DESIGN AND ELECTRICAL CHARACTERIZATION OF A HUMIDITY SENSOR

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

Dr. John Ojur Dennis
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

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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.

Mohd Zul Yusri Mohd Akhir

ABSTRACT

This project objectives are to propose a method to fabricate a humidity sensor based on the changes in the Relative Humidity (RH %). A part for this project is to design and construct the humidity sensor circuit which is necessary to support the humidity sensor. Overall of this project can be classified as to design a working humidity detector prototype which consists of a humidity sensor and the electronic circuit.

Zinc Oxide (ZnO) is identified as one of the best materials that can be used to fabricate the sensor. Zinc Oxide is called a hygroscopic material because of its tendency to absorb moisture. The capacitive type of sensor is chosen as a method to fabricate the sensor because it is the most sensitive to the presence of humidity. The Zinc Oxide is first mixed with diamine and Epoxy (hardener and adhesive) to become a pellet. This pellet becomes the dielectric for whose capacitance is measured to detect the humidity level and convert into the electrical signal.

Laboratory experiments have been conducted to test the sensor performance. The signal conditioning circuit is constructed to complete the test. The Relative Humidity (RH %) is varied in ranges of 10% RH starting from 20% RH until 90% RH. From the experimental observation, the output voltage is found to correspond to the changes in the relative humidity. The output voltage increased when the relative humidity is increased and output voltage decreased when the relative humidity is decreased. The experiment also is conducted to test the standard humidity sensor and the result from the real sensor is become a standard reference for fabricated sensor.

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CHAPTER 1
INTRODUCTION

Sensors are an indispensable part in environment at monitoring and process control and automation. The aim of this project is to fabricate a sensor that is sensitive to the level of humidity in the environment. The sensor will be based on a metal oxide semiconductor device and will be using the capacitive type of sensor where it will change humidity level into measurable electrical signal. The main of ideas how this sensor is implemented is explained in the Background of Study, while in the problem statement a few case studies will be stated. Last but not least is the objectives and scope of study for this project.

1.1 Background of Study

A sensor is often defined as a device that receives and responds to a signal or stimulus. The definition is broad. In fact, it is so broad that it covers almost everything from a human eye to a trigger in a pistol. This world is divided into natural and man-made objects. The natural sensors, like those found in living organisms, usually respond with signals, having an electrochemical character, that is, their physical nature is based on ion transport, like in the nerve fibers. In man-made devices, information is also transmitted and processed in electrical form, however, through the transport of electrons. Sensors that are used in artificial system must speak the same language as the devices with which they are interfaced. This language is electrical in its nature and man-made sensor should be capable of responding with signals where information is carried by displacement of electrons, rather than ions. Thus, it should be possible to connect a sensor to an electronic system through electrical wires, rather than through an electrochemical solution or a nerve fiber.

The purpose of a humidity sensor is to respond to some kind of an input physical property (stimulus) in this case is humidity and to convert into an electrical signal which is compatible with electronic circuits. We may say that a humidity sensor is a translator of a generally nonelectrical value (humidity) into an electrical value. When dealing with the term"electrical" it mean a signal which can be channeled, amplified and modified by electronics devices. The humidity sensor's output signal maybe in the form of voltage or current. Humidity sensor is an energy converter. No matter what levels of humidity are trying to measure, humans always deal with energy transfer from the humidity of measurement to the sensor. The process of sensing is a particular case of information transfer, and any transmission of information requires transmission of energy. Of course, one should not be confused by an positive sign as well as with a negative sign, that is, energy can flow either from humidity to the sensor or vice versa.

The term sensor should be distinguished from transducer. The latter is a converter of one type of energy into another, whereas the former converts any type of energy into electrical. Transducer maybe used as actuators in various systems. An actuator may be described as opposite to a sensor, it converts electrical signal into generally non-electrical energy

Transducer may be parts of complex circuit. In this project it may have a part which converts the humidity in atmosphere into capacitive changes, and these changes afterward will convert into electrical signal. This suggests that many sensors incorporate at least one direct type sensor and a number of transducer. The direct sensors are those that employ such physical effects that make a direct energy conversion into electrical signal generation or modification.

1.2 Problem Statement

This Humidity Sensor's title has been chosen as a FYP project after considering its wide contributions in the world of industries. The details regarding this problem statement would be explained progressively in two sub topics; Problem Identification and Significant of the Project.

1.2.1 Problem Identification

In new modern era, sensors become useful tools to use especially for industrial purposes. A lot of sensors have been created with variety of functions. Engineers or technicians for example, must be familiar with these types of sensors because they are dealing with these sensors everyday in their workplace. Even for students, they already have been exposed to these sensors as they come across to do a project or case studies. These exposures are very good in order for students to familiarize themselves with functionality of sensors. Sensors also are easy to get in the market with a range of price. This project has been proposed in order to get some experience and knowledge on how to design and lastly to fabricate a sensor.

The selected title has been chosen which is to design the humidity sensor or the humidity detection. The focus area for this sensor is at any type of process control, plant automation and etc. But in the early stage, the humidity sensor will be tested inside a humidity test chamber which now is an ongoing design by another FYP student. This humidity chamber will be creating several humidity levels to test the functionality of the sensor. Because this is the first time for students to fabricate their own' sensor, they will be obtaining the humidity sensor from the market that will be used as a standard reference.

An important element is needed to be considered to support the humidity sensor. In this case, electronic interface circuit is needed to support the sensor. The electronic interface circuits maybe such as; signal conditioning circuit, display unit and many more. This project is quite challenging because it require to work in two different areas; firstly involve with some chemical material to fabricate the sensor and secondly work with electronic interface circuit.

1.2.2 Significance of the Project

Even though this project looks simple but in fact, its contribution especially to the industries is very important. One case study has been done in order to understand the problem which normally occurred at plant area. This case study is conducted during a mid-semester brake at PETRONAS FERTILIZER Gurun, Kedah SDN BHD. The case study touched more about the humidity sensor and its effect on the plant process. This case study was very important in tandem to understand better about this sensors use in real application. Hopefully, this case study can help to figure out a certain criteria that still can be improved in the plant environment especially related to humidity.

In the PETRONAS FERTILIZER Gurun, Kedah SDN BHD (PFKSB) plant, humidity sensors are used at two places; one at the Nitrogen Plant Generator and the second place at the Instrument Air. The purpose the manufacturer located a humidity sensor at the Nitrogen Plant Generator is because nitrogen will be used as a seal for certain tanks to avoid corrosion and also is used for purging, draining and cleaning. If there is humidity present in the nitrogen, it will become a poisonous catalyst for another catalyst inside the process and company will be lost their money due to new catalyst replacement. Another reason is because of the corrosion. Humidity will cause corrosion inside the storage tank. The corrosion can cause the chemical substance to expire because it will react with the corrosion.

Humidity sensor also is located at the instrument air system. The instrument air system is used for final control element such as valves. Valves need to be opened and closed due to the process requirement. But these final control elements need a really dry instrument air; this is to avoid corrosion occurring inside the valves. As a pre-caution the valves have a humidity separator in case there is a humidity leakage traveling along the pipe line.

The humidity sensors are capable to send the electrical signal to trigger the alarm inside the control room if the humidity exceeds the set point but the system still running. Maybe for improvement, a trip system can be used for safety concern to the system. Until today, there are no portable devices that can be used to calibrate this sensor, so the probability for the sensor to show an inaccurate reading is high. Company can calibrate these sensors but it requires sending it back to its manufacturer at United State. So it really consumes a lot of time.

From this simple case study, there is an opportunity to make an improvement to the existing system for example a portable calibration device and also a trip system. These two features are needed to improve the reliability of the humidity sensor inside the plant environment.

From the example stated above, humidity sensors therefore to be important in industries. The factory owner cannot simply neglect this sensor. From this point of view, further study would be conducted on how to design and fabricate this sensor.

1.3 Objectives and Scope of Study

The objectives of this study are:

- To design a humidity sensor.
- To design and construct a humidity detector circuit.
- To design a working humidity sensor prototype.

The scopes of the project are as follows:

- Study on sensor material used.
- Sensor type; capacitive type.
- The interface electronic circuit are:
    - Signal Conditioning Circuit.
    - Alarm circuit.
    - Display circuit (to show the humidity reading)
- The real case study at normal plant operation.

Another new feature to focus on is to improve the sensor reliability depending on the specific case that already done during the mid-semester brake at PETRONAS FERTILIZER Gurun, Kedah, It is recommended to have a trip system circuit and calibration device.

The readings of a sensor can be obtained directly from computer by using a PASCO software or probably also using an interface card. To do this, there is needed to familiarize with this software so that easy to find other characteristics in future. This software is available at Physics lab.

The reading is based on the voltage level changes. For example if the humidity is high, voltage also increases and vice versa. The signal transmitted is between 4mA to 20mA. This type of signal is commonly use in the industry to send a signal to the DCS (Distributed Control System). But before it reaches to the DCS this signal is converted into the digital form which is in 1-5 Volts.

CHAPTER 2
LITERATURE REVIEW

Literature review is a very important element before a project can be executed. The strong base of knowledge about the chosen topic is needed in order to understand batter about the project. At the early stage of this project, it is required to do some researches relevant to study, and it should grow from time to time so that the knowledge about the specific part of the project can be enhanced prior to the project proceeding.

2.1 Basic Concept of Humidity Measurement

Humidity is an important factor for operating certain equipment (e.g. high impedance electronics circuit and high voltage device). The rule of thumb is to assure a relative humidity near 50% at normal room temperature (20-25 ^{0}C). Humidity can be measured by instrument called hygrometer. Generally humidity and dew temperature can be capacitive, conductive, oscillating, or optical. There are many ways to express humidity, often depending on the industry or the particular application [1].

Sometimes people will confuse between moisture and humidity. The term moisture generally refers to the water content of any material, but for practical reasons, it is applied only to liquids and solids, whereas the term humidity is reserved for the water vapor content in gases. The following are some useful definitions [1]:

- Mixing ratio (humidity ratio), r:

  The mass of water vapor per unit mass of dry gas

- Absolute humidity (mass concentration or density of water vapor)

  Absolute humidity is the density of the water vapor component. It can be measured, for example, by passing a measured quantity of air through a moisture-absorbing substance (such as silica gel) which is weighted before and after the absorption. Absolute humidity is expressed in grams per cubic meter, or in grains per cubic foot. Because this measure is also a function of atmospheric pressure, it is not generally useful in engineering practice

- Relative humidity

  The ratio of the actual vapor pressure of the air at any temperature to the maximum of saturation vapor pressure at the same temperature

- Dew-point temperature

  The temperature at which the partial pressure of the water vapor present would be at its maximum, or saturated vapor condition, with respect to equilibrium with a plain surface of ice. The Dew point is the temperature at which relative humidity is 100%.

2.2 Capacitive Sensor

A capacitive sensor is a one practical sensor that can be used, this is because the accuracy that it gives is high and more robustness compared to other sensor type like resistive type of sensor. Instead of air, the space between the capacitor plates can be filled with an appropriate isolator whose dielectric constant changes significantly upon being subjected to humidity. The capacitive sensor may be formed of a hygroscopic polymer film with metallized electrodes deposited on the opposite sides. In one design, the dielectric was composed of a hydrophilic polymer thin film (8-12μm) made of cellulose acetate butyrate and the dimetylephtalate as plasticizer. The size of the film sensor is 12 X 12 mm. The 8mm diameter gold porous disk electrodes were deposited on the polymer by vacuum deposition. The film was suspended by a holder and the electrodes were connected to the terminals [1].

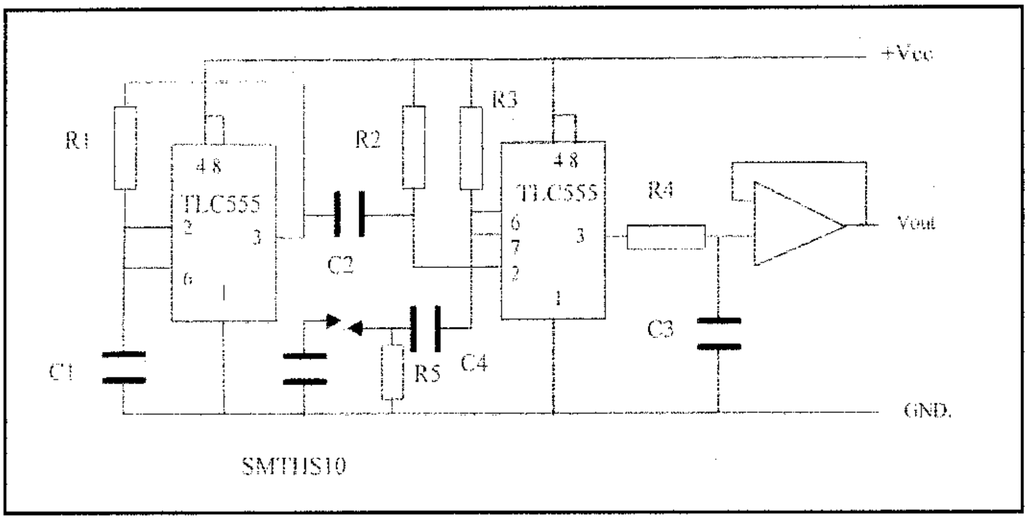


Figure 1 : Application circuit for humidity sensor SMTHS10 DC output

Figure 1 shows the circuit for a typical astable multivibrator application based on the very popular TL 555 (CMOS type). The SMTHS10 is used as variable capacitor. Of course other measurement circuits can be used. R3 and C1 are used to prevent a DC voltage over the humidity sensor. Vout varies between around 0.5 Vcc and Gnd and is influenced by R1 and C1. Circuitry runs around 25 kc (left 555). The monostable based on the HS10 and load resistance of 150 Kohms has a pulse output time of about 25 micro second. Other values are of course also possible. The output of the monostable is low passed filtered by R4 and C3 (time constant 100ms). And buffered by a simple opamp.

