Jonathan W. Valvano May 12, 1999, 9am-12noon

**(10) Question 1**. The instrumentation amp provides differential gain with a large $Z_{in}$. To get a gain of 25, we divide the gain into two equal stages (5•5). We choose $R_2/R_1=2$ and $R_4/R_3=5$. The design steps for the 2 pole Butterworth low pass filter are as follows:

1) select the cutoff frequency, $f_c$ at 1/2 $f_s$, or 5 Hz

2) divide the two capacitors by $2\pi f_c$ (let $C_{1A}$, $C_{2A}$ be the new capacitor values)

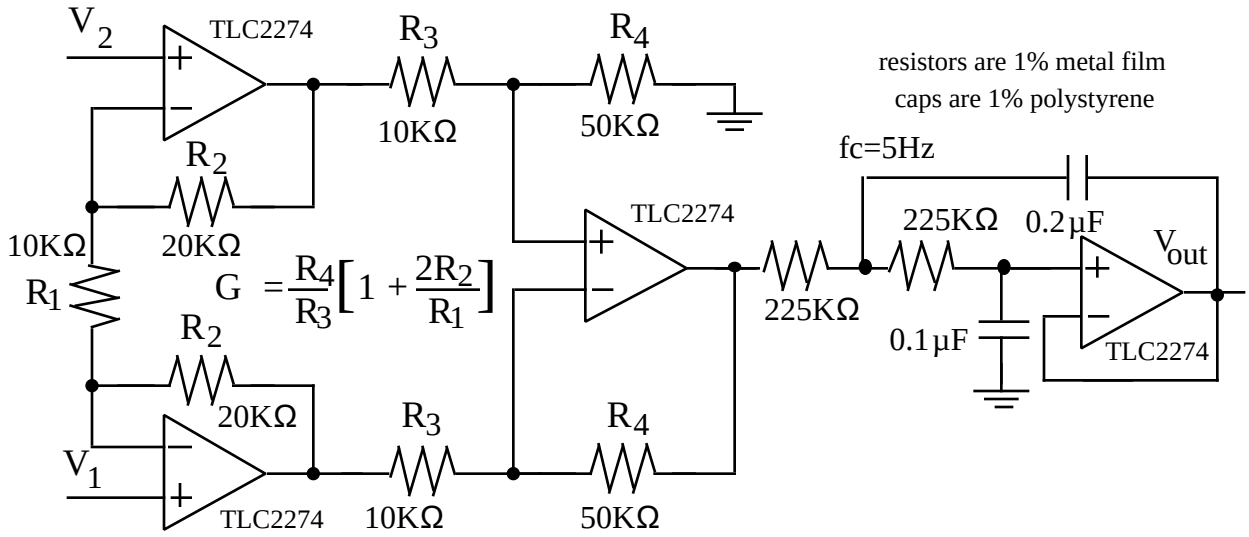
$C_{1A}$ = 141.4µF/2π5 = 4.5 µF

$C_{2A}$ = 70.7µF/2π5 = 2.25 µF

3) locate two standard value capacitors (with the 2/1 ratio) with the same order of magnitude as the desired values. Choose 0.2 and 0.1 µF. So x= 4.5/0.2=22.5

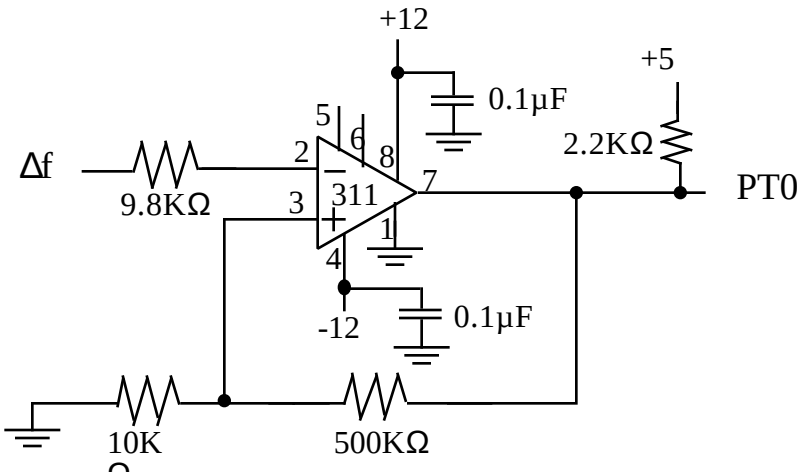
4) adjust the resistors to maintain the cutoff frequency

