

Final Exam**Date:** May 16, 2019

UT EID: _____

Printed Name: _____
Last, First

Your signature is your promise that you have not cheated and will not cheat on this exam, nor will you help others to cheat on this exam:

Signature:

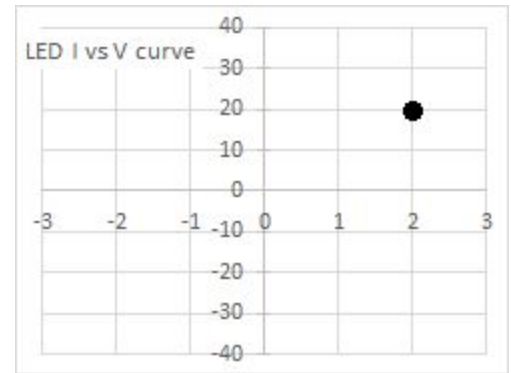
Instructions:

- Closed book and closed notes. No books, no papers, no data sheets (other than the last two pages of this Exam)
- No devices other than pencil, pen, eraser (no calculators, no electronic devices), please turn cell phones off.
- Please be sure that your answers to all questions (and all supporting work that is required) are contained in the space (boxes) provided. Do Not write answers on back of pages
- You have 180 minutes, so allocate your time accordingly.
- Unless otherwise stated, make all I/O accesses friendly.
- Please read the entire exam before starting.

Problem 1	15	
Problem 2	10	
Problem 3	15	
Problem 4	15	
Problem 5	5	
Problem 6	10	
Problem 7	15	
Problem 8	15	
Total	100	

[15 points] **Problem 1: Fundamentals.** Answer the following short questions in the boxes provided.

- (i) (3pt) Consider an LED with a desired operating point of 2V, 20 mA. The 2V, 20mA point is shown as a dot on the graph. Make a rough sketch of the LED current as a function of LED voltage. Include all voltages from -3 to +3V



For parts ii) iii) iv) consider this piece of C code

```
static uint16_t x=5;
uint16_t Operate(const uint16_t y){
    static uint16_t z=6;
```

For parts ii) iii) and iv) answer one letter A-H

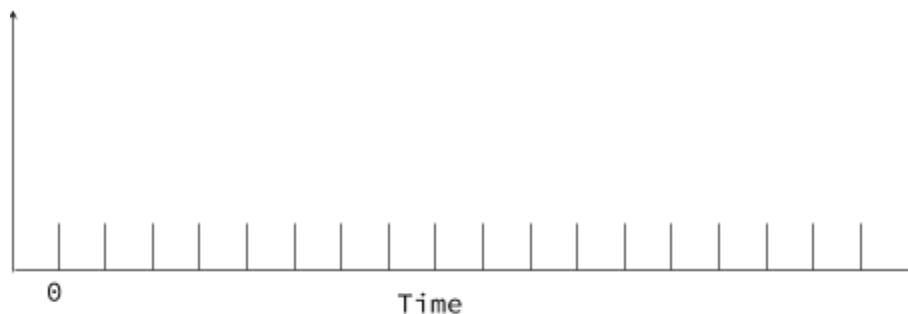
- | | |
|---|--|
| A) Forces compiler to not optimize the access | E) Makes the variable private to the file |
| B) Places the variable in nonvolatile ROM | F) Makes the variable private to the function |
| C) Forces the variable to be placed in a register | G) Restricts function from modifying parameter |
| D) Places the variable in volatile RAM | H) Places the variable to be placed on the stack |

(ii) (2pt) Why do we add the keyword `static` to the variable `x`?

(iii) (2pt) Why do we add the keyword `const` to the `y` parameter?

(iv) (2pt) Why do we add the keyword `static` to the variable `z`?

