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ECE 2504: Introduction to Computer Engineering
Homework Assignment 6 (60 points)

Problem 1 (10 points)
If we know enough about the characteristic information for a flip-flop, we can derive the excitation information for that flip-flop.

Here is the characteristic information for the SR flip-flop:

S	R	Function
0	0	No change $Q^+ = Q$
0	1	Reset $Q^+ = 0$
1	0	Set $Q^+ = 1$
1	1	Invalid $Q^+ = \times$

To derive the excitation for the SR flip-flop, we can make the following observations:
- If Q = 0 and Q^+ = 0, we can make SR = 00 (no change, since Q^+ = Q) or SR = 01 (reset, since Q^+ = 0).
- If Q = 0 and Q^+ = 1, we can make SR = 10 (set, since Q^+ = 1).
- If Q = 1 and Q^+ = 0, we can make SR = 01 (reset, since Q^+ = 0).
- If Q = 1 and Q^+ = 1, we can make SR = 00 (no change, since Q^+ = Q) or SR = 10 (set, since Q^+ = 1).

Here is the excitation table that results:

Q	Q^+	S	R	Functions?
0	0	0	$\times$	No change, Reset
0	1	1	0	Set
1	0	0	1	Reset
1	1	$\times$	0	No change, Set

The "$\times$" represents a don't care; in the case of the first instance of excitation, to change a present state of 0 into a next state of 0, S must be 0 and R does not matter.

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Problem 1 (continued)

a. First, complete the characteristic table for the JK flip-flop.

Use the characteristic information to complete the excitation table for the JK flip-flop. Remember to consider all possible cases of characteristic information that cause a particular transition. Use the "Functions?" table to indicate which characteristic function or functions of the JK flip-flop are capable of causing the specified instance of excitation.

J	K	Function
0	0	No Charge Q+ = Q
0	1	Reset Q+ = 0
1	0	Set Q+ = 1
1	1	Toggle Q+ = Q'

Q	Q^+	J	K	Functions?
0	0	0	X	No change/Reset
0	1	1	X	Set/Toggle
1	0	X	1	Reset/Toggle
1	1	X	0	No Change/Set

b. First, complete the characteristic table for the T flip-flop.

Use the characteristic information to complete the excitation table for the T flip-flop. Remember to consider all possible cases of characteristic information that cause a particular transition. Use the "Functions?" table to indicate which characteristic function or functions of the T flip-flop are capable of causing the specified instance of excitation.

T	Function
0	No Change
1	Toggle

Q	Q^+	T	Functions?
0	0	0	No Change
0	1	1	Toggle
1	0	1	Toggle
1	1	0	No Change

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Download and review the "Counter Design" documents on Scholar under Resources / Additional Material before you do Problems 2 – 4:

<u>Problem 2</u> (20 points)

Design a three-bit counter using D flip-flops that has the following characteristics: When the value of an input *x* is 0, the counter counts up through a standard binary order of counting. When the value of *x* is 1, the counter counts down through the same order.

a. First, complete the state table shown below.

Present State				Next State			Excitation		
x	y_1	y_2	y_3	y_1^+	y_2^+	y_3^+	D_1	D_2	D_3
0	0	0	0	0	0	1	0	0	1
0	0	0	1	0	1	0	0	1	0
0	0	1	0	0	1	1	0	1	1
0	0	1	1	1	0	0	1	0	0
0	1	0	0	1	0	1	1	0	1
0	1	0	1	1	1	0	1	1	0
0	1	1	0	1	1	1	1	1	1
0	1	1	1	0	0	0	0	0	0
1	0	0	0	1	1	1	1	1	1
1	0	0	1	0	0	0	0	0	0
1	0	1	0	0	0	1	0	0	1
1	0	1	1	0	1	0	0	1	0
1	1	0	0	0	1	1	0	1	1
1	1	0	1	1	0	0	1	0	0
1	1	1	0	1	0	1	1	0	1
1	1	1	1	1	1	0	1	1	0

b. Next, derive the logic equations using the Karnaugh maps shown below.

