



2017 final

Digital Systems I (University of Ottawa)



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ITI 1100

**SAMPLE FINAL EXAM
Solutions**

Name:

Student Number:

Good Luck!

Question 1 (8 points)

- a. The solutions to the quadratic equation $x^2 - 10x + 14 = 0$ are $x = 2$ and $x = 6$. What is the base of the numbers? Show your work.

base=8

- b. Show that the dual of the exclusive-OR is equal to its complement.

Q2.24 of the book

$$x \text{ xor } y = x'y + xy' \text{ and } (x \text{ xor } y)' = (x + y')(x' + y)$$

$$\text{Dual of } x'y + xy' = (x' + y)(x + y') = (x \text{ xor } y)'$$

- c. Find the complement of $F = wx + yz$; What is the value of FF' ?

Q2.8 of the book

$$F' = (wx + yz)' = (wx)'(yz)' = (w' + x')(y' + z')$$

$$FF' = wx(w' + x')(y' + z') + yz(w' + x')(y' + z') = 0$$

$$F + F' = wx + yz + (wx + yz)' = A + A' = 1 \text{ with } A = wx + yz$$

Question 2 (8 points)

A majority circuit is a combinational circuit whose output is equal to 1 if the input variables have more 1's than 0's. The output is 0 otherwise.

Design a 3 input majority circuit by finding the circuit's truth table, Boolean equation and a logic diagram.

Q4.6 of the book

$$F = xz + yz + xy$$

Question 3 (11 points)

Design a combinational circuit that generates the 9's complement of a BCD digit by finding the circuit's truth table, Boolean equation and a logic diagram.

Q4.18 of the book

Inputs: **ABCD**

Outputs: **wxyz**

$$d(A, b, c, d) = \Sigma(10, 11, 12, 13, 14, 15)$$

$$w = A'B'C'$$

$$x = BC' + B'C = B \text{ xor } C$$

$$y = C$$

$$z = D'$$

Question 4 (5 points)

A combinational circuit is specified by the following two Boolean functions:

$$F_1(A,B,C) = \sum(1,4,6)$$

$$F_2(A,B,C) = \sum(3,5)$$

Implement the circuit with a decoder. Use a block diagram for the decoder and use NAND gates for the gates connected to the decoder outputs.

Q4.27 of the book

4.27

4.28 (a)

$$F_1 = x'y'z + y'z' + x'y'z' = xy'z + xy'z' + x'y'z' = \Sigma(2, 5, 7)$$

$$F_2 = xy'z' + x'y'z' + xy'z + x'y'z' = \Sigma(2, 3, 4)$$

$$F_3 = x'y'z' + xy'z + z' = x'y'z' + xy'z + xy'z' = \Sigma(0, 6, 7)$$

(b)

Question 5 (8 points)

Implement the following Boolean function with a multiplexer.

$$F(A,B,C) = \sum(2,4,6)$$

Q4.32 of the book

Similar to this one

4.32 (a) $F = \sum(0, 2, 5, 8, 10, 14)$

Inputs ABCD	Max. input line (ABC)	F value	F = $\sum(0, 2, 5, 8, 10, 14)$
000 0 0 0	0	1	$F = D'$
000 1 0 1	1	0	
001 0 1 2	2	1	$F = D'$
001 1 1 3	3	0	
010 0 2 4	4	0	$F = D$
010 1 2 5	5	1	$F = D$
011 0 3 6	6	0	$F = 0$
011 1 3 7	7	0	
100 0 4 8	8	1	$F = D'$
100 1 4 9	9	0	
101 0 5 10	10	1	$F = D'$
101 1 5 11	11	0	
110 0 6 12	12	0	$F = 0$
110 1 6 13	13	0	
111 0 7 14	14	1	$F = D'$
111 1 7 15	15	0	

The diagram shows an 8x1 MUX with inputs 0 through 7. The output is F. The inputs are connected as follows: Input 0 is connected to D' (via an inverter), Input 2 is connected to D', Input 4 is connected to D, Input 5 is connected to D, Input 8 is connected to D', Input 10 is connected to D', and Input 14 is connected to D'. All other inputs (1, 3, 6, 7, 9, 11, 12, 13, 15) are connected to 0.

Question 6 (11 points)

A PN flip-flop has four operations: clear to 0, no change, complement, and set to 1, when the inputs P and N are 00, 01, 10, and 11, respectively.