2.3 Interface Circuit

Humidity sensor can not stand alone without any support from others electronic interface circuit. Under this point, some electronic interface circuit will be covered such as Amplifiers, Signal Conditioning Circuit and Display Unit.

2.3.1 Amplifiers

Most passive sensors produce weak output signals. The magnitudes of these signals may be on the order of microvolts or picoamperes. On the other hand, standard electronic data processor, such as A/D converters, frequency modulators, data recorders, and so forth, require input signals of sizable magnitudes, on the order of volts (V) and miliamperes (mA). Amplification is part of signal conditioning. There are several standard configurations of amplifiers which might be useful for amplifying signals from various sensors. These amplifiers may be built of discrete components, such as semiconductors, resistors, capacitors and inductors. Alternatively, the amplifiers are frequently composed of standard building blocks, such as operational amplifiers and various discrete components [1].

2.3.2 Signal Conditioning Circuit

External power is required for the operation of the active sensors. The power maybe delivered to a sensor in different forms. It can be a constant voltage, constant current or sinusoidal or pulsing currents. It may even be delivered in the form of light or ionizing radiation. The name for that external power is an excitation signal. In many cases, stability and precision of the excitation signal directly relates to the sensor's accuracy and stability. Hence, it is imperative to generate the signal with such accuracy that the overall performance of the sensing system is not degraded [1].

2.3.2.1 Signal Conditioning Circuit Concepts

A resistor-capacitor circuit (RC circuit), or RC filter or RC network, is one of the simplest analogue electronic filters. It consists of a resistor and a capacitor, either in series or in parallel, driven by a voltage or current source.

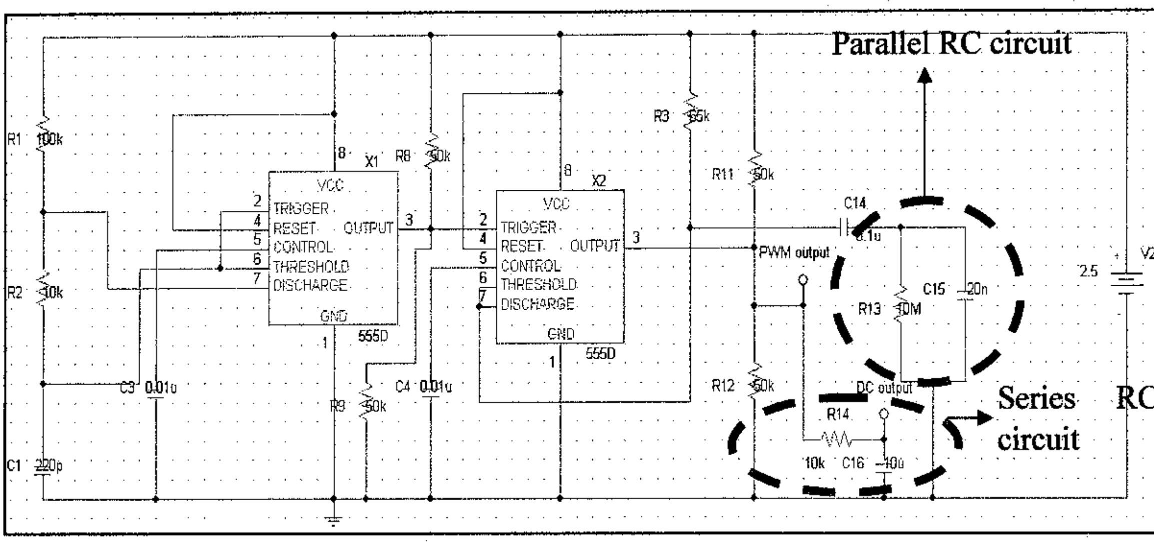
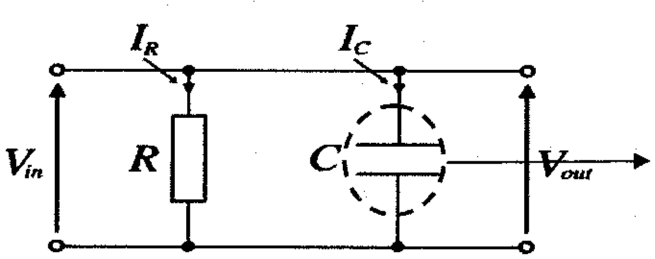


Figure 2 : Signal Conditioning Circuit

There are three basic, linear analog circuit components: the resistor (R), capacitor (C) and inductor (L). These may be combined in four important combinations: the RC circuit, the RL circuit, the LC circuit and the RLC circuit with the abbreviations indicating which components are used. These circuits, between them, exhibit a large number of important types of behavior that are fundamental too much of analog electronics. In particular, they are able to act as passive filters.

Parallel RC circuit



Represent the Humidity Sensor

The parallel RC circuit is generally of less interest than the series circuit. This is largely because the output voltage V_{out} is equal to the input voltage V_{in} — as a result, this circuit does not act as a filter on the input signal unless fed by a current source.

With complex impedances:

$$I_R = \frac{V_{in}}{R} \tag{1}$$

And

$$I_C = j\omega C_{sensor} V_{in} \tag{2}$$

For parallel RC circuit,

$$V_R = V_{Censor} \tag{3}$$

Then

$$I_R R = I_{Csensor} X_{Csensor} \tag{4}$$

$$I_R R = I_{Csensor} \frac{1}{2\pi f C_{sensor}} ; X_{Csensor} = \frac{1}{2\pi f C_{sensor}} \tag{5}$$

$$V_{Csensor} = I_{Csensor} \frac{1}{2\pi f C_{sensor}} \tag{6}$$

$$I_{Csensor} = 2\pi f C_{sensor} V_{Csensor} \tag{7}$$

$$\text{if } C_{sensor} \uparrow I_{Csensor} \uparrow$$

$$I = I_{R1} \downarrow + I_{Csensor} \uparrow \tag{8}$$

$$V_{C2} = I_{C2} X_{C2} \tag{9}$$

$$V_{C2} = I_{C2} \frac{1}{2\pi f_{C2} C_2} \tag{10}$$

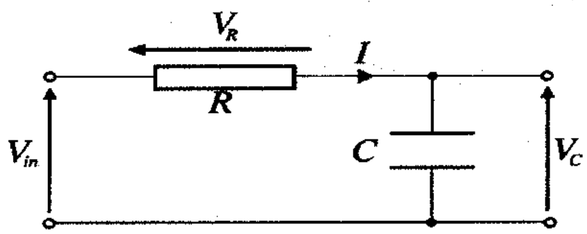
$$V = V_{C2} + V_{par} \tag{11}$$

$$f_{C2} = I_{C2} \frac{1}{2\pi V_{C2} C_2} \tag{12}$$

The relationship;

$$C_{sensor} \uparrow I_{Csensor} \uparrow I_{R1} \downarrow I \text{ constant } V_{C2} \uparrow V_{par} \downarrow f_{C2} \downarrow T \uparrow$$

Series RC circuit



By viewing the circuit as a voltage divider, we see that the voltage across the capacitor is:

$$V_C(s) = \frac{1/Cs}{R+1/Cs}V_{in}(s) = \frac{1}{1+RCs}V_{in}(s) \tag{13}$$

and the voltage across the resistor is:

$$V_R(s) = \frac{R}{R+1/Cs}V_{in}(s) = \frac{RCs}{1+RCs}V_{in}(s) \tag{14}$$

The gains across the two components are:

$$G_C = |H_C(s)| = \left|\frac{V_C(s)}{V_{in}(s)}\right| = \frac{1}{\sqrt{1+(\omega RC)^2}} \tag{15}$$

and

$$G_R = |H_R(s)| = \left|\frac{V_R(s)}{V_{in}(s)}\right| = \frac{\omega RC}{\sqrt{1+(\omega RC)^2}} \tag{16}$$

and the phase angles are:

$$\phi_R = \angle H_R(s) = \tan^{-1}\left(\frac{1}{\omega RC}\right) \tag{17}$$

and

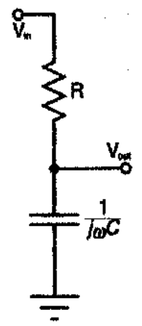
$$\phi_C = \angle H_C(s) = \tan^{-1}(-\omega RC) \tag{18}$$

These expressions together may be substituted into the usual expression for the phasor representing the output:

$$V_R = G_R V_{in} e^{j\phi_R} \tag{19}$$

$$V_C = G_C V_{in} e^{j\phi_C} \tag{20}$$

Impedance divider



A voltage divider is usually thought of as two resistors, but capacitors, inductors, or any combined impedance can be used. For general impedances Z_1 and Z_2, the voltage becomes:

$$V_{out} = \frac{Z_2}{Z_1 + Z_2} \cdot V_{in} \qquad (21)$$

The resistor's impedance is simply its resistance:

$$Z_R = R \qquad (22)$$

The capacitor's impedance is a large resistance at low frequencies and a low resistance at high frequencies. The exact formula is:

$$X_C = \frac{1}{\omega C} \qquad (23)$$

Where ω is a frequency in a radians per second. This divider will then have the voltage ratio:

The Equation to obtain the dc output

$$V_{out} = \frac{X_C}{X_C + R} V_{in} = \frac{\frac{1}{\omega C}}{\frac{1}{\omega C} + R} V_{in} = \frac{1}{1 + \frac{2\pi RC}{T}} V_{in} \qquad (24)$$

The relationship;

$$T \uparrow V_{out} \uparrow$$

2.3.2.2 Concept of Humidity Sensor (Capacitive Type)

When electric charge accumulates on the plates, an electric field is created in the region between the plates that is proportional to the amount of accumulated charge. This electric field creates a potential difference $V = E \cdot d$ between the plates of this simple parallel-plate capacitor.

The capacitor's capacitance (C) is a measure of the amount of charge (Q) stored on each plate for a given potential difference or *voltage* (V) which appears between the plates:

$$C = \frac{Q}{V} \tag{25}$$

In SI units, a capacitor has a capacitance of one *farad* when one *coulomb* of charge is stored due to one volt applied potential difference across the plates. Since the farad is a very large unit, values of capacitors are usually expressed in microfarads (μF), nanofarads (nF), or picofarads (pF).

The capacitance is proportional to the surface area of the conducting plate and inversely proportional to the distance between the plates. It is also proportional to the permittivity of the dielectric (that is, non-conducting) substance that separates the plates.

The *capacitance* of a parallel-plate capacitor is given by:

$$C = \frac{k\varepsilon A}{D} \tag{25}$$

where ε is the permittivity of the dielectric, A is the area of the plates, K is the humidity changes and d is the spacing between them.

Capacitive reactance (symbol X_C) reflects the fact that electrons cannot pass through a capacitor, yet effectively alternating current (AC) can: the higher the frequency the better. There is also a phase difference between the alternating current flowing through a capacitor and the potential difference across the capacitor's electrodes.

Capacitive reactance has the formula

$$X_C = -\frac{1}{\omega C} = -\frac{1}{2\pi f C} \tag{26}$$

where

X_C is the capacitive reactance measured in ohms
ω is the angular frequency, measured in radians per second
f is the frequency, measured in hertz
C is the capacitance, measured in farads

2.3.3 Display Unit

Normally the reading from the sensor can be shown by using the display unit. The easy display unit can be used is LCD. LCD can not straightly connect to the output of the system, it needs a program and setting in order to display something on it. Here, PIC 16F877 is commonly used for this purpose. User is required to write a program usually in C-language to let the LCD display the output of the system.

