0. Name (2 pts):

AME 3623: Embedded Real-Time Systems

Midterm Exam

Solution Set

March 12, 2013

Topic	Max	Grade
Name	2	
Number Systems	25	
Analog Processing	30	
Microcontrollers	20	
Digital Input/Output	25	
Total	100	

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1. **Number Systems** (25 pts)

(a) (5 pts) Given the decimal number 228. What is the binary equivalent? Show your work.

228	
114	*0*
57	*00*
28	*100*
14	*0100*
7	*00100*
3	*100100*
1	*1100100*
0	*11100100*

Answer: 11100100

(b) (5 pts) Consider the following number: $0xFE$. If we interpret this as a signed 8-bit integer, what is the decimal equivalent? Show your work.

$0xFE = 0b11111110 = -128 + 64 + 32 + 16 + 8 + 4 + 2 = -2$

(c) (5 pts) Consider the following number: $0xA3$. If we interpret this as an unsigned 8-bit integer, what is the decimal equivalent? Show your work.

$0xA3 = 10 * 16 + 3 = 163$

(d) (5 pts) Consider the following number: $0x38$. Interpret this as a signed 8-bit integer. What is the negative of this number in binary? Show your work.

$0x38 = 00111000$

Flip: 11000111

Add 1: 11001000

(e) (5 pts) Consider the following code:

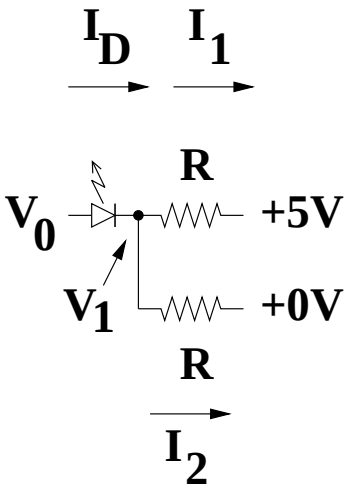
```
uint8_t x = 0x21;
uint8_t y;

y = x >> 4;
y = y << 3;
```

What is the value of y in hexadecimal after the code executes?
$y = 0x10$

2. **Analog Processing** (30 pts)

Given the following circuit:



Assume that $R = 1000\Omega$ and $V_f = 2V$.

(a) (6 pts) What are the equations that are always true?

$$\begin{aligned} V_1 - 5 &= I_1 R \\ V_1 - 0 &= I_2 R \\ I_D &= I_1 + I_2 \end{aligned}$$

(b) (12 pts) Assume $V_0 = 3V$. What is V_1?

Guess: $I_D = 0$ *and* $V_0 - V_1 < V_f$
Therefore:

$$\begin{aligned} 0 &= I_D \\ &= I_1 + I_2 \\ &= \frac{V_1 - 5}{R} + \frac{V_0}{R} \\ &= \frac{2V_1 - 5}{R} \end{aligned}$$

$$V_1 = 2.5\,V$$

Check: $V_0 - V_1 < V_f$
$3 - 2.5 < 2$ *Correct!*

(c) (12 pts) Assume $V_0 = 6V$. What is I_D?

Guess: $I_D > 0$ *and* $V_0 - V_1 = V_f$
Therefore:

$$\begin{aligned} V_1 &= V_0 - V_f \\ &= 6\ V - 2\ V \\ &= 4\ V \end{aligned}$$

$$\begin{aligned} I_D &= I_1 + I_2 \\ &= \frac{2V_1 - 5}{R} \\ &= \frac{2 \times 4 - 5}{1000} \\ &= 3\ mA \end{aligned}$$

3. **Microcontrollers** (20 pts)

(a) (8 pts) Give two examples for how the status register is used by other parts of the microprocessor.

Used by the ALU when adding with a carry.

Can be used when updating the value stored in the program counter (a conditional jump).

(b) (7 pts) When the microprocessor is storing a value into a memory, what two numbers are communicated from the microprocessor to the memory?

i. the value to be stored, and

ii. the address.

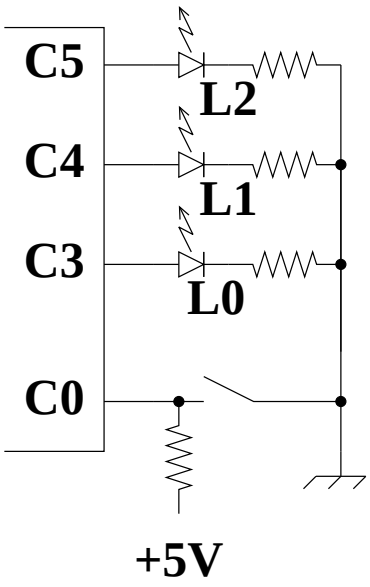
(c) (5 pts) True or False, and briefly explain: the following code results in a change in what is stored in the ROM.

```
x = 42;
```

False. A ROM can't be changed.

4. **Digital Input/Output** (25 pts)

Consider the following circuit diagram:



(a) (5 pts) Given the circuit, how should DDRC be initialized? (there is only one good answer for initialization)

```
DDRC = 0x38;
```

Consider the following code:

```
int main (void)
{
  DDRC = ****;  // However you initialized it above.
  PORTC = 0;
  int8_t val = 1;

  while(1) {
    PORTC = (PORTC & 0xE7) | (val << 3);

    if(PINC & 0x1) {
      val ^= 3;
      delay_ms(10);
    }else{
      val -= 1;
      if(val < 0) {
        val = 2;
      }
      delay_ms(100);
    }
  }
}
```

(b) (10 pts) Explain what happens to the LEDs when the switch is "closed" from the beginning of the program.

Note 1: val proceeds through the sequence: $1, 0, 2, 1, 0, ...$*, with* $100\ ms$ *for each step*
Note 2: val only affects LED 0 and 1 (LED 2 is never turned on at any time)

LEDs 0 and 1 flash at a period of 300ms and 33% duty cycle. Their "on" periods do not overlap. LED 2 stays off the entire time.

(c) (10 pts) Explain what happens to the LEDs when the switch is "opened" from the beginning of the program.

Note: val proceeds through the sequence: $1, 2, 1, 2, 1, ...$*, with* $10\ ms$ *for each step*

LEDs 0 and 1 flash at a period of 20ms with a 50% duty cycle. They flash out of phase. LED 2 stays off the entire time.