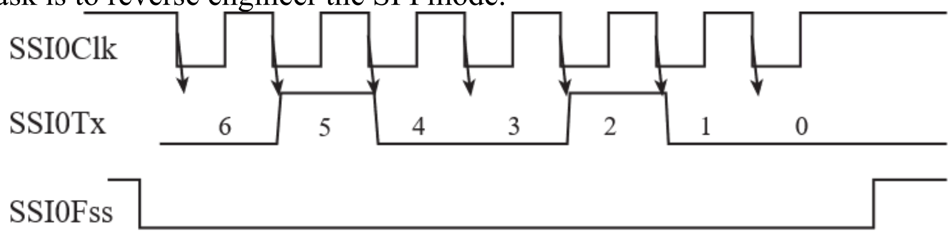
EE445L Spring 2023 Quiz 2 EID =

First: Last:

April 6, 2023, 12:30 to 1:45 pm. Open book, open notes, calculator (no, phones, devices with wireless communication). No devices with screens larger than a calculator or cell phone (basically, the screen cannot be visible to other students).

(10) Question 1. An output device is interfaced to the microcontroller using SPI. The TM4C123 uses Freescale mode with the TM4C123 as master. The following waveforms were captured 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?

7 bits (DSS=6)

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

SPO=1

Idle clock is high

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

SPH=1

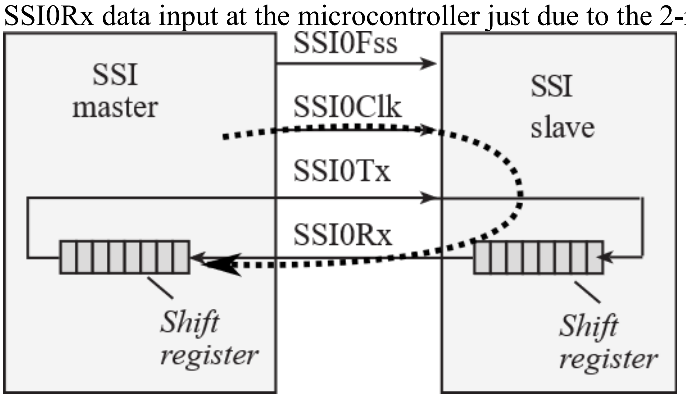
Master Output changes on fall of clock, slave clocks on rise

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

0x24

Look at data bits on rising edge, 7-bit 0100100

(10) Question 2. Consider this SPI interface where the distance between the microcontroller and the device is 2 meters. Assume a velocity factor of 0.6. What is the time delay between clock output at the microcontroller and SSI0Rx data input at the microcontroller just due to the 2-meter cable. Neglect capacitance in cable.



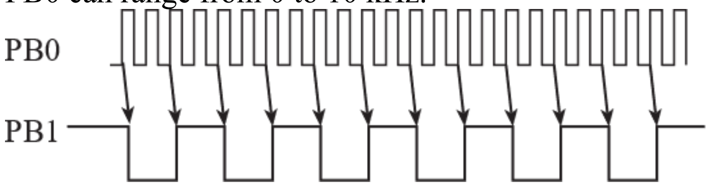
The speed of transmission is VF*c. Speed of light is 3×10^8m/sec. Total distance is there and back, which is 4 meters. With a VF=0.6, and a cable length of 2 meter, the propagation delay will be $2*2\text{m}/(0.6*3*10^8\text{m/sec}) = 22\text{ns}$

(10) Question 3. We will store the value +1.00V with the integer +8. The range of values are -16V to +15.875V, what are the precision and resolution of this fixed-point number system? Give units for each.

Smallest -16V/0.125V = -128
Largest +15.875V /0.125V = +127
Precision = 8 bits

Solve this first
Resolution of the system = 1.00V/+8 = 0.125V

(20) Question 4. You are given a GPIO input on PB0. Create a GPIO output on PB1 with a frequency 4 times slower. E.g., if the frequency of PB0 is 1 kHz, make the frequency of PB1 250 Hz. The frequency of PB0 can range from 0 to 10 kHz.



