0. Name (2 pts):

AME 3623: Embedded Real-Time Systems

Midterm Exam

Solution Set

March 10, 2011

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

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

(a) (5 pts) What is the binary equivalent of $0x2EF$? Show your work.

Each hex digit corresponds to 4 binary digits:

$0x2EF = 10\ 1110\ 1111$

(b) (5 pts) What is the hexadecimal equivalent of decimal 272? Show your work.

$426/16 = 17\ R\ 0$
$17/16 = 1\ R\ 1$
$1/16 = 0\ R\ 1$
Hexadecimal equivalent is the collection of the remainders: 110

(c) (5 pts) What is the binary equivalent of decimal number 78? Show your work.

$78/2 = 39\ R\ 0$
$39/2 = 19\ R\ 1$
$19/2 = 9\ R\ 1$
$9/2 = 4\ R\ 1$
$4/2 = 2\ R\ 0$
$2/2 = 1\ R\ 0$
$1/2 = 0\ R\ 1$
The binary equivalent is the collection of the remainders: 1001110

(d) (5 pts) Consider the following bit pattern: 11011011. If we interpret this as a signed 8-bit integer (i.e., two's complement), what is the decimal equivalent? Show your work.

This is a negative number. The two's complement is: 100101*, which is decimal* 37*. Thus, the original number is* -37

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

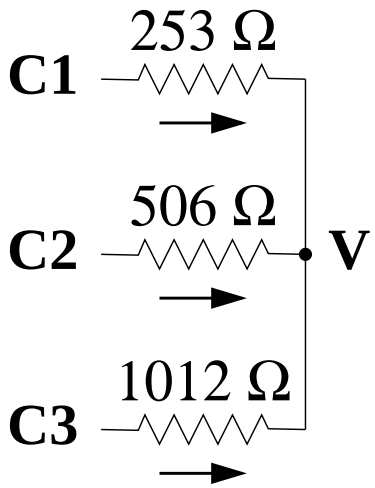
```
uint16_t x;
uint16_t y;

y = (x << 2) + x
```

What mathematical operation is being performed? Give the simplest equation in terms of integer operators $(*, +, /, -)$ and the variables x and y.

Assuming that we do not exceed the representation abilities of the uint16_t, then $y = 5 \times x$.

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

Given the following circuit:



$C1$, $C2$ and $C3$ are digital output pins from a microcontroller. Assume that $Ci \in \{0, 1\}$ and are all known.

(a) (5 pts) What are the four fundamental equations that relate the key variables together? Indicate which variables are unknown.

$$\begin{aligned} 5C_1 - V &= 253I_1 \\ 5C_2 - V &= 506I_2 \\ 5C_3 - V &= 1012I_3 \\ 0 &= I_1 + I_2 + I_3 \end{aligned}$$

(b) (10 pts) Solve for V as a function of $C1$, $C2$, $C3$.

$$\begin{aligned} \frac{5C_1 - V}{253} + \frac{5C_2 - V}{506} + \frac{5C_3 - V}{1012} &= 0 \\ 20C_1 - 4V + 10C_2 - 2V + 5C_3 - V &= 0 \\ 5\left(4C_1 + 2C_2 + C_3\right) &= 7V \\ \frac{5}{7}\left(4C_1 + 2C_2 + C_3\right) &= V \end{aligned} \tag{1}$$

(c) (10 pts) Which bit pattern yields the voltage at V closest to 2 Volts? (the bit pattern can yield a voltage that is either above or below, but it must be the closest)

$C1, C2, C3 = 011$ *yields* $15/7 \approx 2$

3. **Microcontrollers** (20 pts)

(a) (5 pts) True or False, and briefly explain. Both RAM and general purpose registers are used to store program variables.

True. General purpose registers are used as temporary storage as the variables are being manipulated. RAM is used to store the values that are not immediately being manipulated.

(b) (5 pts) Briefly explain the function of the *program counter*.
The program counter keeps track of the memory location that contains the next program instruction to be executed. (we will accept "current program instruction", too)

(c) (5 pts) Does the following C code result in a read or a write operation to the RAM?

