0. Name (2 pts):

AME 3623: Embedded Real-Time Systems

Midterm Exam

Solution Set

March 11, 2010

Problem	Topic	Max	Grade
0	Name	2	
1	Number Systems	10	
2	Sequential Logic	30	
3	Memory	20	
4	Microcontrollers	25	
5	Serial Communication	15	
Total			

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1. **Number Systems** (10 pts)

   (a) (5 pts) What is the binary equivalent of $0xC3A$? Show your work.

   Each hex digit corresponds to 4 binary digits:

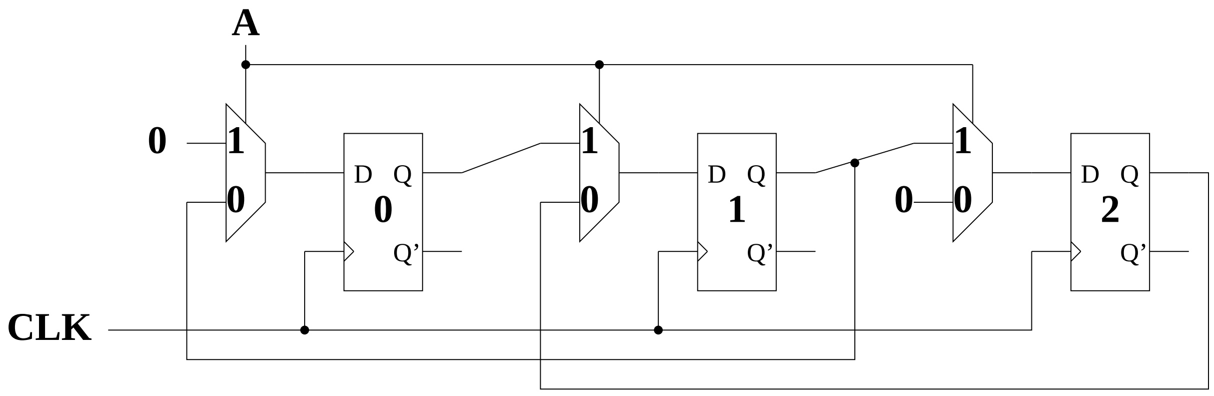
   $0xC3A = 1100\ 0011\ 1010$

   (b) (5 pts) What is the hexadecimal equivalent of decimal 429? Show your work.

   $426/16 = 26\ R\ 13$
   $26/16 = 1\ R\ 10$
   $1/16 = 0\ R\ 1$
   Hexadecimal equivalent is the collection of the remainders: $1AD$

2. **Sequential Logic** (30 pts)

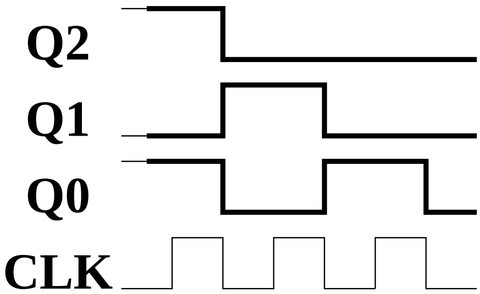
Given the following circuit:



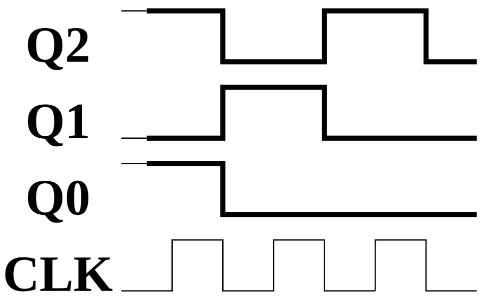
(a) (15 pts) Fill in the following truth table (the Dx and "value D" columns). Note that "value Q" is the decimal value that results from interpreting $Q2, Q1, Q0$ as a binary number. refer to the data input to the flip-flops. "Value D" is the decimal value that results from interpreting $D2, D1, D0$ as a binary number.

