DESIGNING A SENSING UNIT OF A SENSOR NODE

By

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FINAL REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

Dr Norhisham Hamid
(Project Supervisor)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Noreen Syazlin Binti Mohamad Sharip

ABSTRACT

The main objective of this project is to design a sensing unit of a sensor node. Sensor Node is a device that using sensors to gather information and do analysis of data gathered from where it being distributed. Distribution of a set of sensor nodes in a particular area is called as sensor network. Sensing Unit is one of the basic components in a sensor node and its design consideration is very important since it served as the front-end of a particular sensor node. In this project, two sensors will be used which are temperature sensor and humidity sensor to collect data. The methodology of this project includes the collection of data from the sensors, implementation on the microcontroller as the main brain system and the use of LCD and LED to show and verify outputs. Laboratory experiments have been conducted to test the sensors. The data collected than been manipulated in the C Program for the microcontroller to produce usable output which in LCD Display and LED for the binary readout. As a conclusion, the whole project is to design a complete prototype of a typical sensing unit based on the constraints available.

ACKNOWLEDGEMENTS

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Last but not least, special thanks to my colleagues who willing to share their knowledge in helping me to proceed whenever the project get stuck in the middle of the project development.

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CHAPTER 1
INTRODUCTION

Sensing Unit is a very important part of a sensor node. Before going into further discussion regarding the sensing unit design in this project, sensor network and its relation with sensor node are introduced. In the problem statement, few design performance issues is discussed and last but not least are the objectives and scope of study for this project.

1.1 Background of Study

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors called as sensor nodes. WSN play an important role in data gathering and analysis especially from remote or dangerous locations persist.

The importance of sensor networks is highlighted by the number of recent funding initiatives, including the DARPA SENSIT program, military programs, and NSF Program Announcements. Sensing technologies and sensor networks area of study is now considered by international funding agencies such as the European Commission, DARPA and NSF to be one of the top five emerging technologies that will shape the future of human kind and have a major impact on the quality of life over the next 20 years [1].

Although the development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance, however, nowadays wireless sensor networks are used in many other applications such as environment and habitat monitoring, healthcare applications, home automation and traffic control.

In all the application above, a set of sensor nodes are distributed in the sensor field. This set of sensor nodes is the basic component of a sensor network. It is also called as *mote* that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network.

For different application, each sensor node has a certain area of coverage, which it can reliably and accurately report the particular quantity that it is observing. Spatial density of sensor nodes of a sensor network in the field may be as high as 20 nodes/m^2.

A sensor node is composed of four basic components, which are a *sensing unit*, a *processing unit*, a *communication unit* and a *power unit* [2]. The typical architecture of sensor node is shown in Figure 1.

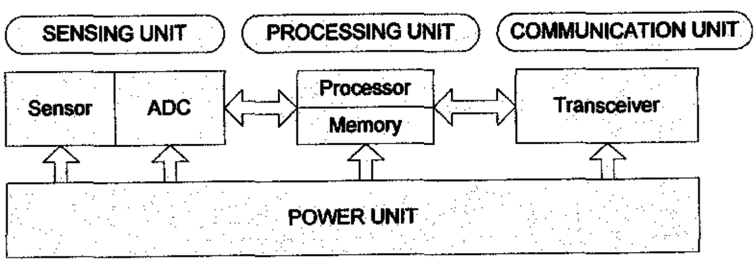

Figure 1: Typical Sensor Node Architecture

The processing unit is usually associated with an embedded operating system, a microcontroller and a storage part. It manages data acquisition, analyzes the raw sensing data and formulates answers to specific user requests. It also controls the communication and performs a wide variety of application specified tasks. Typical design requirement for processing components are energy efficiency and cost.

The transceiver connects the sensor node to the network. Usually each of the sensor nodes has the capability to transmit data to and receive data from another node and the sink. A transceiver is the most power-consuming component of the node.

The power unit delivers power to all the working parts of the node. Because of the limited capacity of the power unit, e.g. the limited lifetime of a battery, the development of the power unit itself and the design of a power saving working mode of the sensor network remain some of the most important technical issues. For some applications, a solar battery may be used.

On the other hand, sensing unit play a key role in a sensor node which it is the very front-end connecting the physical world to the sensor network. As shown in Figure 2, sensing unit is made up of sensors and ADC (Analog to Digital Converter).

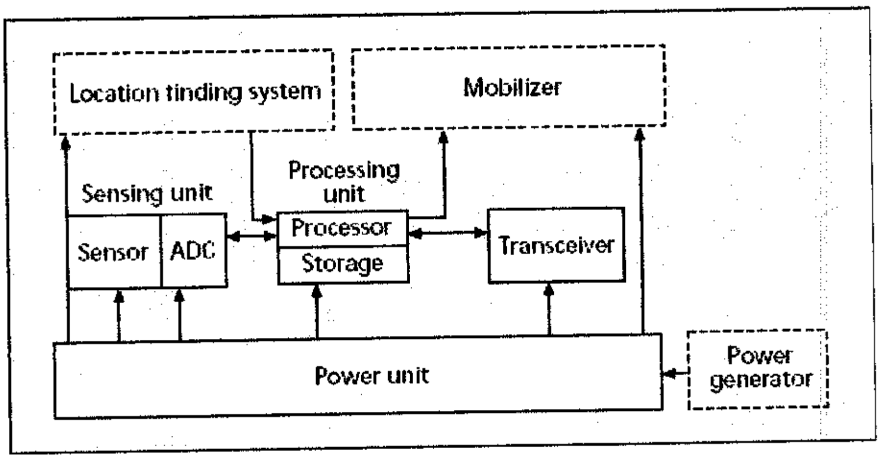

Figure 2: Sensing Unit Components

1.2 Problem Statement

Research on sensor node architecture is currently undertaking to tackle some of the technical issues in order to build a multifunction sensor with a high performance. The main concerns to be solved are the *low power consumption* and *high reliability* design of a sensor node. Other research at the hardware level is concerned pertaining the appropriate dimensions and weight so that they can be randomly dispersed possibly from an aircraft [4].

Therefore in this project design, the main concerns are to design low power consumption and a reliable sensing unit. Although transceiver or communication unit is the most power-consuming component of the sensor node as discussed earlier, it is always better to design a reliable sensing unit with low power consumption.

1.3 Objectives

The objective of the project is to design a complete prototype of sensing unit that will be able to:

1) Monitor and collect data of environmental variables, which are *temperature* and *humidity* by using sensors
2) Capture outputs from the sensors to be transferred to the analog-to-digital converter as inputs
3) Convert analog signals (temperature and humidity) to digital signals (binary data) for processing unit
4) Implement the model of sensing unit using physical components

1.4 Scope of Study

The scope of study focuses on the basic components and specifications of the sensing unit in a sensor node. The prototype designed must meet the requirement of a sensing unit of a particular sensor node for a particular application.

There are various types of application of sensor network that has been discussed in the earlier section. For the purpose of the project, the scope is focuses on the environmental monitoring application which measure the physical parameter; *temperature* and *humidity*.

CHAPTER 2
LITERATURE REVIEW

This chapter will introduce the overview of sensor network, basic structure of a sensor node and theory related to the sensing unit. Theory applied in designing the sensing unit is also discussed.

2.1 Overview of Sensor Network and Sensor Node

History of development of sensor nodes dated back to 1998 in Smartdust project [2]. One of the objectives of this project is to create autonomous sensing and communication in a cubic millimeter [6]. Though this project ended earlier on, it has given birth to more research projects. They are Berkeley NEST and CENS. The researchers involved in this project coined the term 'mote' to refer to a sensor node.

In the NEST Project at Berkeley, they are developing open experimental software/hardware Platform for Network Embedded Systems Technology research that will accelerate the development of algorithms, services, and their composition into challenging applications dramatically. Small, networked sensor nodes are developed to ground algorithmic work in the reality of working with numerous, highly constrained devices.

2.2 Basic Structure of Sensing Unit

Generally, for any sensing unit of any type of sensor node with different application, the basic structure of the sensing unit is shown in Figure 3.

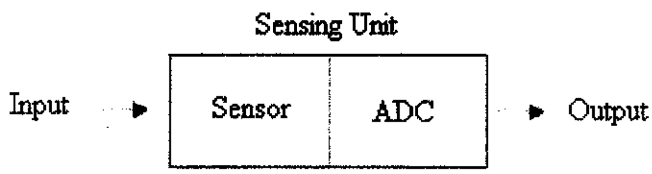

Figure 3: Basic Structure of Sensing Unit

However, Signal Conditioning block is added between the sensors and ADC, which act as an intermediate stage between the captured output from the sensor and the input to the ADC. As clearly label in the Figure 4, the input and output characteristics from each block is different. Details about each block will be discussed in the next section respectively.