You do not write **DisableInterrupts** or **EnableInterrupts**; otherwise, you write all the software needed. The main program is fixed and cannot be changed. Don't worry about priority

```
int main(void){
  DisableInterrupts(); // running at 16 MHz
  Init();              // you write this
  EnableInterrupts();
  while(1){
  }
}
```

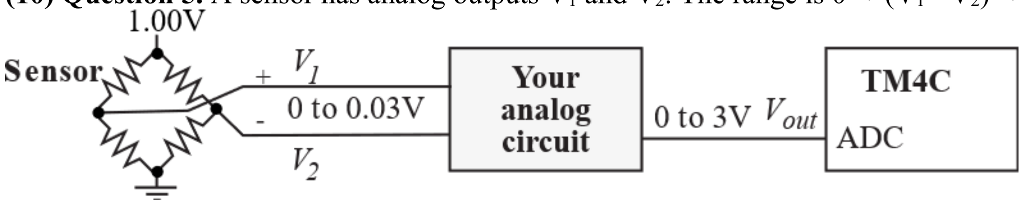
Part a) Write your **Init**

```
uint32_t Count = 0;
void EdgeCounter_Init(void){
  SYSCTL_RCGCGPIO_R |= 0x02;// clk
  Count = 0;
  GPIO_PORTB_DIR_R &= ~0x01;// in
  GPIO_PORTB_DIR_R |= 0x02; // out
  GPIO_PORTB_DEN_R |= 0x03; // en
  GPIO_PORTB_IS_R &= ~0x01; // edge
  GPIO_PORTB_IBE_R &= ~0x01;
//      not both edges
  GPIO_PORTB_IEV_R = 0x01; //rising
  GPIO_PORTB_ICR_R = 0x01; // ack
  GPIO_PORTB_IM_R |= 0x01; // arm
  NVIC_EN0_R = 2;  // enable NVIC
}
```

Part b) Write your **ISR**

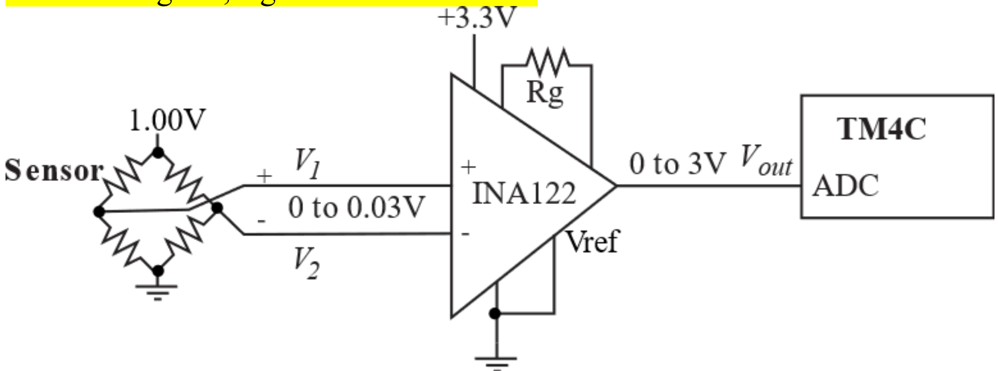
```
void GPIOPortB_Handler(void){
  GPIO_PORTB_ICR_R = 0x01; // ack
  Count++;
  if(Count & 0x01){ // every other
    GPIO_PORTB_DATA_R ^= 0x02;
// toggle
  }
}
// alternate solution
// Bottom bits of Count in binary
// 000
// 001
// 010
// 011
// 100
// 101
// 110
// 111
// PB1 is Bit 1 of Count
void GPIOPortB_Handler(void){
  GPIO_PORTB_ICR_R = 0x01; // ack
  Count++;
  PB1 = Count; // bit specific
}
```

(10) Question 5. A sensor has analog outputs V_1 and V_2. The range is $0 < (V_1 - V_2) < 0.03V$.