A	Q2	Q1	Q0	value Q	D2	D1	D0	value D
0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	0	0
0	0	1	0	2	0	0	1	1
0	0	1	1	3	0	0	1	1
0	1	0	0	4	0	1	0	2
0	1	0	1	5	0	1	0	2
0	1	1	0	6	0	1	1	3
0	1	1	1	7	0	1	1	3
1	0	0	0	0	0	0	0	0
1	0	0	1	1	0	1	0	2
1	0	1	0	2	1	0	0	4
1	0	1	1	3	1	1	0	6
1	1	0	0	4	0	0	0	0
1	1	0	1	5	0	1	0	2
1	1	1	0	6	1	0	0	4
1	1	1	1	7	1	1	0	6

(b) (5 pts) Assume that the initial state is $Q2, Q1, Q0 = 101$ and that $A = 0$. Fill in the following timing diagram:



(c) (5 pts) Assume the same initial state and that $A = 1$. Fill in the following timing diagram:

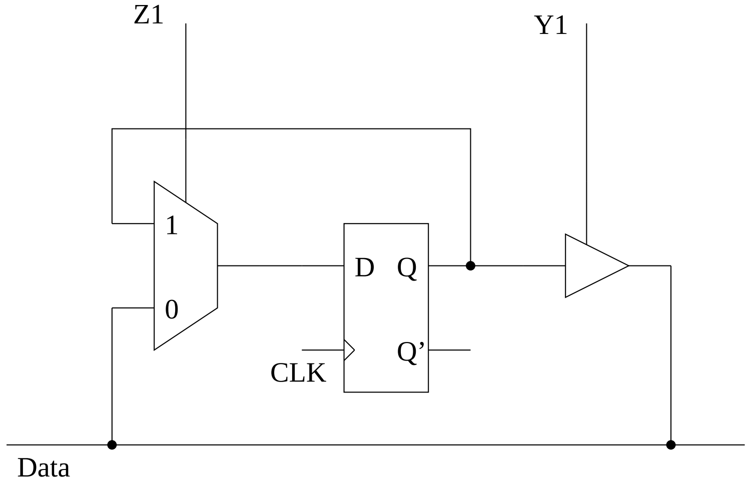


(d) (5 pts) If you interpret $Q2, Q1, Q0$ as a 3-bit number, what mathematical operations does this device perform on each clock cycle? Give one answer for each of $A = 0$ and $A = 1$

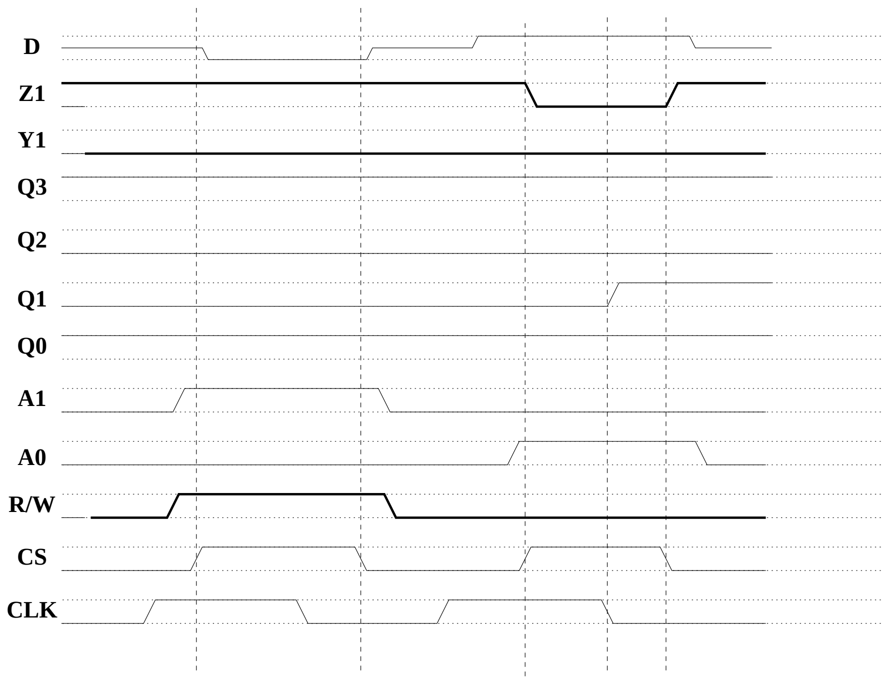
When $A = 0$, the number is divided by 2, with the remainder lost.
When $A = 1$, the number is multiplied by 2, with the carry bit being dropped.

