First:__________________ Last:____________________ EID:_________________

April 21, 2022, 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).

(25) Question 1. Consider the MAX549A, a two channel 8-bit DAC. V_{DD} is the 3.3V supply. REF is a 3.0V analog reference for the DAC. GND is connected to ground. OUTA and OUTB are analog outputs.

(5) Part a) Give equations to prove this chip can be interfaced directly to the TM4C123 without voltage level shifters.

$V_{IH} = 0.7*3.3 = 2.31 < V_{OH} = 2.4V$

$V_{IL} = 0.3*3.3 = 0.99 > V_{OL} = 0.4V$

$I_{IH} = 1\mu A < I_{OH} = 2mA$

$I_{IL} = 1\mu A < I_{OL} = 2mA$

(5) Part b) Show the connections between Port B of the TM4C123 and the MAX549A

PB4 SSI2Clk to MAX549A SCLK

PB5 SSI2Fss to MAX549A CS

PB7 SSI2Tx to MAX549A DIN (MOSI)

(5) Part c) What architecture type is this DAC? Describe how the DAC works with one or two sentences

R-2R ladder. Impedance to ground the same at each pin, so injected current is equal at each pin. The ladder divides the current at each stage, so the output voltage/current is binary weighted value of the digital control pins.

(5) Part d) What is the fastest clock frequency possible? Show your work.

Min SCLK period is 80 ns

However, speed is limited by setup time

Required time starts at ½ T – t_{su} = ½ T – 30ns

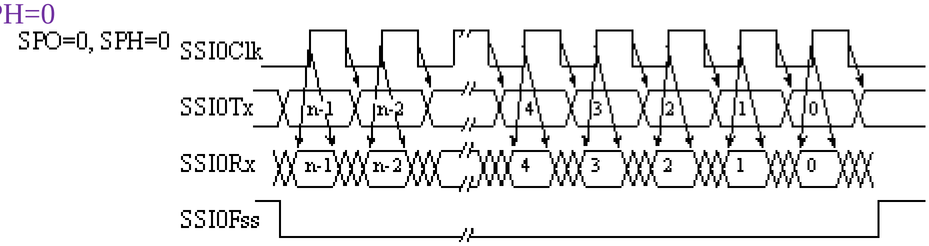
Available time is 0+S6 = 15.7ns, so T>2*(30+15.7) = 91.4ns

Max frequency = 1/91.4ns = 10.94 MHz

(5) Part e) What values for MS, SPO, SPH are needed to make this interface operational? Justify your answer.

TM4C123 is master, Clocks DIN in on rise (so TM4C123 changes on fall), SCLK idle is low

MS=0, SPO=0, SPH=0



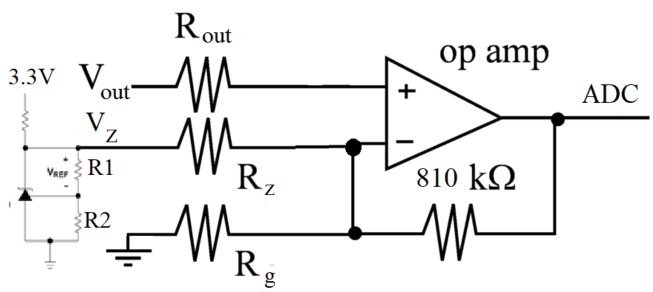
(25) Question 2. You are given a GPIO input on PA7. There will be exactly one rising edge once a day

```
uint32_t Last,Count,Sleep;
void YourInit(void){
  SYSCTL_RCGCGPIO_R |= 0x01;
  SYSCTL_RCGCTIMER_R |= 0x02;   // 0) activate TIMER1
  Last = Count = Sleep = 0;
  GPIO_PORTA_DIR_R &= ~0x80; // input
  GPIO_PORTA_DEN_R |= 0x80;  // enable
  GPIO_PORTA_PCTL_R &= ~0xF0000000;
  TIMER1_CTL_R = 0x00000000;    // 1) disable TIMER1A during setup
  TIMER1_CFG_R = 0x00000000;    // 2) configure for 32-bit mode
  TIMER1_TAMR_R = 0x00000002;   // 3) configure for periodic mode
  TIMER1_TAILR_R = 79999999;    // 4) reload value for 1 second
  TIMER1_TAPR_R = 0;            // 5) bus clock resolution
  TIMER1_ICR_R = 0x00000001;    // 6) clear TIMER1A timeout flag
  TIMER1_IMR_R = 0x00000001;    // 7) arm timeout interrupt
  NVIC_PRI5_R = (NVIC_PRI5_R&0xFFFF00FF)|0x00008000; // 8) priority 4
  NVIC_EN0_R = 1<<21;           // 9) enable IRQ 21 in NVIC
  TIMER1_CTL_R = 0x00000001;    // 10) enable TIMER1A
}
void Timer1A_Handler(void){ uint32_t now;
  TIMER1_ICR_R = TIMER_ICR_TATOCINT;// acknowledge TIMER1A timeout
  now = GPIO_PORTA_DATA_R&0x80;
  if((Last == 0)&&(now == 0x80)){ // rising edge
    Count = 0; // active
  }
  if((Last == 0x80)&&(now == 0)){ // falling edge
    Sleep = Count
  }
  Count++;
  Last = now;
}
void YourInitAlternate(void){ // alternate solution using SysTick
  SYSCTL_RCGCGPIO_R |= 0x01;
  Last = Count = Sleep = 0;
  GPIO_PORTA_DIR_R &= ~0x80; // input
  GPIO_PORTA_DEN_R |= 0x80;  // enable
  GPIO_PORTA_PCTL_R &= ~0xF0000000;
  NVIC_ST_RELOAD_R = 7999999;   // 10 Hz
  NVIC_ST_CTRL_R = 7; // arm
  NVIC_SYS_PRI3_R = (NVIC_SYS_PRI3_R&0x00FFFFFF)|0x40000000; // priority 2
}
void SysTick_Handler(void){ uint32_t now;
static uint32_t tenths=0;
  tenths++ ;
  if(tenths == 10){
    tenths = 0; // 1 Hz
    now = GPIO_PORTA_DATA_R&0x80;
    if((Last == 0)&&(now == 0x80)){ // rising edge
      Count = 0; // active
    }
    if((Last == 0x80)&&(now == 0)){ // falling edge
      Sleep = Count
    }
    Count++;
    Last = now;
  }}
```

