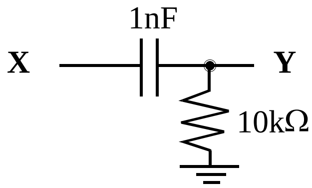
Jonathan W. Valvano First:_________________ Last:_______________

This is the closed book section. Calculator is allowed (no laptops, phones, devices with wireless communication). You must put your answers in the boxes. Do not write on the back of the page. When you are done, you turn in the closed-book part and can start the open book part.

**(4) Question 1a.** State two differences between ceramic and tantalum capacitors.

**(4) Question 1b.** State two differences between TCP and UDP communication.

**(4) Question 1c**. Sketch the gain (Y/X) versus frequency response of this circuit. 1nF*10kΩ is 10 μsec.

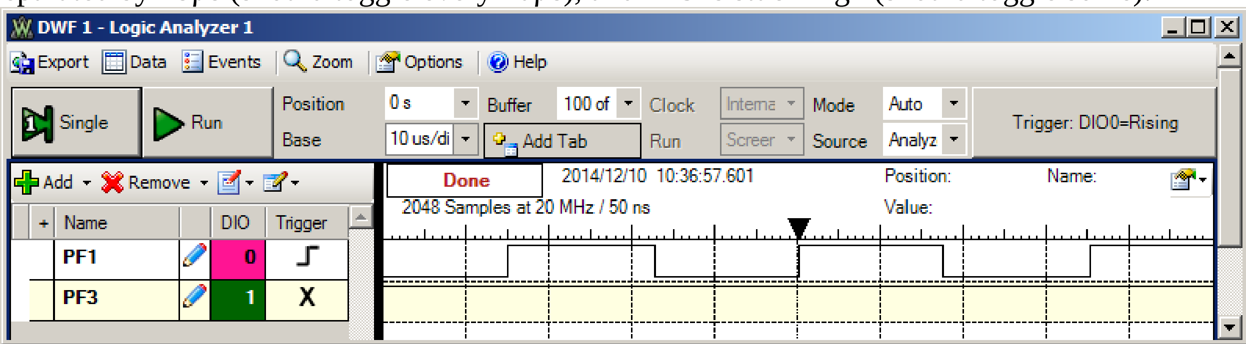



**(4) Question 1d.** Consider this digital controller. Explain why this software is classified as an I controller?

```
uint32_t Period;
uint32_t Speed;
int32_t E;
int32_t U;
void Timer2A_Handler(void){
  TIMER2_ICR_R = 0x01;
  Speed = 800000000/Period;
  E = 250-Speed;
  U = U+(3*E)/64;
  if(U < 40) U=40;
  if(U>39960) U=39960;
  PWM0_Duty(U);
}
```

**(4) Question 1e.** List any four of the ten points of the IEEE Code of Ethics?

**(10) Question 2.** The goal of this system is to test a DAC, by creating a sine wave with a period of 2.56ms using a Timer2A periodic interrupt. The DAC uses SPI running at with a 4 MHz clock. The **`SineWave`** buffer has 256 entries per cycle. **`TIMER2_TAILR_R`** is 799, making the interrupt rate 100 kHz (10µS). Each ISR execution outputs one point of the **`SineWave`** buffer to the DAC. The debugging profiles for PF3 and PF1 are shown in the following plot. The PLL is active (80MHz). The edges of PF1 are separated by 18µs (should toggle every 10µs), and PF3 is stuck high (should toggle some).




```
void UserTask(void){ uint32_t static I=0;
  PF1 ^= 0x02;            // toggle PF1, profiling
  DAC_Out(SineWave[I]);   // Output one point using the DAC
  I = (I+1)&0xFF;}
int main(void){
  PLL_Init(Bus80MHz);     // bus clock at 80 MHz
  PortF_Init();           // make PF1, PF3 outputs
  Timer2A_Init(&UserTask,800);  // initialize timer2A (100kHz)
  EnableInterrupts();
  while(1){
    PF3 ^= 0x08;}}
```

**(5) Part a)** Which of the following changes would you make to fix the error in this DAC test? The period of the sine wave output must remain at 2.56ms. If there is more than one answer, choose just one answer.