2.4 Background of Epoxy Resin

Epoxy actually is chemical binders that will be used afterward bind the dielectric. The first production of epoxy resins occurred simultaneously in Europe and in the United State in the late 1930s and early 1940s. The families of epoxy resins commercialized were used as casting compounds and coatings. Epoxy resins are also used extensively in structural and specialty composite applications because they offer a unique combination of properties that are unattainable with other thermoset resins.

2.4.1 Characteristic of Epoxy Resin

The term "epoxy resins" describes a broad class of thermosetting polymers in which the primary crosses linking occurs through the reaction of an epoxide group. In general, an epoxy resins can be though of as a molecule containing a three membered ring, consisting of one oxygen atom and two carbon atoms [3].

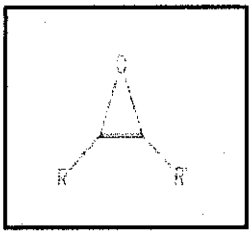


Figure 3 : Basic chemical structure of epoxy group

2.4.2 Curing the Epoxy with Diamine

An epoxy resin is made from diepoxy pre-polymer cured by adding a diamine. The widely used diepoxy pre-polymer is DGEBA. The DGEBA should tied-up together by adding the curing agent which is aliphatic diamine. The curing process normally occurs in stages. The stage 1 is combination of two reactive materials which are epoxy resin and diamine. The next stage, when heat is added, the epoxy resin and diamine react with release of additional heat, thus they are classified as exothermic reaction. This second stage of reaction results in formation of linear chains of combined DGEBA and diamine. As in linear chain form, the material is still in a liquid form but the viscosity is increasing [3].

According to the Waddill G [1], heat promotes further reaction, thus linear polymer chains are combined through chemical reactions in a cross-linking process to form a polymerized system approaching an extremely high molecular weight. During this third stage of reaction, the material changes from a viscous liquid to a solid gel. In this stage, the material is developing strength. It is at this stage, the material is removed from the mould and placed in a cure oven. This material, just strong enough to be moved, is at a stage of incomplete cure, relatively weak and unsuitable for the intended use. The final stage of curing, a length process carried out at elevated results in completion of the cross-linking process. The final product is a very strong, chemically resistant material which is suitable for a variety of applications (Waddill G.). Figure 3 shows a simplified diagram of development of cure for epoxy system [3].

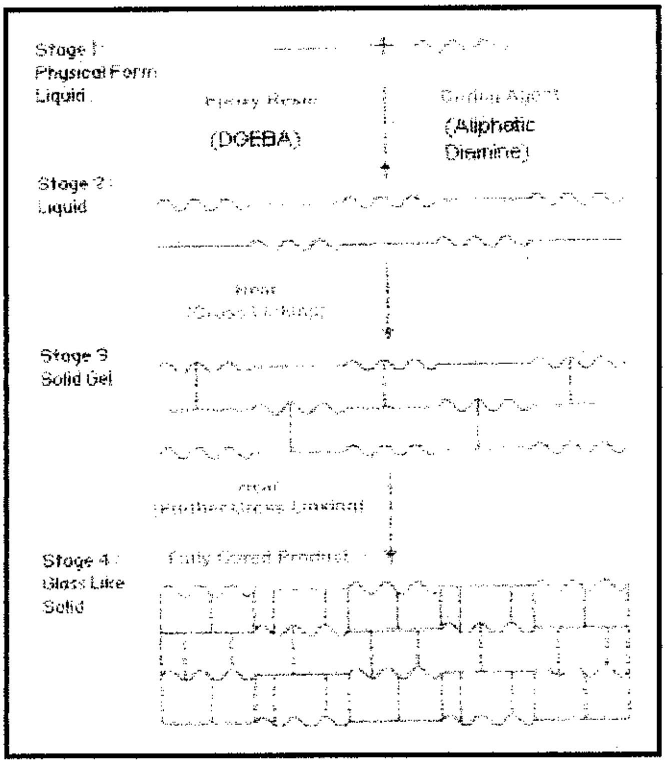


Figure 4 :Simplified diagram of development of cure for epoxy system

2.4.3 Application of Epoxy Resin

The industrial application of epoxy resin system, such as [3]:

1. Protective coating: maintenance coating for industrial and marine, tank linings, industrial floorings, beer and beverage can coating, food cans, appliance primers and hospital and laboratory furniture.
2. Bonding and adhesive: automotive and air craft industries adhesive to metals and composites.
3. Molding, casting and tooling: Molding compound in electrical and electronic industries, casting resins, potting resins. Prototype and master model tools.
4. Laminating and composites: binders in fiber reinforced laminates and composites. Laminates are used in printed wiring boards. Composite applications include filament winding (high performance pipes in oil fields, pressure vessels, tank and rocket motor housing), pultrusion, casting and molding (graphite composites for aerospace applications).
5. Building and construction: flooring (seamless, self-leveling, or epoxy terrazzo floors), repair bridge and roads with glass and carbon fiber wraps, concrete

crack repair, coat reinforced bars, binders for patios, swimming pool decks, and soil around oil-well drilss-drilling fluids.

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 Procedure Identification

Table 1 shows the research planning starting from researches, design until the implementation stage.

Table 1 : Research Planning

No	Tasks	Activities
1.	Researches	1.1 Sensor - Material used. - Study on the capacitive type of sensor. - Check on the current trend at the market. - Find an example of circuit construction for reference. 1.2 Interface Electronic Circuit - Study on alarm circuit. - Study on signal conditioning circuit. - Study on amplifier circuit - Study on the PIC16F877 1.3 Display Unit - Prefer to use LCD - Check on current trend at market 1.4 Case Study - Make a study about the important of humidity sensor at industry.

2.	Design	2.1 Humidity sensor 2.2 Interface Electronic Circuit. - Signal Conditioning Circuit - Alarm Circuit - PIC16F877 2.3 Display Circuit - Using LCD
3.	Implementation	3.1 Humidity Sensor Fabrication. 3.2 Interface Electronic Circuit Fabrication. 3.3 Display Unit Fabrication.

3.2 Sensor Material

In the sensor material, a lot of material can be used to fabricate the humidity sensor. For this project the material used are listed below:

- Zinc Oxide Powders
- Epoxy (Adhesive)
- Diamine (Hardener)
- copper electrode

3.3 Interface Electronic Circuit

This Interface Electronic Circuit such as signals conditioning circuit will be used to support the sensor. This signal conditioning circuit provides a constant reading for the capacitive type of sensor. Also Researches will be conducted to find the best circuit that can be used. After the researches and sensor's fabrication is completed, Interface Electronic Circuit is constructed. After that some testing will be done to test the circuit and the sensor performance. If everything is smooth so redesign is unnecessary. Maybe in future there is some enhancement can be done to improve sensor's reliability and robustness.

3.4 Tools and Equipment

Some equipments and tools will be used for this project, but there are additional equipments and tools will be used from time to time.

3.4.1 List of Hardware Equipment

As shown in table 2 and table 3 are the components used to fabricate the signal conditioning circuit and the PIC circuit

Table 2 : List of Components used for Signal Conditioning Circuit

Component	Quantity
555 Timer	2
Timer socket	2
Resistor (56K)	4
Resistor (100K)	1
Resistor (10K)	1
Resistor (65K)	1
Resistor (10M)	2
Capacitor (220u)	1
Capacitor (0.1u)	2
Capacitor (0.01u)	3

Table 3 : List of Components used for PIC Circuit

Component	Quantity
PIC 16F877	1
PIC Socket	1
Wire Cable PIC	1
Crystal Oscillator	1
LCD Display	1
Alarm Buzzer	1
Warning Light	1
Veraboard	1

3.4.2 List of Testing Equipments

- Multimeter (to test sensor output)
- Oscilloscope (to observe the PWM)
- DC power supply (supply the power to sensor's circuit)
- Test System (Humidity Chamber)

3.4.3 List of Software

- Pspice Students (to simulate the circuit)

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Zinc Oxide Preparation

Zinc Oxide is a hygroscopic type of chemical because this substance can absorb water or humidity. Even though this substance can absorb water or humidity there is still need to make a simple experiment to prove on its characteristic. The epoxy and amine is identified as a suitable chemical binder and adhesive that will be used to bind the zinc oxide without changing its characteristics. There are a few methods that can be used to bind the Zinc Oxide which is by using a warm compressor method or just let the Zinc Oxide harden at room temperature.

For this project it is enough to dry the Zinc Oxide within the room temperature. The reason is to ensure the Zinc Oxide has a high porosity. The experiment is conducted later to see the changes between the humidity with sensor's capacitance and also with output voltage. If the change is too fast and there is difficulty to get the reading, a warm compression method is an alternative that can be replaced because Zinc Oxide has a less porosity due to high compaction of the material. But for now, the Zinc Oxide is hardened in normal room temperature. Figures 5 ,6 and 7 show the material used to prepare the Zinc Oxide:

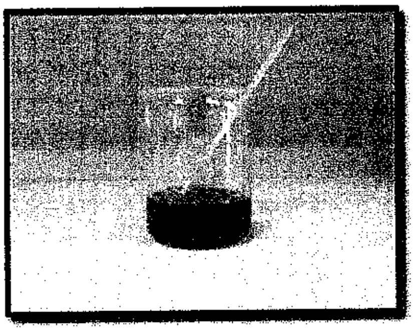


Figure 5 : Epoxy

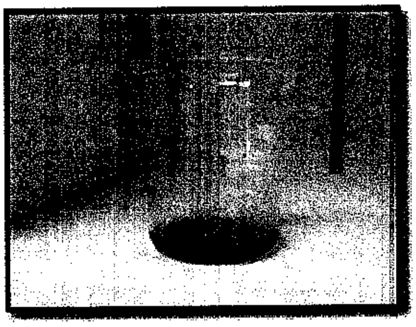


Figure 6 : Amine

Figure 7 : Zinc Oxide

Below are the methods used to get the right amount of the epoxy and diamine:

For this experiment, 10 gram Zinc Oxide is mixed with the binder.

Weight plastic cup = 2.8262 gram

Weight plastic cup + Zinc Oxide = 12.8600 gram

From here, 10 gram Zinc Oxide is obtained. Next step is to get 10 gram epoxy and 3.2 gram Diamine. This is a fix ratio to mix both chemicals in order to prepare the complete hardener:

Weight beaker (50ml) = 29.00 gram

Weight beaker (50ml) + Epoxy = 39.89 gram

Weight beaker (50ml) = 29.00 gram

Weight beaker (50ml) + Diamine = 32.2 gram

After the Epoxy and Diamine amount is obtained, both chemical are mixed in one beaker. Figure 8 shows the mixture:

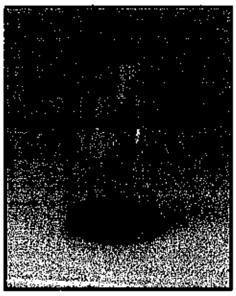


Figure 8 Epoxy + Amine

Next, the 10 gram Zinc Oxide powder is mixed with the mixture and will be stirred around 3-4 minutes to get a complete solution. Figure 9 shows for Zinc Oxide + (Epoxy&Diamine):

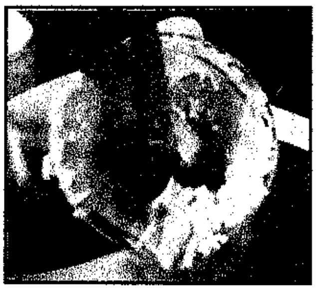


Figure 9 :Zinc Oxide +(Epoxy + Amine)

4.2 Humidity Sensor Fabrication

A capacitive type is chosen in stead of using resistive type because capacitive type will give a good response with presence of humidity. The materials used for this sensor fabrication are:

1. Copper – as a sensor electrode
2. Two jumper wire – to connect between sensor and circuit
3. Laminate plastic – as a mask to prepare a zinc oxide shape
4. Zinc oxide – as a sensor's dielectric

For this sensor, a copper is used as a sensor electrode. Copper is one of the best conductors. In figure 10 shows a plate of copper:

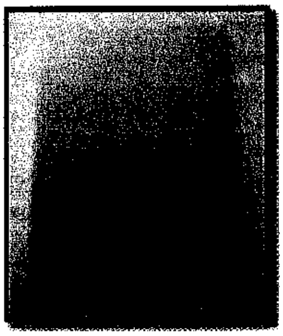


Figure 10 :Copper Plate

For the capacitive type sensor, two electrodes are placed in parallel with each other. As shows in figure 10, the copper plate is cut into two shapes:

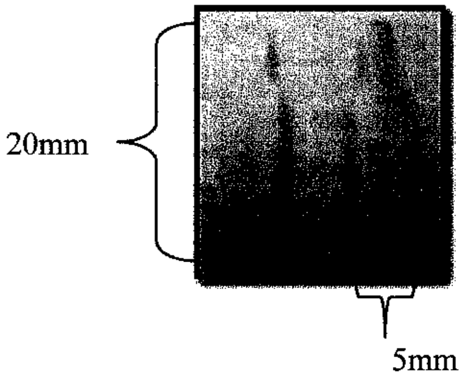


Figure 11 : Copper Plate Cut into Two Shapes

After the copper plate is cut into two shapes, zinc oxide is paste in between of copper plate to form the capacitive type of sensor. After zinc oxide is paste, the sensor now needs to be dry in room temperature within 24 hours. The reason is drying in room temperature is because to ensure the sensor has higher porosity. As shown in figure 12, the sensor is ready to use:

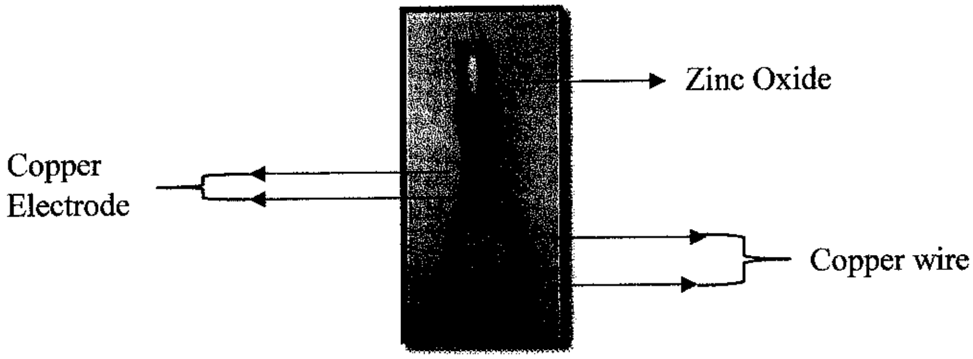


Figure 12 : Humidity Sensor

4.3 Humidity Sensor Casing

The challenge in sensor casing is to allow the sensor to respond to its environment, its primary role in condition that may not necessarily be ideal for the sensing technology of choice. Since many sensing technologies involve fragile or tiny sensing elements, this is almost always the situation. The main objectives for sensor casing are:

- Making the package compatible with the sensor itself, to prevent false readings or degeneration of the sensor.
- Protecting the sensor from the outside environment while still allowing it to function

Figure 13 shows the casing diagram:

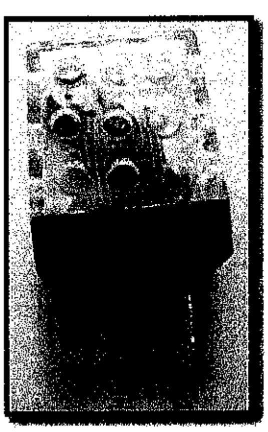


Figure 13 : Sensor Casing

4.4 The Humidity Detector Prototype

This humidity detector prototype consists of four main parts which are humidity sensor, signal conditioning circuit, PIC circuit and LCD display. Humidity sensor is attached at the signal conditioning circuit where the sensor's capacitance is varying with presence of humidity. These capacitance changes will become the disturbances to the pulse width produced by timer. This pulse width then will convert into a DC output by the series RC circuit. The dc output from the signal condition circuit will be translated by the PIC 16F877 into the respective humidity reading that will be shown into the LCD panel. Figure 14 shows the schematic diagram for overall the humidity detector prototype.

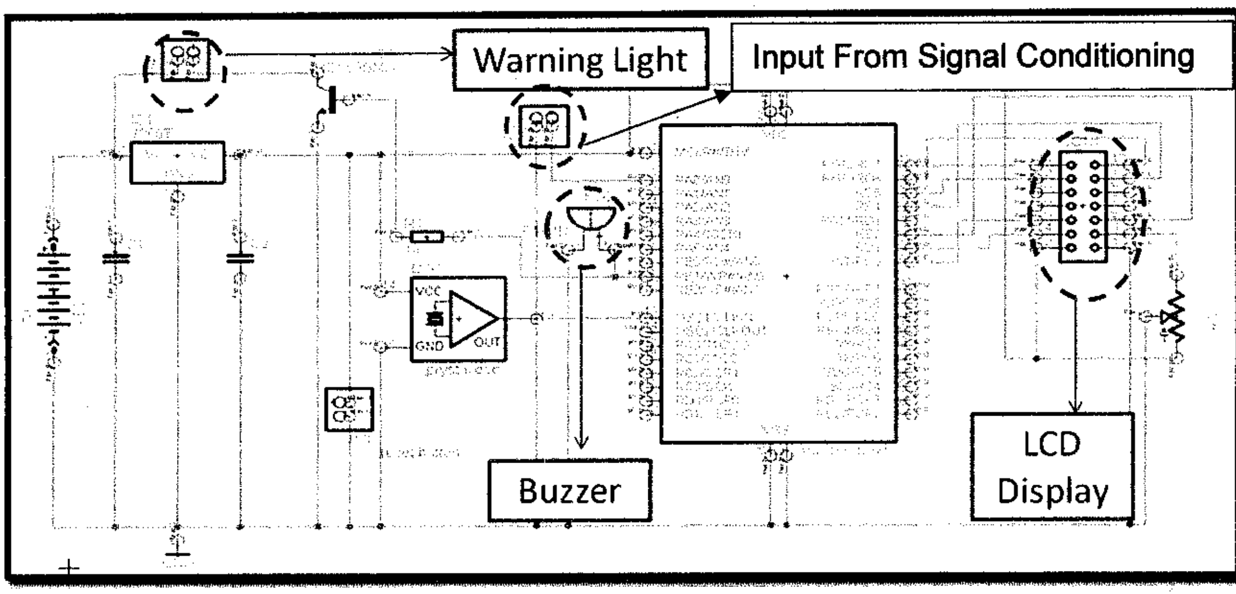


Figure 14 : Schematic Diagram for Humidity Detector Prototype

4.4.1 PIC Flowchart

The flow chart below shows the PIC algorithm in order to control the whole humidity detector model.

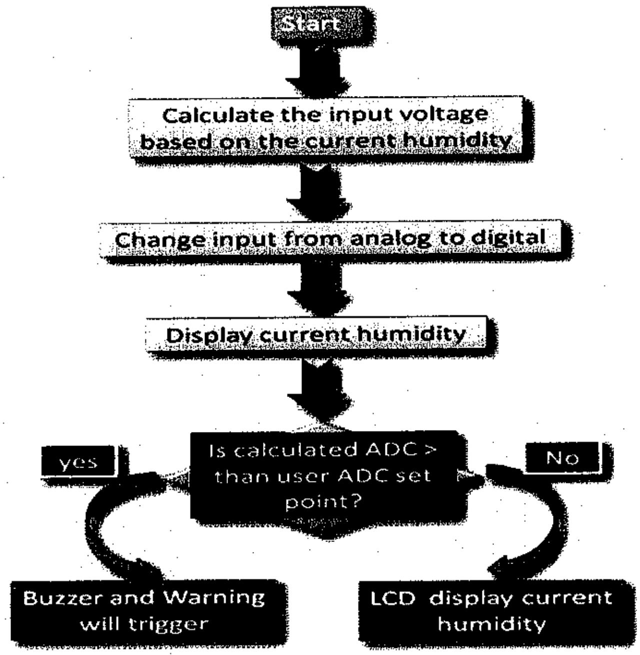


Figure 15 : PIC Flowchart

4.5 Humidity Sensor Experiment

The purpose of this lab experiment is to test the sensor and signal conditioning performance. Also during the lab experiment the reliability of the sensor and signal conditioning are observed. Before start with the lab experiment, a simulation using PSPICE is first conducted in order to prove on the continuous pulse wave is created at the both timer. Then the signal conditioning circuit is tested during the lab experiment to ensure the pulse produced by the signal conditioning circuit is constant and close from what is already design at PSPICE. This is very important to get the fix output voltage later. The signal condition circuit consists of two main parts which are first timer and second timer. Basically for first timer will produce the continuous pulse train to trigger the second timer, and pulse for the second timer is controlled by the humidity sensor where the capacitance change with respect to the humidity.

4.5.1 Experiment using PSPICE to Check the Timer Waveform

A signal conditioning circuit scheme recommended by several sensor manufactured for capacitive RH sensor is shown in figure 16.

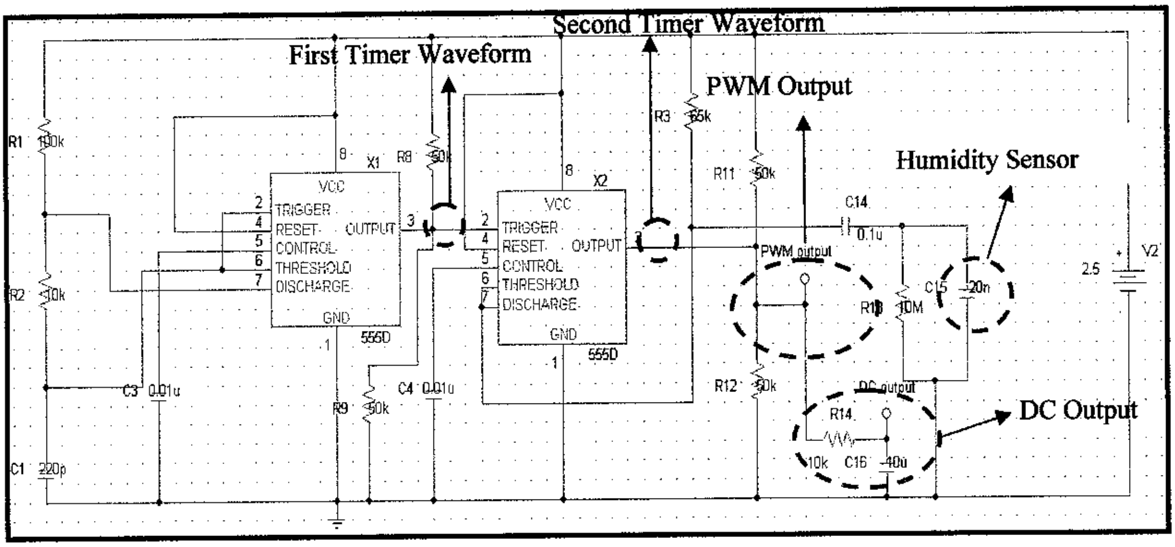


Figure 16 :Signal Conditioning Circuit

The circuit provides a DC output directly proportional to relative humidity. Timer X1 acts as a fixed pulse train generator to trigger the second timer circuit. The pulse width of the second timer is controlled by the RH sensor and varies linearly with sensor capacitance. The pulse from timer X2 is a pulse width modulated that can be measured by using a DC voltmeter.

SIMULATION RESULT

To perform this simulation, it is suggested to do part by part simulation in order to check and ensure the circuit is fully functioning. The circuit can be divided into four partitions, which is:

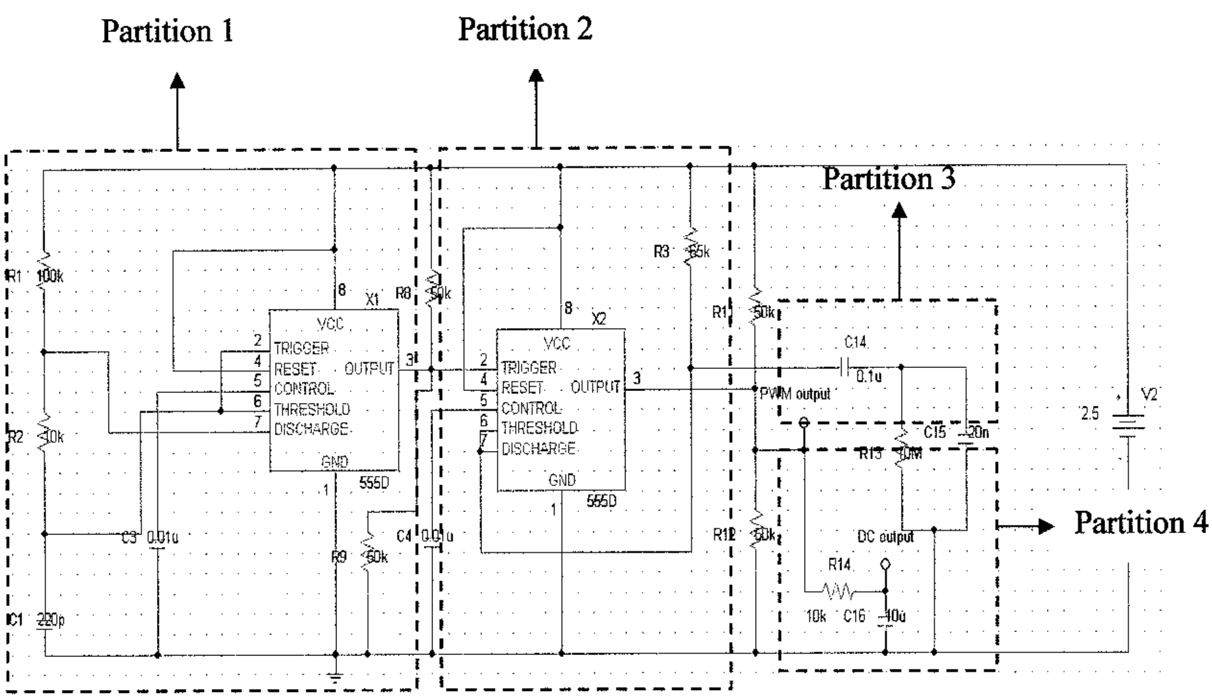


Figure 17 :Partitions for Signal Conditioning Circuit

For partition 1, actually this 555 timer circuit provides a fixed pulse train generator to trigger the 555 timer circuit in partition 2. But the output pulse train generator from the circuit in partition 2 is controlled by the circuit in partition 3.Circuit in partition 3 is attached together with the humidity sensor, this sensor will detect the humidity and then will transfer its output in terms of frequency change which is shown by Pulse Width Modulated (PWM) output in partition 2 circuit. This PWM output varies proportionally with the sensor capacitance. Last but not least, the circuit in partition 4 will convert the frequency into a voltage output. This voltage output also varies linearly with sensor capacitance.

