

(2 pts) Name: _____

AME 3623: Embedded Real-Time Systems: Final Exam

May 10, 2012

- This examination booklet has 16 pages.
- Write your name at the top of this page and sign your name below.
- The exam is closed book, closed notes, and closed electronic device. The exception is that you may have one page of your own notes.
- The exam is worth a total of 200 points (and 20% of your final grade).
- Explain your answers clearly and be concise. Do not write long essays (even if there is a lot of open space on the page). A question worth 5 points is only worth an answer that is at most 1.5 sentences.
- You have 2 hours to complete the exam. Be a smart test taker: if you get stuck on one problem go on to the next. Don't waste your time giving details that the question does not request. Points will be taken off for answers containing extraneous information.
- Show your work. Partial credit is possible, but only if you show intermediate steps.

Problem	Topic	Max	Grade
0	Name	2	
1	Interrupt Service Routines and Digital I/O	35	
2	Number Representation and Arithmetic	20	
3	Finite State Machines	45	
4	Analog Circuits	35	
5	Analog Processing	40	
6	Microprocessors	25	
Total		202	

On my honor, I affirm that I have neither given nor received inappropriate aid in the completion of this exam.

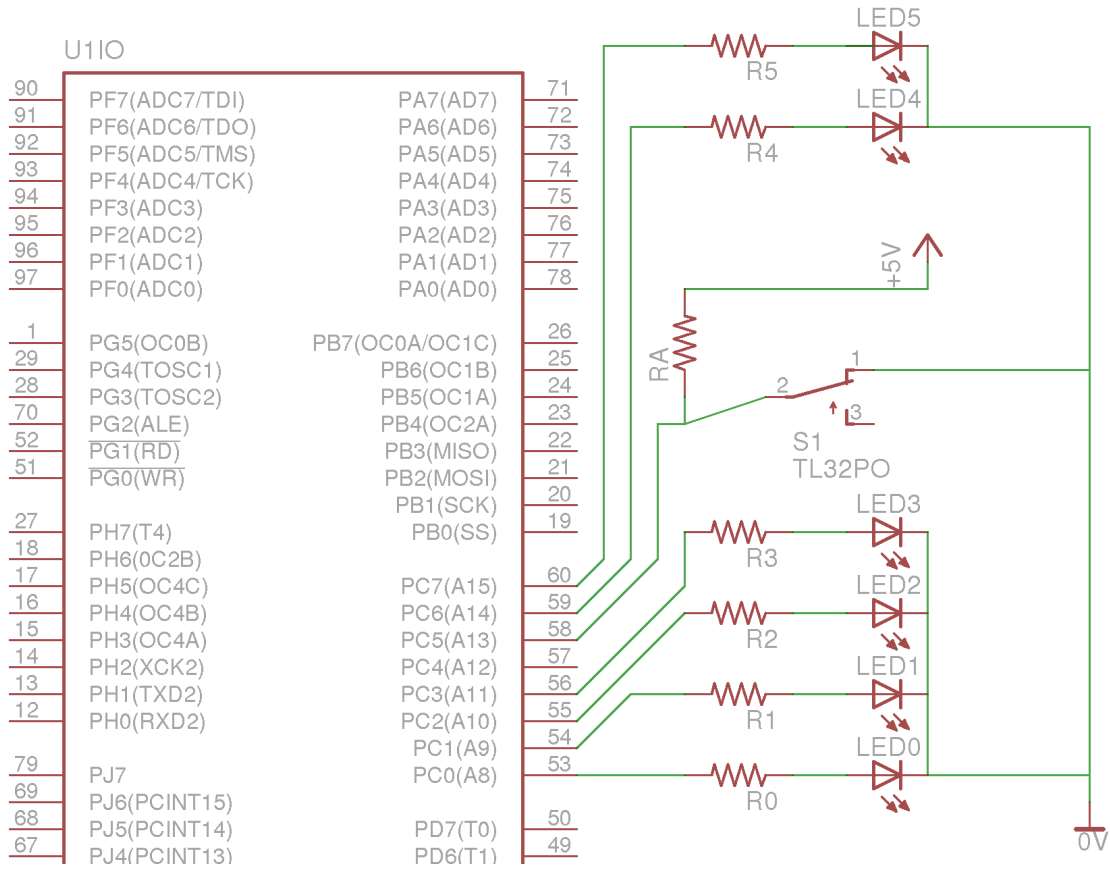
Signature: _____

Date: _____

1. Interrupt Service Routines and Digital I/O

(35 pts)

Carefully consider the following circuit:



And consider the following program:

```
ISR(TIMER5_OVF_vect) {
    static uint8_t counter = 0;

    if(counter == 9) {
        PORTC ^= 0x40;
    }

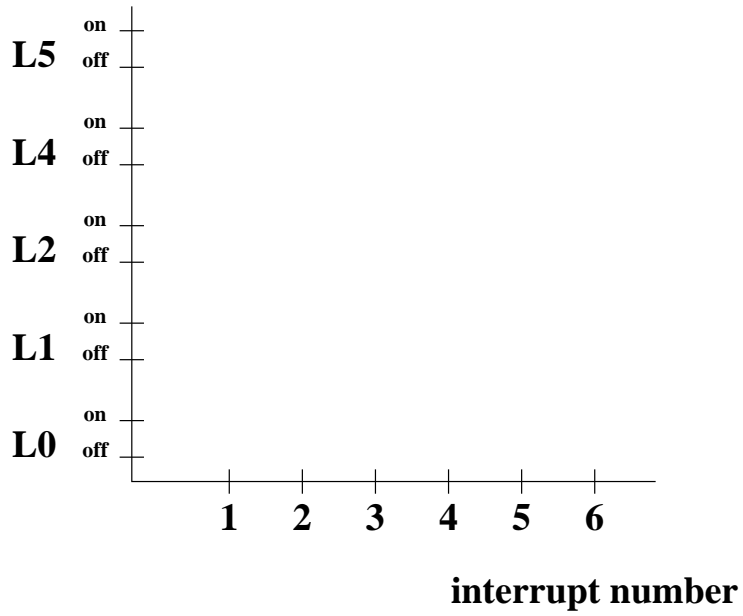
    PORTC = PORTC & 0xF0 | counter & 0xF;
    counter += 3;
}

int main(void) {
    DDRC = 0xCF;
    PORTC = 0;
    timer5_config(TIMER5_PRE_64);
    timer5_enable();
    sei();

    while(1) {
    }
}
```

- (a) (5 pts) Assuming a system clock of $16MHz$, at what frequency is the timer 5 counter incrementing? (give the ratio with units)
- (b) (5 pts) At what frequency is the timer 5 overflow interrupt being generated? (give the ratio with units)

(c) (25 pts) Show the state of LEDs 0, 1, 2, 4 and 5 as a function of interrupt number for interrupts 1 through 6.



2. **Number Representation and Arithmetic**

(20 pts)

- (a) (5 pts) What is the binary equivalent of hexadecimal 78? Show your work.
- (b) (5 pts) Take the two's complement (the negative) of the above number (assume an 8-bit, signed representation). Show your work.
- (c) (5 pts) Compute $78 - 0x78$ using binary arithmetic. Show your work and give your answer in 8-bit binary two's complement.

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

3. Finite State Machines and Control

(45 pts)

Consider the problem of controlling the door of an elevator. The properties and rules of behavior are as follows:

- The door may be commanded to **CLOSE** or **OPEN**. Once commanded, these take time to complete.
- A sensor indicates when the door is **CLOSED**. Once closed, a **SIGNAL** must be sent to the elevator monkeys to indicate that they may move the elevator car.
- A sensor indicates when the door is **OPENED**.
- A timer may be **RESET** or may **TIMEOUT(t)**.
- The door has a sensor that detects whether a passenger has crossed the threshold of the door (**DETECT**).
- The door must remain open until a request is received to move the elevator (**CALLED**).
- Once a passenger has been detected, the door must be opened (if it isn't already). After it is opened, the door must wait at least 5 seconds before starting to close.
- On initialization, the FSM must ensure that the door is open before doing anything else.
- The FSM can do nothing (**Z**).
- The FSM also has a non-event (**X**).

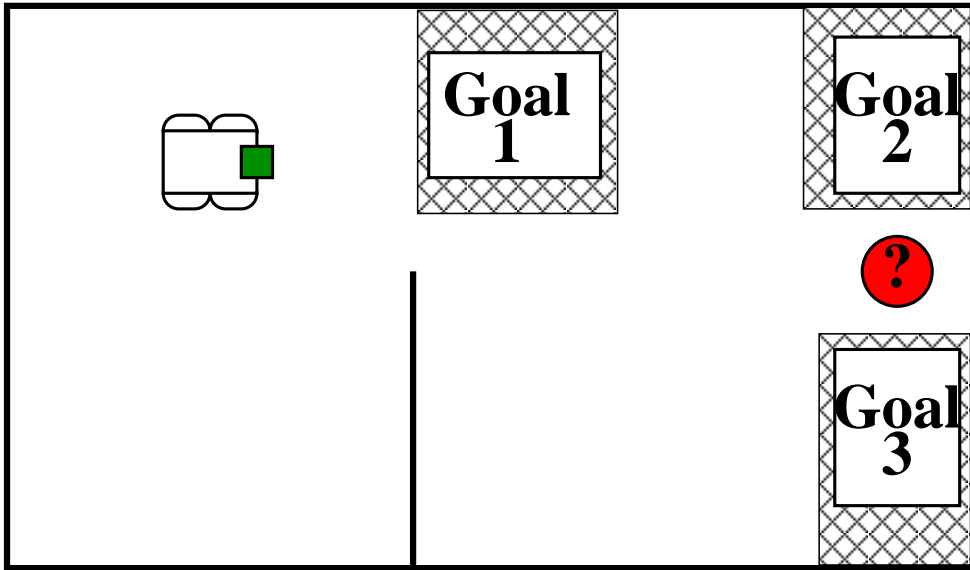
All of the possible events and actions are listed above in bold.