**A)** Increase **`TIMER2_TAILR_R`** so the Timer2A interrupts occur less frequently.
**B)** Decrease **`TIMER2_TAILR_R`** so the Timer2A interrupts occur more frequently.
**C)** Change the PLL so the TM4C123 runs slower than 80 MHz.
**D)** Change **`uint32_t static I=0;`** to **`uint32_t volatile I=0;`**
**E)** Use a FIFO queue to pass data between threads, decoupling the two execution of the two threads
**F)** Change **`I=(I+1)&0xFF;`** to **`I=(I+1)%256;`**
**G)** Skip every other point in the **`Wave`** buffer (by changing **`I=(I+1)&0xFF`** to **`I=(I+2)&0xFF)`**, and set **`TIMER2_TAILR_R`** to 1599.
**H)** Replace the DAC with a version with a faster SPI clock
**I)** Because of the critical section, remove the line **`PF1 ^= 0x02;`**
**J)** None of the above changes will remove the bug.

**(5) Part b)** How would you characterize the debugging profile in the above figure?

**A)** Nonintrusive **C)** Highly intrusive **E)** Invasive
**B)** Stabilization **D)** Minimally intrusive **F)** Desk check

**(3) Question 3.** The use of the Central Limit Theorem (CLT) assumes the noise is random, and the noise in each sample is independent from the noise in the other samples. For an ADC-based measurement we will apply an additional assumption that the noise has zero mean. In order to improve signal to noise ratio in our ADC samples, we can take multiple samples and calculate the average (e.g., ADC Sample Averaging Control, **`ADC0_SAC_R`**). List two consequences of the CLT as it applied to this situation.

| | |
|---|---|
| | |

**(3) Question 4.** In a communication system, as data is passed from point X to point Y, in what form is the information transmitted? Choose the best answer for all communication systems in general.

A) Voltage D) Energy
B) Current E) Time
C) Power F) Resistance

| |
|---|
| |

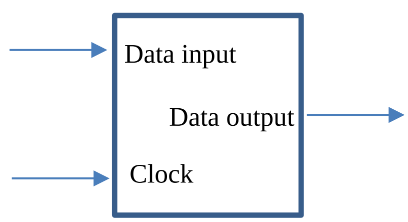
**(9) Question 5.** The following FIFO has one or more critical sections. This FIFO is used in a multithreaded application, such that data is passed from the main program (**`Fifo_Put`**) to one ISR (**`Fifo_Get`**). Add code/edit this module to remove the critical section(s).

```
uint16_t Buf[3]; // place for three 16-bit numbers
uint8_t Size;    // 0 means empty, 1 means one, 2 means 2, 3 means full
int Fifo_Init(void){
  Size = 0; // runs during initialization with interrupts disabled
  return 0;
}
int Fifo_Put(uint16_t data){ // store data into FIFO
  if(Size >= 3){
    return 1; // full, fail
  }
  Buf[Size] = data;
  Size++;     // one more
  return 0;   // success
}

int Fifo_Get(uint16_t *p){  // remove data from FIFO
  if(Size == 0){
    return 1; // empty, fail
  }
  *p = Buf[0];          // return data
  Buf[0] = Buf[1];      // shift buffer
  Buf[1] = Buf[2];      // shift buffer
  Size--;               // one less
  return 0;             // success
}
```

**(5) Question 6.** Estimate the lifetime of a battery-operated embedded system. The system uses a 3.7-volt LiIon battery with a storage of 740 joules. The regulator has a power efficiency of 50%, creating the 3.3V supply for the system. The average current in the system is 1 mA, because it sleeps most of the time. Determine how many seconds will this battery run the system? Show your work.