D_1

xy_1 \ y_2y_3	00	01	11	10
00	0	0	1	0
01	1	1	0	1
11	0	1	1	1
10	1	0	0	0

D_2

xy_1 \ y_2y_3	00	01	11	10
00	0	1	0	1
01	0	1	0	1
11	1	0	1	0
10	1	0	1	0

D_3

xy_1 \ y_2y_3	00	01	11	10
00	1	0	0	1
01	1	0	0	1
11	1	0	0	1
10	1	0	0	1

D1 = Y2' Y3' + Y1 Y2' Y3 + X Y1 Y2 Y3 + X' Y1' Y2 Y3 + Y1 Y2 Y3'

D2 = X Y2' Y3' + X' Y2' Y3 + X Y2 Y3 + X' Y2 Y3'

D3 = Y3'

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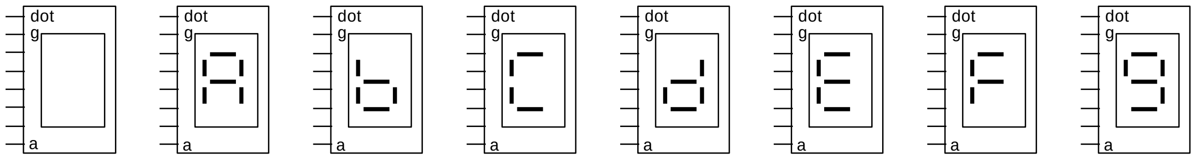
Problem 3 (20 points)
The purpose of the counter is to drive a seven-segment LED display like the one you used in Project 1. Specifically, you want the counter to cause the LED display to cycle through the characters:



The last character is a blank – none of the segments should light during that cycle.
Of course, when the counter is counting up, the characters will appear in regular order, and when the counter is counting down, the characters will appear in reverse order. Since each character is associated with a specific present state, we don't actually have to include x as an input in the equations.

a. First, complete the truth table shown below. Remember that a lit segment requires a value of 0, while an unlit segment requires a value of 1.

y_1	y_2	y_3	Character	T	U	V	W	X	Y	Z
0	0	0	(blank)	1	1	1	1	1	1	1
0	0	1	A	0	0	0	1	0	0	0
0	1	0	b	1	1	0	0	0	0	0
0	1	1	C	0	1	1	0	0	0	1
1	0	0	d	1	0	0	0	0	1	0
1	0	1	E	0	1	1	0	0	0	0
1	1	0	F	0	1	1	1	0	0	0
1	1	1	g	0	0	0	0	1	0	0

b. Next, derive the logic equations using the Karnaugh maps shown below.

T

y_1 \ y_2y_3	00	01	11	10
0	1	0	0	1
1	1	0	0	0

U

y_1 \ y_2y_3	00	01	11	10
0	1	0	1	1
1	0	1	0	1

V

y_1 \ y_2y_3	00	01	11	10
0	1	0	1	0
1	0	1	0	1

W

y_1 \ y_2y_3	00	01	11	10
0	1	1	0	0
1	0	0	0	1

X

y_1 \ y_2y_3	00	01	11	10
0	1	0	0	0
1	0	0	1	0

Y

y_1 \ y_2y_3	00	01	11	10
0	1	0	0	0
1	1	0	0	0

Z

y_1 \ y_2y_3	00	01	11	10
0	1	0	1	0
1	0	0	0	0

$T = Y'Y3' + Y2'\ Y3'$
$U = Y1'\ Y3' + Y1'\ Y2 + Y2\ Y3' + Y1\ Y2'\ Y3$
$V = Y1'\ Y2'\ Y3' + Y1\ Y2'\ Y3 + Y1'\ Y2\ Y3 + Y1\ Y2\ Y3'$
$W = Y1'\ Y2' + Y1\ Y2\ Y3'$
$X = Y1'Y2'Y3' + Y1\ Y2\ Y3$
$Y = Y2'\ Y3'$
$Z = Y1'\ Y2'\ Y3' + Y1'\ Y2\ Y3$

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Problem 4 (10 points)
Using your equations from Problems 2 and 3, draw the circuit you have designed. Use the framework I have provided to represent the flip-flop excitation equations and the LED display driver equations. I have already tied a clock line to the flip-flops. You may use your tablet to draw the circuit diagram. I have turned the framework sideways to make the diagram as large as possible for you.