Q5.4 of the book

5.3 $Q'(t+1) = (JQ' + K'Q)' = (J' + Q)(K + Q') = JQ' + KQ$

5.4

(a)

P	N	Q(t+1)
0	0	0
0	1	Q(t)
1	0	Q'(t)
1	1	1

(b)

P	N	Q(t)	Q(t+1)
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	1

(c)

Q(t)	Q(t+1)	P	N
0	0	0	x
0	1	1	x
1	0	x	0
1	1	x	1

(d) Connect P and N together.

5.5

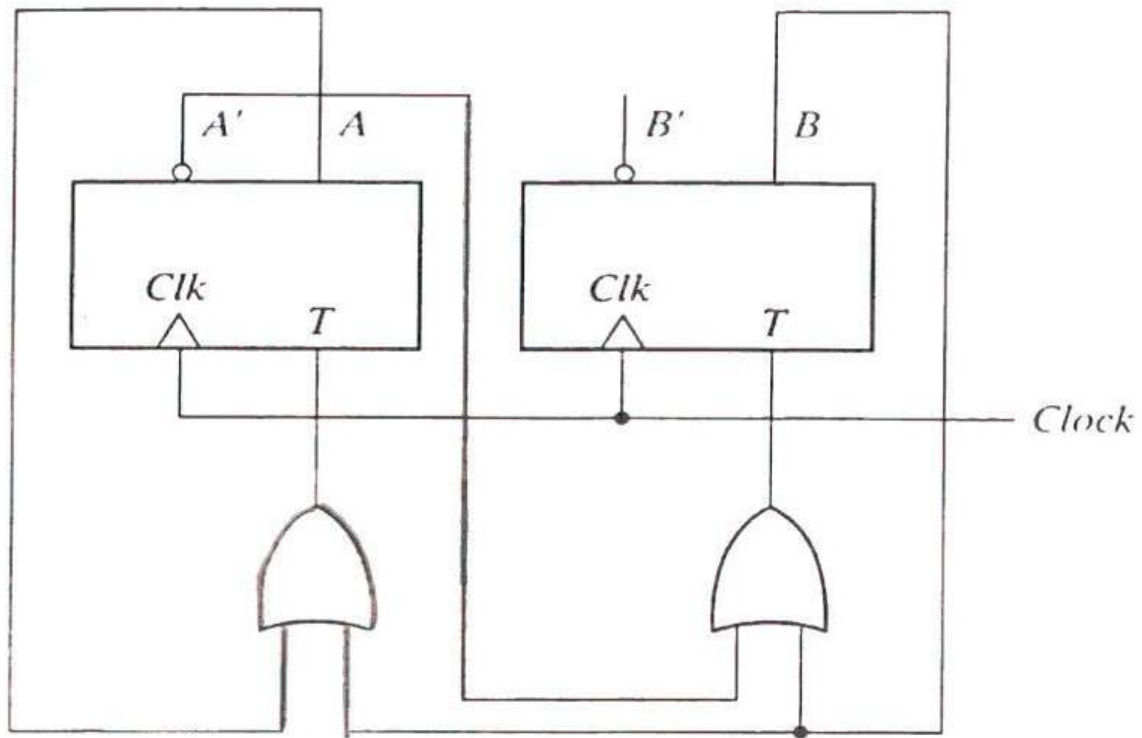
The truth table describes a combinational circuit.
 The state table describes a sequential circuit.
 The characteristic table describes the operation of a flip-flop.
 The excitation table gives the values of flip-flop inputs for a given state transition.
 The four equations correspond to the algebraic expression of the four tables.

- a. Tabulate the characteristic table.

- b. Derive the characteristic equation.
- c. Tabulate the excitation table or the transition table.

Question 7 (8 points)

Derive the state table, state equations and the state diagram of the following sequential circuit:

Q5.8 of the book

0132774232_ism.pdf - Adobe Acrobat Pro

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5.8 A counter with a repeated sequence of 00, 01, 10.

Present state			Next state			FF Inputs	
A	B	A	B	T _A	T _B		
0	0	0	0	0	1		
0	1	1	0	1	1		
1	0	0	0	1	0		
1	1	0	0	1	1		

$T_A = A + B$
 $T_B = A' + B$

Repeated sequence:
 $00 \rightarrow 01 \rightarrow 10 \rightarrow$

5.9

$J_A = x$
 $J_B = x$

$K_A = B$
 $K_B = A'$

$A(t+1) = J_A A' + K_A A = x A' + B A$
 $B(t+1) = J_B B' + K_B B = x B' + A B$

x	A	B	$x A' + B A$	$x B' + A B$
0	0	0	0	0
0	0	1	0	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	1
1	0	1	1	0
1	1	0	1	1
1	1	1	0	1

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Question 8 (10 points)

For the following state table:

Present State	Next State		Output	
	x = 0	x = 1	x = 0	x = 1
a	e	d	0	0
b	d	c	0	1
c	a	e	1	0
d	a	b	1	0
e	d	c	0	1

Q5.12 and 5.13 of the book

The screenshot shows a PDF document titled "0132774232_ism.pdf" in Adobe Acrobat Pro. The document contains the following content:

(c)

input	state	next st	output
0	0	0	0
1	0	1	0
0	1	0	0
1	1	1	1

State machine: D-flop with direct input of the input to the original machine;
output logic: $y = (\text{input}) \ \&\& \ (\text{state} == b)$

5.12

Present state	Next state		Output	
	0	1	0	1
a	f	b	0	0
b	d	a	0	0
d	g	a	1	0
f	f	b	1	1
g	g	d	0	1

Digital Design With An Introduction to the Verilog HDL - Solution Manual. M. Mano. M.D. Ciletti. Copyright 2012. All rights reserved.

5.13 (a) State: $a f b c e d g h g g h a$

Input: 0 1 1 1 0 0 1 0 0 1 1

Output: 0 1 0 0 0 1 1 1 0 1 0

(b) State: *a f b a b d g d g g d a*

Input: 0 1 1 1 0 0 1 0 0 1 1

Output: 0 1 0 0 0 1 1 1 0 1 0

- Draw the corresponding state diagram.
- Tabulate the reduced table.
- Draw the state diagram corresponding to the reduced state table.
- Starting from state a, and the input sequence 0111000, determine the output sequence for the above reduced state table.

Question 9 (12 points)

- a. The contents of a four-bit register is initially 0110. The register is shifted six times to the right with the serial input being 1011100. What is the content of the register after each shift.

Q6.4 of the book

6.4 0110 => 0011, 0001, 1000, 1100, 1110, 0111, 1011

- b. List the sequence of states produced with 3 and 4 flip-flops in a Johnson counter. The initial value of the register is 000 and 0000 respectively.

Q6.30 of the book

0132774232_ism.pdf - Adobe Acrobat Pro

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6.30

The 5-bit Johnson counter has the following state sequence:

ABCDE decoded output:	00000 A'E'	10000 AB'	11000 BC'	11100 CD'	11110 DE'
11111 A'E'	01111 AB'	00111 BC'	00011 CD'	00001 DE'	

6.31

```

module Reg_4_bit_beh (output reg A3, A2, A1, A0, input I3, I2, I1, I0, Clock, Clear);
always @ (posedge Clock, negedge Clear)
if (Clear == 0) {A3, A2, A1, A0} <= 4'b0;
else {A3, A2, A1, A0} <= {I3, I2, I1, I0};
endmodule

module Reg_4_bit_Str (output A3, A2, A1, A0, input I3, I2, I1, I0, Clock, Clear);
DFF M3DFF (A3, I3, Clock, Clear);
DFF M2DFF (A2, I2, Clock, Clear);
DFF M1DFF (A1, I1, Clock, Clear);
DFF M0DFF (A0, I0, Clock, Clear);
endmodule

module DFF(output reg Q, input D, clk, clear);
always @ (posedge clk, posedge clear)
if (clear == 0) Q <= 0; else Q <= D;
endmodule

module t_Reg_4_bit ();
wire A3_beh, A2_beh, A1_beh, A0_beh;
wire A3_str, A2_str, A1_str, A0_str;
reg I3, I2, I1, I0, Clock, Clear;

```

- c. A Johnson counter with n flip-flops produces a sequence of many states?
- d. What is the characteristic equation for the complement output of a JK flip-flop?

Q5.3 of the book

$$5.3 \quad Q'(t+1) = (JQ' + K'Q)' = (J' + Q)(K + Q') = J'Q' + KQ$$

Question 10 (8 points)

Using D flip-flops,

Q6.28 of the book

6.28

Present state ABC	Next state ABC
000	001
001	010
010	100
011	xxx
100	110
101	xxx
110	000
111	xxx

Three Karnaugh maps for D flip-flop inputs are shown:

- $D_A = A \oplus B$
- $D_B = AB' + C$
- $D_C = A'B'C'$

State transition diagram (Self-correcting):

```

graph TD
    111((111)) --> 110((110))
    001((001)) --> 110
    110 --> 010((010))
    010 --> 111
  
```

- a. Design a synchronous counter with the following repeated binary sequence 0, 1, 2, 4, 6.

- b. Draw the logic diagram of the counter.

Question 11 (11 points)

Design a 3-bit ring counter using T Flip-flops. The initial value of the register is 100.
Draw the logic diagram of the counter.

Q6.x of the book