

ECE 376 - Homework #6

A/D Converters, Chi-Squared Test

A/D Converters

- 1) Use your PIC board along with your thermistor to measure resistance and temperature.
 - Take an A/D reading every 1 second
 - Display the raw A/D reading, the computed resistance, and the computed temperature on the LCD display

Assume the resistance-temperature of the thermistor in your lab kit is

$$R = 2000 \cdot \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right) \Omega$$

(as a check, the resistance at room temperature should be close to 2000 Ohms (25C). If not, you might have a 1k or 10k thermistor in your lab kit (change the formula accordingly).

Give your resulting C code and compiled code size.

Code:

```
// Main Routine

void main(void)
{
    int A2D;
    float VOLT, X, CELSIUS, OHM;
    unsigned int i, j;

    TRISA = TRISD = TRISC = TRISE = 0;
    TRISB = 0xFF;
    ADCON1 = 0x0F;

    LCD_Init(); // initialize the LCD

    LCD_Move(0,0); for (i=0; i<20; i++) LCD_Write(MSG0[i]);
    Wait_ms(500);

    LCD_Inst(0x01);

    // Initialize the A/D port
    TRISA = 0xFF;
    TRISE = 0x0F;
    ADCON2 = 0x85;
    ADCON1 = 0x07;
    ADCON0 = 0x01;
    i = 0;

    // Initialize Serial Port to 9600 baud
    TRISC = TRISC | 0xC0;
    TXIE = 0;
    RCIE = 0;
    BRGH = 0;
    BRG16 = 1;
    SYNC = 0;
    SPBRG = 255;
    TXSTA = 0x22;
    RCSTA = 0x90;
```

```

while(1) {

    A2D = A2D_Read(1);
    VOLT = 0.488 * A2D;
    OHM = 1000.0 * (A2D / (1023.0 - A2D) );
    // remove the 100k
    OHM = 1 / (1/OHM - 1/100000.0);

    X = log( OHM / 2000.0 );
    X = X + 3905.0 / 298.0;
    CELSIUS = 3950.0 / X - 273.0;

    LCD_Move(0,0); LCD_Out(A2D, 4, 0);
    LCD_Move(0,8); LCD_Out(VOLT, 3, 2);
    LCD_Move(1,0); LCD_Out(OHM*10, 5, 1);
    LCD_Move(1,8); LCD_Out(CELSIUS*100, 4, 2);

    SCI_Out(VOLT, 5, 2);
    SCI_Out(OHM, 4, 0);
    SCI_Out(CELSIUS*100, 4, 2);
    SCI_CRLF();

    Wait_ms(1000);

}
}