3. **Memory** (20 pts)

Consider the following circuit for a single bit memory element (this is one of four bits in our memory chip):



(a) (10 pts) For the timing diagram below, fill in the missing control signals: R/W, Y1, and Z1 (the Y's and Z's for the other bits are not shown below and you do not need to provide them). Note: there are two possible (but overlapping) answers. Pick one.



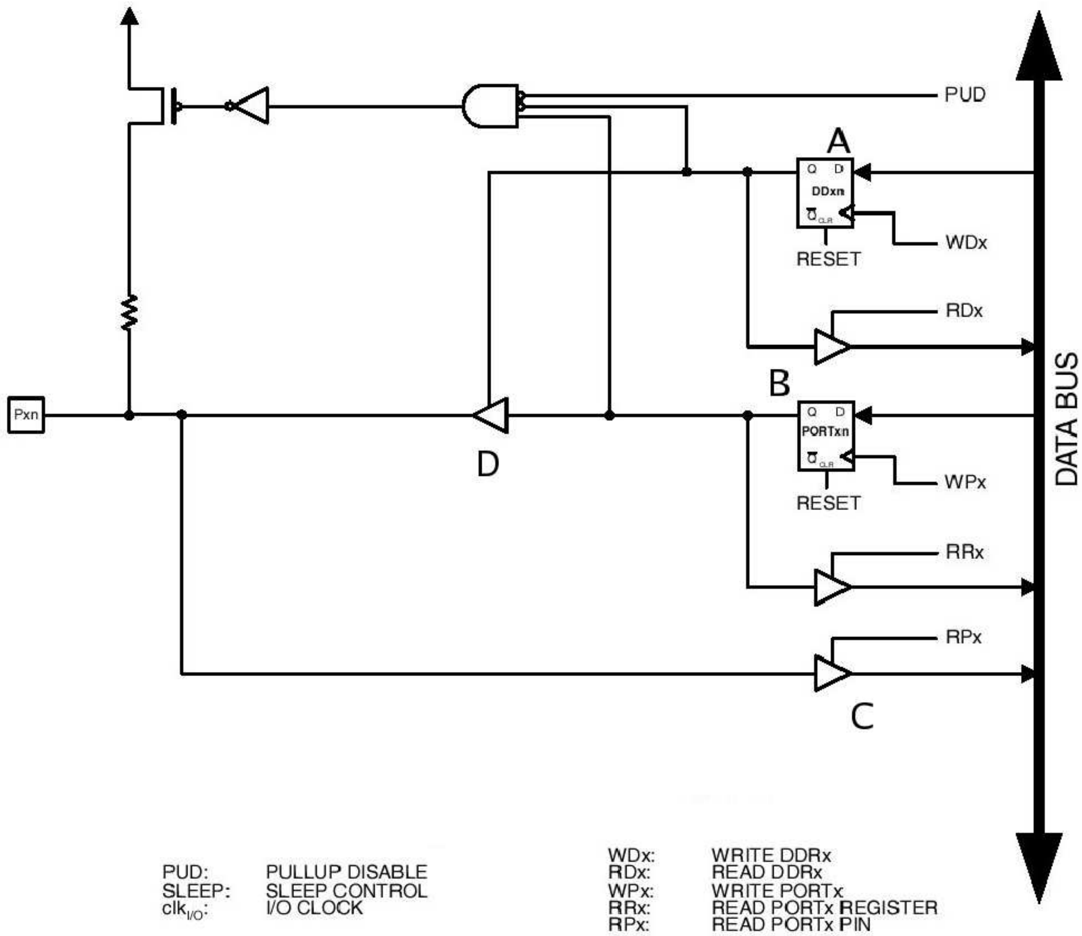
Note: we were pretty liberal about grading the timing diagram. In addition to having *the signals be in the correct states (at certain times), we looked for having the signals be set up in time for the read or write operation. Specifically, the address and R/W lines needed to be configured before the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

(b) (5 pts) What is the function of the *general purpose registers*? (be brief)
General purpose registers are fast memories that are used for temporary storage data that are currently being manipulated.

(c) (5 pts) True/False and explain: The chip select is an output from the memory chip.
False. The chip select is an input that tells the memory chip when it is active (i.e., it can either read from the bus or write to the bus).

4. **Microcontrollers** (25 pts)

Here is a diagram of a generic pin and its associated components.