(25) Question 3. A pressure sensor has a single analog output (not differential). The range of distances are 0 to 100 psi. A pressure of 0 maps to an analog output of 0.1V. A pressure of 100 psi maps to an analog output of 0.2V. The desired pressure resolution is 0.1 psi. The frequencies of interest of pressure are 0 to 10 Hz, and desired frequency resolution of pressure is 0.01Hz.

(10) Part a) Design an analog circuit to interface this sensor to the ADC on the TM4C123. A pressure of 0 should map to an ADC input of 0V. A pressure of 100 psi should map to an ADC input of 3.0V. You may use any chips included in lab.

ADC = m*Vout + b
0.0V = m*0.1V + b
3.0V = m*0.2V + b
Subtract 3.0V = m*0.1V, m=30
Substitute 0.0V = 30*0.1V + b, b = -3V
ADC = 30*Vout – 3
Let Vz = 1.5V
ADC = 30*Vout – 2*Vz
Let Vg = 0
ADC = 30*Vout – 2*Vz – 27Vg
810 is common multiple of 30, 27, 2
30 = 810k/Rout, Rout=27k
27 = 810k/Rg, Rg = 30k
2 = 810k/Rz, Rz = 405k



Vref = Vz * R1 /(R1 + R2) => 1.2 = 1.5 * R1 /(R1 + R2) => 1.5/1.2 = 1+R2/R1 => 0.25 = R2/R1
R1 = 40k, R2=10k

(5) Part b) What is the slowest possible sampling rate? Justify your answer.

Nyquist, fs>2*10Hz, so 21 Hz

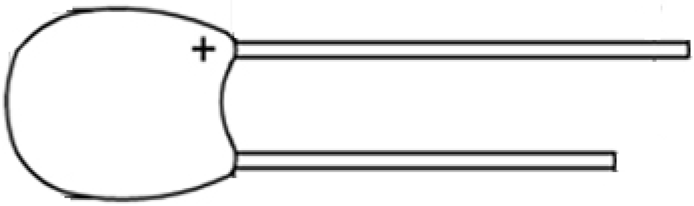
(5) Part c) How do you configure the system to achieve a frequency resolution of 0.01 Hz? Justify your answer.

Frequency resolution is 1/T, where T is the total sampling time. Sample the input at fs, fill a buffer. Make the size of the buffer large enough so it contains at least 100 seconds of data.

(5) Part d) Assume the 12-bit 0 to 3.3V ADC on the TM4C123. Derive an equation that maps the 12-bit ADC digital value in **ADC0_FIFO3_R** into the integer portion of the recorded pressure in the software.

Let pressure = I *0.1psi, 0 maps to 0 so there is no offset
At max pressure of 100 psi, V_{ADC} = 3V, sample = 3*4095/3.3V=3723
100 psi = I*0.1psi, I = 1000, map 3723 to 1000
I = (1000*ADC0_FIFO3_R)/ 3723

(5) Question 4. What is this Lab 6 component? There is a + symbol on the side of the longer lead



Tantalum capacitor

(5) Question 5. A ceramic capacitor is labeled with the marking 123. What value is it in nF?

$12*10^3$ pF = 12 nF

(15) Question 6. You are given a 1000 mA-hr 3.7V battery. A buck-boost regulator converts the 3.7V battery input to the 3.3V supply for the TM4C123 system. The bus clock of the TM4C123 is reduced to 1 MHz to save power. The efficiency of the buck-boost regulator is 90%. The software runs in two modes. Sleep mode draws 1mA of 3.3V current, and active mode draws 50 mA of 3.3V current. The active mode occurs once a second and lasts T time. The remaining 1-T time is in sleep mode. What is the maximum time T (in sec) you could run if the system needs to run for 1 week = 168 hours? Show your work.

Average current at 3.7V (input of regulator) is I_{out} = T*50 + (1-T) in mA, with T in sec
Efficiency of regulator is extra information, not needed, because the 3.7V currents are given
To run for a week, I_{out} must be less than 1000/168 mA = 5.95mA
5.95mA > (T*49 +1)
(5.95mA – 1)/49 > T
0.101sec > T