0. Name (2 pts):

AME 3623: Embedded Real-Time Systems

Midterm Exam

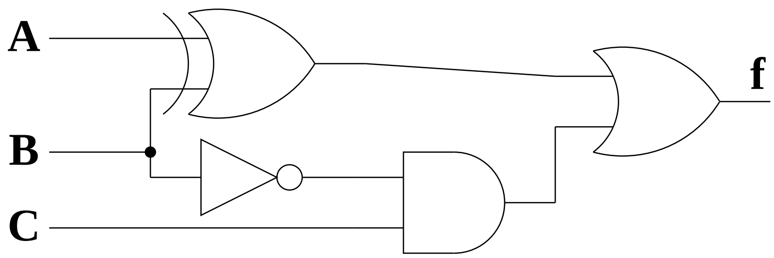
Solution Set

March 12, 2008

Problem	Topic	Max	Grade
0	Name	2	
1	Digital Logic	30	
2	Number Systems	15	
3	Sequential Logic	15	
4	Memory	15	
5	Microcontrollers	25	
Total			

1. **Digital Logic** (30 pts)

Given the following circuit:



(a) (8 pts) Show the corresponding truth table.

A	B	C	f
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	0

Given the following truth table:

A	B	C	f
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	0

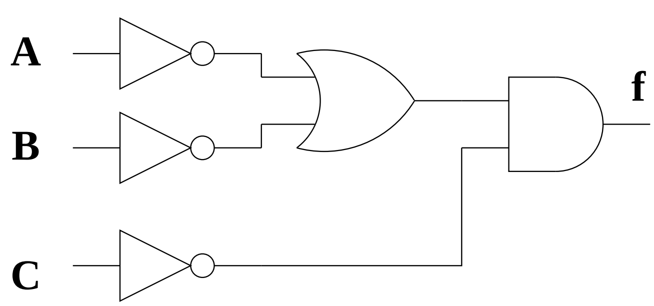
(b) (5 pts) Give the "minterm" form of the corresponding algebraic expression.

$f = \bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + A\bar{B}\bar{C}$

(c) (7 pts) Derive a simplified algebraic description for f. Justify each step (provide the name of the rule that you are using).

$\bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + A\bar{B}\bar{C}$	
$\bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + A\bar{B}\bar{C}$	$X + X = X$
$\bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + \bar{A}\bar{B}\bar{C} + A\bar{B}\bar{C}$	*Commutative Law*
$(\bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C}) + (\bar{A}\bar{B}\bar{C} + A\bar{B}\bar{C})$	*Associative Law*
$\bar{A}(\bar{B} + B)\bar{C} + (\bar{A} + A)\bar{B}\bar{C}$	*Distributive Law*
$\bar{A}(1)\bar{C} + (1)\bar{B}\bar{C}$	$X + \bar{X} = 1$
$\bar{A}\bar{C} + \bar{B}\bar{C}$	$X \times 1 = X$
$(\bar{A} + \bar{B})\bar{C}$	*Distributive Law*

(d) (5 pts) Draw the corresponding circuit.

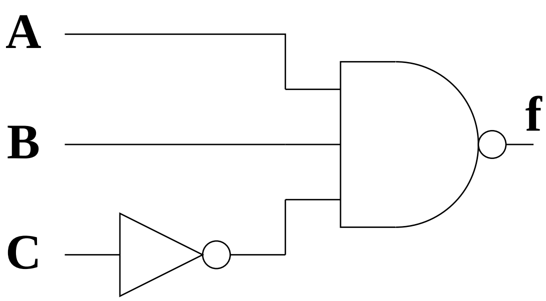


Given the following truth table:

A	B	C	f
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

(e) (5 pts) Give the reduced circuit (and yes, this is only worth 5 pts).

Insight: $\bar{f}$ is a very simple function (it has a single minterm).



2. **Number Systems** (15 pts)

(a) (5 pts) What is the binary equivalent of $0xB3$? Show your work.

$0xB3 = 10110011$

(b) (5 pts) What is the decimal equivalent of $0x3E$? Show your work.