**(5) Question 7.** Use a D flip flop with rising edge trigger to define setup and hold time. Include a timing diagram. *Use words and figures to define setup; use words and figures to define hold.*



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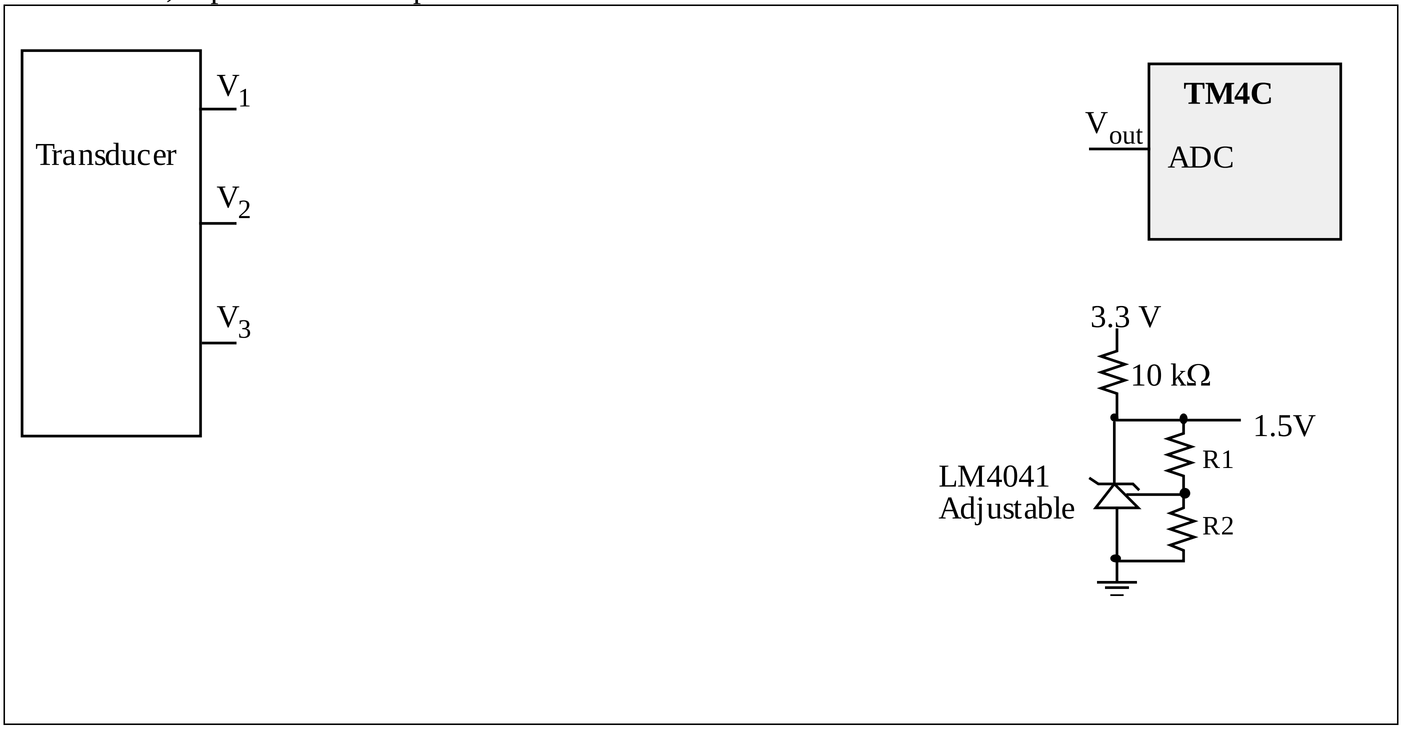
Open book, open notes, calculator (no laptops, phones, devices with screens larger than a TI-89 calculator, devices with wireless communication). You must put your answers in these boxes. Please don't turn in any extra sheets or write on the back of the pages.