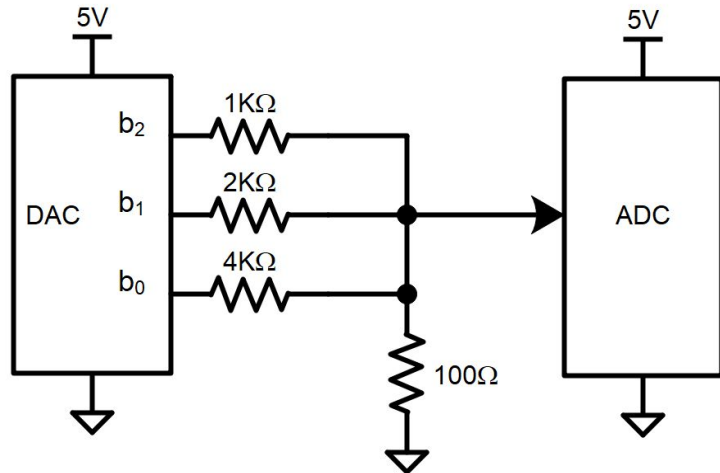
- (v) (6pt) Draw the UART waveform for a frame when a byte **0xf0** is transmitted. Each bit time is one time slot on the plot. The frame starts at Time=0 and goes right. Assume the UART is idle prior to this frame.



[10 points] Problem 2: DAC.

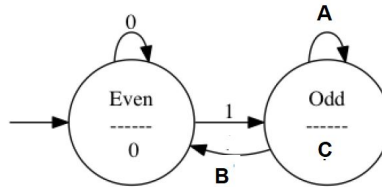
Given the 3-bit DAC with the 5V reference, provide the NUMERICAL EXPRESSION for the input voltage seen at the ADC input for the following DAC output codes with the 100 Ω load attached. The ADC reference is also 5V.

For each question below, a numerical answer is not required. Instead, provide a NUMERICAL EXPRESSION (you may leave it as unreduced) for your answer.



	DAC output code (binary) $b_2 b_1 b_0$	ADC input voltage expression (V)
(a)	0 0 0	
(b)	0 0 1	
(c)	0 1 0	
(d)	1 0 0	
(e)	1 1 1	

[15 points] Problem 3: Finite State Machine. The following state-machine is designed to be an Odd 1's detector. It detects if there are an odd number of 1's in a stream of 0's and 1's. It outputs a 1 when the stream thus far has an odd number of 1's, a 0 otherwise.



1. (3 points) What are the values of **A**, **B** and **C** in the FSM state-graph shown above.

A =	B =	C =
------------	------------	------------

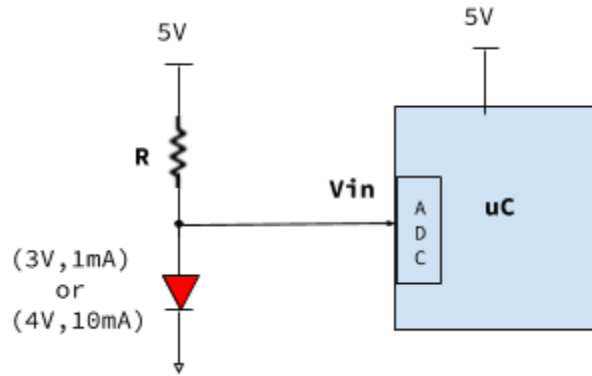
2. (7 points) The code below encodes this FSM in software. Fill in the missing pieces (marked _____).

<pre> #define Odd _____ #define Even _____ struct State { uint32_t out; uint32_t next[_____]; } typedef struct State State_t; State_t FSM[2]={ {_____, {Even, _____}}, {_____, {Odd, _____}} }; </pre>	<pre> int main(){ uint32_t CS=Even,in; while(1){ doOutput(FSM[CS].out); in = getInput(); CS = FSM[CS].next[in]; // XXX } } </pre>
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3. (5 points) Give the assembly code conversion of the one line of C code marked **XXX**, above. You may assume that CS and in are allocated in registers R1 and R2 respectively.

