Jonathan W. Valvano May 16, 2000, 9 am to 12 noon

**(10) Question 1.** The first error component is due to the finite DAC resolution. The DAC resolution is the range (5V) divided by the precision ($2^n$), $\Delta = 5/2^n$. Therefore the maximum error (in V) at that time is $\Delta/2$ or $5/2^{n+1}$. The other error arises from the DAC output rate. If the desired signal has a slope of **m**, it will change by $\mathbf{m}/\mathbf{f_s}$ during the interval between periodic interrupts. The worse case occurs when $5/2^{n+1}$ and $\mathbf{m}/\mathbf{f_s}$ have the same sign, therefore

$$\mathbf{e_{max}} = 5/2^{n+1} + \mathbf{m}/\mathbf{f_s}$$

**(30) Question 2.** Design a pulse width measurement system with a range of 10ms to 50s and a resolution of 10ms. You may use any of the PORTT input capture, output compare features, but you MUST USE interrupt synchronization. Assume the digital signal is connected to PT0. You need not worry about pulse width too small, but you need to check for overflow, i.e., if the pulse-width is longer than 50s, then an error condition must be set.

**(10) Part a)** Design the user-level device driver prototypes. You will need to define initialization, and measurement functions. In particular, give the *.H header file, including documentation. This file contains the public functions and public data structures. This section will be graded on style.

```
#define TOOBIG -1
#define WAIT 0
#define BUSY 1
#define DONE 2
void PulseMeasInit(void); // initialize, start measurements
short PulseMeasStatus(void){; // 0 waiting for rise, +1 busy counting, +2 done, -1 toobig
unsigned short PulseMeasResult(void); // return last measurement, 1 to 50000 ms, restart next
/* example usage
void main(void){ unsigned short data;
    PulseMeasInit():  // start measurements
    while(1){         // infinite loop
      if(PulseMeasStatus()==TOOBIG){
          OutString("error\n);
          PulseMeasInit():  // restart measurements
      }
      if(PulseMeasStatus()==DONE){
          data=PulseMeasResult():  // get and continue measurements
          OutString("PW = "); OutUDec(data); OutString(" ms\n);
      }
     // other stuff
} */
```

**(20) Part b)** This software contains the implementation and is protected from the user.

```
short theStatus;     // 0 waiting for rise, +1 busy counting, +2 done, -1 toobig
unsigned short cnt;  // number of 10ms intervals in this pulse
unsigned short PW;   // measured pulse width in 10 ms units
#define resolution 10000
#pragma interrupt_handler TC1handler()
void TC1handler(void){
    TFLG1= 0x02;         // Acknowledge
    TC1=TC1+resolution;  // every 10 ms
    if(thestatus==BUSY){ // currently measuring
        Cnt++;
        if(Cnt>50000U){
            PW=50000U;
            theStatus=TOOBIG;
        }
    }
}
#pragma interrupt_handler TC0handler()
void TC0handler(void){
    TFLG1=0x01;             // ack, clear C0F
    if(PORTT&0x01){         // rising interrupt
        if(thestatus==WAIT){ // currently waiting
            thestatus=BUSY;  // now start counting
            Cnt=0;
        }
    }
    else{                   // falling edge interrupt
```

```
        if(thestatus==BUSY){ // currently counting
            thestatus=DONE;  // now finished
            PW=Cnt;
        }
    }
}
void PulseMeasInit(void){ // initialize, start measurements
    asm(" sei");    // make atomic
    TIOS| = 0x01;   // enable OC1
    TSCR  = 0x80;   // enable
    TMSK2 = 0x33;   // 1 us clock
    TFLG1 = 0x03;   // Clear C1F,C0F
    TMSK1 = 0x03;   // Arm OC1 and IC0
    TCTL4 |= 0x03;  // both edges */
    TC1=TCNT+resolution;
    thestatus=WAIT; // first look for rising edge
    asm(" cli"); }
short PulseMeasStatus(void){ // 0 waiting for rise, +1 busy counting, +2 done, -1 toobig
    return theStatus;
}
unsigned short PulseMeasResult(void){ // 1 to 50000 ms
    thestatus=WAIT; // first look for rising edge
    return PW;
}
```

**(40) Question 3**. In this problem, you will design a 6812-based ohmmeter.

(5) Part a) The measurement resolution is 1000/256 = 3.9 Ω.

(5) Part b) A sampling rate of 2 Hz satisfies the Nyquist Theorem. I choose 2 Hz to improve the LPF approach to removing 60 Hz noise.

(5) Part c) Since 60 Hz does not exist in the frequencies of interest, the best way in this system to eliminate 60 Hz noise pickup is to use an analog LPF. A 10 Hz LPF will pass 0 to 1 Hz, but reject 60 Hz and its harmonics.

(15) Part c) The first Op Amp creates the 1 mA constant current across R. The instrumentation amp provides a high input impedence gain=5 amplifier, and the LPF at 10 Hz prevents aliasing and removes 60 Hz.

