First:________________ Last:__________________

(5) Question 1. Put your answer A, B, C, D, E, or F in the box.

(7) Question 2. Design a circuit

(7) Question 3. Show your equations and the final calculation.

(5) Question 4. Part a)

(15) Question 4. Part b) Show the SysTick ISR

```
int32_t X[3],Y[3];
void SysTick_Handler(void){
```

(12) Question 5

(3) Part a) What value did the software write to **DSS** during initialization?

(3) Part b) What value did the software write to **SPO** during initialization?

(3) Part c) What value did the software write to **SPH** during initialization?

(3) Part d) What data value is being transmitted (in hexadecimal)?

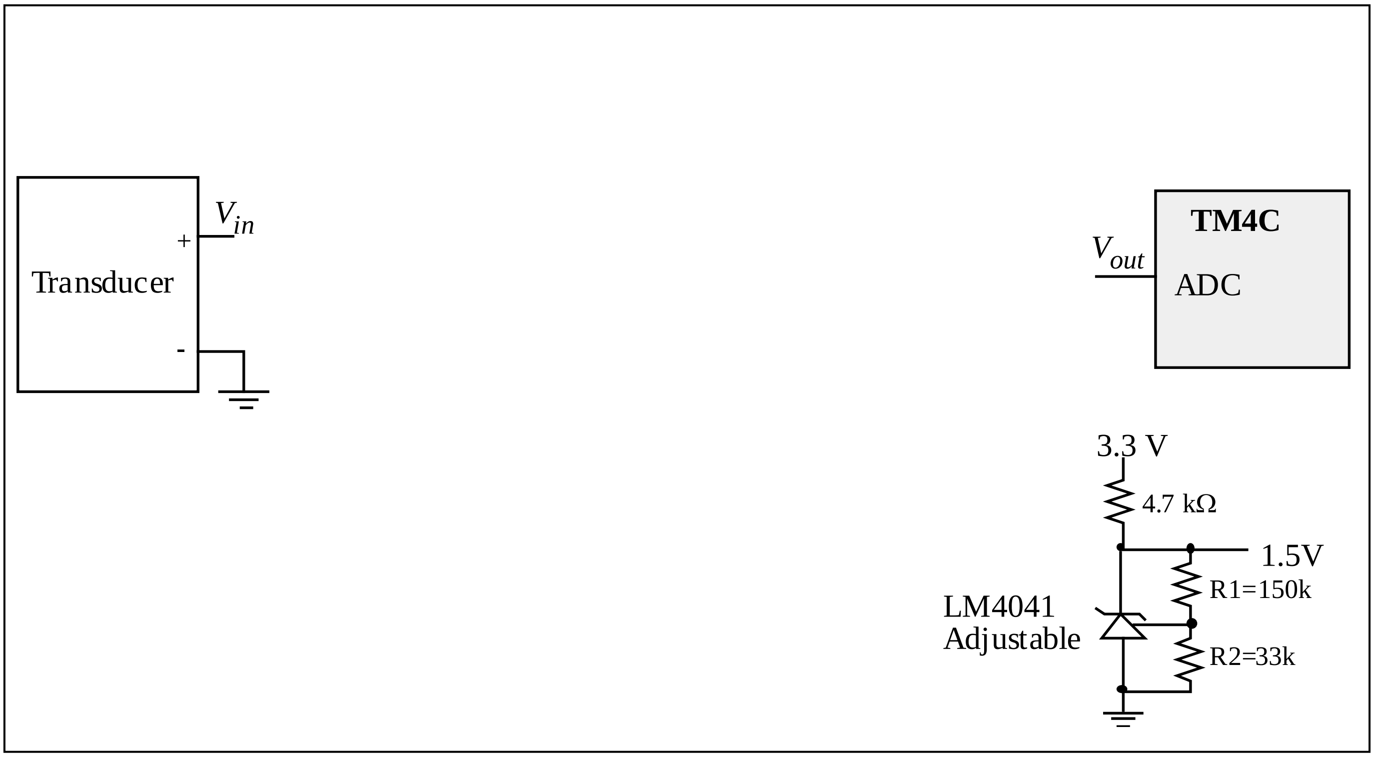
(10) Question 6. 12-bit ADC measures a 20 kHz sine wave.