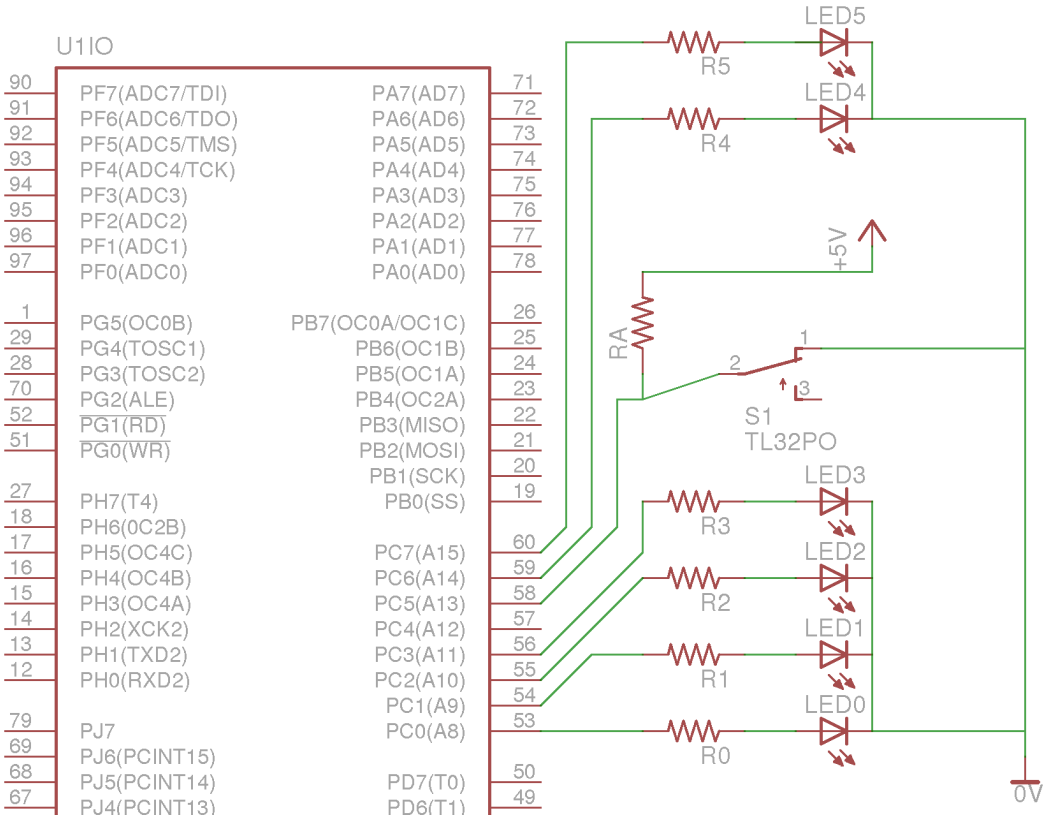
```
uint8_t x = 5;
```

This is a write operation.

(d) (5 pts) True or False and briefly explain: A ROM device allows data to be written to a requested address.
False, a ROM does not allow data to be written to it at all.

4. **Input/Output** (30 pts)

Consider the following circuit diagram:



And consider the following code:

```
int main (void)
{
  DDRC = 0xCF;
  PORTC = 0;

  while(1) {
    if(PINC & 0x20) {
      PORTC ^= 0x3;
      delay_ms(100);
    }else{
      PORTC ^= 0x98;
      delay_ms(50);
    };
  };
}
```

(a) (10 pts) Explain what happens when the switch is in an "open" state.

LEDs 0 and 1 flash at 5 Hz with a 50% duty cycle.

(b) (10 pts) Explain what happens when the switch is in a "closed" state.

LEDs 5 and 3 flash at 10 Hz with a 50% duty cycle. (note that bit 4 is not connected to anything)

(c) (10 pts) Assume the same circuit. The following program is intended to produce a 100 Hz, 20% duty cycle signal on LED 4. However, there are several bugs in the code. Provide fixes for each.

```
int main (void)
{
  DDRC = 0x4;
  PORTC = 0;

  while(1) {
    PORTC &= 0x4;
    delay_ms(2);
    PORTC |= ~0x4;
    delay_ms(10);
  };
}
```

The fixed code:

```
int main (void)
{
  DDRC = 0x40;      // Fixed pin
  PORTC = 0;

  while(1) {
    PORTC |= 0x40;   // | and fixed pin
    delay_ms(2);
    PORTC &= ~0x40; // & and fixed pin
    delay_ms(8);     // Fixed timing
  };
}
```