1) select the cutoff frequency, $f_c$ = 10 Hz

2) divide the two capacitors by $2\pi f_c$

$C_{1A} = 141.4\mu F/2\pi f_c = 141.4\mu F/(2\pi 10) = 2.25\ \mu F$

$C_{2A} = 70.7\mu F/2\pi f_c = 70.7\mu F/(2\pi 10) = 1.125\ \mu F$

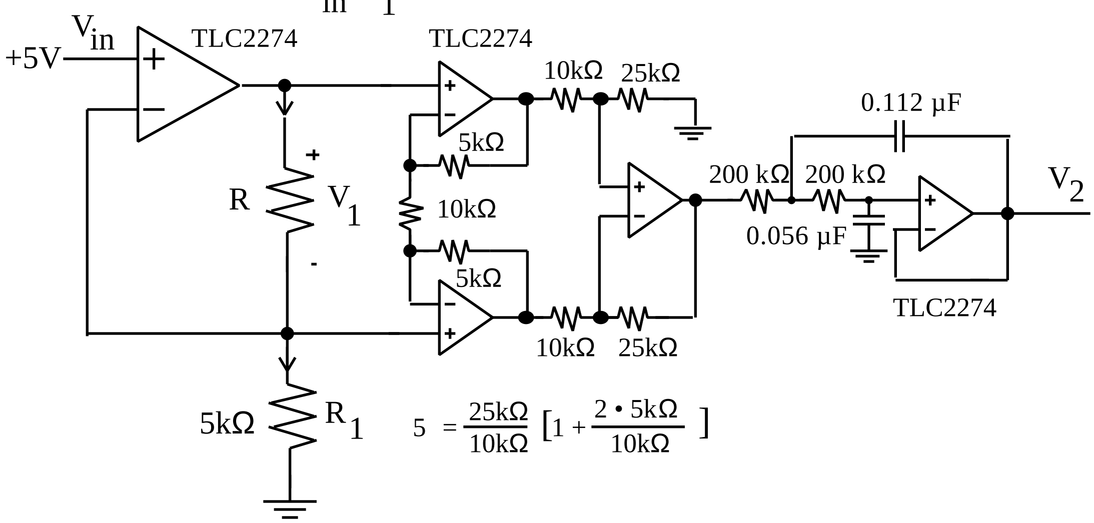
3) resistance scale to get R= 200 kΩ. let x =20

$R = 10\ k\Omega \bullet x$

$C_{1B} = C_{1A}/x = 2.25/20\ \mu F = 0.112\ \mu F$

$C_{2B} = C_{2A}/x = 1.125/20\ \mu F = 0.056\ \mu F$

$I = V_{in}/R_1 = 5V/5k\Omega = 1\ mA$



(5) Part e) Show the ritual that initializes the system.
(5) Part f) Show the interrupt service routine that samples the ADC and calculates resistance in Ω.

```
#define OC5 0x20
unsigned short R;   // resistance measurement in ohms
unsigned short cnt; // used to count interrupts to create 2 Hz sampling
void ritual(void){
asm(" sei");      // make atomic
  TIOS|=OC5;      // enable OC5
  TSCR|=0x80;     // enable
  TMSK2=0x35;     // 4 us clock
  TMSK1|=OC5;     // Arm output compare 5
  cnt= 0;
  TFLG1=OC5;      // Initially clear OC5F
  TC5=TCNT+25000; // First one in 100 ms
  ATDCTL2 = 0x80; // Activate ADC
  ATDCTL5=0;      // Start A/D, channel 0
  asm(" cli"); }
#pragma interrupt_handler TC5handler()
void TC5handler(void){
  TFLG1=OC5;              // Ack interrupt
  TC5=TC5+25000;          // Executed every 100 ms
  if((++cnt) == 5){
     cnt=0;               // start over
     R=(ADR0H*125+16)>>5; // 1000/256=125/32
     ATDCTL5=0;           // Start A/D for next time, channel 0
  }
}
```

**(20) Question 4**. Consider the 8K RAM MC68HC812A4/60L64 interface presented in Section 9.7.2.
(10) Part a) For a read cycle, the terms that matter are $t_{AVQV}$ and $t_{E1LQV}$

| | | | |
|---|---|---|---|
| Address | $60 + t_{AVQV} \le 125 - 30$ | so | $t_{AVQV} \le 35$ |
| E1 | $60 + t_{E1LQV} \le 125 - 30$ | so | $t_{E1LQV} \le 35$ |

For a write cycle, the term that matters is the setup $t_{DVWH}$

| | | | |
|---|---|---|---|
| data setup | $106 \le 125+10-t_{DVWH}$ | so | $t_{DVWH} \le 29$ |

(10) Part b) For a read cycle, again the terms that matter are $t_{AVQV}$ and $t_{E1LQV}$

| | | | |
|---|---|---|---|
| Address | $60 + 150 \le t_1 - 30$ | so | $t_1 \ge 240$ |
| E1 | $60 + 150 \le t_1 - 30$ | so | $t_1 \ge 240$ |

For a write cycle, the term that matters is the setup $t_{DVWH}$

| | | | |
|---|---|---|---|
| data setup | $106 \le t_1+10-60$ | so | $t_1 \ge 156$ |

The read cycle is the worst case, so $t_1 \ge 240$