Partition 1 result

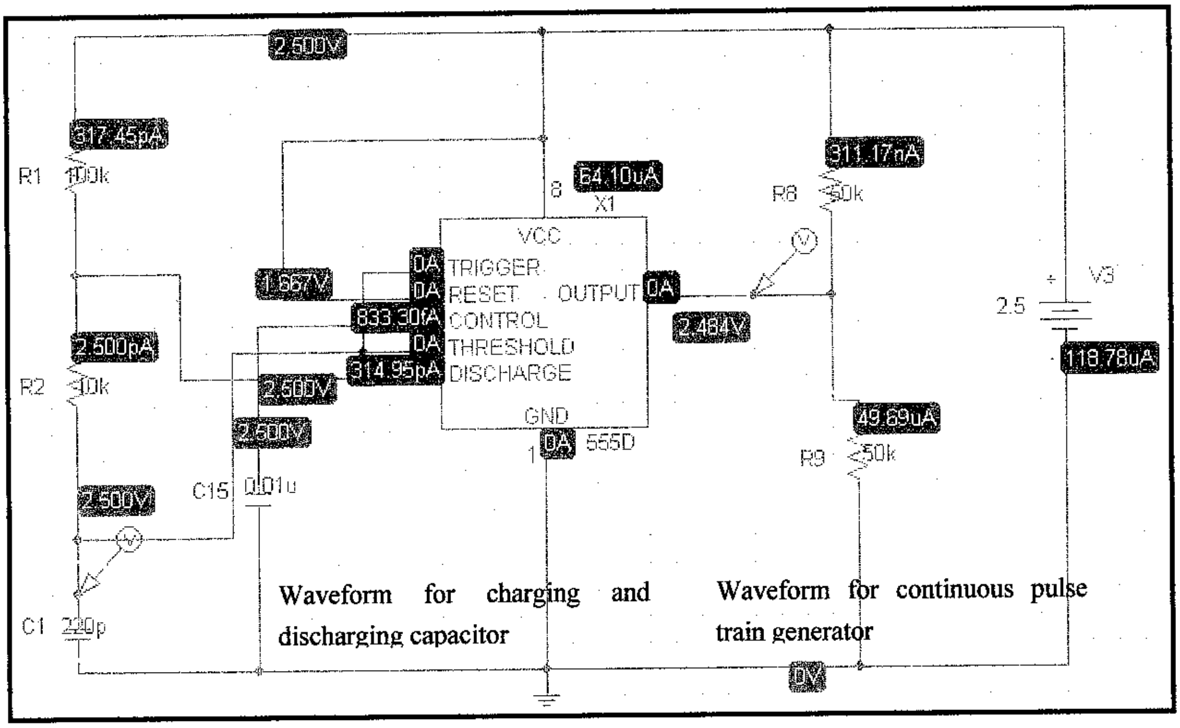


Figure 18 :Partition 1 Signal Conditioning Circuit

Waveform:

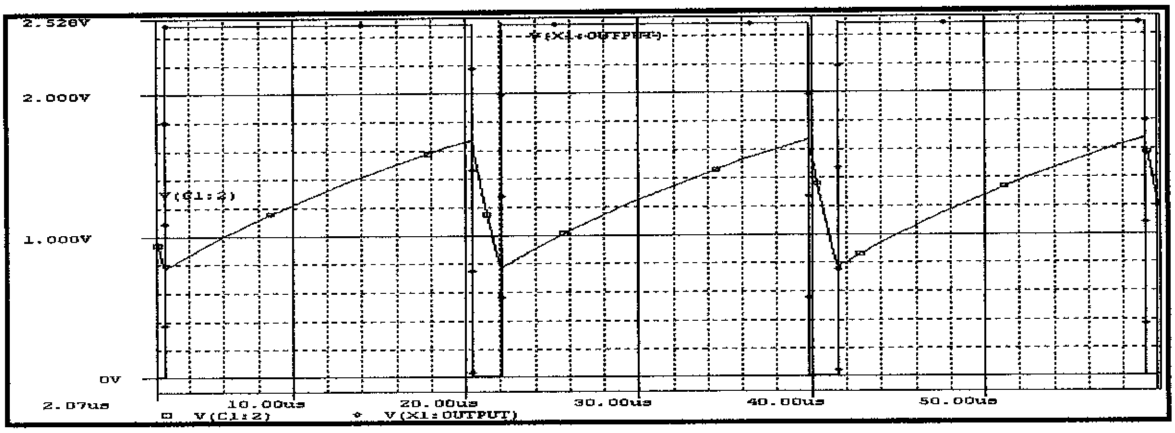


Figure 19 :Continuous Pulse train Generator

Partition 2 result

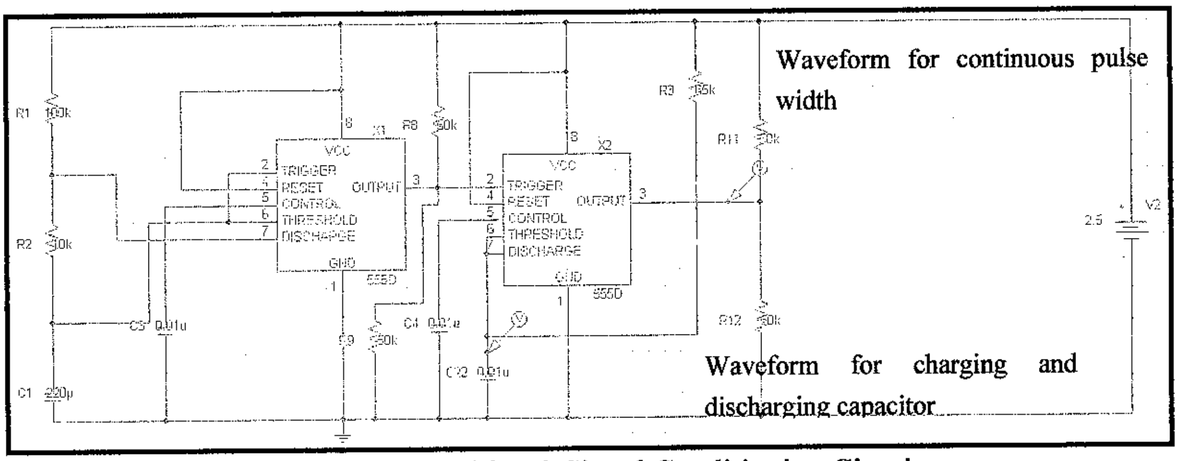


Figure 20 : Partition 2 Signal Conditioning Circuit

Waveform:

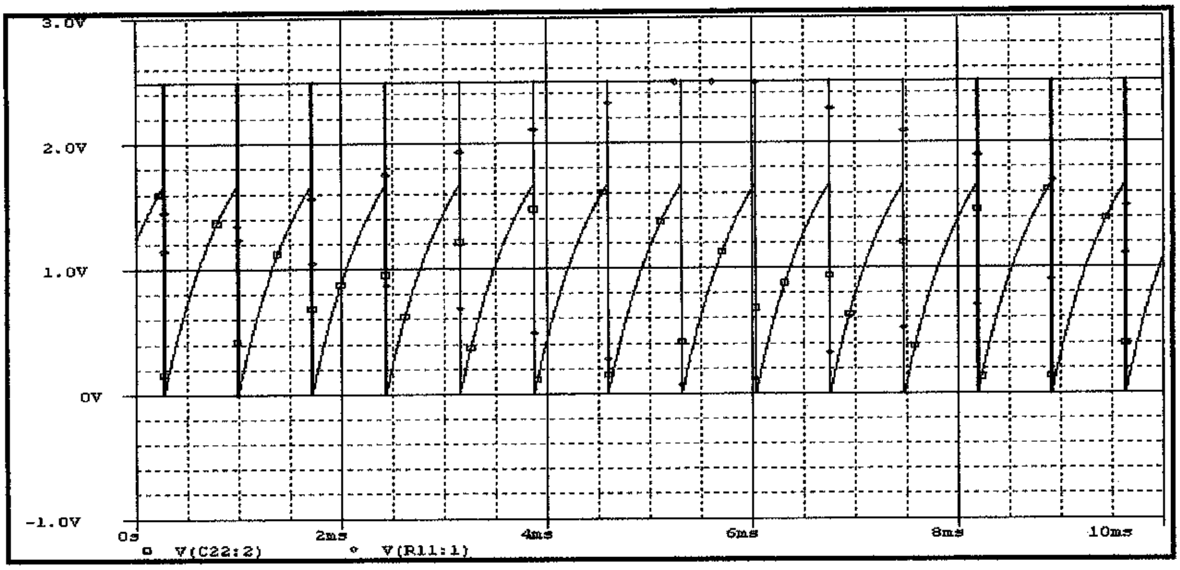


Figure 21 : Waveform for continuous pulse train generator

4.5.2 Lab Experiment 1 – to Observe Capacitance Changes

Table 4 shows the result for the outputs signal conditioning circuit base on the reading from the oscilloscope.

Table 4 : Result for Signal Conditioning Circuit Using Oscilloscope

	First timer	Second timer
Peak-Peak	2.10 V	2.32 V
Frequency	34.26 kHz	1.486 kHz
Period	29.78 us	674 us
Mean	30.7 mV	24.2 mV

The result above shows that the output voltage from the second timer is constant although there is a changing at the frequency but it is little. Before beginning with the experiment, the humidity sensor is tested with variety of humidity level to see the capacitance change against the humidity. These experiments are conducted several times to ensure the capacitances are the same for each experiment. Table 5 shows the experiment result.

Table 5 : The result for the humidity versus capacitance

RH%	Experiment 1 (nF)	Experiment 2 (nF)	Experiment 3 (nF)
20	0.125	0.123	0.127
30	0.130	0.126	0.127
40	0.133	0.134	0.128
50	0.138	0.135	0.129
60	0.146	0.137	0.131
70	0.158	0.154	0.135
80	0.178	0.179	0.160
90	0.216	0.211	0.192

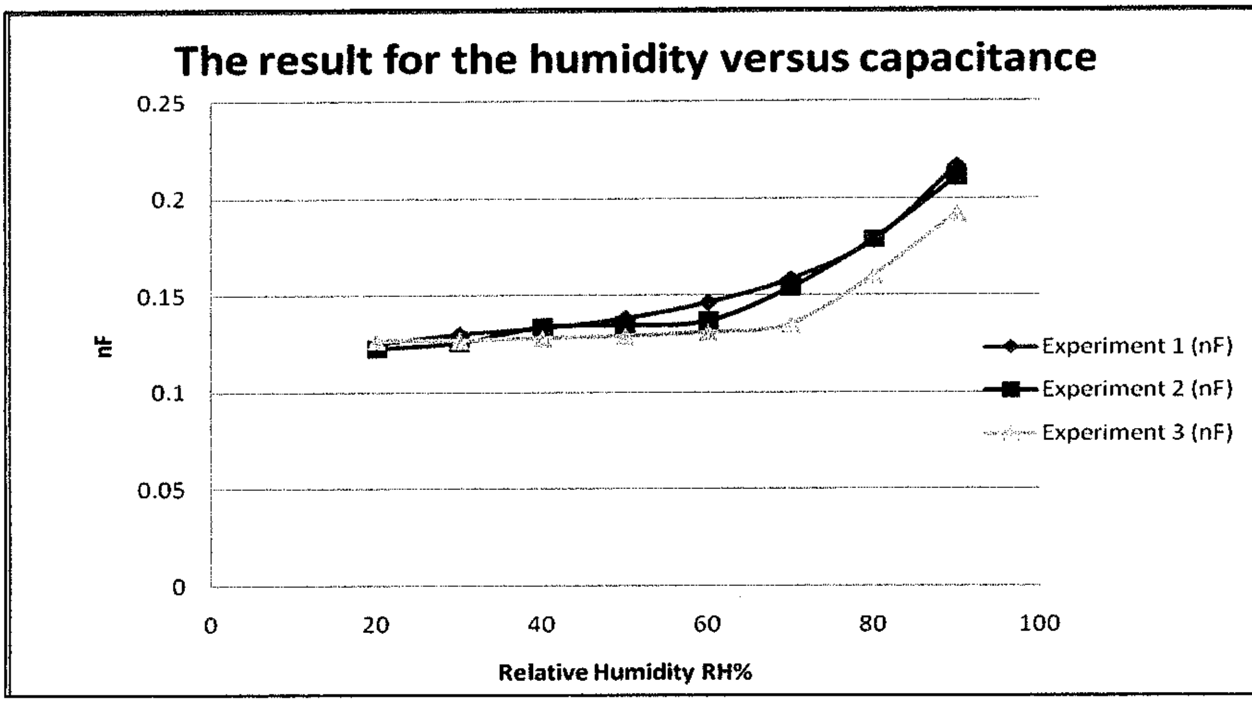


Figure 22 : Sensor Capacitances Comparison for Each Experiment

4.5.3 Lab Experiment 2 – to Observe Output Voltage Changes

After seen the humidity sensor capacitance change with respect to relative humidity, RH%, next the humidity sensor is attached to the signal conditioning circuit to observe the changes at the output voltage. Table 6 shows the result for the output voltage against the relative humidity.