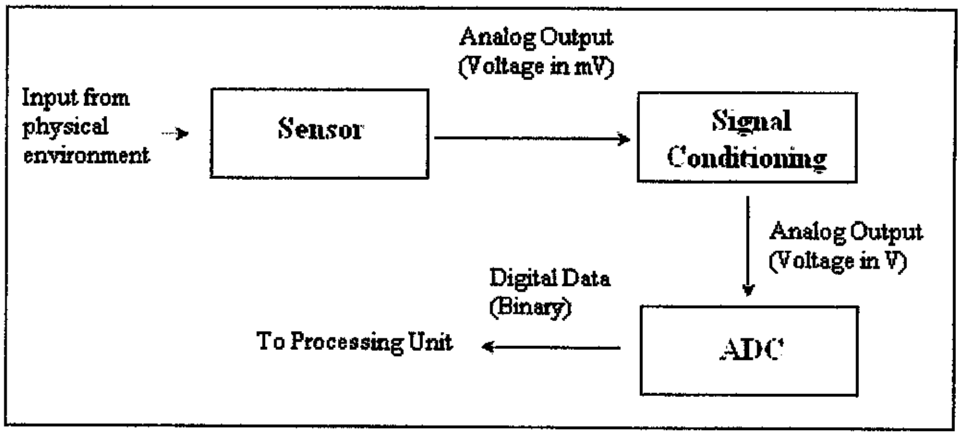

Figure 4: Architecture of Sensing Unit

2.2.1 Sensors

Sensor is a device that converts a signal or stimulus into an electrical signal. Sensors become important tools to measure physical properties such as temperature, pressure, humidity and etc. However, since they are various types of sensors available in the market nowadays, selecting the appropriate sensor is not always easy. This depends on factors such as the ranges, required accuracy, environment, speed of response, ease of use, cost, interchangeability and so on. Table 1 below shows the comparison of temperature sensors [5].

Table 1: Comparison of temperature sensors [5]

Sensor	Advantages	Disadvantages
Thermocouple	Wide Operating Range Low cost Rugged	Non-linear Low sensitivity Reference junction compensation required Subject to electrical noise
RTD	Linear Wide Operating Range High Stability	Slow response time Expensive Current source required Sensitive to shock
Thermistor	Fast response Time Low cost Small size Large change in resistance vs temperature	Non linear Current source required Limited Operating Range Not easily interchangeable without re-calibration
Integrated Circuit	Highly Linear Low cost Digital Output sensors can be directly connected to a microprocessor without and A/D converter	Limited operating range Voltage or current source required Self heating errors Not good thermal coupling with the environment

RTDs, thermistors and semiconductor sensors require an external power supply. This external power can cause the sensor to heat, causing the effect of the self heating. These types of sensors shall not be use in the project since it will contribute to more power consumption which opposes our design objectives.

Therefore, thermocouple is chosen to be used in this project since it does not suffer self heating and its disadvantages can be minimally eliminated in the design project. Details of the thermocouple are tabulated in Table 2.

Table 2: Thermocouple Details

Thermocouple Type	K
Range	-50 to 400°C
Accuracy	<400°C ± 3°C
Probe	TP-02A

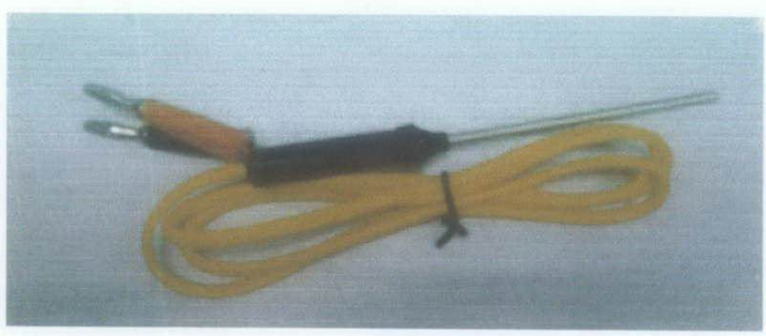

Figure 5: Thermocouple

There are several ways to describe the temperature-voltage relationship of thermocouples which are using:

- Thermocouple References Table
- Power Series Method
- Linear Approximation

In this project, linear approximation method will be used to describe the temperature-voltage relationship of the thermocouple. This method can be used to represent most thermocouples over limited temperature ranges. The linear approximation method applies the equation stated below which V is the thermocouple voltage, s is the slope, T is the temperature and b is the offset voltage.

$$V = sT + b \qquad (1)$$

The offset voltage for all thermocouples is equal to zero. The slope can be determined from the required operating range. Over the temperature range of 0 to 50°C, the averaged Seeback Coefficients can be used as the slope. Table 3 shows the Seeback Coefficients for each type of thermocouple.

Table 3: Seeback Coefficients

Type	µV/°C
K	40.46
J	51.71
T	40.69
E	60.93
B	0.05
S	6.02
R	5.93

From Table 3, the slope is 40.46µ since thermocouple type K is used. Therefore, the equation now for the thermocouple used in this project is,

$$V = (40.46e-6)T \qquad (2)$$

Next sensor that will be used is the humidity sensor that will sense humidity. Humidity Sensor is a device consisting of a special plastic material which its electrical characteristics change according to the amount of humidity in the air. Basically it is a sensor that senses the amount of water vapor in air.

In this project humidity sensor, HSM-20G as shown in Figure 6 will be used to sense relative humidity within the range of 20% to 60% RH.

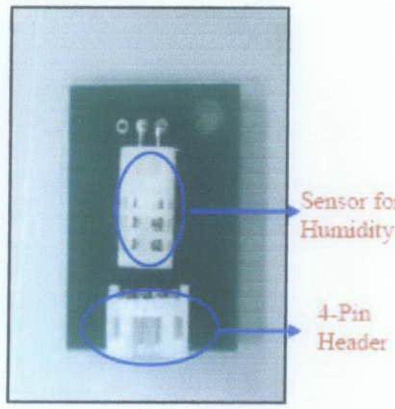

Figure 6: HSM-20G Humidity Sensor

This humidity sensor is chosen to be used in the project because of the features offered by this product which are:

- Analog voltage output
- Small in size
- Compatible with all type of microcontrollers
- High sensitivity to humidity in the air

Figure 7 shows the typical response of HSM-20G at temperature of 25°C and standard characteristics of RH-voltage relationship are described in Table 4.

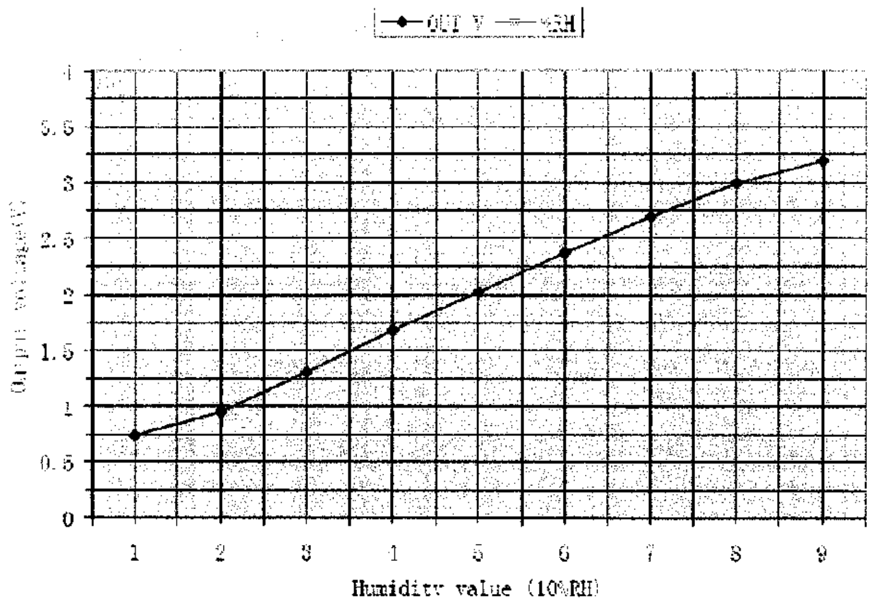

Figure 7: Humidity Value Vs Output Voltage

Table 4: RH-Voltage Relationship

%RH	10	20	30	40	50	60	70	80	90
Output Voltage	0.74	0.95	1.31	1.68	2.02	2.37	2.69	2.99	3.19

2.2.2 Signal Conditioning

Outputs for most sensors (passive or active) are relatively small voltages, currents, or resistance changes, and therefore their outputs must be properly conditioned before further analog or digital processing can occur [3]. Regardless of type of sensors and transducers used, the proper signal conditioning can improve the quality and performance of the measurement.

"Conditioning" of a signal basically means to manipulate a signal in such a way that it meets the requirements of the next stage for further processing. Fundamental signal conditioning functions that may be required includes *amplification, level translation, galvanic isolation, impedance transformation, linearization* and *filtering*.

For thermocouple, signal conditioning requirement that need to be consider in this project are amplification, filtering for electrical noise and cold junction compensation. However, there is no need signal conditioning for humidity sensor since its output voltage is big enough to be used in ADC.

Because real world signals are often very small in magnitude, signal conditioning can improve the accuracy of the data collected by amplification. Amplifiers boost the level of the input signal to better match the range of the analog to digital converter (ADC), thus increasing the resolution and the sensitivity of the measurement. In addition, amplification does improve the signal-to-noise ratio of the measurement before it is affected by environmental noise.

For amplification, amplifier and resistors are used to achieve appropriate gain. In this project, a non-inverting amplifier is chosen to amplify the signal as shown in Figure 8. The required amplifier gain is approximately 1235. Therefore the resistors value is chosen to achieve the required gain which can be determined by the following equation.

$$\frac{Vout}{Vin} = \frac{Rf}{Rin} + 1 \qquad (3)$$

$$Rs = Rf \,//\, Rin \qquad (4)$$

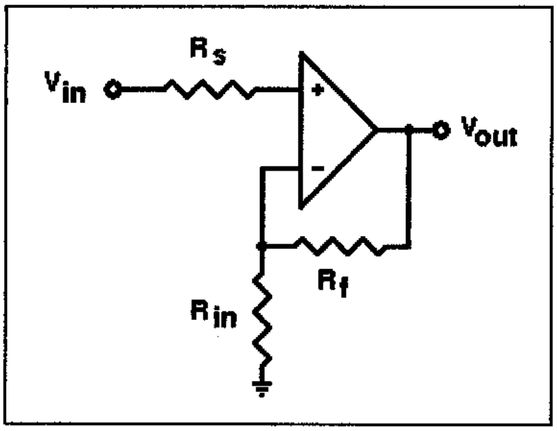

Figure 8: Non-Inverting Amplification Circuit

2.2.3 Analog to Digital Converter (ADC)

A large number of physical devices generate output signals that are analog or continuous variables in nature. For digital processing, as it is a requirement for a sensing unit to send digital signals to processing unit in the same sensor node, the input signal must be converted into a binary form of ones and zeros. This can be achieved by using analog to digital converter (ADC or A/D).

