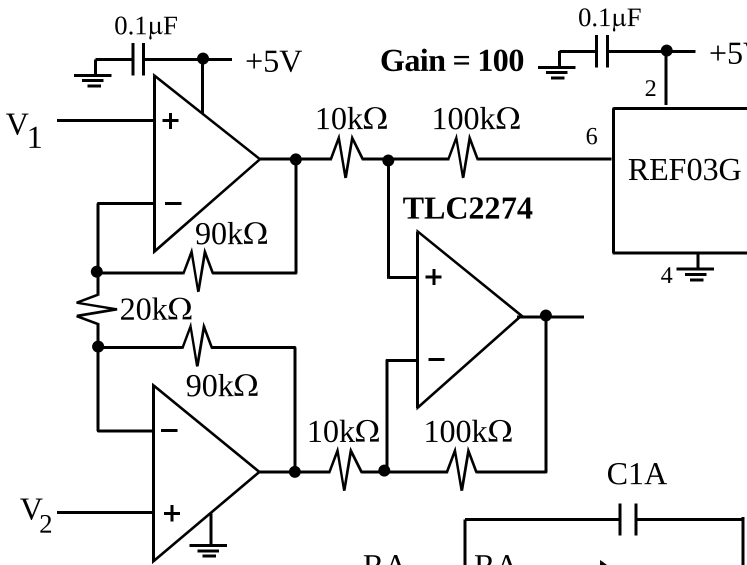
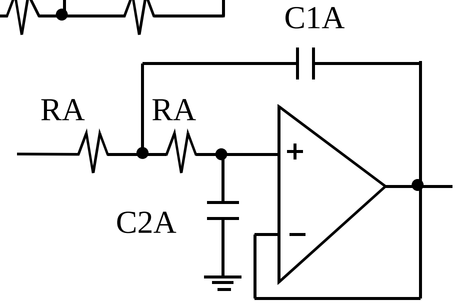
Jonathan W. Valvano December 15, 2005, 2-5pm

(10) Question 1. We use an instrumentation amp, because of the differential nature and the input impedance. We add a 2.5V to the ground signal of the amp to scale the signals near 2.5V. Gain of 100 is calculated as 100k/10k(1+2*90k/20k).



(5) Question 2. Design a two pole analog low-pass filter with a cutoff frequency of 1150 Hz.



initial starting point Using **`LPF.xls`**

fc (Hz)	1	
R (kohm)	10	
C1 (µF)	141	
C2 (µF)	70.7	
first design step is to select the cutoff frequency		
fc (Hz)	1125	fill this in
RA (kohm)	10	same as initial R
C1A (µF)	0.02	is 141.4/(2•π•fc)
C2A (µF)	0.01	is 70.7/(2•π•fc) or 0.5•C1A

(5) Question 3. First, determine the measurement resolution, which is 10 cm/sec divided by the ADC precision of 4096. This system can resolve velocity differences of 0.00244 cm/sec. Binary fixed-point is selected because multiple calculations will be required. A **16-bit unsigned binary fixed-point** number system with a **resolution of 1/512 cm/sec** will be able to represent all measured values. The range is 0 to 127 cm/sec. Possible 16-bit unsigned binary fixed-point solutions are

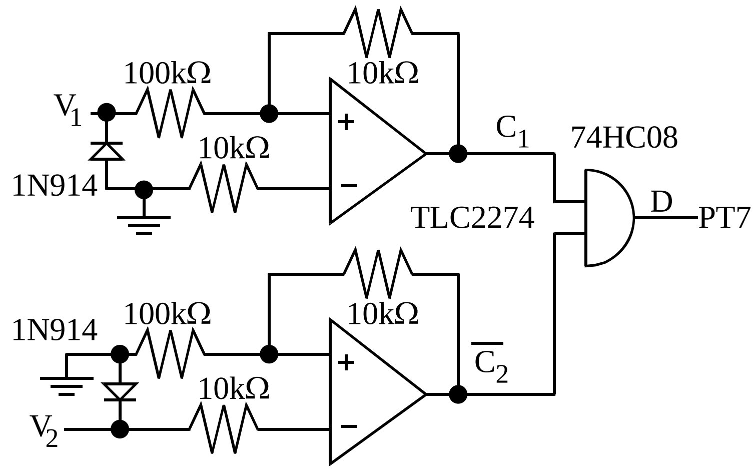
resolution=1/512 cm/sec	range = 0 to 127 cm/sec	5cm/sec stored as 2560
resolution=1/1024 cm/sec	range = 0 to 63 cm/sec	5cm/sec stored as 5120
resolution=1/2048 cm/sec	range = 0 to 31 cm/sec	5cm/sec stored as 10240
resolution=1/4096 cm/sec	range = 0 to 15 cm/sec	5cm/sec stored as 20480

(5) Question 4. Frame size is 29+32+36= 97 bits. Bandwidth is 4bytes/frame times 100,000bits/sec divided by 97 bits/frame = **4123 BYTES/SEC**.