Table 6 : The Result for the Humidity versus Output Voltage

RH%	Experiment 1(mV)	Experiment 2(mV)	Experiment 3(mV)
20	879	875	870
30	880	878	873
40	882	880	874
50	883	884	878
60	886	885	881
70	887	891	886
80	890	892	887
90	895	893	889

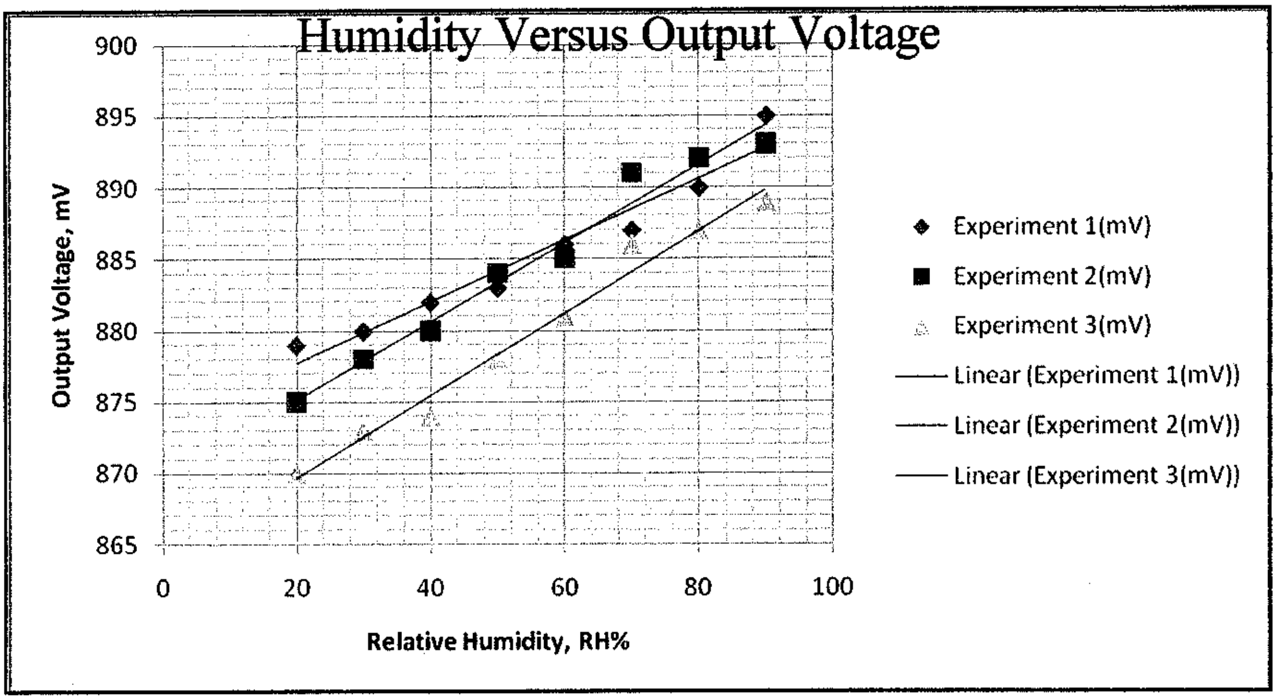


Figure 23 : Output Voltage Comparison for Each Experiment

From the result above, what can be observed is that the output voltages are not the same for each experiment but it is close. Some modification is required maybe to improve the sensor performance and the signal conditioning circuit itself. More experiments are required to perform in future to prove the sensor performance.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The Humidity sensor fabrication is done and laboratory experiments also are conducted to prove on the method used. The sensor output is corresponded to the humidity present and what can be observed is that the output voltage is found to increase when the humidity level is increased and vice versa. Also the sensor's capacitance is increased when the humidity is increased. A signal conditioning circuit is used during the laboratory experiment in order to get a measurement. More researches with chemical substances are required to be done in order to find the best methods and materials for humidity detection. The Zinc Oxide (ZnO) is found to be a good material to detect the humidity in ambient temperature because it has a hygroscopic characteristic. Last but not least, the method used to fabricate the sensor is succeeded and some enhancement can be executed later to improve the sensor sensitivity. Humidity sensor can be improved more especially to get a stable reading and also prepare for suitable sensor's casing.

5.2 Future Recommendations

For future recommendation, Zinc Oxide can be replaced with polymer substance such as cellulose acetate butyrate and the dimetylephtalate for better humidity detection because this polymer is well known established as a good material for humidity detection but the only thing is this material is quite expensive. A new feature can be added at the signal conditioning circuit. Instead of using the series RC circuit to get the output voltage, the future researcher can tries to use series LC circuit where the resonance concept is taken into consideration.

REFERENCES

[1] Handbook of Modern Sensor,pg 124-258 (physics, designs, and application), third edition by Jacob Fraden

[2] Artificial bone for zincornium, Metal powder injection module

[3] Bamboo process and study characteristic by Nurhayati Ismail

[4] Ieee Sensors Journal, Vol. 6, No. 1, February 2006 (Configurable Electrodes for Capacitive-Type Sensors and Chemical Sensors) byAdrian M. Kummer and Andreas Hierlemann

[5] An Artificial Neural Linearizer For Capacitive Humidity Sensor A. Chatterjee, **S.** Munshi, M. Dutta, **A.** Rakshit Electrical Engineering Department Jadavpur University Calcutta-700 **032,** India.j

[6] Silicon Carbide Membrane Relative Humidity Sensor With Aluminium Electrodes

'E.J.** Connolly, 'HTMPhum, **2J Groeneweg,** 'PMSurro, **'PJFrench

Laboratory for Electronic Instrumentation & DIMES, Delft Univ. of Technology, Mekelweg 4, 2628 CD Delft, The Netherlands ' DIMES, Delft University of Technology, Mekelweg 4,2628 CD Delft, The Netherlands

[7] Impedance Characteristics Of Carbon Nitride Films For Humidlty Sensors

Ji Gong Lee', and Sung Pi1 Lee' 'Department of Electronic and Electrical Engineering, Kyungnam University, Korea .E-mail: areil98@kyungnam.ac.kr

APPENDICES

APPENDIX A
PIC 16F877 CODING

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

float adcValue;
float voltage;
float humidity;
```

Purpose of this function is want to initialize these character within the program

```
void main()
{

setup_adc_ports(ALL_ANALOG);
setup_adc(ADC_CLOCK_INTERNAL);
set_adc_channel(0);
```

This function use to initialize the pins use at the PIC 16F877

```
while (1)
{

delay_us(50);
adcValue=read_adc();

delay_us(50);
voltage= 5.000*adcValue/255.000;
```

Voltage value in this function will be the same with the signal conditioning circuit output voltage

```
humidity= voltage*5;
```

This formula will use to calculate the humidity P/S: this is not yet the final formula, maybe will change later

```
  lcd_init();

  lcd_putc('\f');
  lcd_gotoxy(1,1);
  printf(lcd_putc, "%f", humidity);
```

This function will display the humidity value into the LCD

```
  lcd_gotoxy(7,1);
  lcd_putc("%RH");

  lcd_putc('\n');
  printf(lcd_putc,"%f",voltage);
```

This function will display the output voltage into the LCD

```
  lcd_gotoxy(7,2);
  lcd_putc("V");

} delay_ms(2000);
```

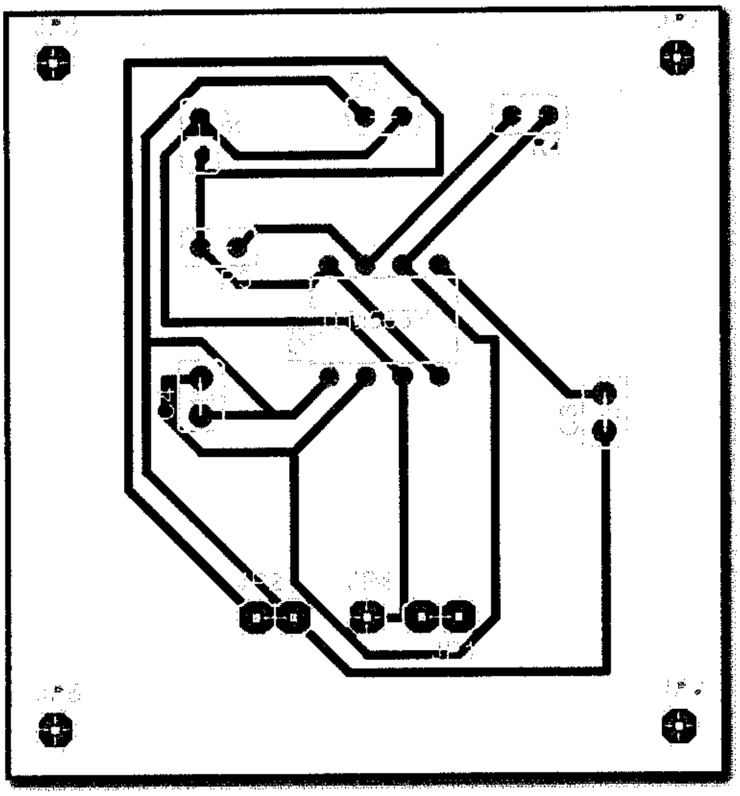
This function will update the humidity value in every 2 second