(2) Part a) What is the large component at f= 0Hz?

(4) Part b) What is the signal to noise ratio in dB?

(4) Part c) What is the equivalent precision in bits?

(14) Question 7. Design the circuit; show your work



(10) Question 8 Part a) Show the initialization for Port B edge-triggered interrupts

```
void PortB_Init(void){
  SYSCTL_RCGCGPIO_R    |= 0x02; delay();
  GPIO_PORTB_DIR_R
  GPIO_PORTB_DEN_R
  GPIO_PORTB_IS_R
  GPIO_PORTB_IBE_R
  GPIO_PORTB_IEV_R
  GPIO_PORTB_IM_R
                       Max=0;
  NVIC_EN0_R
  EnableInterrupts(); }
```

(15) Part b) Show the edge-triggered interrupt service routine.

```
void GPIOPortB_Handler(void){
```

April 19, 2018, 3:30 to 4:45 pm. Open book, open notes, calculator (no laptops, phones, devices with screens larger than a TI-89 calculator, devices with wireless communication). You have 75 minutes, so please allocate your time accordingly. ***Place your EID at the top of each page. Please read the entire quiz before starting***. We will use **Gradescope**, so you must put your answers in the boxes provided.

(5) Question 1. *Efficiency* (η) is defined as output power divided by input power. Noise is **not** an important design factor for this 3.3V-supply system. What type of circuit component do you need to create a power management system that optimizes for efficiency? Put your answer A,B,C,D,E, or F in the box.

A) LM4041, a shunt-diode with 3.3V output
B) TIP120, a Darlington NPN with 3.3V output
C) LP2981-3.3, a linear regulator with 0.2V dropout with 3.3V output
D) INA122, an instrumentation amp with 3.3V output
E) TPS63001, a buck-boost regulator with 3.3V output
F) OPA2350, a rail-to-rail op amp with 3.3V output

(7) Question 2. Design a circuit that takes a 3.6V input (from a Li-ion battery) and creates the 3.3V output. The maximum output current is 50 mA. Show part numbers, and all values for passive components.

(7) Question 3. The battery-powered embedded system requires a constant +3.3V supply. There is a 95% efficient power circuit used to create the 3.3V supply from a 7.4V battery. The goal is to determine system operating time for one 7.4V battery. In sleep mode the system needs 0.1 mA of current, and in active mode the system requires 100 mA of current. It runs in sleep mode 90% of the time and runs in active mode 10% of the time. How long will one 7.4V 2200 mA-hour battery run the system? Show your equations and the final calculation.

(20) Question 4. Let f_s be the sampling rate, and f_c be a high noise frequency we wish to remove. The following is a high-Q digital notch (rejects the frequency f_c).

$$y(n) = x(n) - 2\cos(\theta)x(n-1) + x(n-2) + 2\alpha\cos(\theta)y(n-1) - \alpha^2 y(n-2)$$

where α determines the Q (α<1), and θ sets the reject frequency ($\theta = 2\pi f_c/f_s$). If $\alpha = 0.9$ (very high Q), f_c is 60 Hz, and f_s is 250 Hz, then this filter becomes

$$y(n) = x(n) - 0.12558x(n-1) + x(n-2) + 0.11302y(n-1) - 0.81y(n-2)$$

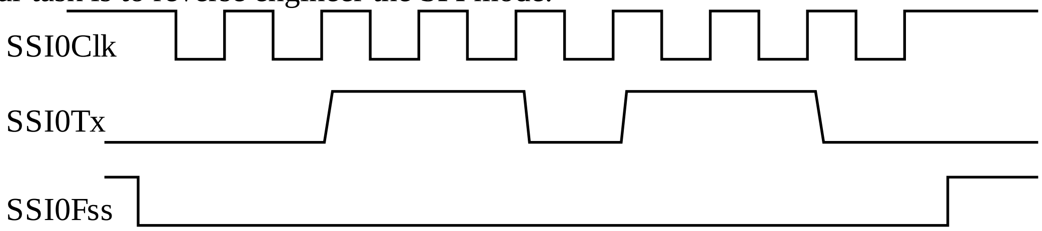
(5) Part a) Rewrite the filter equation using **fixed-point math**, calculating $y(n)$ from $x(n)$, $x(n-1)$, $x(n-2)$, $y(n-1)$, and $y(n-2)$. You want to maximize accuracy with no overflow. Show your work