In this project, ADC that will be used is the one which is embedded in the PIC microcontroller. The Analog-to-Digital (A/D) Converter has five inputs for the 28-pin devices and eight for the other devices.

The analog input charges a sample and hold capacitor. The output of the sample and hold capacitor is the input into the converter. The converter then generates a digital result of this analog level via successive approximation.

The ADC in this PIC has a 10-bit resolution. When an incoming voltage is measure, the voltage will be compare to a reference voltage and the comparison is represented as a 10-bit number (0 – 1023).

Only the analog pins of the PIC are attached to the ADC which labels as AN0, AN1, AN2 until AN7 as shown in Figure 9.

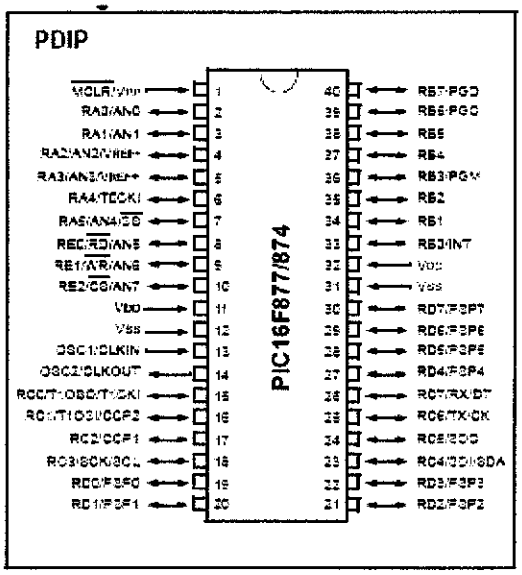

Figure 9: PIC Pin Diagram

In this project, two analog inputs will be used represent analog voltage from sensors used which are thermocouple and humidity sensor, HSM-20G. Therefore AN0 and AN1 will be used as analog inputs for thermocouple and HSM-20G respectively.

2.3 Display Unit

In order to verify outputs, display unit which consists of LCD Display and LEDs are used. LCD Display is used to display current temperature/humidity and voltage produced by the respective temperature/humidity. On the other hand, LEDs will be used to show the binary readout of each input voltage applied to the analog inputs. This binary readout also shows the binary data that will be sent to processing unit. Figure 10 shows LCD Display that will be used in the project.

Figure 10: LCD Display

CHAPTER 3
METHODOLOGY

In this chapter, project methodology and activities will be elaborated based on the block diagram of this project which is divided to several partitions. Figure 11 shows the block diagram of the overall design of the sensing unit which consists of 2 sensors, signal conditioning circuit, PIC16F877 and outputs.

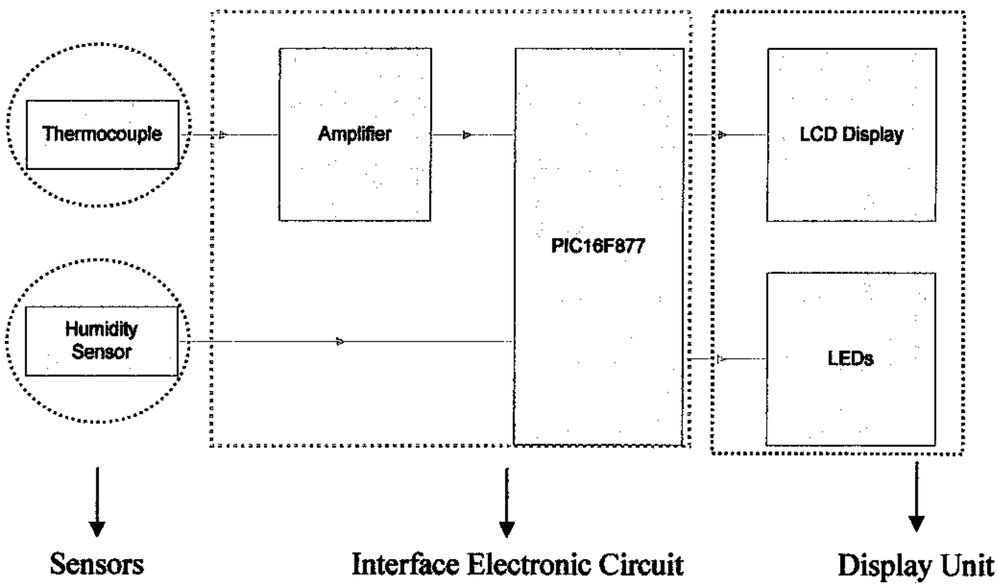

Figure 11: Block Diagram of Project

3.1 Procedure Identification

Table 5 shows the project planning starting from researches, design & simulation and until the hardware implementation stage.

Table 5: Project Planning

No	Tasks	Activities
1	Researches	1.1 Sensor - Study on the sensor characteristics - Sensor selection 1.2 Interface Electronic Circuit - Study on Signal Conditioning Requirement - Study on the PIC16F877 1.3 Display Unit - Prefer to use LEDs as output - Check on efficient way to verify output on LCD
2	Design & Simulation	2.1 Interface Electronic Circuit - Design and Simulate Signal Conditioning Circuit - Design and Simulate Program in PIC16F877 - Design and Simulate Display Circuit 2.2 PIC Program
3	Implementation	3.1 Fabricate Signal Conditioning Circuit (SCC) 3.2 Interface sensor, SCC and PIC16F877 3.3 Fabricate display circuit

3.2 Tools and Equipment

As shown in Table 6 and Table 7, these are the components used to fabricate the interface electronic circuit which include signal conditioning circuit and PIC circuit.

Table 6: List of Circuits used for Signal Conditioning Circuit

Component	Quantity
Amplifier (LM324N)	1
Resistor (100k)	1
Resistor (200k)	1
Resistor (1k)	2

Table 7: List of Components used for PIC Circuit

Component	Quantity
PIC 16F877	1
PIC Socket	1
Wire Cable PIC	1
Crystal Oscillator 4 MHz	1
Capacitor (33pF)	2
LED	8
Veraboard	1

List of Testing Equipments includes:

- Multimeter (to test sensor output)
- Oscilloscope (to observe waveforms)
- DC Power Supply (to power up circuit)
- Temperature Calibrator
- Industrial Thermometer

List of software used:

- PSPICE Students 9.1
- PIC Compiler

3.3 PIC Flowchart

The flowchart in Figure 12 shows the PIC algorithm in order to control inputs and outputs of the sensing unit prototype.