```
}
```

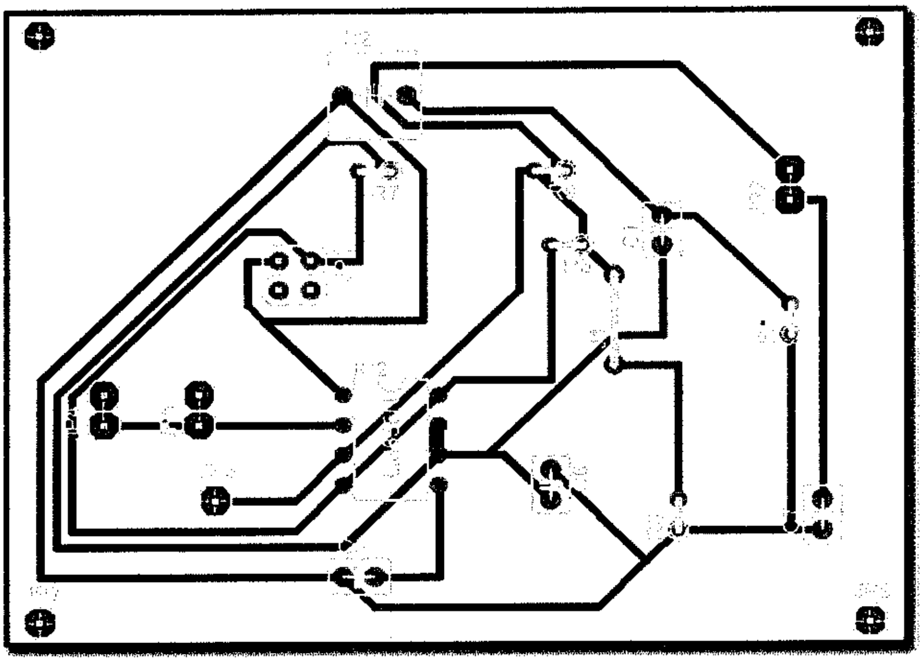
APPENDIX B

GERBER FILE FOR SIGNAL CONDITIONING CIRCUIT

First timer

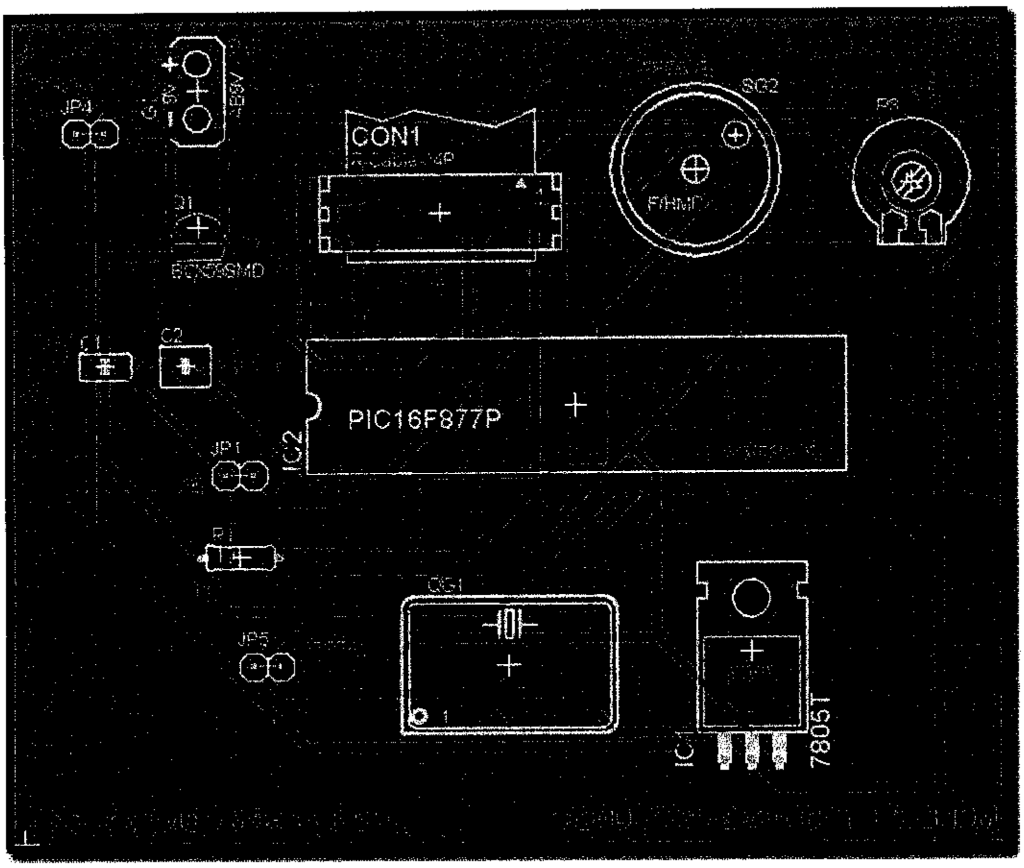


Second timer



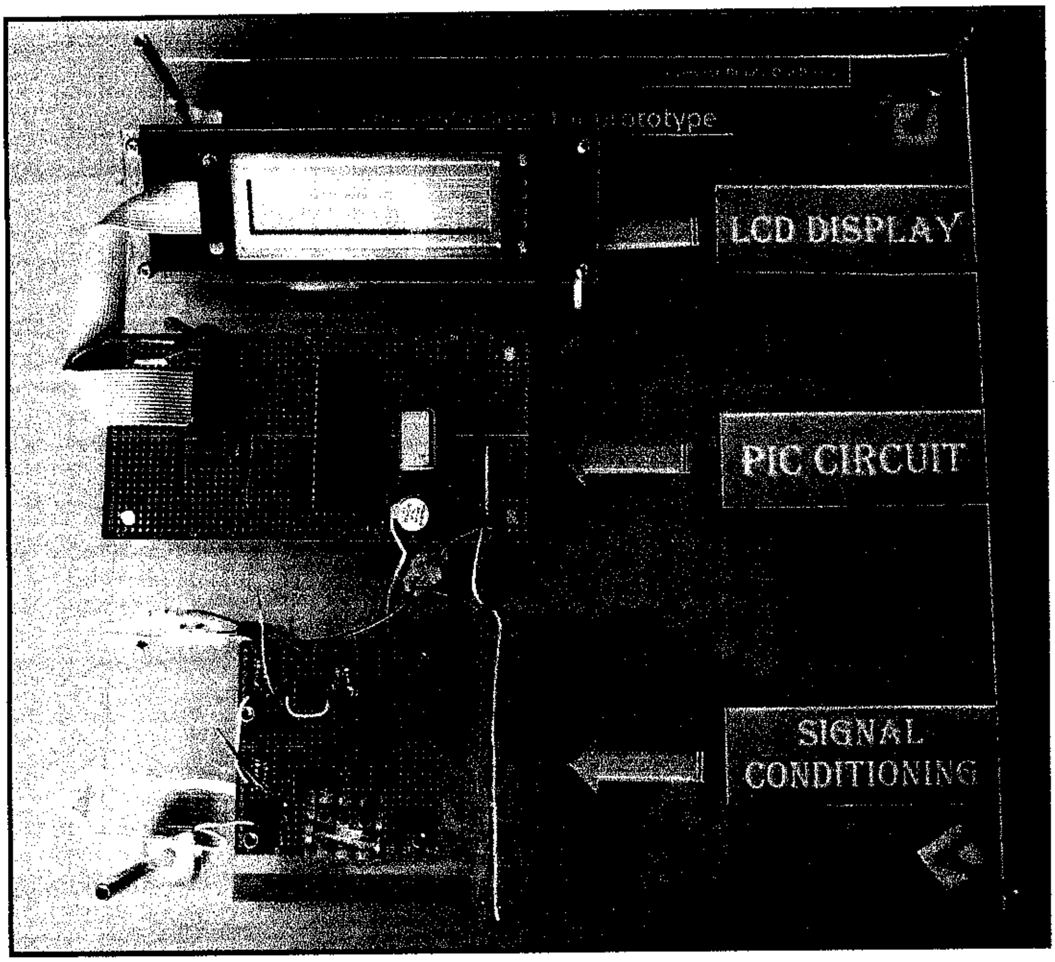
APPENDIX C

GERBER FILE FOR PIC CIRCUIT



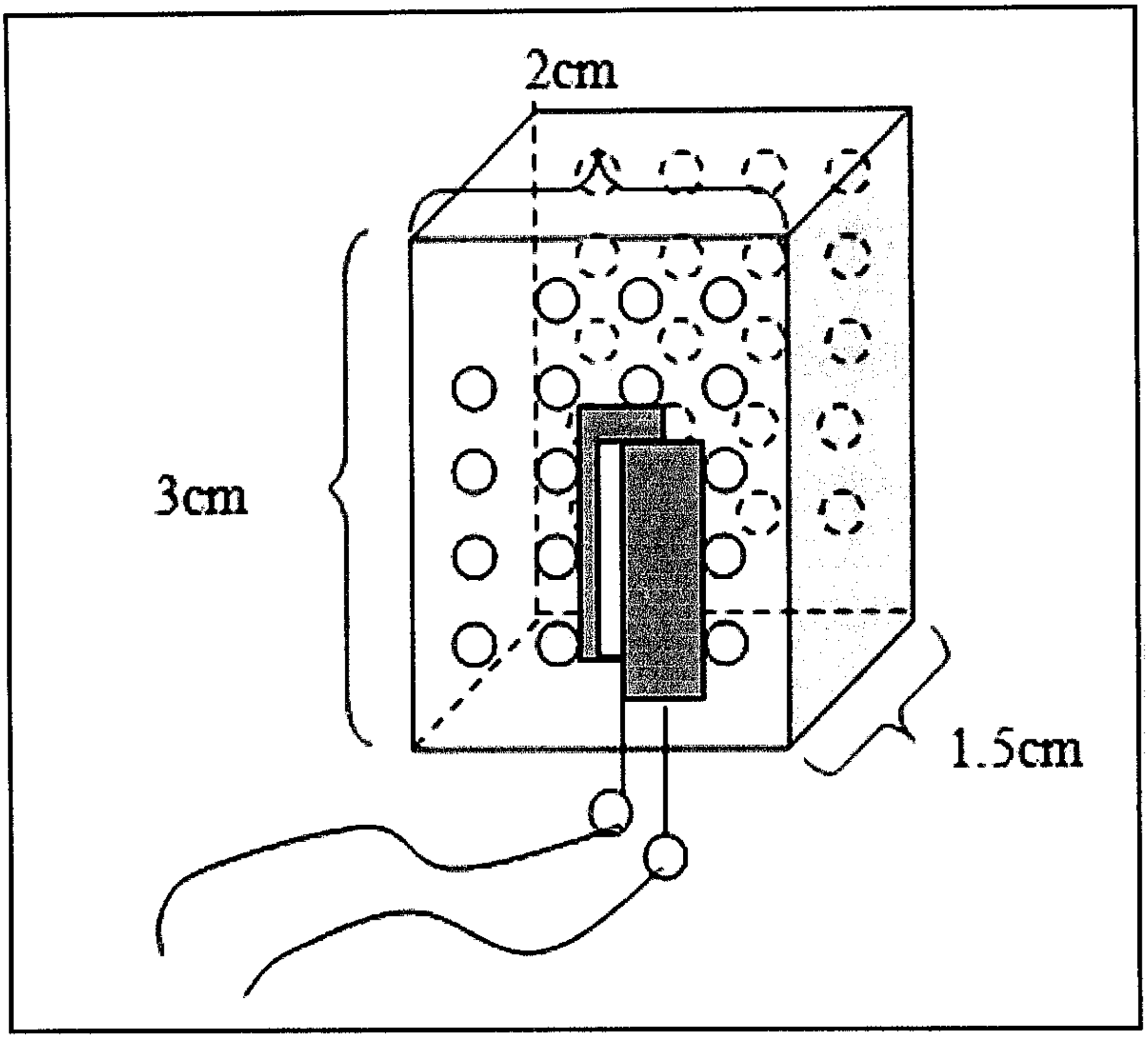
APPENDIX D

HUMIDITY DETECTOR PROTOTYPE



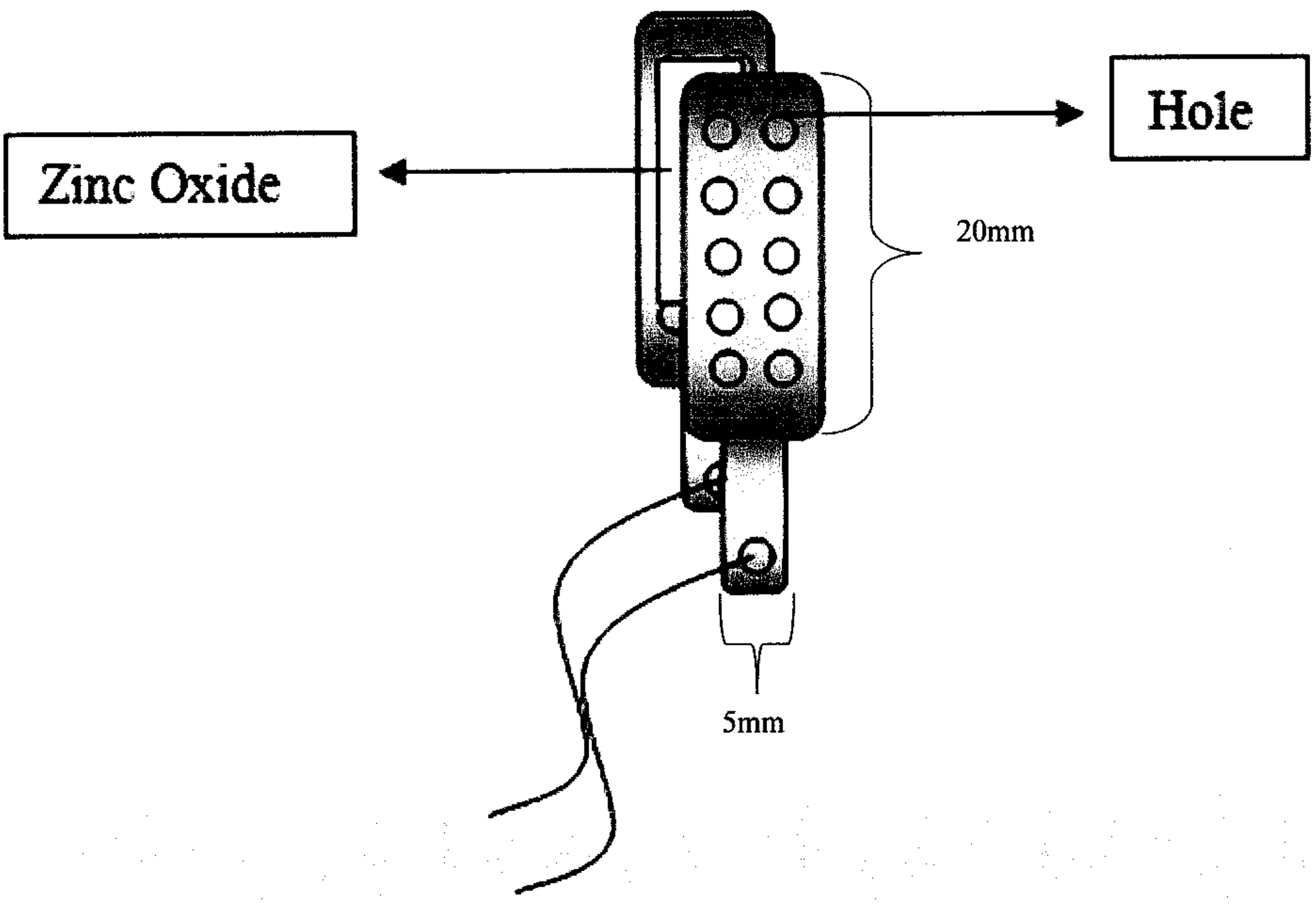
APPENDIX E

HUMIDITY SENSOR CASING



APPENDIX F

HUMIDITY SENSOR SCHEMATIC



APPENDIX G

GANNT CHART

Gannt Chart for First

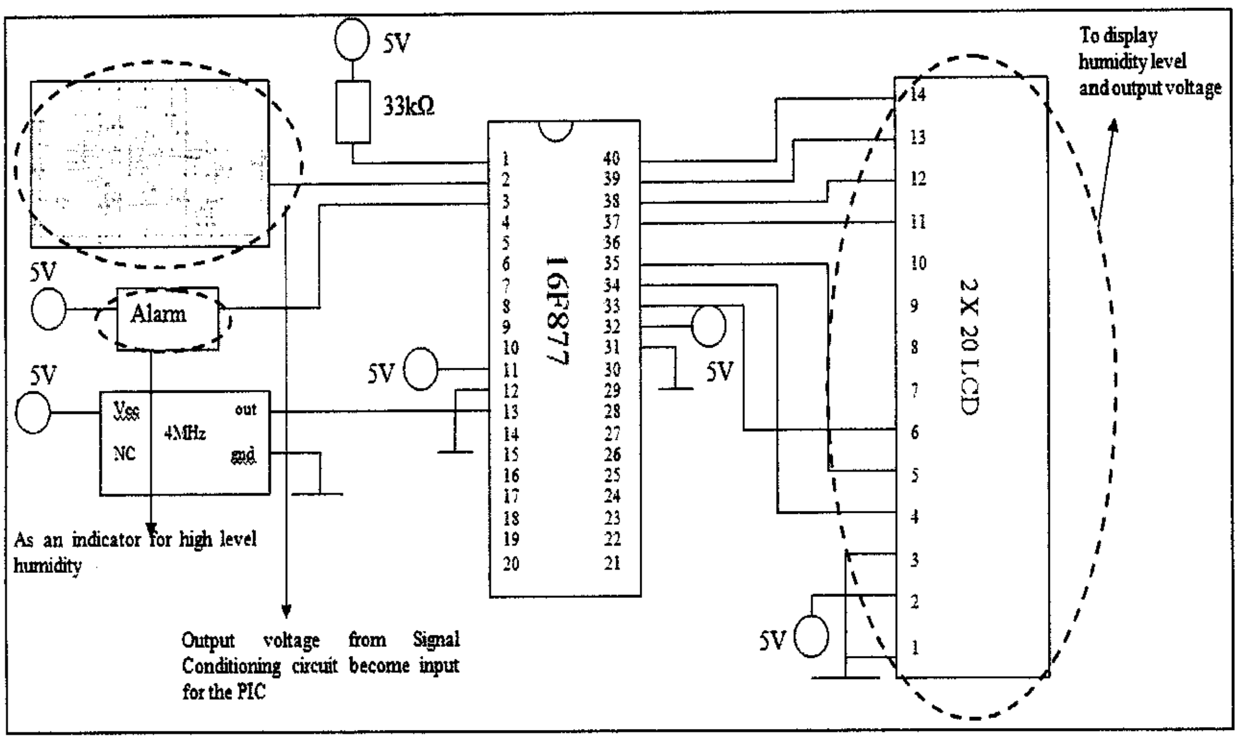
DEPARTMENT / SECTION	PROJECT ACTIVITIES	WEEK NO / DATE													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electrical Department	**1. Selection of Project Topic**	■													
	2. Submit the proposal	■													
	3. Project Work (Research)														
	3.1 Sensor			■	■	■	■								
	- Material Used			░	░	░	░								
	- Current Trend					░	░								
	- Example of Construction														
	3.2 Interface Electronic Circuit					■	■	■	■	■					
	- Alarm Circuit					░	░								
	- Study on Others Interface circuit								░	░					
	3.3 PASCO			■	■	■									
	- Check on it Application			░	░	░									
	3.4 Display					■	■	■	■						
	- Use LCD					░	░	░							
	- Current Trend								░						
	3.5 Case Study			■	■	■									
	- Normal Operation			░	░										
	- Check on Trip Cases				░	░									
	4. Design														