**(20) Problem 8.** You are given two analog inputs signal connected to the microcontroller (any pins you wish). Your goal is to produce a single analog output, which is the arithmetic average of the two inputs. You must use the ADC, interrupts, and a DAC. The signals of interest are 0 to 100 Hz. The simplest way to solve this is to call existing software functions defined in the book (without showing the book code), and you may assume corresponding external circuits associated with the software. Your answer and the book code together should compile and run (don't just list programs you want to use).

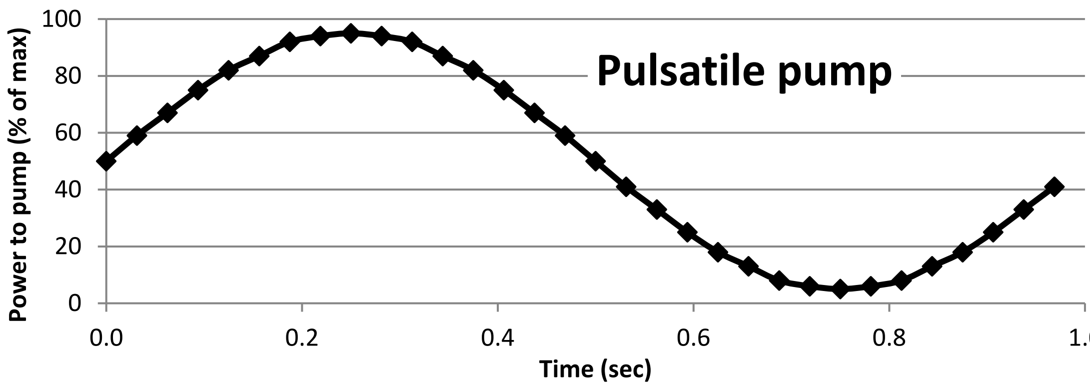
**(12) Part a)** Show the main program that initializes the ADC, periodic interrupts and the DAC.

**(8) Part b)** Show the interrupt service routine that runs in the background, sampling the ADC, calculating the average, and outputting to the DAC.

**(10) Question 9.** Design an analog circuit that has three inputs and one output, such that the output is the arithmetic average of the three inputs. The input voltages are constrained to 0 to 3.3V. No analog filter is required in this question. The only available power supply voltage is 3.3V. Assume R1 and R2 are already chosen to achieve a reference of 1.5V. Please use one or more op amps. Show design steps, and specify all resistors, capacitors and chip numbers.




**(15) Question 10.** The goal of this problem is to build a controller for a DC motor that drives a pump. Full power to the pump motor occurs at 12 V 10 A. In order to reduce shear stress between the fluid and the pipes, you will implement a pulsatile pump controller. Over the course of 1 second, you will vary the applied power according this waveform. The time constant of the motor is about 100ms. Because this 1 second wave is 10 times slower than the time constant of the motor, the motor will respond to this wave.




The 32 points of this waveform are captured in the following ROM-based array.

```
uint8_t const Wave[32] = {50,59,67,75,82,87,92,94,95,94,92,87,82,
     75,67,59,50,41,33,25,18,13,8,6,5,6,8,13,18,25,33,41};
```

The simplest way to solve this is to call existing software functions defined in the book (without showing the book code). Your answers and the book code together should compile and run (don’t just list programs you want to use).

**Part a)** The first task is to interface the DC motor to the microcontroller. Pick which interface circuit you would use from the book. If there is more than one answer, choose the best answer.

A) Figure 6.14 with a 2N2222 BJT
B) Figure 6.14 with a 7406 open collector driver
C) Figure 6.14 with a TIP120 Darlington
D) Figure 6.16 with both a 2N2222 BJT and IRF540 MOSFET
E) Figure 6.17 with a L293 H-bridge

**Part b)** Show the ritual that initializes the system. The main program calls this initialization, enables interrupts, and then performs other unrelated tasks. Assume the bus clock is 80 MHz.

**Part c)** Show the interrupt service routine that produces the desired output to the DC motor.