The decimal equivalent of this is: $16 * 3 + 14 = 62$
Or:
The binary equivalent is: 111110
And the decimal equivalent is:

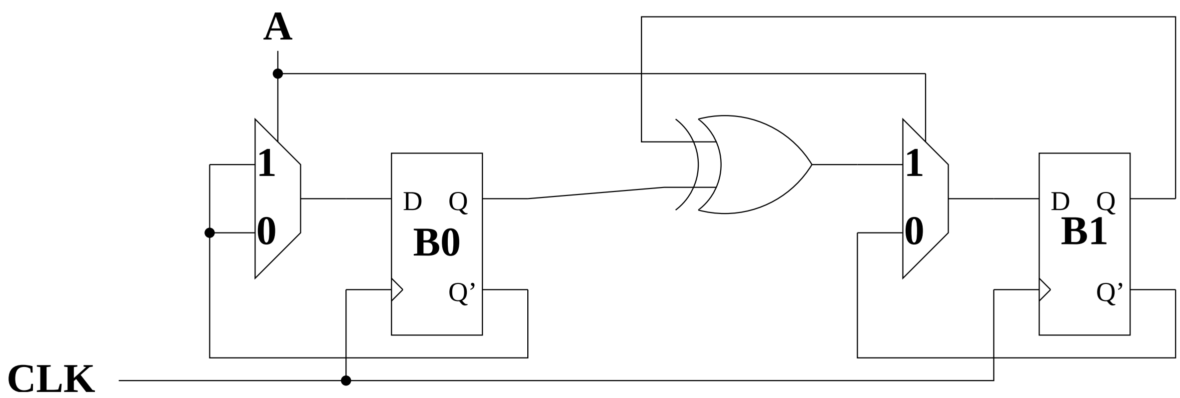
$$32 + 16 + 8 + 4 + 2 = 62$$

(c) (5 pts) What is the binary equivalent of decimal number 129? Show your work.

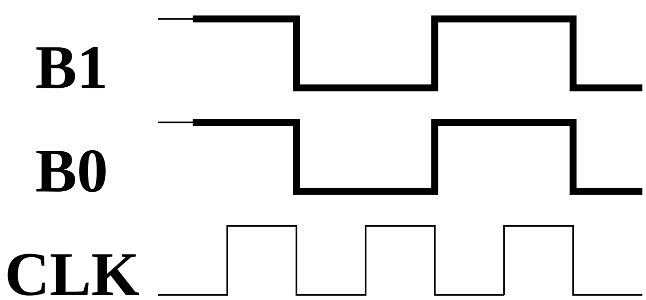
value	**binary**	i	2^i
129	*00000000*		
		7	*128*
1	*10000000*		
		0	*1*
0	*10000001*		

3. **Sequential Logic** (15 pts)

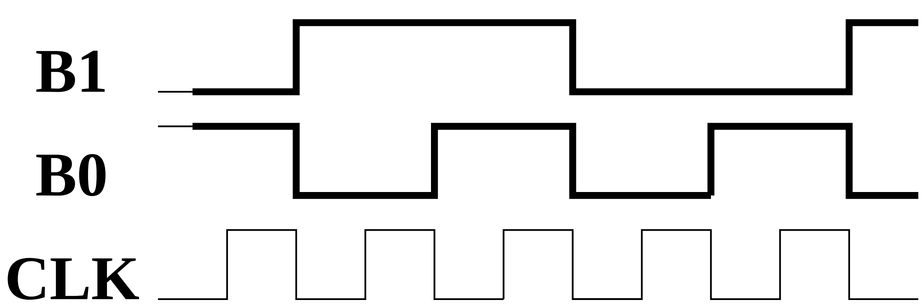
Given the following circuit:



(a) (5 pts) Assume that the initial state is $B1 = 1$ and $B0 = 1$, and that $A = 0$. Fill in the following timing diagram:



(b) (5 pts) Assume that the initial state is $B1 = 0$ and $B0 = 1$, and that $A = 1$. Fill in the following timing diagram:



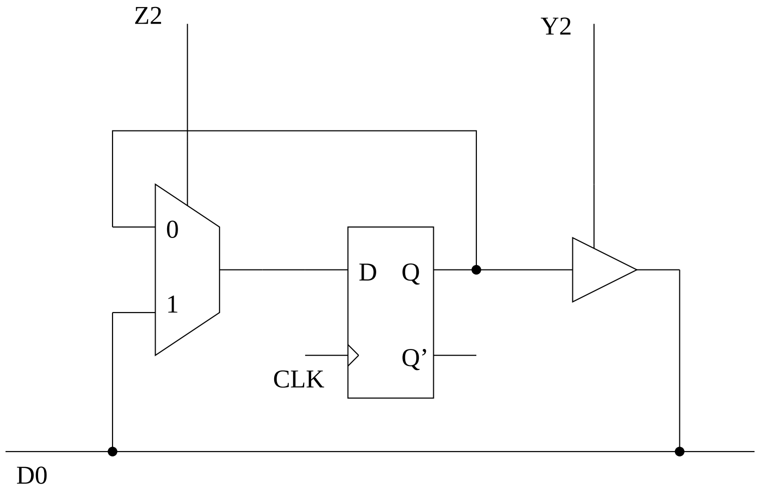
(c) (5 pts) If you interpret $B1, B0$ as a 2-bit number, what mathematical operation(s) does this device perform on each clock cycle?

When $A = 0$, the number is bit-wise NOTed

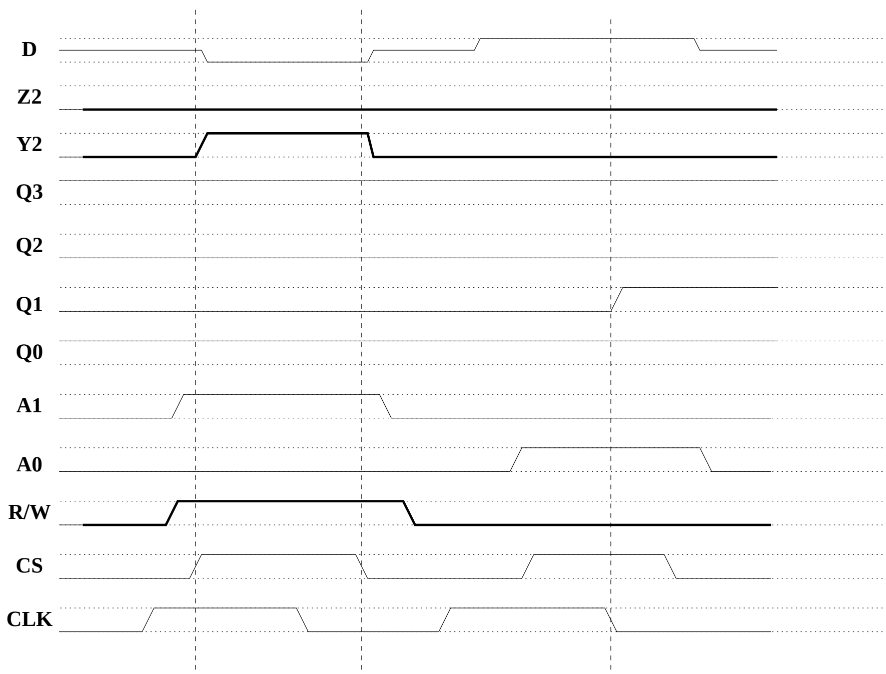
When $A = 1$, the number is incremented by one (and carries are lost).

4. **Memory** (15 pts)

Consider the following circuit:



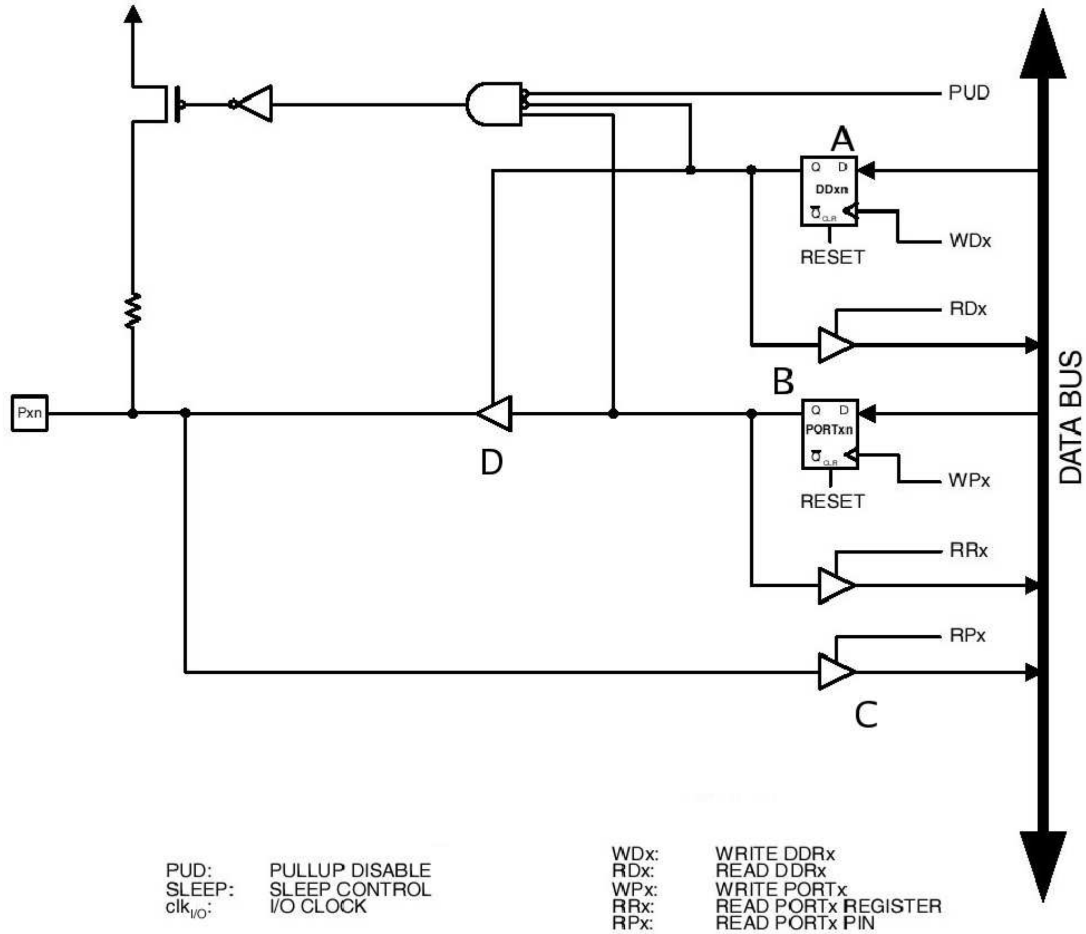
(a) (10 pts) For the timing diagram below, fill in the missing control signals: R/W, Y2, and Z2 (the Y's and Z's for the other bits are not shown below and you do not need to provide them).



Note: we were pretty liberal about grading the timing diagram. In addition to having the signals be in the correct states (at certain times), we looked for having the signals *be set up in time for the read or write operation. Specifically, the address and R/W lines needed to be configured before the chip select line goes high.*

(b) (5 pts) What type of information is stored in RAM in the atmel mega8? (be brief)
Program variables.

5. **Microcontrollers** (25 pts)



(a) (5 pts) Identify component "D". Briefly explain the function of this component in this circuit.

Component D is a tristate buffer. It determines whether this pin is an input (0) or an output (1). If an output, then the output from component B will be copied to the pin.

Assume an initial state of:
$DDRB = 0xC3$
$PORTB = 0xA5$

(b) (5 pts) What effect does the following code have on $DDRB$ and on the above circuit (in terms of components A, B, C, and D)?

```
DDRB = DDRB | 0x40;
```

This line of code ensures that bit 6 of DDRB is turned on (component A), but leaves the other bits of DDRB unchanged. In this context, however, bit 6 is already turned on. Therefore, there is no change to the circuit state.

(c) (5 pts) What effect does the following code have on the state of this circuit (in terms of components A, B, C, and D)?

```
PORTB = PORTB & ~0xC0;
```

This line of code ensures that bits 6 and 7 of PORTB are turned off (component B). However, in this case, only bit 7 changes state (bit 6 is already turned off). Because pin 7 is configured as an output, the output of component D is changed to logic 0. In turn, this means that pin 7 is at $0V$.

(d) (5 pts) What effect does the following code have on the state of this circuit (in terms of components A, B, C, and D)? What is the value of variable "foo" after this line is executed? (be as specific as possible)

```
foo = (PINB & 0x1C) >> 2;
```

This line of code briefly selects the input tristate buffer, component C – this is for **all** *bits. The state of pins 4,3,2 are placed in bits 2,1,0, respectively, of the variable foo; all other bits of foo are logic 0.*

(e) (5 pts) When is pin 7 set to a logic low?

```
    PORTB |= 0x80;
    while(!(PINB & 0x4)) {};
    PORTB &= ~0x80;
```

Pin 7 is set to low by the 3rd line of code when pin 2 is set (externally) to logic high.