[15 points] Problem 4: LED Interfacing and ADC

Valvano mixed up his two bags of LEDs. Now there is one bag with both types in it. You will help him sort them. The two possible LED types have operating points of either (3V,1mA) or (4V,10mA). A microcontroller interfaces to the circuit below, monitoring the voltage and computing the current. This allows you to determine which type of LED is connected. The ADC converter voltage range is [0V, 5V] (different from the TM4C range which is [0,3.3V]).



The LEDs do not need to light up, the test system must be able to distinguish one type from the other without destroying the LED. For each question below, a numerical answer is not required. Instead, provide a NUMERICAL EXPRESSION (you may leave it unreduced) for your answer.

- (a) (5pts) Compute the resistor values for the two LED types.

R (ohms) =

R (ohms) =

- (b) (5pts) If you can choose only one of the above resistor values to distinguish between the two LED types, which is an appropriate choice and why?

- (c) (5pts) If using a 13-bit ADC converter, what is the ADC digital value when the current is 1mA? Show your work.

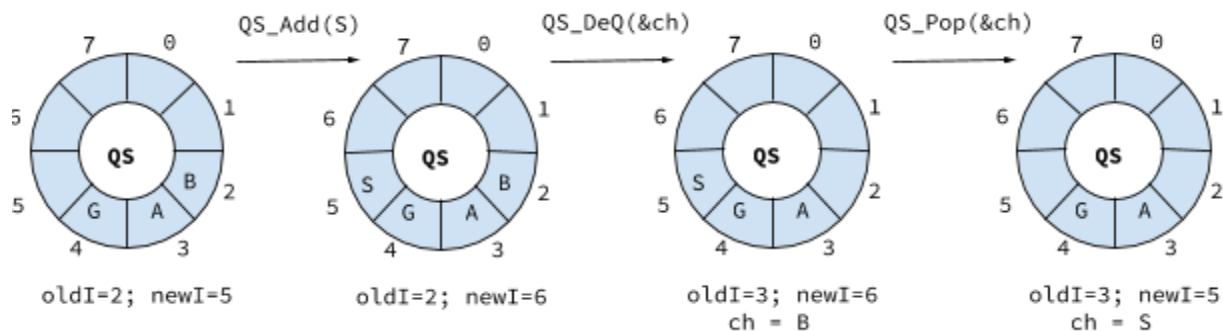
[15 points] Problem 7: Queue and/or Stack.

You will complete the implementation of a data structure (called **QS**) that provides both a FIFO (*First In First Out like a Queue*) and LIFO (*Last In First Out like a Stack*) access mechanism. A wrap-around circular buffer (see figure below) is used to store the items being enqueued/dequeued and pushed/popped. A partially complete implementation of the data structure is given below with two missing subroutines (on next page) which you have to complete. You are not allowed to add any other variables to the implementation. Note that the same routine, QS_Add can be used to both enqueue an item and push an item to QS. The two routines you are to implement involve removing an item, when QS is treated as a Queue (QS_DeQ) and, when QS is treated as a Stack (QS_Pop).

<pre> // Variables and Constants #define N 8 // Capacity is 7 #define Fail 0 #define Success 1 char QS[N]; // Data store // index of oldest item uint8_t oldI; // index of next item to be added uint8_t newI; // Initialize the QS, making it empty // Input: None // The QS is empty void QS_Init(){ oldI = newI = 0; } </pre>	<pre> // Adds an item to QS // Input: data has item to add // Output: Success or Fail uint8_t QS_Add(char data){ if ((newI+1)%N == oldI) return Fail; QS[newI] = data; newI = (newI+1)%N; return Success; } </pre>
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The following figure shows how the three operations work. The leftmost figure shows the state of QS after some arbitrary Add, DeQ and Pop operations have been performed, leaving 3 items with oldest (B) at index 2 and newest (G) at index 4. The second figure from left shows the state of QS after adding an item (S). The third figure shows the state after an item(B) is de-queued, and the last shows the state after an item (S) is popped.

Note: The figure only shows valid items; inaccessible items need not be cleared on a dequeue/pop operation.