(5) Question 5. The short messages can arrive every 75*5µs (375 µs). There are five receive buffers on the 9S12C32 CAN interface. After one buffer is full, the RXF flag is set. 4*375 µs (1.5ms) later it is possible that all five buffers will be full. Latency requirement is 1.5ms. This value assumes the CAN interrupt will receive all pending messages, emptying the FIFO.

(10) Question 6. See Table 9.17 in View22.
(5) Part a) The propagation delay from clock to output change through the 74FCT374 has a minimum of 2ns and a maximum of 6.5ns. Assuming 9 ns 74FCT139 gate delay max and 1.5 ns delay minimum, E1 falls at [127,131.5]+[1.5,9] ns. RDR is (735, 750). Thus, the access time must be less than 735-140.5 = 594.5ns.
(5) Part b) The fall of E2 is 750ns. WDA is (132, 752). So the setup time must be less than 750-132 = 618ns.

(20) Question 7. The first step is to convert the sin waves into square waves. A Rail-to-Rail op amp with positive feedback will give a clean 0-to-5 V squarewave with the same phase as the original sin wave. Positive feedback creates hysteresis, making it more immune to noise. The diode protects the op amp input from negative voltages. A HPF could have been used to center both waves at 0V. The AND gate creates a 100 Hz square-wave such that the duty cycle is linear with phase. The 9S12C32 input capture measures pulse width of the wave.



Part a) Show the hardware analog circuit
Part b) 0 to 90 deg is converted to Phase 0 to 10000 (0.009deg resolution).

```
unsigned short Phase;  // units of 360deg*250ns/10ms = 0.009 deg
unsigned short Rising; // TCNT at rising
void Init(void) {
  asm sei         // make atomic
  TIOS &=~0x80;   // clear bit 7
  DDRT &=~0x80;   // PT7 is input capture
  TSCR1 =0x80;    // enable
  TSCR2 =0x00;    // 250 ns clock
  TCTL3|=0xC0;    // Both edges IC7
  TIE |= 0x80;    // arm IC7
  TFLG1 = 0x80;   // clear C7F
  Rising = TCNT;  // first measurement may be wrong
  asm cli
}
```

Part c) Show the interrupt service routine(s) that measure phase.

```
void interrupt 15 TC7handler(void){
  if(PTT&0x80){    // PT7=1 if rising
    Rising = TC7;  // Setup for next
  }
  else{
    Phase = TC7-Rising; // measurement resolution 0.009 deg
  }
  TFLG1 = 0x80;   // ack, clear C7F
```

```
}
```

(10) Question 8. From the problem description

Δ**U** = 2500 (duty-units)

From the graph

L = 1 second

R = (10000-5000)/(2-1) = 5000 (period-units/sec)

It is recommended to run PI controllers with Δ**t** = 0.1**L = 0.1sec**.

K_P = 0.9 ΔU/(**L***R) = 0.9 * 2500/(1*5000) = **0.45**

K_I = K_P /(3.33L) **= 0.135**

E(n) = `Desired` - `Period`

P(n) = K_P*E(n) = 0.45*E(n) = (9*E(n))/20

I(n) = I(n-1) + K_I*E(n)* Δt = I(n-1) + 0.135*E(n) = I(n-1) + (27*E(n)/200)

Duty = U(n) = P(n) + I(n)

Putting together, and simplifying

E = Desired – Period;
P = (9*E)/20;
I = I + (27*E/200);
Duty = P + I;

(20) Question 9. A detailed solution will not be given because this problem will become a lab assignment. No major changes are required to the existing Lab17 code. The basic idea is to implement **fork()** as a software interrupt call. This will push all the registers on the stack. The SWI handler will

Allocate a block to be used for a new TCB
Copy all the data from the running TCB to the new TCB
Generate a new ID and set the ID field of the new TCB
Adjust the SaveSP field to point to the new stack of the new TCB
Link the new TCB into the circular linked list
Set the value on the New TCB so RegD returns 0
Set the value on the running TCB so RegD returns the ID of the new thread