0. Name (2 pts):

AME 3623: Embedded Real-Time Systems

Midterm Exam

Solution Set

March 8, 2012

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

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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.

$$\begin{array}{r} 111011100 \\ +\ \ 10000100 \\ \hline 1001100000 \end{array}$$

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

$1001100000 = 512 + 64 + 32 = 608$

(c) (5 pts) Consider the following number: $0x8F$. If we interpret this as a signed 8-bit integer, what is the decimal equivalent? Show your work.

$0x8F = 10001111 = -128 + 8 + 4 + 2 + 1 = -113$

(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:

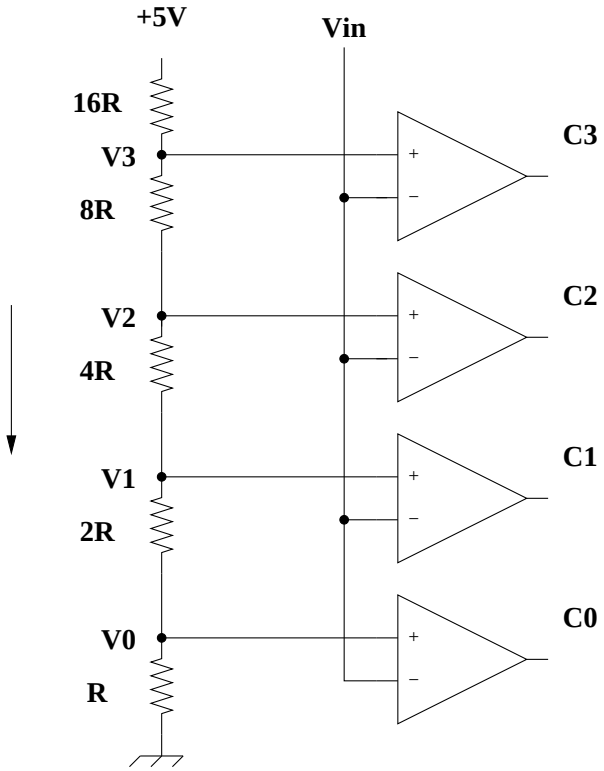
```
uint8_t x = 0x11;
uint8_t y;

y = x << 4
```

What is the value of y in hexadecimal?
$y = 0x10$ *(the highest order digit is dropped)*

2. **Analog Processing** (25 pts)

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?

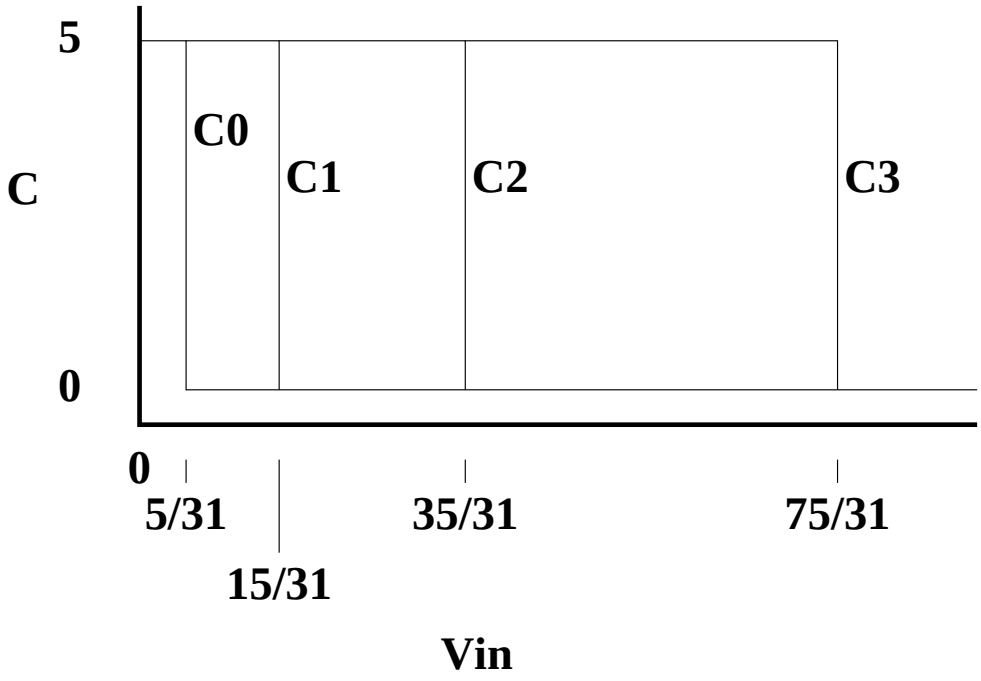
$$\begin{aligned} 5 - V_3 &= 16RI_4 \\ V_3 - V_2 &= 8RI_3 \\ V_2 - V_1 &= 4RI_2 \\ V_1 - V_0 &= 2RI_1 \\ V_0 - 0 &= RI_0 \\ I_4 &= I_3 = I_2 = I_1 = I_0 \end{aligned}$$