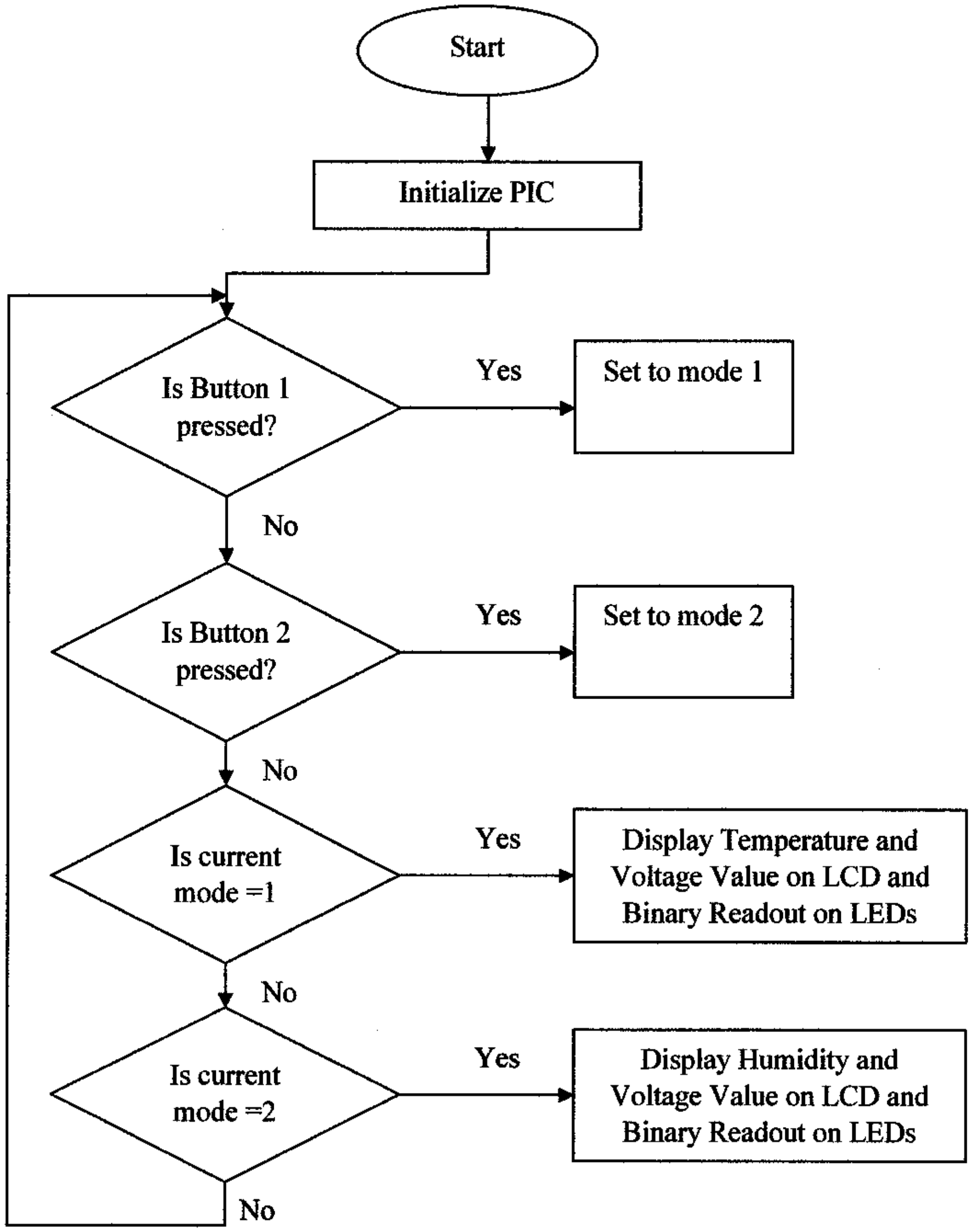

Figure 12: PIC Algorithm Flowchart

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Thermocouple

Thermocouple is been tested to check for the voltage produced when certain temperature is applied. In this testing, the probe of the thermocouple is inserted to the Temperature Calibrator as shown in Figure 13.

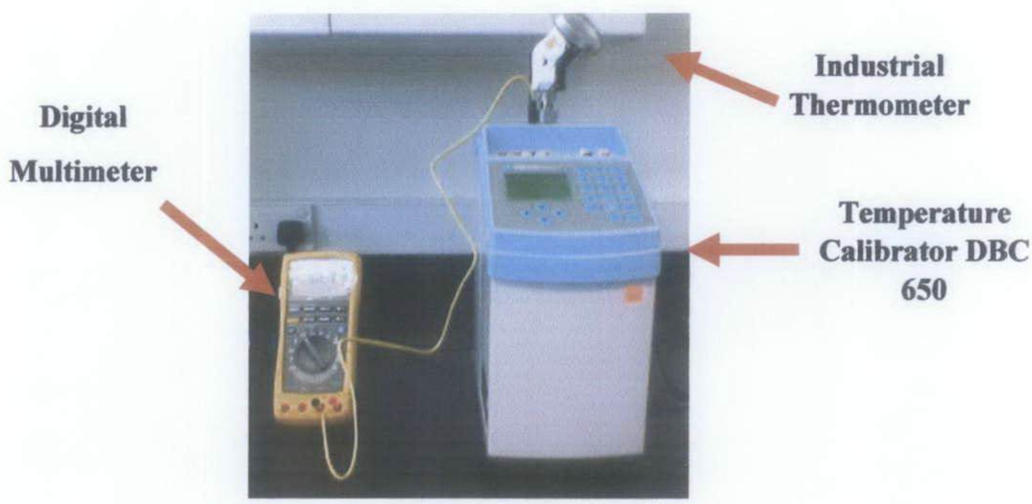

Figure 13: Thermocouple Experiment Setup

Different temperature value is applied and the resulting voltage output measured by the digital multimeter is recorded. Table 8 and Table 9 show the result of the two experiments done.

Table 8: Output Voltage for Thermocouple in Experiment 1

Temperature, T (°C)	Expected Voltage, V (mV)	Multimeter Reading for Experiment 1 (mV)
30	1.203	0.333
35	1.416	0.522
40	1.612	0.711
45	1.821	0.911
50	2.023	1.111

Table 9: Output Voltage for Thermocouple in Experiment 1

Temperature, T (°C)	Expected Voltage, V (mV)	Multimeter Reading for Experiment 2 (mV)
30	1.203	0.356
35	1.416	0.566
40	1.612	0.773
45	1.821	0.930
50	2.023	1.140

From the experiment done, it shows that output voltage from the multimeter reading for both experiments is not the same as the expected voltage. The differences are shown in Table 10 and Table 11.

Table 10: Comparison Table for Experiment 1

Expected Voltage (mV)	Experiment 1 (mV)	Error (mV)
1.203	0.333	0.870
1.416	0.522	0.894
1.612	0.711	0.901
1.821	0.911	0.910
2.023	1.111	0.912

Table 11: Comparison Table for Experiment 2

Expected Voltage (mV)	Experiment 2 (mV)	Error (mV)
1.203	0.356	0.847
1.416	0.566	0.850
1.612	0.773	0.839
1.821	0.930	0.891
2.023	1.140	0.883

For both experiment, the average differences is given by 0.8797 mV. This error happens due to the effect of the cold junction of the thermocouple.

A thermocouple operates on the principle that the junction of two dissimilar metals generates a voltage that varies with temperature. When thermocouple is connected to the terminals, it creates another junction (called as reference junction/cold junction) which produces their own voltages. Thus, it will give errors to the reading.

Thus, the final measured voltage shall include both the thermocouple and the cold junction voltages. This method which called as cold junction compensation is used to compensate for these unwanted cold-junction voltage.

The average differences voltage is actually the cold junction voltage. The cold junction voltage is 0.8797 mV and the cold junction temperature is 21.74°C which is approximately the room temperature (20 to 24 °C). Thus, the actual voltage, V produced by the thermocouple is described in Equation (6).

$$V = Vmeasured + Vcoldjunction \qquad (5)$$

Based on the Equation (5), change is then applied to Equation (2) and the new equation is described in Equation (6).

$$Vmeasured + Vcoldjunction = (40.46e - 6)T \qquad (6)$$

4.2 Simulation

A signal conditioning circuit in Figure 14 for the thermocouple is designed and simulated using PSPICE Student 9.1. The input voltage, V1 is the representation of the thermocouple output which gives 42.46μV per 1°C.

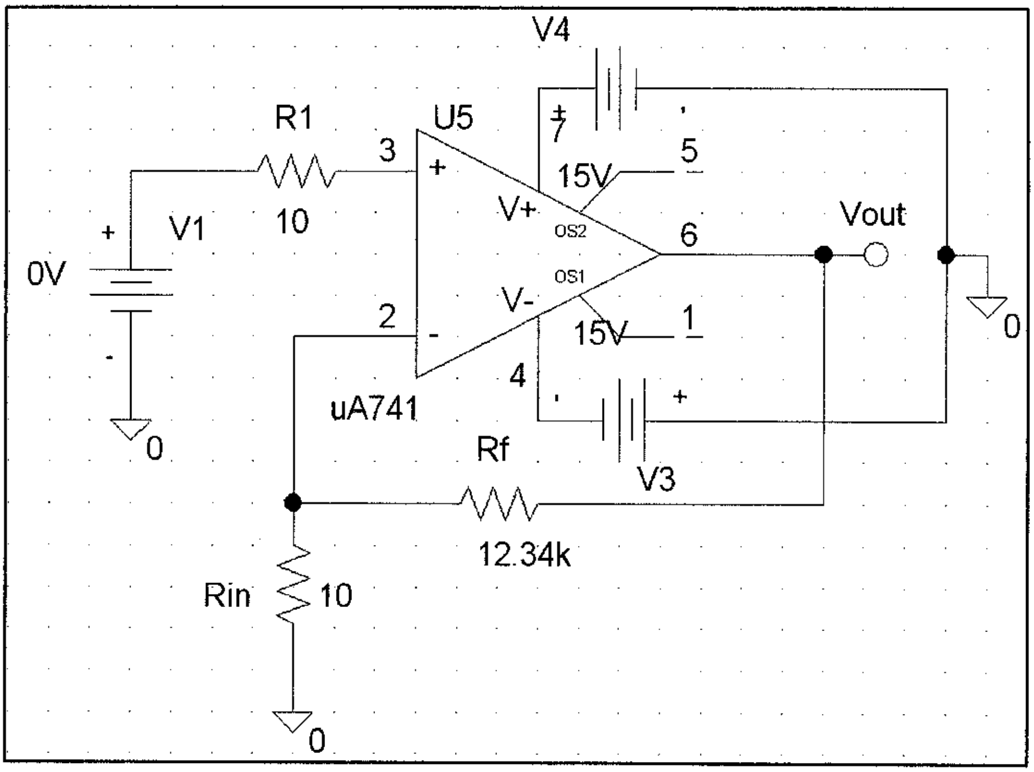

Figure 14: Signal Conditioning Circuit

Input Voltage, V1 is applied from 0.3mV to 1.1mV to represent output voltage produced by the thermocouple. As discussed before, gain of approximately 67 is used to amplify the input voltage, V1. Table 12 shows the amplified voltage given an input voltage where it applies Equation (4).

Table 12: Amplification Result

Temperature, T (°C)	Input Voltage, Vin (mV)	Amplified Voltage, Vout (V)
30	0.3	0.3705
35	0.6	0.7410
40	0.8	0.9880
45	0.9	1.1115
50	1.1	1.3585

The result of the simulation is shown in Figure 15. As observed in the simulation graph below, the output of the amplifier circuit is the same as the data tabulated in Table 12.