```

Compilation Results

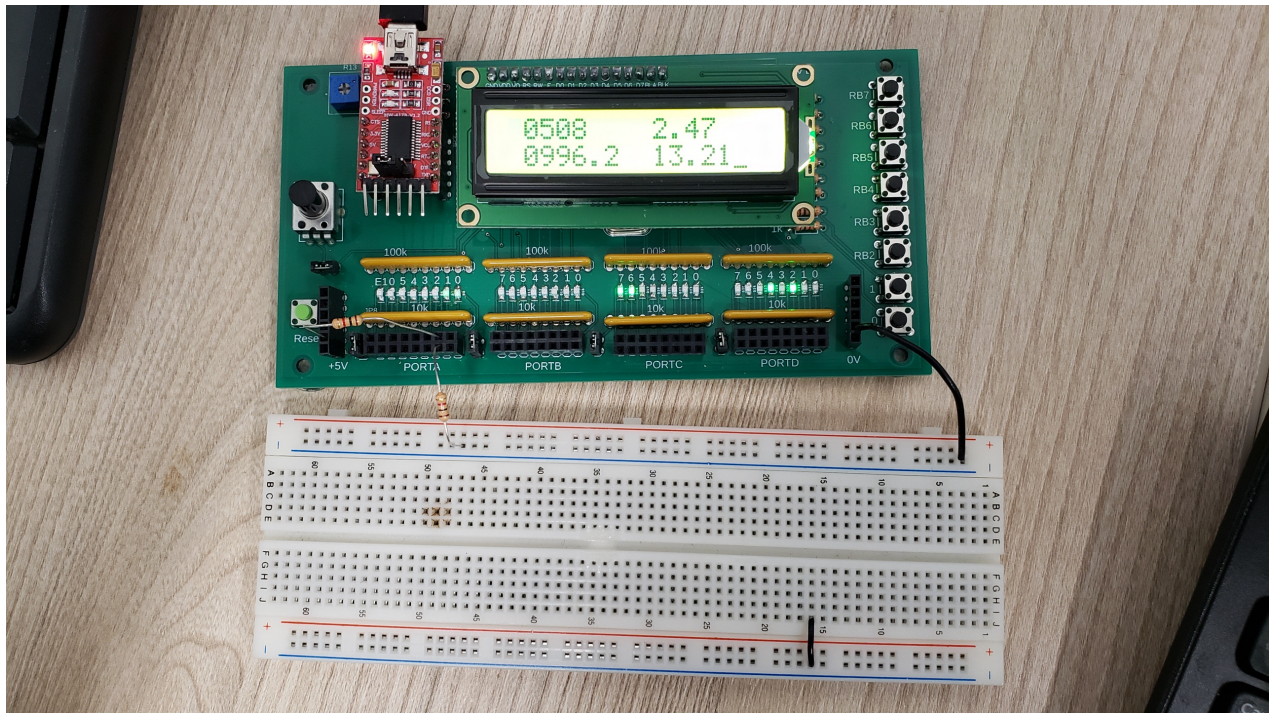
Memory Summary:

Program space	used	1EC6h (7878)	of 10000h bytes	(12.0%)
Data space	used	43h (67)	of F80h bytes	(1.7%)
EEPROM space	used	0h (0)	of 400h bytes	(0.0%)
ID Location space	used	0h (0)	of 8h nibbles	(0.0%)
Configuration bits	used	0h (0)	of 7h words	(0.0%)

2) Check the accuracy of your resistance meter

- Replace R2 with a known resistor in the range of 100 to 10k Ohms
- Find the measured value or R
- Compare the measured value vs. the marked value (or actual resistance if you have an ohm-meter)

R	Multimeter Ohms	PIC Board Ohms	% Error
1k	996.6	996.2	-0.04
330	329.6	329.6	0
100	99.36	97.7	-1.67
3.3k	3,249	3,225.7	-0.72



