions produce a logic 1 voltage on each line.
A: The control switch is closed.
B: The safe is in its normal position in the closet.
C: The clock is between 10:00 and 14:00 hours (banking hours).
D: The closet door is closed.

Write the equation of the control logic for the burglar alarm that produces a logic 1 (rings a bell) when the safe is moved and the control switch is closed, or when the closet is opened after banking hours, or when the closet is opened with the control switch open.

B'A + D'C' + D'A'

6. Mr. and Ms. Boren have two children, John and Jane. When eating out they will go to a restaurant that serves only hamburgers or one that serves only chicken. Before going out, the family votes to decide on the restaurant. The majority wins, except when Mom and Dad agree, and in that case, they win. Any other tie votes produce a trip to the chicken restaurant. Design a logic circuit that will automatically select the restaurant when everyone votes.

hamburgers = 1, chicken = 0

Mom&Dad + (Mom + Dad)John&Jane

7. In most automobiles, the lights, radio, and power windows operate only if the ignition switch is turned on. In this case, the ignition switch acts as an “enabling” signal. Design the circuit to model this automotive subsystem using the following variables and definitions:

Ignition switch IG: Value 0 if off and value 1 if on
Light switch LS: Value 0 if off and value 1 if on
Radio switch RS: Value 0 if off and value 1 if on
Power window switch WS: Value 0 if off and value 1 if on
Lights L: Value 0 if off and value 1 if on
Radio R: Value 0 if off and value 1 if on
Power windows W: Value 0 if off and value 1 if on

IGLS = L

IGRS = R

IGWS = W

8. Design a circuit that counts the number of 1's present in 3 inputs A, B and C. Its output is a two-bit number X1X0, representing that count in binary.

a) Write the truth table for this circuit.

A	B	C	X1	X0
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

b) Find the minimized logic equations for outputs X1 and X0 using Boolean algebra and K-map. Determining the one gives better simplification for X1 and X0.

X1 = A'B' + AC

A\BC	00	01	11	10
0	0	1	1	0
1	1	1	0	0

X0 = A'C' + AB

A\BC	00	01	11	10
0	1	0	0	1
1	0	1	1	0

c) Draw the corresponding logic diagram for this circuit. Label all inputs and outputs.

9. Draw a block diagram of a 4-bit adder, using one 1-bit half and three 1-bit full adders. Do not draw a gate-level diagram. Show and label all inputs and outputs.

10. There are three inputs A, B, and C (least significant bit) and one output Y of a digital circuit. The inputs represent a 3-bit unsigned number. The output Y is a 1 if and only if the input number is a multiple of 2 or 3 but not both.

a) Draw the truth table

A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	0

b) Draw the K-map for Y

A\BC	00	01	11	10
0	0	1	1	0
1	1	0	0	0

c) Determine the simplified Boolean function Y

Y = A'B' + AC

Sequential Circuit design problems

11. Design an up/down wraparound counter with four states (0, 1, 2, 3) using clocked JK flip-flops.

A control signal x is to be used as follows:

When x = 0 the circuit counts forward (up); when x = 1, backward (down).

(Note: You need to draw the state diagram, truth table for JK flip flop inputs, and also find expressions of the flip flops by using Karnaugh map)

X	ab	ab	JaKa	JbKb
0	00	01	0X	1X
0	01	10	1X	X1
0	10	11	X0	1X
0	11	00	X1	X1
1	00	11	1X	1X
1	01	00	0X	X1
1	10	01	X1	1X
1	11	10	X0	X1

Ja

X\ab	00	01	11	10
0	1	X	X	1
1	1	X	X	1

JA = 1

Ka

X\ab	00	01	11	10
0	X	1	1	X
1	X	1	1	X

Ka = 1

Jb

X\ab	00	01	11	10
0	0	1	X	X
1	1	0	X	X

Kb

X\ab	00	01	11	10
0	X	X	1	0
1	X	X	0	1

12. Design a binary counter that goes through the sequence 0 1 2 3 4 5 6 7 8 9 0 using four JK flip flops. Find the expressions for all the JK flip flops using the Karnaugh map (Note that there will be a number of don't care conditions in your design.)

Q3	Q2	Q1	Q0	JK0	JK1	JK2	JK3
0	0	0	0	1X	0X	0X	0X
0	0	0	1	X1	1X	0X	0X
0	0	1	0	XX	X0	0X	0X
0	0	1	1	X1	X1	1X	0X
0	1	0	0	XX	0X	X0	0X
0	1	0	1	X1	1X	X0	0X
0	1	1	0	1X	X0	X0	0X
0	1	1	1	X1	X1	X1	1X
1	0	0	0	1X	0X	0X	X0
1	0	0	1	X1	0X	0X	X1
0	0	0	0				

13. We want to design a 3-bit binary wraparound down-counter using J-K flip-flops. Draw the state diagram, considering the 3-bit flip-flop outputs as the state.

J1 = Q1

Q2\Q1Q1	00	01	11	10
0	X	0	X	1
1	X	0	X	1

K1 = Q1

Q2\Q1Q1	00	01	11	10
0	1	X	0	X
1	1	X	0	X

J2 = Q2

Q2\Q1Q1	00	01	11	10
0	X	0	0	0
1	1	X	X	X

K2 = Q2

Q2\Q1Q1	00	01	11	10
0	1	X	X	X
1	X	0	0	0

14. A sequential circuit has two D Flip-Flops (A and B), two inputs (x and y), and one output (z). The circuit is specified by the following next-state and output equations:
A(t+1) = x′y + xA
B(t+1) = x′B + xA
z = B
a) List the state table for the sequential circuit.
b) Draw the corresponding state diagram.

Da = Ax + Bx = x(A+B)

A\Bx	00	01	11	10
0	0	0	1	0
1	0	1	1	0

Db = Ax + Bx

A\Bx	00	01	11	10
0	0	1	0	0
1	0	1	1	0

Y = AB

A\Bx	00	01	11	10
0	0	0	0	0
1	0	0	1	1

15. Design a sequential circuit with two D Flip-Flops, A and B, and one input x. When x = 0, the the state of the circuit remains the same. When x =1, the circuit goes through the state transitions from 00 to 01 to 11 to 10 back to 00, and repeats. Find the expressions for the D flip flops using the Karnaugh map

A	B	x	y	A	B	Z
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	0	1	0	1	0	0
0	0	1	1	0	0	1
0	1	0	0	0	1	1
0	1	0	1	0	0	1
0	1	1	0	1	1	1
0	1	1	1	0	1	1
1	0	0	0	0	0	1
1	0	0	1	1	0	1
1	0	1	0	1	0	1
1	0	1	1	1	0	1
1	1	0	0	0	1	1
1	1	0	1	1	0	1
1	1	1	0	1	1	1
1	1	1	1	1	1	1