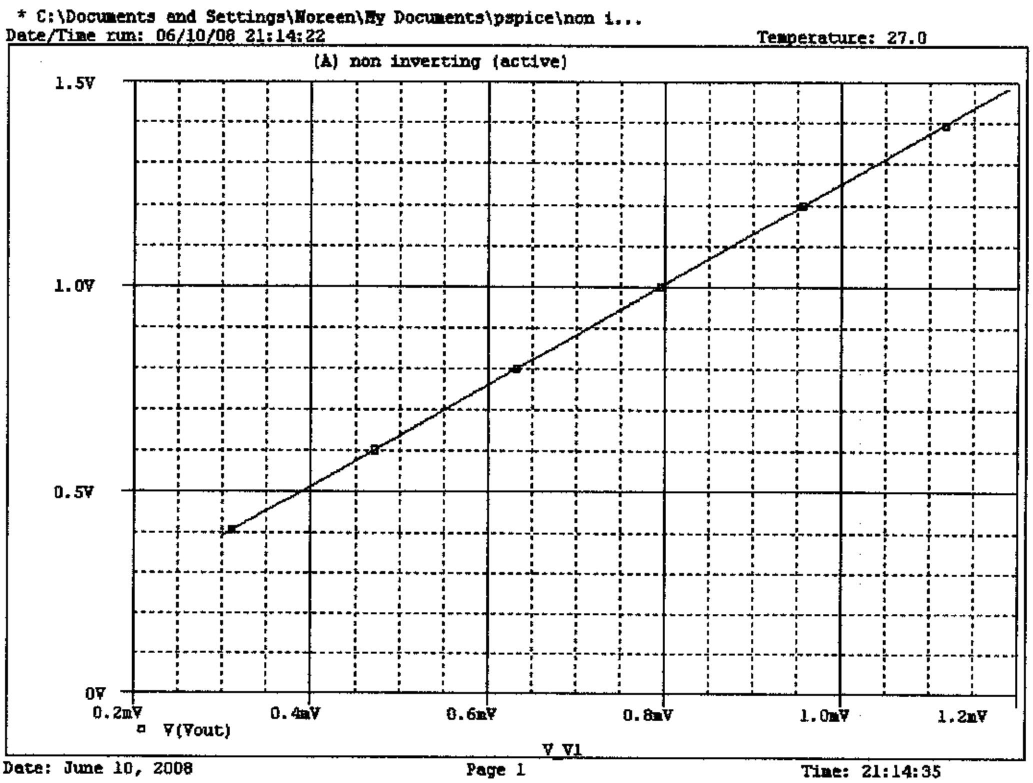

Figure 15: Thermocouple Output Voltage vs Input Voltage

From the performance characteristics in Figure 14, it shows variation of output voltage with respect to changes in input voltage in mV which is practically applied. It shows that as input voltage increases the output voltage also increases and this change is linear. This satisfied the signal conditioning criteria which is to achieve linearization and amplification between the input and output of the thermocouple.

4.3 LED (Binary Readout) Testing

LED is been tested to check for the output produced whenever certain voltage is applied at pin number 2 (AN0) of the PIC16F877. In this testing, the voltage is applied by using the power supply as shown in Figure 13.

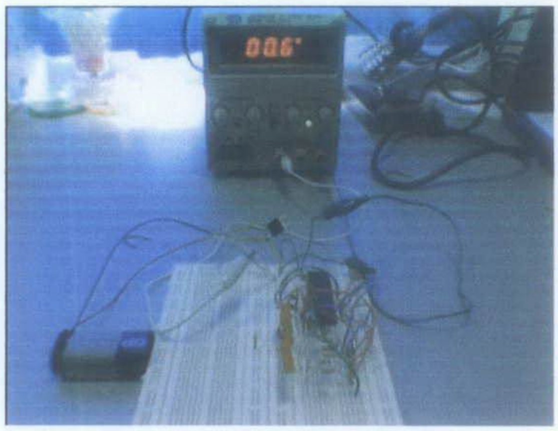

Figure 16: Experiment Setup for LED Testing

Voltage applied in this experiment ranging from 0V to 5V with step voltage 0.5V. When certain voltage is applied to the analog input port, LED must show the corresponding binary value done by the ADC of the PIC16F877. Figure 17 shows how LEDs respond when such a voltage applied.

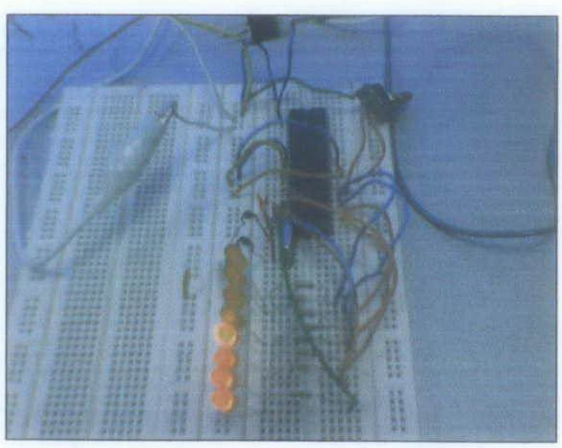

Figure 17: Result of LED Testing

Table 13 summarizes the output of the LED when certain temperature is applied. The corresponding voltage for every experiment is obtained by looking at the appendix F.

Table 13: LED Output

Voltage (V)	Binary Readout (LEDs)			
	Experiment 1	Corresponding Voltage (V)	Experiment 2	Corresponding Voltage (V)
0	0000 0000	0.0	0000 0000	0.0
1.0	0010 1111	0.9216	0010 1111	0.9216
1.5	0100 1111	1.5490	0100 1001	1.4314
2.0	0110 0011	1.9412	0110 0011	1.9412
2.5	0111 1111	2.4902	0111 1010	2.3922
3.0	1001 0111	2.9608	1001 0111	2.9608
3.5	1010 1111	3.4314	1010 1111	3.4314
4.0	1100 1011	3.9804	1100 1011	3.9804
4.5	1110 0111	4.5294	1110 0011	4.4510
5.0	1111 1111	5.0	1111 1111	5.0

From the table, it can be seen that for both experiments, binary readout of applied voltage 1.5V, 2.5V and 4.5V is not the same. Though, they still give the correct results.

This is due to the low sensitivity of the voltage applied from the power supply. Power supply used generates voltage with only one decimal place. The ADC of the PIC16F877 will give different results with any changes of voltage swing with 4 decimal places.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Sensing unit is a very important unit in a sensor node thus in a sensor network. Error in reading outputs from the sensor will cause error in the database of the sensor network system. In this project, only two constraints of environmental is measure which are temperature and humidity. Other types of environmental variables can be considered in the design such as pressure and etc.

Thus far, the sensors has been tested accept for HSM-20G which needs further attention since it is very sensitive. Though, assumption can be made to the analog input of the microcontroller PIC16F877 to test the C program.

The interface electronic circuits and display unit have been constructed and tested, but no signals are sent to LCD Display or in other words LCD Display did not display the result. This could be due to several reasons, including inappropriate design of C Program and failure of operation in any hardware used or connection in the circuits. Hence, some of the result may not be discussed.

5.2 Recommendation

For future recommendation, instead of using thermocouple, other non self-heating temperature sensors can be used for better measurement of temperature. Future researcher can tries to find alternative solution to replace better temperature sensors than thermocouple. On the other hand, other humidity sensor can be used to replace HSM-20G in measuring humidity. HSM-20G is chosen in this project because of it produce analog voltages and compatible with microcontroller.

In addition, more complex signal conditioning circuit can be added to modify the signal received from the thermocouple. As discussed before, signal conditioning can be more than amplification such as linearization and filtering for noise. More complex signal conditioning circuit can be designed so that data collected from the sensors may be more accurate.

Last but not least, the C program in the microcontroller can be further modified to do the PIC algorithm. More complicated C program can be used to manipulate the analog input to display output.

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APPENDIX A: SUGGESTED MILESTONE FOR THE FYP I

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12		13	14
1	Selection of Project Topic															
2	Preliminary Research Work															
3	Submission of Preliminary Report															
4	Project Work: Research & Design															
5	Submission of Progress Report															
6	Seminar 2 (compulsory)															
7	Project work continues: Simulation															
8	Submission of Draft Report															
9	Submission of Interim Report															
10	Oral Presentation (Study Week)															

Suggested Milestone

APPENDIX B: SUGGESTED MILESTONE FOR THE FYP II

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work: Hardware														
2	Submission of Progress Report 1														
3	Project Work Continue: Troubleshooting														
4	Submission of Progress Report 2														
5	Seminar (compulsory)														
6	Project work continue: Testing														
7	Poster Exhibition														
8	Submission of Dissertation (soft bound)														
9	Oral Presentation														
10	Submission of Project Dissertation (Hard Copy)														