3) Using a thermistor, measure the temperature of four different items

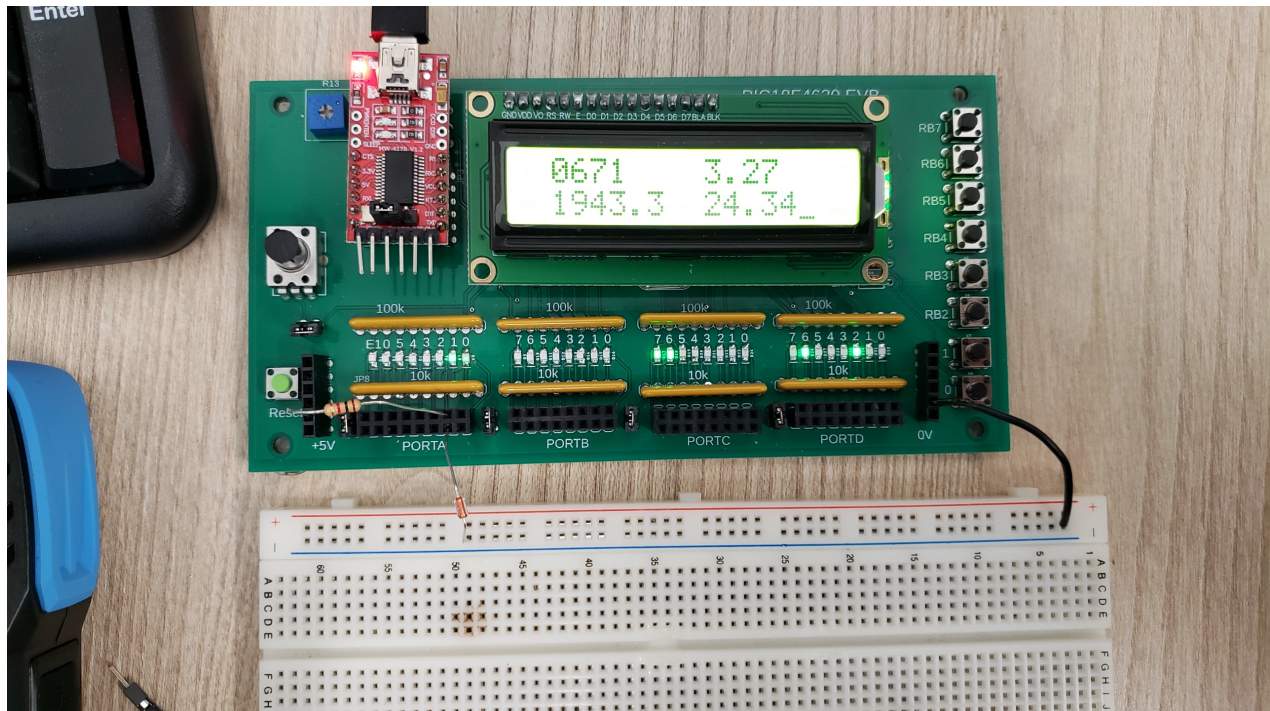
- Replace R2 with your thermistor
- Record the raw A/D reading, the computed resistance, and the computed temperature

Room Temperature:

- $R = 2003 \text{ Ohms}$
- It's probably a 2k thermistor

$$R = 2000 \cdot \exp\left(\frac{3905}{T+273} - \frac{3905}{298}\right) \Omega$$

	Ohms	Degrees C
hot water	1,539	34.04C
room temp	1,943.3	24.34C
cold water	2,365.3	21.23C
damp towel	2,457.6	20.39C