	4.1 Sensor										■	■			
	4.2 PASCO												■		
	4.3 Interface Electronic Circuit													■	■

Gannt Chart for Second Semester

DEPARTMENT / SECTION	PROJECT ACTIVITIES	WEEK NO / DATE													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Electrical Department	**1. Design the Signal Conditioning Circuit**	■	■	■	■	■	■								
	1.1 Choose the component														
	1.2 Construct the circuit														
	1.3 Testing														
	2. Design the PIC circuit					■	■	■	■	■	■				
	2.1 Choose the component														
	2.2 Construct the circuit														
	2.3 Testing PIC circuit														
	2.4 Interface with Signal Conditiong Circuit														
	2.5 Testing interface circuit														
	3. Design new sensor								■						
	3.1 Fabricate new sensor														
	4. PCB board									■	■				
	4.1 Transfer all the circuit into PCB board														
	5. Lab experiment										■	■	■	■	
	5.1 Simulate circuit using PSPICE														
	5.2 Experiment 1 - Check sensor capacitance														
	5.3 Experiment 2 - Check output voltage														
	5.4 Experiment 3 - Calibrate the sensor														

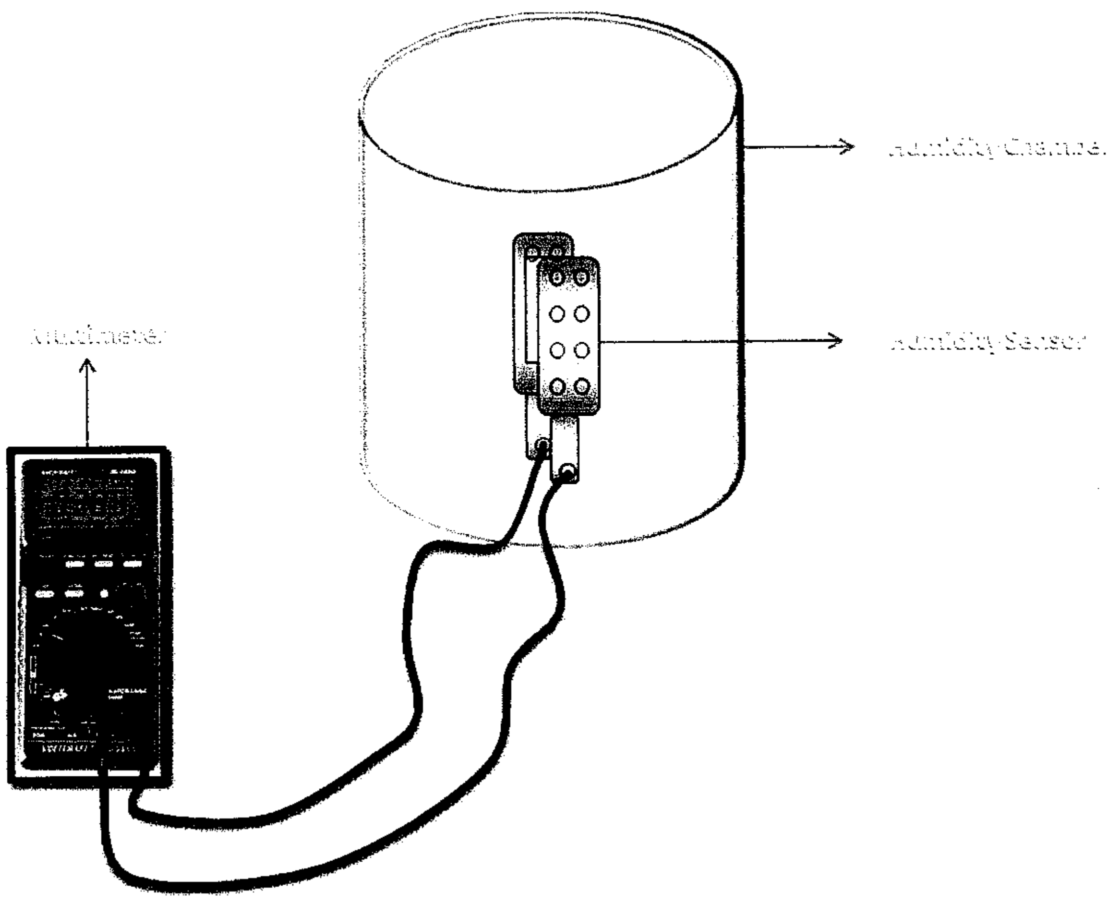
APPENDIX H

HUMIDITY DETECTOR PROTOTYPE SCHEMATIC



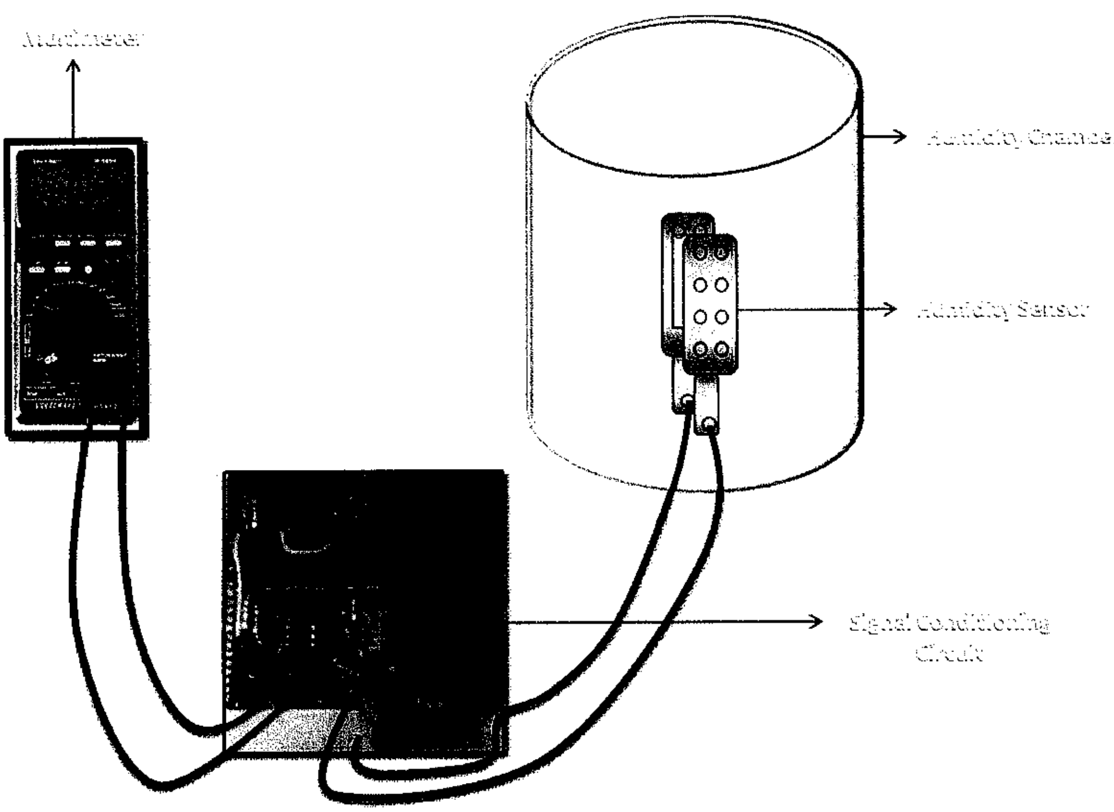
APPENDIX I

EQUIPMENT SETUP FOR LAB EXPERIMENT 1



APPENDIX J

EQUIPMENT SETUP FOR LAB EXPERIMENT 2



APPENDIX K

ZINC OXIDE PREPARATION