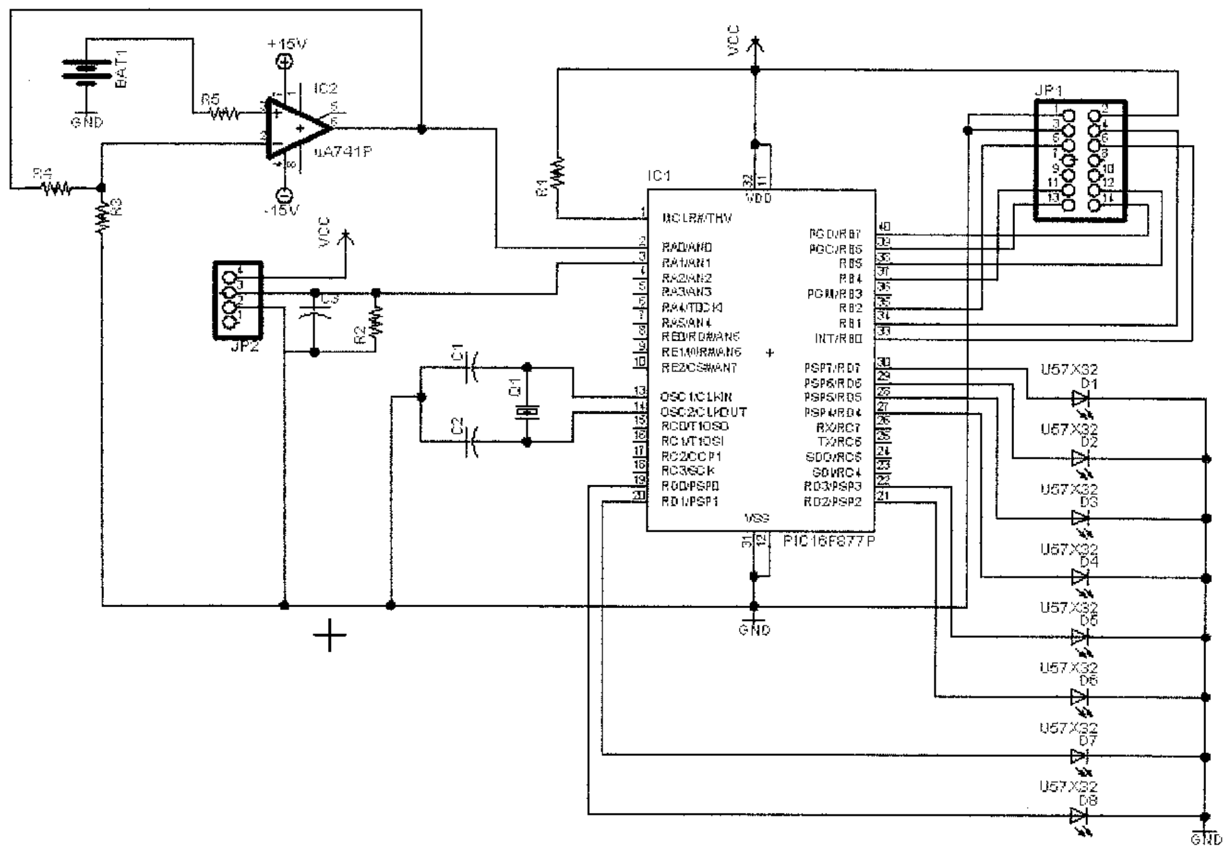
Suggested milestone

APPENDIX C: PIC 16F877 CODING

```
#include <16F877.h>
#device ADC=8
#fuses XT,NOWDT,NOPROTECT,NOPUT,NOBROWNOUT,NOLVP
#use delay (clock=4000000)
#include <LCD.C>

unsigned int8 value;
float adcValue;
float voltage;
float temp;
float humidity;


void main()
{
set_tris_d(0xf0);
set_tris_c(0x00);
setup_adc_ports(ALL_ANALOG);
setup_adc (ADC_CLOCK_INTERNAL);

while (1)
{
        if(input(pin_D4==1))
        {       output_d(0x01);
                set_adc_channel(0);

                delay_us(50);
                adcValue=read_adc();
                delay_us(50);
                voltage=5.000*adcValue/255.000;
                temp=(voltage/0.05)-21.74;
```

```
            lcd_init();
            lcd_putc('\f');
            lcd_gotoxy(1,1);
            printf(lcd_putc,"%f Celcius\n",temp);
            printf(lcd_putc,"%f V",voltage);

            value=adcValue;
            output_c(value);
        }
        else if(input(pin_D4==0))
        {
            output_d(0x02);
            set_adc_channel(1);

            delay_us(50);
            adcValue=read_adc();
            delay_us(50);
            voltage=5.000*adcValue/255.000;
            humidity=(voltage/0.05)-21.74;

            lcd_init();
            lcd_putc('\f');
            lcd_gotoxy(1,1);
            printf(lcd_putc,"%f RH\n",humidity);
            printf(lcd_putc,"%f V",voltage);

            value=adcValue;
            output_c(value);
        }
    }
    delay_ms(2000);
    }
```

APPENDIX D: PROJECT SCHEMATIC



APPENDIX E: PROTOTYPE

APPENDIX F: TABLE OF BINARY READOUT

np	Input Voltage V	Gain Required	Analog Voltage V	ADC (8 bits)								Decimal
.00	0.0000000	0.0000000	0	0	0	0	0	0	0	0	0	0
.39	0.0000159	1235.7884330	0.0196	0	0	0	0	0	0	0	1	1
.78	0.0000317	1235.7884330	0.0392	0	0	0	0	0	0	1	0	2
.18	0.0000476	1235.7884330	0.0588	0	0	0	0	0	0	1	1	3
.57	0.0000635	1235.7884330	0.0784	0	0	0	0	0	1	0	0	4
.96	0.0000793	1235.7884330	0.0980	0	0	0	0	0	1	0	1	5
.35	0.0000952	1235.7884330	0.1176	0	0	0	0	0	1	1	0	6
.75	0.0001111	1235.7884330	0.1373	0	0	0	0	0	1	1	1	7
.14	0.0001269	1235.7884330	0.1569	0	0	0	0	1	0	0	0	8
.53	0.0001428	1235.7884330	0.1765	0	0	0	0	1	0	0	1	9
.92	0.0001587	1235.7884330	0.1961	0	0	0	0	1	0	1	0	10
.31	0.0001745	1235.7884330	0.2157	0	0	0	0	1	0	1	1	11
.71	0.0001904	1235.7884330	0.2353	0	0	0	0	1	1	0	0	12
.10	0.0002063	1235.7884330	0.2549	0	0	0	0	1	1	0	1	13
.49	0.0002221	1235.7884330	0.2745	0	0	0	0	1	1	1	0	14
.88	0.0002380	1235.7884330	0.2941	0	0	0	0	1	1	1	1	15
.27	0.0002539	1235.7884330	0.3137	0	0	0	1	0	0	0	0	16
.67	0.0002697	1235.7884330	0.3333	0	0	0	1	0	0	0	1	17
.06	0.0002856	1235.7884330	0.3529	0	0	0	1	0	0	1	0	18
.45	0.0003015	1235.7884330	0.3725	0	0	0	1	0	0	1	1	19
.84	0.0003173	1235.7884330	0.3922	0	0	0	1	0	1	0	0	20
.24	0.0003332	1235.7884330	0.4118	0	0	0	1	0	1	0	1	21
.63	0.0003491	1235.7884330	0.4314	0	0	0	1	0	1	1	0	22
.02	0.0003649	1235.7884330	0.4510	0	0	0	1	0	1	1	1	23
.41	0.0003808	1235.7884330	0.4706	0	0	0	1	1	0	0	0	24
.80	0.0003967	1235.7884330	0.4902	0	0	0	1	1	0	0	1	25
.20	0.0004125	1235.7884330	0.5098	0	0	0	1	1	0	1	0	26
.59	0.0004284	1235.7884330	0.5294	0	0	0	1	1	0	1	1	27
.98	0.0004443	1235.7884330	0.5490	0	0	0	1	1	1	0	0	28
.37	0.0004601	1235.7884330	0.5686	0	0	0	1	1	1	0	1	29
.76	0.0004760	1235.7884330	0.5882	0	0	0	1	1	1	1	0	30
.16	0.0004919	1235.7884330	0.6078	0	0	0	1	1	1	1	1	31
.55	0.0005077	1235.7884330	0.6275	0	0	1	0	0	0	0	0	32
.94	0.0005236	1235.7884330	0.6471	0	0	1	0	0	0	0	1	33
.33	0.0005395	1235.7884330	0.6667	0	0	1	0	0	0	1	0	34
.73	0.0005553	1235.7884330	0.6863	0	0	1	0	0	0	1	1	35
.12	0.0005712	1235.7884330	0.7059	0	0	1	0	0	1	0	0	36
.51	0.0005871	1235.7884330	0.7255	0	0	1	0	0	1	0	1	37
.90	0.0006029	1235.7884330	0.7451	0	0	1	0	0	1	1	0	38
.29	0.0006188	1235.7884330	0.7647	0	0	1	0	0	1	1	1	39
.69	0.0006347	1235.7884330	0.7843	0	0	1	0	1	0	0	0	40
.08	0.0006505	1235.7884330	0.8039	0	0	1	0	1	0	0	1	41
.47	0.0006664	1235.7884330	0.8235	0	0	1	0	1	0	1	0	42
.86	0.0006823	1235.7884330	0.8431	0	0	1	0	1	0	1	1	43
.25	0.0006981	1235.7884330	0.8627	0	0	1	0	1	1	0	0	44
.65	0.0007140	1235.7884330	0.8824	0	0	1	0	1	1	0	1	45
.04	0.0007299	1235.7884330	0.9020	0	0	1	0	1	1	1	0	46
.43	0.0007457	1235.7884330	0.9216	0	0	1	0	1	1	1	1	47
.82	0.0007616	1235.7884330	0.9412	0	0	1	1	0	0	0	0	48
.22	0.0007775	1235.7884330	0.9608	0	0	1	1	0	0	0	1	49