(15) Part b) Assume SysTick interrupts at 250 Hz. Assume the function **`ADC_In()`** is given to you, which will sample the ADC and return a 12-bit digital sample. These two arrays are located in global RAM.

```
int32_t X[3],Y[3];
```

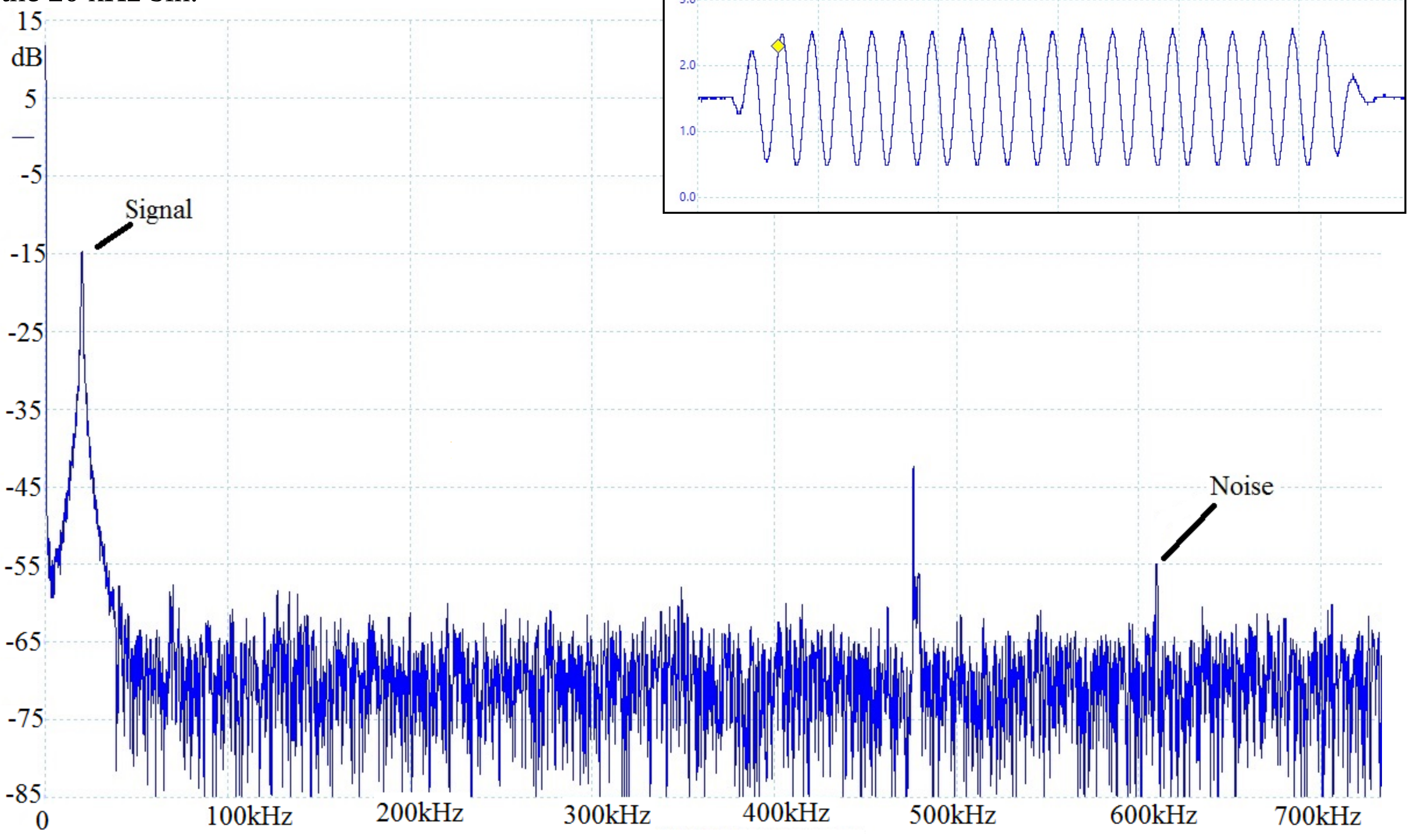
`X[0]` is *x(n)* the current ADC sample, **`X[1]`** is *x(n-1)* the previous ADC sample, **`X[2]`** is *x(n-2)* the ADC sample two times ago, **`Y[0]`** is *y(n)* the current filter output, **`Y[1]`** is *y(n-1)* the previous filter output, **`Y[2]`** is *y(n-2)* the filter output two times ago. Show the SysTick ISR that adjusts values in the two arrays as needed, calls **`ADC_In()`**, and implements the digital filter using **fixed-point math**. Calculating the filter means setting **`Y[0]`** as a function of **`X[0]`**, **`X[1]`**, **`X[2]`**, **`Y[1]`**, and **`Y[2]`**. Your ISR is the only software that reads and writes to these two arrays. Your ISR must write data into the arrays and use the array values to implement the filter.