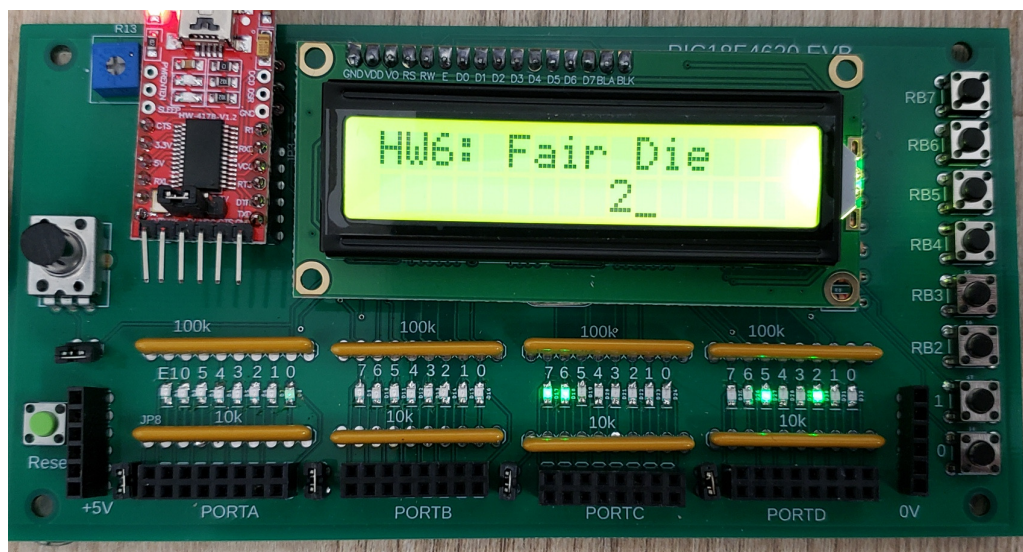
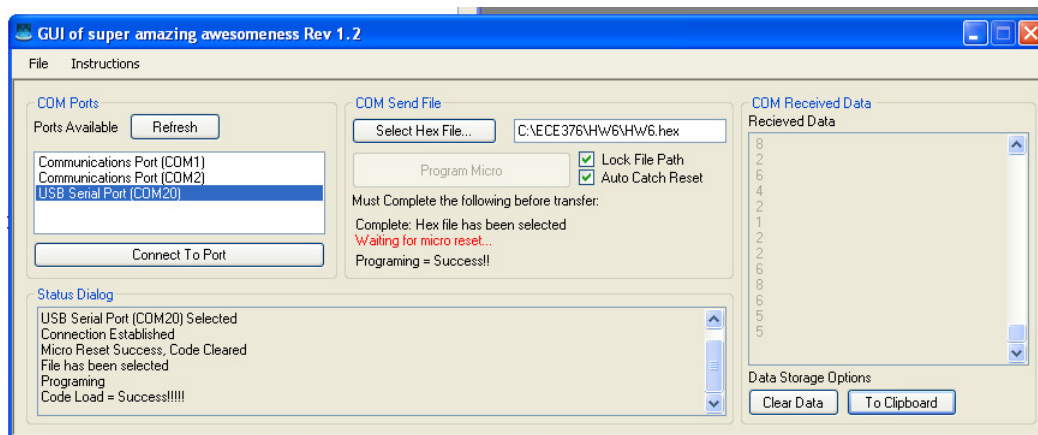
Chi-Squared Test - Fair Die

The following code implements a fair 8-sided die

```
while(1) {  
    while(!RB0);  
    while(RB0) {  
        d8 = (d8 + 1) % 8;  
    }  
    d8 = d8 + 1;  
    LCD_Move(1,8); LCD_Out(d8, 1, 0);  
    SCI_Out(d8, 1, 0);  
    SCI_CRLF();  
}
```

4) Collect data for the fair 8-sided die. From your data, what is the probability that the die is fair?

Push RB0 a bunch of times created random die rolls - which show up in the COM Received Data window



The results are

Roll	1	2	3	4	5	6	7	8
N	14	15	21	17	17	19	17	18

Do a chi-squared test to see if this data is consistent with a uniform distribution

Roll	p	np	N	chi-squared
1	1 / 8	17.38	14	0.66
2	1 / 8	17.38	15	0.32
3	1 / 8	17.38	21	0.76
4	1 / 8	17.38	17	0.01
5	1 / 8	17.38	17	0.01
6	1 / 8	17.38	19	0.15
7	1 / 8	17.38	17	0.01
8	1 / 8	17.38	18	0.02
Total				1.94

Fair Die

From StatTrek, a chi-squared value of 1.94 with seven degrees of freedom (eight bins) gives a probability of 0.03691 There is a 3.6% chance that this is a loaded die (no conclusion)

- Enter value for degrees of freedom.
- Enter a value for one, and only one, of the other textboxes.
- Click **Calculate** to compute a value for the remaining textbox.

Degrees of freedom

7

Chi-square value (x)

1.94

Probability: $P(\chi^2 \leq 1.94)$

0.03691

Probability: $P(\chi^2 \geq 1.94)$

0.96309

Calculate

Chi-Squared Test - Loaded Die

The following code implements a fair 8-sided die (the number 1 should come up 3/17 of the time rather than 2/16).

```
while(1) {
    while(!RB0);
    while(RB0) {
        d8 = (d8 + 1) % 17;
    }
    d8 = (d8 % 8) + 1;
    LCD_Move(1,8); LCD_Out(d8, 1, 0);
    SCI_Out(d8, 1, 0);
    SCI_CRLF();
}
```

5) Collect data for the loaded 8-sided die. From your data, what is the probability that the die is fair?