.61	0.0007933	1235.7884330	0.9804	0	0	1	1	0	0	1	0	50
.00	0.0008092	1235.7884330	1.0000	0	0	1	1	0	0	1	1	51
.39	0.0008251	1235.7884330	1.0196	0	0	1	1	0	1	0	0	52
.78	0.0008409	1235.7884330	1.0392	0	0	1	1	0	1	0	1	53
.18	0.0008568	1235.7884330	1.0588	0	0	1	1	0	1	1	0	54
.57	0.0008727	1235.7884330	1.0784	0	0	1	1	0	1	1	1	55
.96	0.0008885	1235.7884330	1.0980	0	0	1	1	1	0	0	0	56
.35	0.0009044	1235.7884330	1.1176	0	0	1	1	1	0	0	1	57
.75	0.0009203	1235.7884330	1.1373	0	0	1	1	1	0	1	0	58
.14	0.0009361	1235.7884330	1.1569	0	0	1	1	1	0	1	1	59
.53	0.0009520	1235.7884330	1.1765	0	0	1	1	1	1	0	0	60
.92	0.0009679	1235.7884330	1.1961	0	0	1	1	1	1	0	1	61
.31	0.0009837	1235.7884330	1.2157	0	0	1	1	1	1	1	0	62
.71	0.0009996	1235.7884330	1.2353	0	0	1	1	1	1	1	1	63
.10	0.0010155	1235.7884330	1.2549	0	1	0	0	0	0	0	0	64
.49	0.0010313	1235.7884330	1.2745	0	1	0	0	0	0	0	1	65
.88	0.0010472	1235.7884330	1.2941	0	1	0	0	0	0	1	0	66
.27	0.0010631	1235.7884330	1.3137	0	1	0	0	0	0	1	1	67
.67	0.0010789	1235.7884330	1.3333	0	1	0	0	0	1	0	0	68
.06	0.0010948	1235.7884330	1.3529	0	1	0	0	0	1	0	1	69
.45	0.0011107	1235.7884330	1.3725	0	1	0	0	0	1	1	0	70
.84	0.0011265	1235.7884330	1.3922	0	1	0	0	0	1	1	1	71
.24	0.0011424	1235.7884330	1.4118	0	1	0	0	1	0	0	0	72
.63	0.0011583	1235.7884330	1.4314	0	1	0	0	1	0	0	1	73
.02	0.0011741	1235.7884330	1.4510	0	1	0	0	1	0	1	0	74
.41	0.0011900	1235.7884330	1.4706	0	1	0	0	1	0	1	1	75
.80	0.0012059	1235.7884330	1.4902	0	1	0	0	1	1	0	0	76
.20	0.0012217	1235.7884330	1.5098	0	1	0	0	1	1	0	1	77
.59	0.0012376	1235.7884330	1.5294	0	1	0	0	1	1	1	0	78
.98	0.0012535	1235.7884330	1.5490	0	1	0	0	1	1	1	1	79
.37	0.0012693	1235.7884330	1.5686	0	1	0	1	0	0	0	0	80
.76	0.0012852	1235.7884330	1.5882	0	1	0	1	0	0	0	1	81
2.16	0.0013011	1235.7884330	1.6078	0	1	0	1	0	0	1	0	82
2.55	0.0013169	1235.7884330	1.6275	0	1	0	1	0	0	1	1	83
2.94	0.0013328	1235.7884330	1.6471	0	1	0	1	0	1	0	0	84
.33	0.0013487	1235.7884330	1.6667	0	1	0	1	0	1	0	1	85
.73	0.0013645	1235.7884330	1.6863	0	1	0	1	0	1	1	0	86
.12	0.0013804	1235.7884330	1.7059	0	1	0	1	0	1	1	1	87
.51	0.0013963	1235.7884330	1.7255	0	1	0	1	1	0	0	0	88
.90	0.0014121	1235.7884330	1.7451	0	1	0	1	1	0	0	1	89
5.29	0.0014280	1235.7884330	1.7647	0	1	0	1	1	0	1	0	90
.69	0.0014439	1235.7884330	1.7843	0	1	0	1	1	0	1	1	91
.08	0.0014597	1235.7884330	1.8039	0	1	0	1	1	1	0	0	92
.47	0.0014756	1235.7884330	1.8235	0	1	0	1	1	1	0	1	93
.86	0.0014915	1235.7884330	1.8431	0	1	0	1	1	1	1	0	94
7.25	0.0015073	1235.7884330	1.8627	0	1	0	1	1	1	1	1	95
7.65	0.0015232	1235.7884330	1.8824	0	1	1	0	0	0	0	0	96
8.04	0.0015391	1235.7884330	1.9020	0	1	1	0	0	0	0	1	97
.43	0.0015549	1235.7884330	1.9216	0	1	1	0	0	0	1	0	98
.82	0.0015708	1235.7884330	1.9412	0	1	1	0	0	0	1	1	99
9.22	0.0015867	1235.7884330	1.9608	0	1	1	0	0	1	0	0	100
9.61	0.0016025	1235.7884330	1.9804	0	1	1	0	0	1	0	1	101

.00	0.0016184	1235.7884330	2.0000	0	1	1	0	0	1	1	0	102
.39	0.0016343	1235.7884330	2.0196	0	1	1	0	0	1	1	1	103
.78	0.0016501	1235.7884330	2.0392	0	1	1	0	1	0	0	0	104
.18	0.0016660	1235.7884330	2.0588	0	1	1	0	1	0	0	1	105
.57	0.0016819	1235.7884330	2.0784	0	1	1	0	1	0	1	0	106
.96	0.0016977	1235.7884330	2.0980	0	1	1	0	1	0	1	1	107
.35	0.0017136	1235.7884330	2.1176	0	1	1	0	1	1	0	0	108
.75	0.0017295	1235.7884330	2.1373	0	1	1	0	1	1	0	1	109
.14	0.0017453	1235.7884330	2.1569	0	1	1	0	1	1	1	0	110
.53	0.0017612	1235.7884330	2.1765	0	1	1	0	1	1	1	1	111
.92	0.0017771	1235.7884330	2.1961	0	1	1	1	0	0	0	0	112
.31	0.0017929	1235.7884330	2.2157	0	1	1	1	0	0	0	1	113
.71	0.0018088	1235.7884330	2.2353	0	1	1	1	0	0	1	0	114
.10	0.0018247	1235.7884330	2.2549	0	1	1	1	0	0	1	1	115
.49	0.0018405	1235.7884330	2.2745	0	1	1	1	0	1	0	0	116
.88	0.0018564	1235.7884330	2.2941	0	1	1	1	0	1	0	1	117
.27	0.0018723	1235.7884330	2.3137	0	1	1	1	0	1	1	0	118
.67	0.0018881	1235.7884330	2.3333	0	1	1	1	0	1	1	1	119
.06	0.0019040	1235.7884330	2.3529	0	1	1	1	1	0	0	0	120
.45	0.0019199	1235.7884330	2.3725	0	1	1	1	1	0	0	1	121
.84	0.0019357	1235.7884330	2.3922	0	1	1	1	1	0	1	0	122
.24	0.0019516	1235.7884330	2.4118	0	1	1	1	1	0	1	1	123
.63	0.0019675	1235.7884330	2.4314	0	1	1	1	1	1	0	0	124
.02	0.0019833	1235.7884330	2.4510	0	1	1	1	1	1	0	1	125
.41	0.0019992	1235.7884330	2.4706	0	1	1	1	1	1	1	0	126
.80	0.0020151	1235.7884330	2.4902	0	1	1	1	1	1	1	1	127
.20	0.0020309	1235.7884330	2.5098	1	0	0	0	0	0	0	0	128
.59	0.0020468	1235.7884330	2.5294	1	0	0	0	0	0	0	1	129
.98	0.0020627	1235.7884330	2.5490	1	0	0	0	0	0	1	0	130
.37	0.0020785	1235.7884330	2.5686	1	0	0	0	0	0	1	1	131
.76	0.0020944	1235.7884330	2.5882	1	0	0	0	0	1	0	0	132
2.16	0.0021103	1235.7884330	2.6078	1	0	0	0	0	1	0	1	133
2.55	0.0021261	1235.7884330	2.6275	1	0	0	0	0	1	1	0	134
2.94	0.0021420	1235.7884330	2.6471	1	0	0	0	0	1	1	1	135
3.33	0.0021579	1235.7884330	2.6667	1	0	0	0	1	0	0	0	136
3.73	0.0021737	1235.7884330	2.6863	1	0	0	0	1	0	0	1	137
.12	0.0021896	1235.7884330	2.7059	1	0	0	0	1	0	1	0	138
.51	0.0022055	1235.7884330	2.7255	1	0	0	0	1	0	1	1	139
.90	0.0022213	1235.7884330	2.7451	1	0	0	0	1	1	0	0	140
5.29	0.0022372	1235.7884330	2.7647	1	0	0	0	1	1	0	1	141
5.69	0.0022531	1235.7884330	2.7843	1	0	0	0	1	1	1	0	142
6.08	0.0022689	1235.7884330	2.8039	1	0	0	0	1	1	1	1	143
6.47	0.0022848	1235.7884330	2.8235	1	0	0	1	0	0	0	0	144
6.86	0.0023007	1235.7884330	2.8431	1	0	0	1	0	0	0	1	145
7.25	0.0023165	1235.7884330	2.8627	1	0	0	1	0	0	1	0	146
7.65	0.0023324	1235.7884330	2.8824	1	0	0	1	0	0	1	1	147
8.04	0.0023483	1235.7884330	2.9020	1	0	0	1	0	1	0	0	148
8.43	0.0023641	1235.7884330	2.9216	1	0	0	1	0	1	0	1	149
8.82	0.0023800	1235.7884330	2.9412	1	0	0	1	0	1	1	0	150
9.22	0.0023959	1235.7884330	2.9608	1	0	0	1	0	1	1	1	151
9.61	0.0024117	1235.7884330	2.9804	1	0	0	1	1	0	0	0	152
0.00	0.0024276	1235.7884330	3.0000	1	0	0	1	1	0	0	1	153