R = 10KΩ•x = 225KΩ




**(30) Question 2.** Design a noninvasive doppler ultrasound blood velocity meter.

**(10) Part a)** Show the electronic interface between **Δf** and the input capture pin PT0.




**(10) Part b)** Show the ritual that initializes the system. The frequency resolution is 7542Hz/200 or 37.71Hz. So if we use an output compare interrupt at 1/37.71=26.5ms, then the frequency measurement will generate values from 0 to 200 (exactly what we need for velocity in cm/sec) as frequency varies from 0 to 7542 Hz. I used a 1 µs TCNT clock, but you could have used a 0.5 µs clock with `rate` set to `53000U`.

```
#define rate 26518
```

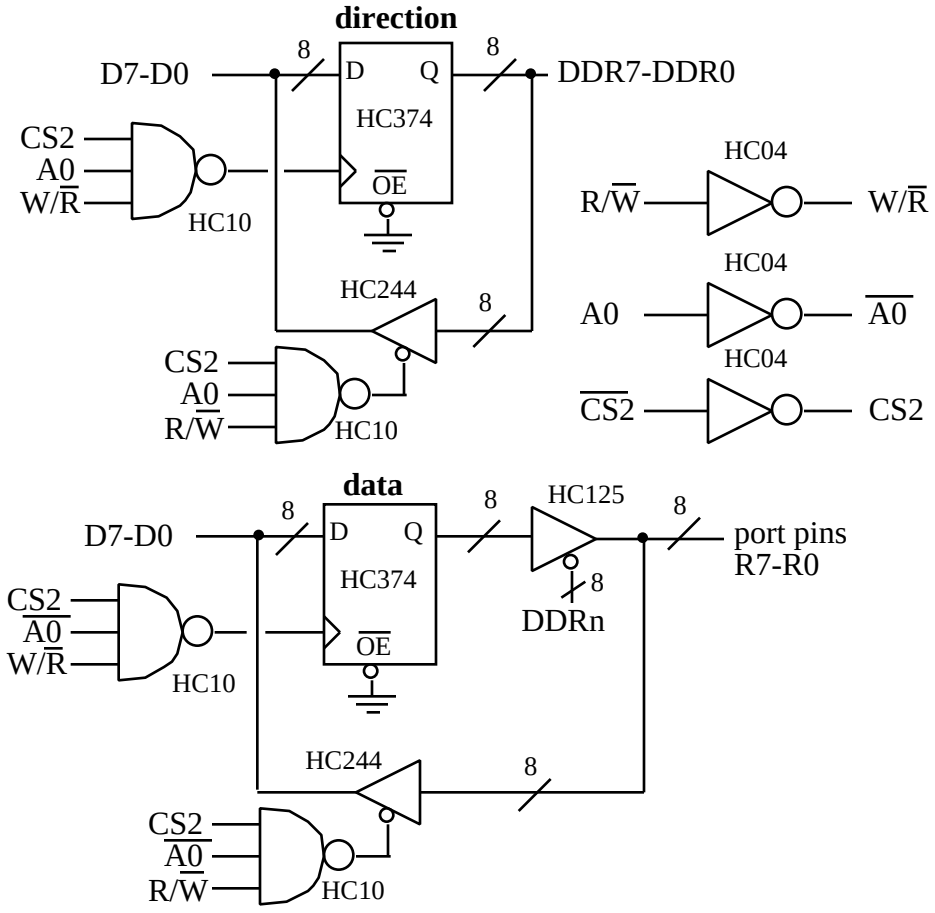
```
unsigned short count; // running count as measurement is occurring
unsigned short done;  // set on completion
void ritual(void) {
asm(" sei");      // make atomic
    TIOS|=0x02;   // enable OC1
    TSCR=0x80;    // enable
    TMSK2=0x33;   // 1 us clock
    TMSK1|=0x03;  // Arm OC1 and IC0
    TC1=TCNT+Rate;   // First in 26.5 ms
    TCTL4 = (TCTL4&0xFC)|0x01;  // C0F set on rising edges
    Count = 0;    // Set up for first
    TFLG1=0x03;   // clear OC1F, IC0F
asm(" cli"); }
```

