0. Name (2 pts):

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AME 3623: Embedded Real-Time Systems
Midterm Exam
Solution Set
March 8, 2012

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

(a) (5 pts) What is the sum of binary numbers 111011100 and 10000100? Show your work.

\[
\begin{array}{c}
111011100 \\
+ 10000100 \\
\hline
1001100000
\end{array}
\]

(b) (5 pts) What is the decimal equivalent of the above result?

\[1001100000 = 512 + 64 + 32 = 608\]

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

\[0xF = 10001111 = -128 + 8 + 4 + 2 + 1 = -113\]

(d) (5 pts) Consider the following number: 0x813. If we interpret this as a signed 16-bit integer, what is the decimal equivalent? Show your work.

\[0x813 = 100000010011 = 2048 + 16 + 2 + 1 = 2067\]

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

```c
uint8_t x = 0x11;
uint8_t y;

y = x << 4
```

What is the value of y in hexadecimal?

\[y = 0x10\ (the\ highest\ order\ digit\ is\ dropped)\]
2. Analog Processing

Given the following circuit:

Assume that \( R \) is known and that the analog comparators are powered with \(+5V\).

(a) (5 pts) What are the equations that are always true for the left-hand-side of the circuit?

\[
\begin{align*}
5 - V_3 &= 16RI_4 \\
V_3 - V_2 &= 8RI_3 \\
V_2 - V_1 &= 4RI_2 \\
V_1 - V_0 &= 2RI_1 \\
V_0 - 0 &= RI_0 \\
I_4 &= I_3 = I_2 = I_1 = I_0
\end{align*}
\]
(b) (10 pts) Solve for $V_0.. V_3$ (simplified fractions are sufficient).

\[
\begin{align*}
R_T &= 31R \\
I_* &= \frac{5 - 0}{31R} \\
V_0 &= RI_0 = \frac{5}{31} \\
V_1 &= 2RI_1 + V_0 = \frac{5}{31} \\
V_2 &= 4RI_1 + V_1 = \frac{7}{31} \\
V_3 &= 8RI_1 + V_2 = \frac{15}{31}
\end{align*}
\]

(c) (10 pts) Sketch $C_0 ... C_3$ as a function of $Vin$

*(note that $Vin$ is connected to the negative side of the analog comparator)*
3. Microcontrollers (20 pts)

(a) (8 pts) Briefly explain the function of the instruction decoder.

*The instruction decoder translates an instruction into a set of control signals for all of the other components in the microprocessor, including which operations to perform and which addresses to use.*

(b) (5 pts) True or False, and briefly explain: the ALU receives values for the addition operation from RAM.

*False. The ALU receives values from the General Purpose Registers.*

(c) (7 pts) Briefly explain the role of the status register in this line of code:

```plaintext
if (x == 5) { ... }
```

*Stores the result of the comparison between x and 5. This result is then used to decide which instruction is next to execute.*
4. Digital Input/Output

Consider the following circuit diagram:

Assume that DDRC = 0xC, $V_f = 3V$ and $R_0 = 100\Omega$.

(a) (5 pts) What equations are always true for the LED0 subcircuit? (Assume that positive currents for $I_D$ and $I_{R_0}$ flow from right to left).

$$V - V_{C2} = R_0 I_{R_0}$$
$$I_{R_0} = I_D$$

(b) (5 pts) Assume that $PC[3, 2] = 1, 0$. What are $V$ and $I_D$?

We know that $V_{C3} = 5$ and $V_{C2} = 0$

Assume that the diode is on. Therefore:

$I_D > 0$ and $V_{C3} - V = V_f$
\[ V = 5 - 3 = 2 \text{ Volts} \]
\[ I_D = I_R = 2/100 = 20 \text{ mA} \]

Consider the following code:

```
int main ( void )
{
    DDRC = 0xC;
    PORTC = 0;
    uint8_t val1 = 0;
    uint8_t val2 = 4;

    while(1) {
        if (PINB & 0x10 ) {
            PORTC = (PORTC & ^0xC) | (val1 << 2); // Note bit-wise not
            ++val1;
            if (val1 == 4) val1 = 0;

            delay_ms(100);
        } else {
            PORTC = (PORTC & ^0xC) | val2; // Note bit-wise not
            val2 ^= 0xC;

            delay_ms(50);
        }
    }
}
```

(c) (10 pts) Explain what happens when the switch is in a “closed” state.

The LED flashes at 10 Hz and a 50% duty cycle.

(d) (10 pts) Explain what happens when the switch is in a “open” state.

(Note: there are four phases to each cycle. However, the LED is only on for one of them.)

The LED flashes at 2.5 Hz and a 25% duty cycle.