- (a) (5 pts) Which are the events?

(b) (20 pts) Draw the corresponding FSM

Hint: you need 5 states.

Consider the following robot world:



The robot is able to execute the following actions:

- Move forward (F): continues to move forward until another action is issued
- Stop (S)
- Turn left (L): initiate a turn to the left. This turn will complete exactly at 90 degrees within a short period of time
- Turn right (R)
- Grasp (G): grasp an object that is in front of the robot

The robot is sensitive to the following events:

- Bump Wall (BW): bumped into a wall
- Bump Red Ball (BR): bumped into a red ball
- Bump Green Ball (BG): bumped into a green ball
- Turn complete (TC)
- Grasp complete (GC)

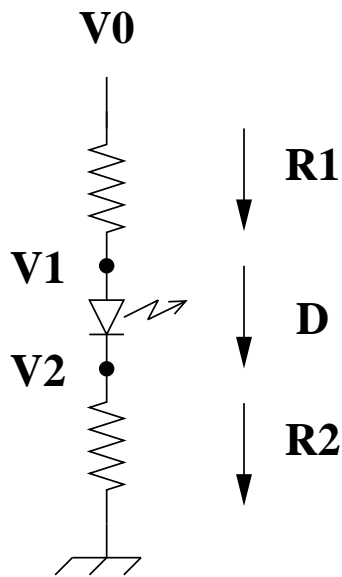
The robot always starts in the indicated configuration (with the front facing to the right). A red or green ball is located at the red circle. Your task is to design a finite state machine that will navigate to and grasp the ball. If the ball is red, then the robot must navigate to goal 2 and stop. If the ball is green, then the robot must navigate to goal 1 and stop.

(c) (20 pts) Draw the FSM diagram that describes the behavior of this robot. Only use the given actions and events.

4. Analog Circuits

(35 pts)

Consider the following circuit:



Assume that $R1 = 750\Omega$, $R2 = 250\Omega$, and $V_f = 2V$.

(a) (5 pts) List the equations that are **always** true.

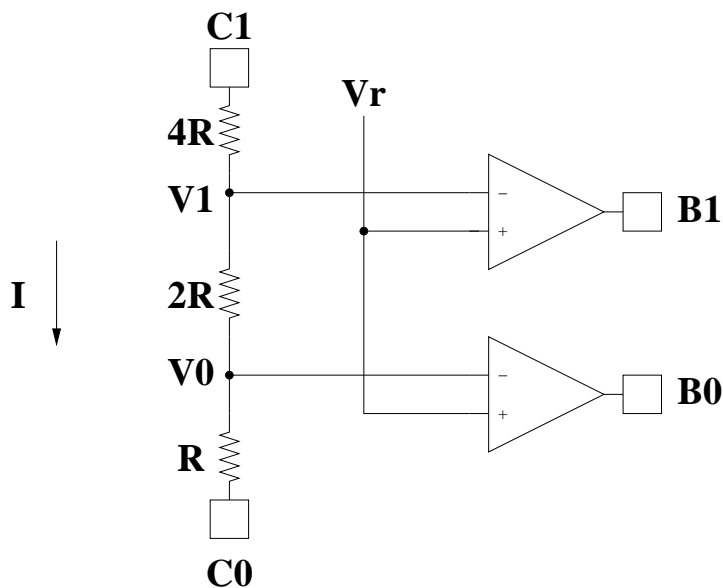
(b) (15 pts) Assume that $V0 = 1.5V$. What are $V1$, $V2$ and I_D ?

(c) (15 pts) Assume that $V_0 = 3V$. What are V_1 , V_2 and I_D ?

5. Analog Processing

(40 pts)

Consider the following circuit:



C_1 and C_0 are logical values determined by your Atmel Mega processor (i.e., 0 and 1). The voltage at pin i is $5C_i$. B_1 and B_0 are inputs into the processor. Assume that the analog comparators produce an output of $0V$ or $5V$.

(a) (20 pts) For each combination of C_1 and C_0 , derive the voltage at points V_1 and V_0 .

C_1	C_0	V_1	V_0
0	0		
0	1		
1	0		
1	1		

(b) (10 pts) Assume that $V_r = 2 V$ and $C_1, C_0 = 10$. What are B_1 and B_0 ?

(c) (10 pts) Assume that a standard 5-bit digital-to-analog converter in which the minimum voltage is zero Volts and the maximum voltage is 5 Volts. Assume a digital value of 0x11. What is the corresponding voltage?

6. Microprocessors

(25 pts)

(a) (5 pts) Briefly explain the function of the *instruction decoder*.

(b) (5 pts) True or False and briefly explain. The status register is updated by the general purpose registers.

(c) (7 pts) List two ways in which the information in the status register may be used.

(d) (8 pts) List two key properties of every type of memory.