.39	0.0024435	1235.7884330	3.0196	1	0	0	1	1	0	1	0	154
.78	0.0024593	1235.7884330	3.0392	1	0	0	1	1	0	1	1	155
.18	0.0024752	1235.7884330	3.0588	1	0	0	1	1	1	0	0	156
.57	0.0024911	1235.7884330	3.0784	1	0	0	1	1	1	0	1	157
.96	0.0025069	1235.7884330	3.0980	1	0	0	1	1	1	1	0	158
.35	0.0025228	1235.7884330	3.1176	1	0	0	1	1	1	1	1	159
.75	0.0025387	1235.7884330	3.1373	1	0	1	0	0	0	0	0	160
.14	0.0025545	1235.7884330	3.1569	1	0	1	0	0	0	0	1	161
.53	0.0025704	1235.7884330	3.1765	1	0	1	0	0	0	1	0	162
.92	0.0025863	1235.7884330	3.1961	1	0	1	0	0	0	1	1	163
.31	0.0026021	1235.7884330	3.2157	1	0	1	0	0	1	0	0	164
.71	0.0026180	1235.7884330	3.2353	1	0	1	0	0	1	0	1	165
5.10	0.0026339	1235.7884330	3.2549	1	0	1	0	0	1	1	0	166
5.49	0.0026497	1235.7884330	3.2745	1	0	1	0	0	1	1	1	167
5.88	0.0026656	1235.7884330	3.2941	1	0	1	0	1	0	0	0	168
6.27	0.0026815	1235.7884330	3.3137	1	0	1	0	1	0	0	1	169
6.67	0.0026973	1235.7884330	3.3333	1	0	1	0	1	0	1	0	170
7.06	0.0027132	1235.7884330	3.3529	1	0	1	0	1	0	1	1	171
7.45	0.0027291	1235.7884330	3.3725	1	0	1	0	1	1	0	0	172
7.84	0.0027449	1235.7884330	3.3922	1	0	1	0	1	1	0	1	173
8.24	0.0027608	1235.7884330	3.4118	1	0	1	0	1	1	1	0	174
8.63	0.0027767	1235.7884330	3.4314	1	0	1	0	1	1	1	1	175
9.02	0.0027925	1235.7884330	3.4510	1	0	1	1	0	0	0	0	176
9.41	0.0028084	1235.7884330	3.4706	1	0	1	1	0	0	0	1	177
9.80	0.0028243	1235.7884330	3.4902	1	0	1	1	0	0	1	0	178
0.20	0.0028401	1235.7884330	3.5098	1	0	1	1	0	0	1	1	179
0.59	0.0028560	1235.7884330	3.5294	1	0	1	1	0	1	0	0	180
0.98	0.0028719	1235.7884330	3.5490	1	0	1	1	0	1	0	1	181
1.37	0.0028877	1235.7884330	3.5686	1	0	1	1	0	1	1	0	182
1.76	0.0029036	1235.7884330	3.5882	1	0	1	1	0	1	1	1	183
2.16	0.0029195	1235.7884330	3.6078	1	0	1	1	1	0	0	0	184
2.55	0.0029353	1235.7884330	3.6275	1	0	1	1	1	0	0	1	185
2.94	0.0029512	1235.7884330	3.6471	1	0	1	1	1	0	1	0	186
3.33	0.0029671	1235.7884330	3.6667	1	0	1	1	1	0	1	1	187
3.73	0.0029829	1235.7884330	3.6863	1	0	1	1	1	1	0	0	188
4.12	0.0029988	1235.7884330	3.7059	1	0	1	1	1	1	0	1	189
4.51	0.0030147	1235.7884330	3.7255	1	0	1	1	1	1	1	0	190
4.90	0.0030305	1235.7884330	3.7451	1	0	1	1	1	1	1	1	191
75.29	0.0030464	1235.7884330	3.7647	1	1	0	0	0	0	0	0	192
75.69	0.0030623	1235.7884330	3.7843	1	1	0	0	0	0	0	1	193
76.08	0.0030781	1235.7884330	3.8039	1	1	0	0	0	0	1	0	194
76.47	0.0030940	1235.7884330	3.8235	1	1	0	0	0	0	1	1	195
76.86	0.0031099	1235.7884330	3.8431	1	1	0	0	0	1	0	0	196
77.25	0.0031257	1235.7884330	3.8627	1	1	0	0	0	1	0	1	197
77.65	0.0031416	1235.7884330	3.8824	1	1	0	0	0	1	1	0	198
78.04	0.0031575	1235.7884330	3.9020	1	1	0	0	0	1	1	1	199
78.43	0.0031733	1235.7884330	3.9216	1	1	0	0	1	0	0	0	200
78.82	0.0031892	1235.7884330	3.9412	1	1	0	0	1	0	0	1	201
79.22	0.0032051	1235.7884330	3.9608	1	1	0	0	1	0	1	0	202
79.61	0.0032209	1235.7884330	3.9804	1	1	0	0	1	0	1	1	203
80.00	0.0032368	1235.7884330	4.0000	1	1	0	0	1	1	0	0	204
80.39	0.0032527	1235.7884330	4.0196	1	1	0	0	1	1	0	1	205

78	0.0032685	1235.7884330	4.0392	1	1	0	0	1	1	1	0	206
18	0.0032844	1235.7884330	4.0588	1	1	0	0	1	1	1	1	207
57	0.0033003	1235.7884330	4.0784	1	1	0	1	0	0	0	0	208
96	0.0033161	1235.7884330	4.0980	1	1	0	1	0	0	0	1	209
35	0.0033320	1235.7884330	4.1176	1	1	0	1	0	0	1	0	210
75	0.0033479	1235.7884330	4.1373	1	1	0	1	0	0	1	1	211
14	0.0033637	1235.7884330	4.1569	1	1	0	1	0	1	0	0	212
53	0.0033796	1235.7884330	4.1765	1	1	0	1	0	1	0	1	213
92	0.0033955	1235.7884330	4.1961	1	1	0	1	0	1	1	0	214
31	0.0034113	1235.7884330	4.2157	1	1	0	1	0	1	1	1	215
71	0.0034272	1235.7884330	4.2353	1	1	0	1	1	0	0	0	216
10	0.0034431	1235.7884330	4.2549	1	1	0	1	1	0	0	1	217
49	0.0034589	1235.7884330	4.2745	1	1	0	1	1	0	1	0	218
88	0.0034748	1235.7884330	4.2941	1	1	0	1	1	0	1	1	219
27	0.0034907	1235.7884330	4.3137	1	1	0	1	1	1	0	0	220
67	0.0035065	1235.7884330	4.3333	1	1	0	1	1	1	0	1	221
06	0.0035224	1235.7884330	4.3529	1	1	0	1	1	1	1	0	222
45	0.0035383	1235.7884330	4.3725	1	1	0	1	1	1	1	1	223
84	0.0035541	1235.7884330	4.3922	1	1	1	0	0	0	0	0	224
24	0.0035700	1235.7884330	4.4118	1	1	1	0	0	0	0	1	225
63	0.0035859	1235.7884330	4.4314	1	1	1	0	0	0	1	0	226
02	0.0036017	1235.7884330	4.4510	1	1	1	0	0	0	1	1	227
41	0.0036176	1235.7884330	4.4706	1	1	1	0	0	1	0	0	228
80	0.0036335	1235.7884330	4.4902	1	1	1	0	0	1	0	1	229
20	0.0036493	1235.7884330	4.5098	1	1	1	0	0	1	1	0	230
59	0.0036652	1235.7884330	4.5294	1	1	1	0	0	1	1	1	231
98	0.0036811	1235.7884330	4.5490	1	1	1	0	1	0	0	0	232
37	0.0036969	1235.7884330	4.5686	1	1	1	0	1	0	0	1	233
76	0.0037128	1235.7884330	4.5882	1	1	1	0	1	0	1	0	234
16	0.0037287	1235.7884330	4.6078	1	1	1	0	1	0	1	1	235
55	0.0037445	1235.7884330	4.6275	1	1	1	0	1	1	0	0	236
94	0.0037604	1235.7884330	4.6471	1	1	1	0	1	1	0	1	237
33	0.0037763	1235.7884330	4.6667	1	1	1	0	1	1	1	0	238
73	0.0037921	1235.7884330	4.6863	1	1	1	0	1	1	1	1	239
.12	0.0038080	1235.7884330	4.7059	1	1	1	1	0	0	0	0	240
.51	0.0038239	1235.7884330	4.7255	1	1	1	1	0	0	0	1	241
90	0.0038397	1235.7884330	4.7451	1	1	1	1	0	0	1	0	242
29	0.0038556	1235.7884330	4.7647	1	1	1	1	0	0	1	1	243
69	0.0038715	1235.7884330	4.7843	1	1	1	1	0	1	0	0	244
.08	0.0038873	1235.7884330	4.8039	1	1	1	1	0	1	0	1	245
.47	0.0039032	1235.7884330	4.8235	1	1	1	1	0	1	1	0	246
.86	0.0039191	1235.7884330	4.8431	1	1	1	1	0	1	1	1	247
25	0.0039349	1235.7884330	4.8627	1	1	1	1	1	0	0	0	248
.65	0.0039508	1235.7884330	4.8824	1	1	1	1	1	0	0	1	249
.04	0.0039667	1235.7884330	4.9020	1	1	1	1	1	0	1	0	250
43	0.0039825	1235.7884330	4.9216	1	1	1	1	1	0	1	1	251
82	0.0039984	1235.7884330	4.9412	1	1	1	1	1	1	0	0	252
.22	0.0040143	1235.7884330	4.9608	1	1	1	1	1	1	0	1	253
.61	0.0040301	1235.7884330	4.9804	1	1	1	1	1	1	1	0	254
.00	0.0040460	1235.7884330	5.0000	1	1	1	1	1	1	1	1	255