Roll	1	2	3	4	5	6	7	8
N	23	13	13	16	10	8	15	13

Determine the chi-squared value

Roll	p	np	N	chi-squared
1	1 / 8	13.88	23	6
2	1 / 8	13.88	13	0.06
3	1 / 8	13.88	13	0.06
4	1 / 8	13.88	16	0.33
5	1 / 8	13.88	10	1.08
6	1 / 8	13.88	8	2.49
7	1 / 8	13.88	15	0.09
8	1 / 8	13.88	13	0.06
Total				10.15

From StatTrek, a chi-squared value of 10.15 with seven degrees of freedom corresponds to a probability of 0.81977

There is an 81.97% chance that the die is loaded

(no conclusion)

- Enter value for degrees of freedom.
- Enter a value for one, and only one, of the other textboxes.
- Click **Calculate** to compute a value for the remaining textbox.

Degrees of freedom

Chi-square value (x)

Probability: $P(\chi^2 \leq 10.15)$

Probability: $P(\chi^2 \geq 10.15)$

Calculate

6) How loaded does the die have to be for you to be able to reliably detect that something is amiss?

Assume

- 100 rolls
- two bins (1 and 2-7)
- 95% chance of detection (chi-squared = 3.84180)

Roll	p	np	N	chi-squared
1	0.13	12.5	$12.5 + x$	$0.08 \cdot x^2$
2-7	0.88	87.5	$87.5 - x$	$0.0114 \cdot x^2$
Total				$0.0914 \cdot x^2$

or

$$0.0914 \cdot x^2 = 3.84180$$

$$x = 6.48$$

You can have an extra six 1's and get away with it (6% loading)

Another way to analyze this is to use eight bins and assume equal distribution of the missing values

Roll	p	np	N	chi-squared
1	1 / 8	12.5	$12.5 + x$	$0.08 x^2$
2	1 / 8	12.5	$12.5 - x/7$	$0.0016 x^2$
3	1 / 8	12.5	$12.5 - x/7$	$0.0016 x^2$
4	1 / 8	12.5	$12.5 - x/7$	$0.0016 x^2$
5	1 / 8	12.5	$12.5 - x/7$	$0.0016 x^2$
6	1 / 8	12.5	$12.5 - x/7$	$0.0016 x^2$
7	1 / 8	12.5	$12.5 - x/7$	$0.0016 x^2$
8	1 / 8	12.5	$12.5 - x/7$	$0.0016 x^2$
Total				$0.0914 x^2$

From StatTrek, 95% probability of detection with seven dof corresponds to a chi-squared score of 14.06

$$0.0914x^2 = 14.06$$

$$x = 12.40$$

You can have 12 extra 1's and get away with it (12% loading)

Am I Psychic?

7) Going back to the fair 8-sided die...

- Predict what number is going to come up, then roll the die.
- Count the number of times you're right and wrong.

Use a chi-squared test to determine if you're just guessing ($p = 1/8$) or if you're psychic.

Results;

- 30 trials
- Correct 5 times
- Incorrect 25 times

Finding the chi-squared score:

Roll	p	np	N	chi-squared
Correct	1/8	3.75	5	0.42
Incorrect	7/8	26.25	25	0.06
Total				0.48

From StatTrek, a chi-squared score of 0.48 with one dof corresponds to a probability of 0.51

- There's a 51% chance I'm not just guessing (I'm psychic)

- Enter value for degrees of freedom.
- Enter a value for one, and only one, of the other textboxes.
- Click **Calculate** to compute a value for the remaining textbox.

Degrees of freedom

1

Chi-square value (x)

0.48

Probability: $P(\chi^2 \leq 0.48)$

0.51158

Probability: $P(\chi^2 \geq 0.48)$

0.48842

Calculate