Assume an initial state of:
$DDRC = 0x36$
$PORTC = 0x24$

(a) (5 pts) What effect does the following code have on $DDRC$ and on the above circuit (in terms of components A, B, C, and D)? Be specific.

```
DDRC = DDRC | 0x1;
```

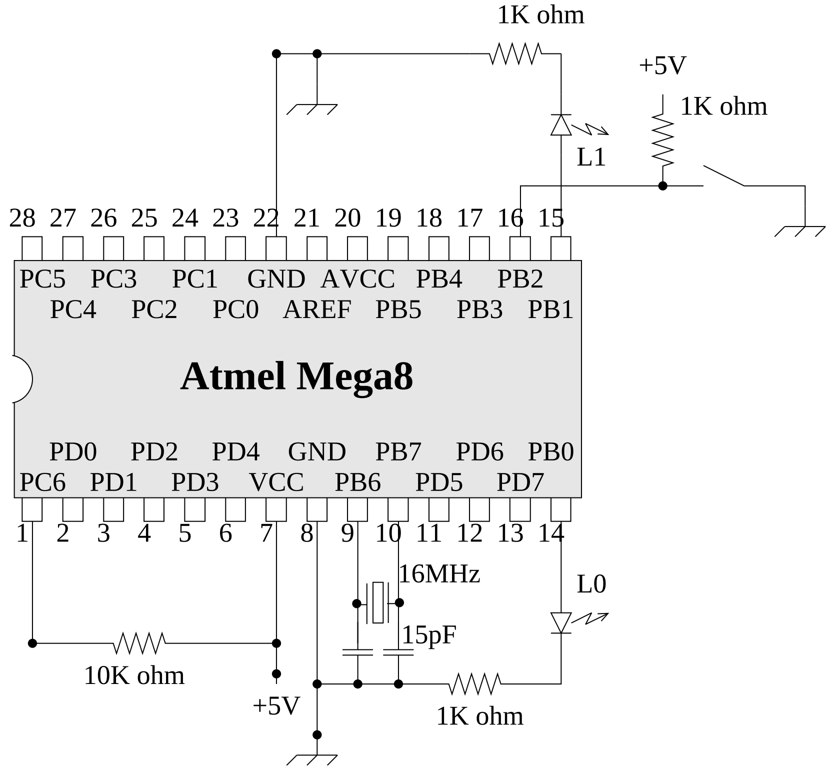
This line of code ensures that bit 0 of DDRC is turned on (component A), but leaves the other bits of DDRC unchanged. In this case, this line of code results in a change of state of this flip-flop. In turn, this brings the select line of component D high, which brings the pin into a state of logic 0.

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

```
PORTC = PORTC & ~0x02;
```

This line of code ensures that bit 1 of PORTC is turned off (component B). In this case, there is no change in the state of the flip-flop, so there are no changes in the rest of the circuit.

Consider the following circuit:



And consider the following code snippet:

```
DDRB = 0x3;

while(1) {
  if(PINB & 0x4) {
    PORTB |= 6;
    PORTB ^= 1;
    delay_ms(200);
  }else{
    PORTB |= 1;
    PORTB ^= 10;
    delay_ms(400);
  }
}
```

(c) (5 pts) What happens to the LEDs when the switch is open (no connection)?
LED L1 is on all the time. L0 flashes at 2.5 Hz.

(d) (5 pts) What happens to the LEDs when the switch is closed?
LED L0 is on all the time. L1 flashes at 1.25 Hz.

(e) (5 pts) Briefly define a *bus*.

A bus is a channel of communication. Potentially many devices can be connected to the bus, but only one device is allowed to drive the bus at a given time (and there is usually one reading device as well).

5. **Serial Communication** (15 pts)

(a) (5 pts) Briefly describe the function of a *start bit* in asynchronous serial protocols (such as the one that we are using to communicate between the Atmel chip and the compass module).

A start bit serves to inform the receiver that a byte is coming and to also synchronize the receiver clock with that of the sender.

(b) (10 pts) Assume that the next three characters to be read from the serial port are '5', '2' and '6'. What is the value of variable *val* in decimal after the following code completes its execution?

```
int i;
int val = 0;

for(i = 0; i < 2; ++i) {
   val = val * 8 + getchar() - '0';
}
```

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(Note: only the first two characters are read by the code)