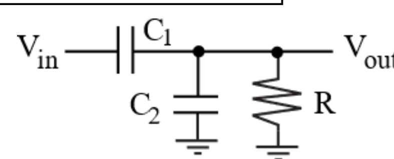


Design an analog circuit to interface this sensor to the 0 to 3V at the ADC on the TM4C123. Show all chip numbers and resistors. Show equations used to define resistance values. No LPF is needed here.

Gain is 3/0.03 = 100, differential with large gain needs instrumentation amp. The fact that the sensor is a resistance bridge means the input impedance of the amp must be large. Vref=0
G = 200k/Rg + 5, Rg = 200k/95 = 2.105k



(10) Question 6. Consider this analog filter. First, write the complex impedances of the two capacitors (Z_1 and Z_2) in terms of $j2\pi f$, where f is the frequency of the input V_{in}, and j is the sqrt(-1). Next, use these impedances to characterize the filter as low-pass, high-pass, or band-pass. C_1 is much bigger than C_2.



This architecture is very similar to the microphone circuit in Lab 9

$Z_1 = 1/(j2\pi fC_1)$
$Z_2 = 1/(j2\pi fC_2)$

No need to reduce, Z is the parallel combination of R and C_2,
$Z = R \parallel C_2 = R*Z_2/(R+Z_2)$
$V_{out}/V_{in} = Z/(Z+Z_1)$

At f=0, Z_1 is infinite and Z_2 is infinite, Z=R, so V_{out} =0, so $V_{out}/V_{in} = 0$
At f=infinite, Z_1 is 0 and Z_2 is 0, Z = 0, so V_{out} =0, so $V_{out}/V_{in} = 0$
Let $f_1 = 1/(2\pi RC_1)$. Let $f_2 = 1/(2\pi RC_2)$, with f_1 much smaller than f_2
For $f_1 << f << f_2$, Z_1 is 0 and Z_2 is infinite, Z=R, so $V_{out}/V_{in} = 1$
High pass filter with cutoffs f_1 f_2.

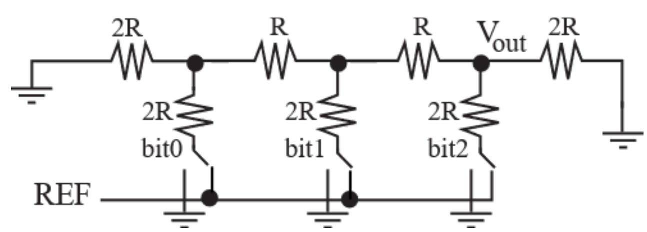
(15) Question 7. Implement the following digital filter: y(n)=0.75*y(n-1)+0.25*x(n), where y(n) is stored in global **y**, and x(n) is stored in global **x. Use only integer addition and integer shift.**

```
uint32_t x,y;
void ADC0Seq0_Handler(void){
  ADC0_ISC_R = 0x01;      // acknowledge ADC sequence 0 completion
  x = ADC0_SSFIFO0_R;     // input x(n)
```

```
// y(n)=0.75*y(n-1)+0.25*x(n)
// y=(3*y+x)/4  where right y is y(n-1) and left y is y(n)
y = (y+y+y+x)>>2;
// we move shift right to last operation to improve accuracy
```

```
}
```

(15) Question 8. REF is 3.00V for this 3-bit DAC. What is the maximum DAC output voltage? Show your work. *Hint*: solve for the current in the right-most 2R for digital input equal to 7.



Use Law of Superposition.

Study basis elements: In=001, 010, 100.

For every case, the resistance from REF to ground is 3R. If digital input is 1, the injected current at the switch is REF/(3R)

In = 001, current divided in half three times, I_{out} = REF/(24R), V_{out} = REF/12,
In = 010, current divided in half two times, I_{out} = REF/(12R), V_{out} = REF/6,
In = 100, current divided in half once, I_{out} = REF/(6R), V_{out} = REF/3,

Law of Superposition
In = 111, V_{out} = REF/3 + REF/6 + REF/12 = 1 + ½ + ¼ = 7/4 V = 1.75V