(12) Question 5. An output device is interfaced to the microcontroller using SPI. The TM4C123 uses Freescale mode with the TM4C123 as master. The following response was measured with the logic analyzer. Your task is to reverse engineer the SPI mode.



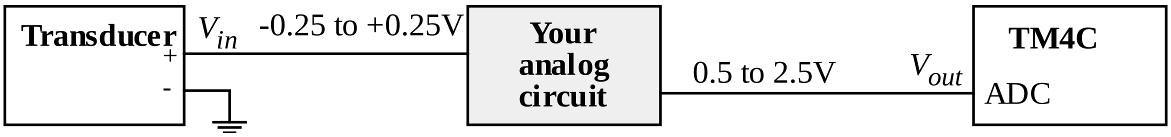
(3) Part a) What value did the software write to **DSS** during initialization?
(3) Part b) What value did the software write to **SPO** during initialization?
(3) Part c) What value did the software write to **SPH** during initialization?
(3) Part d) What data value is being transmitted (in hexadecimal)?

(10) Question 6. This TM4C123 system uses its 12-bit ADC with timer-triggered 640 kHz real-time sampling to measure a sine wave at 20 kHz. The analog input to the ADC was measured with a spectrum analyzer. The y-axis signal amplitude in dB_{fs}, and the full scale for this spectrum analyzer is 5V. The data at 20 kHz is the signal and the information at 620 kHz is considered noise, because 620 kHz will alias into the 20 kHz bin.



(2) Part a) What is the large component at f = 0 Hz?
(4) Part b) What is the signal to noise ratio in dB?
(4) Part c) What is the equivalent measurement precision in bits due to noise?

(14) Question 7. Your job is to interface this transducer to the ADC on the TM4C123. The transducer output is a single voltage called V_{in}, such that V_{in} varies from -0.25 to +0.25V. Your goal is to make the output voltage vary from 0.5 to 2.5 V. The output, V_{out}, is connected to the microcontroller ADC. R1 and R2 are already chosen with a LM4041 circuit such that the analog reference is 1.5V. You may use any chips shown in the book or presented in class. Show your work and label all chip numbers and resistor values. You do not have to show pin numbers. You do not need to add a low pass filter.



(25) Question 8. Eight positive logic input switches are interfaced to Port B. The overall goal is to establish a global, `Max`, containing the maximum number of switches that are simultaneously pressed. This is not the number of times switches are pressed in general, but maximum number of switches pressed at any one time. The hardware interface includes external pull down resistors for each switch. Your software should initialize edge-triggered interrupts such that you generate an interrupt when any of the switches are pressed. You may assume the switches do not bounce. Your system must handle simultaneous or *near-simultaneous* switch presses. However, you may assume switches will not be released within 50 µs of another switch being pressed.

```
uint32_t Max=0;
```

(10) Part a) Show the initialization code that configures Port B. The software will delay after setting the clock. It should arm and enable the appropriate edge-triggered interrupts. Do not worry about interrupt priority. You may add private global variables. Assume you have access to all of Port B.

(15) Part b) Show the edge-triggered interrupt service routine. No time delays are allowed in the ISR. You do not need to show the main program. The value of `Max` is initially 0 and monotonically increases up to 8. It contains a historical recording of the maximum number of switches simultaneously pressed at any point in the past.