(b) (10 pts) Solve for $V0$.. $V3$ (simplified fractions are sufficient).

$$\begin{aligned} R_T &= 31R \\ I_* &= \frac{5-0}{31R} \\ V_0 &= RI_0 = \frac{5}{31} \\ V_1 &= 2RI_1 + V_0 = 3\frac{5}{31} \\ V_2 &= 4RI_1 + V_1 = 7\frac{5}{31} \\ V_3 &= 8RI_1 + V_2 = 15\frac{5}{31} \end{aligned}$$

(c) (10 pts) Sketch $C0$ ... $C3$ 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.

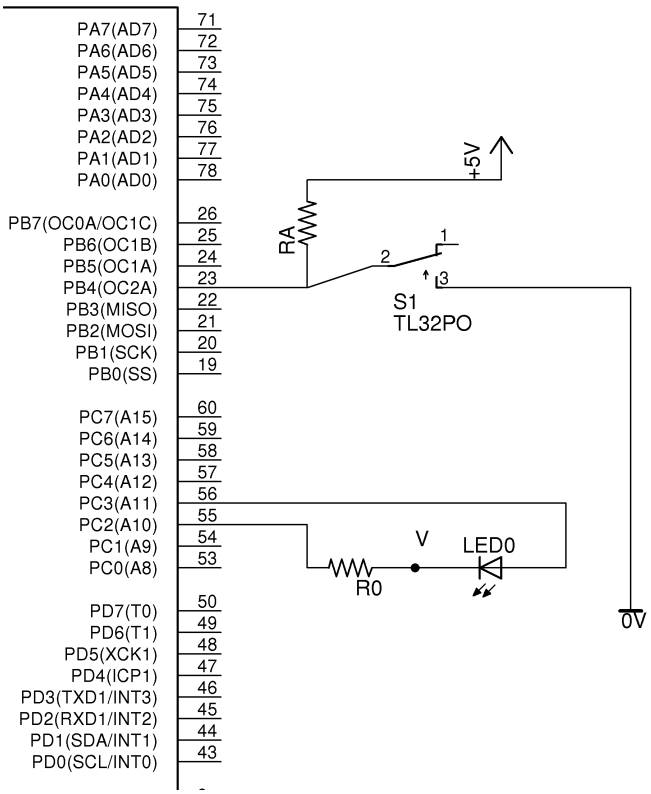
(c) (7 pts) Briefly explain the role of the status register in this line of code:

```
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** (30 pts)

Consider the following circuit diagram:



Assume that DDRC = 0xC, $V_f = 3V$ and $R0 = 100\Omega$.

(a) (5 pts) What equations are always true for the LED0 subcircuit? (Assume that positive currents for I_D and I_{R0} flow from right to left).

$$\begin{aligned} V - V_{C2} &= R_0 I_{R0} \\ I_{R0} &= I_D \end{aligned}$$

(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* $V_{C3} - V = V_f$

$V = 5 - 3 = 2$ *Volts*
$I_D = I_R = 2/100 = 20$ *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.