(6 points)

```
// De-queues oldest item from QS
// Input: Pointer to data to hold item removed
// Output: Success or Fail
uint8_t QS_DeQ(char *data){
```

```
}
```

(9 points)

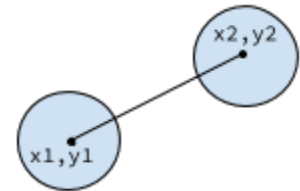
```
// Pops newest item from QS
// Input: Pointer to data to hold item removed
// Output: Success or Fail
uint8_t QS_Pop(char *data){
```

```
}
```


[15 points] Problem 8: programming, design.

Consider a game with birds flying in a 2-D world. The parameters of a bird are stored as fields in a structure. The parameters x, y are the center coordinates of the bird in 2-D space, which are the integer components of 32-bit signed binary fixed-point numbers. The resolution of the fixed-point number system is 1/256 meters. For example, if a position parameter is 2.125 meters, then the integer stored in memory is $2.125 \times 256 = 544$. You will write two functions, one to detect collision and one to process elastic bouncing. The movement occurs every 10ms (100 Hz), so the units of velocity are meters/10ms. We define a bird as a circle of radius 0.25 meters. A bird that is dead or lost will not move, will not be drawn, and will not be considered for collision detection. A bird that is alive will move, will be drawn, and will be considered for collision detection. You may not add any fields to this structure. You may not add more global variables. You do not need to move or draw the birds.

```
typedef enum {dead,lost,alive} status_t;
typedef struct{
    int32_t x,y;          // 2-D position in 1/256 meter
    int32_t vx,vy;       // 2-D velocity in 1/256 meter/10ms
    const int16_t *image; // pointer image to draw
    status_t life;       // dead/alive
} Bird_t;
```



There are 100 birds in the game, defined in global RAM like this
 Bird_t Flock[100];

The first function you will write will determine if two birds have collided. For this function, you assume both birds are alive. A collision is defined if the distance from the center of one bird to the center of the other bird is less than or equal to 0.5 meters. Think about how to do this without using square root; however, partial credit will be given if you call an existing integer `sqrt()` function. No credit will be given for using floating point. The prototype for your first function is

```
// Input: pointers to two birds
// Output: true if these two birds have collided, false if not collided
int Collision(Bird_t *p1, Bird_t *p2);
```

The second function you will traverse the array of 100 birds, and check if any two birds have collided. A collision event can occur between any two birds that are both **alive**. Consider birds 1 and 2 with masses m_1, m_2 , and velocities u_1, u_2 before collision, v_1, v_2 after collision. An elastic collision in physics conserves both momentum ($m \cdot v$) and kinetic energy ($0.5 \cdot m \cdot v^2$). In an elastic collision,

$$v_1 = (m_1 - m_2) \cdot u_1 / (m_1 + m_2) + 2 \cdot u_2 \cdot m_2 / (m_1 + m_2)$$

$$v_2 = (m_2 - m_1) \cdot u_2 / (m_1 + m_2) + 2 \cdot u_1 \cdot m_1 / (m_1 + m_2)$$

If the two birds have the same mass ($m_1 = m_2$), this simplifies to swapping the velocities

$$v_1 = u_2$$

$$v_2 = u_1$$

You will implement elastic collisions in both x and y dimensions, More specifically, if a collision occurs, swap the vx between the two birds, and swap the vy between the two birds. You must call the Collision function in part a) to determine if a collision has occurred. Be careful not to swap the velocities twice. E.g., if bird 12 has collided with bird 37, then bird 37 will also have collided with bird 12. On a collision, please change the vx vy of both birds once and not twice. You do not have to specifically handle the case with 3 or more birds colliding at the same time. The prototype for your second function is

```
void ElasticBounce(void);
```

You may use this swap function if you wish

```
void swap(int32_t *pt1, int32_t *pt2){int32_t data;
    data = *pt1; *pt1 = *pt2; *pt2 = data;
}
```

(7) Part a) Write the collision function in C

```
int Collision(Bird_t *p1, Bird_t *p2){
```

(8) Part b) Write the bounce function in C

```
void ElasticBounce(void){
```