**(10) Part c)** Show the input capture and output compare handlers that implement the velocity meter.

```
#pragma interrupt_handler TIC0handler()
void TIC0handler(void){
  Count++;      // number of rising edges
  TFLG1=0x01;}  // ack, clear C0F
#pragma interrupt_handler TOC1handler()
void TOC1handler(void){
    TFLG1= 0x02;      // Acknowledge
    TC1 = TC1+Rate;   // every 26.5 ms
    v = Count;        // cm/sec units
    LCDout("v=",v," cm/sec");
    Count = 0; }      // Setup for next
```

**(25) Question 3.** Design a digital circuit that implements an I/O port.

**(20) Part a)** The data register is at address $380 and the direction register at address $0381.



**(5) Part b)** Give the ritual program to initialize CS2 with the appropriate number of clock stretches.

```
void ritual(void){
    CSCTL0=CSCTL0|0x04; // enable CS2
    CSSTR1=CSSTR1&0xCF; // no cycle stretching on CS2
}
```

**(20) Question 4**. In this problem we start with the interrupt-driven DAS from Section 11.9.

**(5) Part a)** Additional *privite* global variables.

```
unsigned short DebugPrevious;  // TCNT at previous A/D start
short DebugValid;              // false if first measurement
```

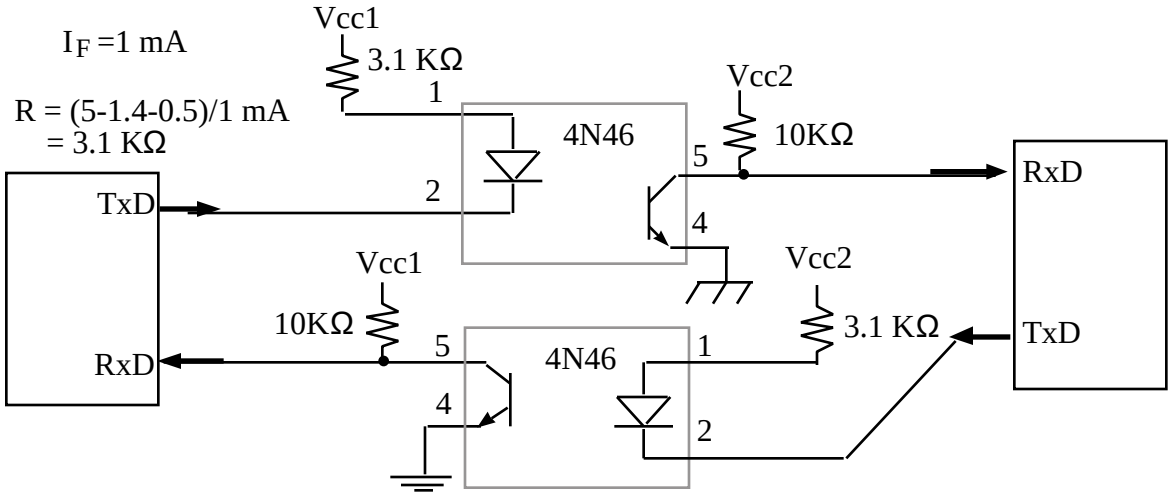
**(15) Part b)** Write the two debugging instruments.

```
void DebugInit(void){
        Minimum=0xFFFF; // initialize to largest
        Maximum=0;      // initialize to smallest
        DebugValid=0;}  // used to invalidate first measurement
      void DebugMeas(void){ unsigned short delay;
        delay=TCNT-DebugPrevious;  // elapsed time since last A/D
        DebugPrevious=TCNT;        // next starts from now
        if(DebugValid){            // skip first interrupt
            delay = delay>>1;      // convert to usec
            if(delay<Minimum) Minimum=delay;
            if(delay>Maximum) Maximum=delay;
        }
        else
            DebugValid=1;          // activate measurements
      }
```

**(*bonus*) Part c)** The minimum execution time might be much less than expected if the execution time goes just above 65,535 μs.

**(15) Question 5**. full-duplex communication without connecting the two grounds.

**(10) Part a)** Show the interface between the two microcomputers.




**(5) Part b)** Given $R_L$=10 KΩ, $t_{PLH}$<500 μs, so baud rate is much slower than 1000 bits/sec. E.g., 100 bits/sec.