AUTOMATED GREENHOUSE

by

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Dissertation Submitted in Partial Fulfillment of

the Requirements for the

Degree Bachelor of Engineering (Hons)

(Electrical & Electronics Engineering)

MAY 2011

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(ELECTRICAL & ELECTRONICS ENGINEERING)

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2011

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.

NURUL AFIQAH NADIAH BT ISHAK

ACKNOWLEDGEMENT

First and foremost, I would like to express my greatest gratitude to Allah the Almighty for giving me the opportunity to complete my Final Year Project successfully and with great achievement. Carrying out this project had been a wonderful and invaluable experience. A lot of knowledge gained will definitely be very useful in applying my engineering skills in future.

Therefore, I would like to express my deepest appreciation and thanks to my supervisor of this project, Assoc Prof Josefina Barnachea Janier for the inspirations and guidance in this project. She constantly provides valuable guidance and advice which has motivated me to contribute my fullest to this project.

Additionally, gratitude is dedicated to my parents and family, for having faith in me and also for the words of inspiration that kept me going. To my close friends and colleagues, thank you for been there through thick and thin in providing moral and technical support during the course of this project. Their constant support has greatly motivated me to continuously put in effort towards the completion of this project, especially during challenging times.

Finally, special mention goes to Ms. Siti Hawa and all other technician in assisting with all the reports and equipment being used throughout this project.

ABSTRACT

This project is about a design of miniature greenhouse that is equipped with the automated monitoring system. The system will constantly monitor the natural environmental conditions in the greenhouse to ensure that the plant will achieve the maximum plant growth. There are two sensors, which operate in the real-time, that will be used - temperature sensor and air humidity sensor to monitor the conditions. The output of the sensors will provide the inputs to a microcontroller, PIC16F877A, which act as the brain and compares these values with the preset values. Subsequently, the microcontroller will actuate the environment maintaining devices, respectively according to the necessary condition of the plant. Besides, output from microcontroller also will give the input to the LCD to display the temperature and air humidity reading of the greenhouse.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Since early civilizations, agriculture has been one of the primary occupations of man and even today, manual interventions in farming are inevitable. Greenhouses form an important part of the agriculture and horticulture sectors in our country as they can provide an ideal condition for the plant growth and production throughout the year [1].

The microclimate of the greenhouse is controlled by growth factors such as temperature and humidity. These are scientifically controlled to the optimum level throughout the cultivation period, thus increasing the agriculture productivity. The closed environment of a greenhouse has its own unique requirements, compared with outdoor production. Besides that, it can keep the plants away from pets, extreme heat and humidity.

Greenhouse can be divided into glass greenhouses and plastic greenhouses, yet the plastics are mostly used [2]. Inside the greenhouse, there is a buildup of heat. This is due to the radiation from the sun that warms the plants and the soil. Even so, the air is retained and stocked inside the house. Because of the temperature and air humidity of greenhouses must be constantly monitored to ensure optimal conditions, an automated monitoring system can be used to remote it.

1.2 Problem Statement

1.2.1 Problem Identification

Temperature and air humidity are generally the parameters considered in greenhouse as they influence the plant growth. Traditionally, a small window near the roof of a greenhouse is open to drain away the warm air that traps inside the greenhouse and hence reduce the temperature considerably.

According to [3] it was mentioned that the adoption of software configuration management (SCM) or computer control is not convenient as they have many disadvantages such as complex structure, higher cost, not suit for the middle and small scales agriculture greenhouses. Hence, the automated control is seems more suitable and reliable.

Most of the work, in the farming, is done manually and it is hard for the farmers to maintain the quality of their crops. As a result, their harvest comes in various sizes and weight, different residue content and timing, making it hard for them to compete in the export market [4].

The development of automated system is a good solution to provide and to improve the productivity through application of greenhouse technology.

1.2.2 Significant of The Project

The significant of this project is that in the future, the number of greenhouses will increase and thus leading to a great demand for this automated monitoring systems. Furthermore, crops such as fruits and vegetables can yield better results if they are grown in a controlled environment and with the inclusion of farming technology [4]. In addition, the Automated Greenhouse is one of the low cost and equipped with low power application.

This Automated Greenhouse has many advantages such as:

- Automatically control the growing environment, such as temperature and air humidity, within the walls so that any type of plants can be grown all year round.
- Could be an economical, portable and a low maintenance solution for greenhouse applications, especially in rural areas and for small scale agriculturists.
- Keep the plants away from pets, extreme heat and humidity.
- Minimizes the labor costs involved in maintaining a greenhouse.
- User-friendly and flexible as the preset environmental condition could be changed based on the specific requirements of the user.

1.3 Objectives

The main goal is to build a miniature greenhouse that could carry out an automatic monitoring system purpose. This system will constantly monitor the conditions in the greenhouse to ensure that it remains at the required temperature and air humidity conditions. If these conditions differ from the required levels, the monitoring system will automatically turn on and off certain devices to return the greenhouse to the required conditions. As the system also employs an LCD display for continuously alerting the user about the condition inside the greenhouse.

1.4 Scope of Study

The study is limited to the following:

- Use of the PIC16F877A as the microcontroller.
- Use of LCD as real time display of data acquired from the environmental sensors
- Study on how to maintain the microclimate of a greenhouse.
- Study on the operation of temperature sensor and air humidity sensor.

CHAPTER 2

LITERATURE REVIEW

2.1 Automation of Greenhouse.

Automating a greenhouse envisages monitoring and controlling of the climatic parameters which directly or indirectly govern the plant growth and hence their produce. Automation is process control of industrial machinery and processes, thereby replacing human operators. The Automated Greenhouse is a system with a number of sensors that could monitor the important environmental factors which affect crop growth. In response to these sensors, the output of control system will adjust vent position, fans, heating, shading, lighting and water irrigation [15].

Obviously, there will be the labor saving aspect but far more importantly, factors such as improved quality of produce and increase the earning of profit. Automation systems have had a large impact upon the operation and efficiency of modern industrial plants [17]. Additionally, the sensor system features intelligent farming methodology and real time monitoring. This means farmers now have the total control of their crops and are able to make fast and reliable decision.

2.2 Environmental Sensors

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument [5]. Monitoring of a greenhouse environment involves sensing the changes occurring inside it which can influence the rate of growth in plants. The parameters of temperature and air humidity are important as it might affect the photosynthetic and transpiration processes of plant.

According to [6], the greenhouse requires a temperature control system and air humidity detection which has ability to read the differences between the measured data and data stored in the database of microclimate with sufficient accuracy and real-time control.

2.2.1 Temperature Sensor

A temperature sensor is used to detect the level of temperature and produce an electrical output proportional to the temperature (in ^{o}C). After the sensor detects the temperature, it sends a signal to the microcontroller. The microcontroller analyzes this signal and then turns on or off the fan or heater to bring the conditions back to the preset level.

Thermistor is a solid-state device that operates on the basis of change of electrical resistance with temperature and are available as negative temperature coefficient (NTC – resistance falls with rising temperature), or positive temperature coefficient (PTC – resistance increases with rising temperature). NTC is the most usual type for temperature measurement, and the rate of change of resistance with temperature is very much higher than that of a resistance thermometer, providing high sensitivity within a small temperature span. This makes thermistor very suitable for measuring temperatures around ambient applications [11].

2.2.2 Humidity Sensor

A humidity sensor also called as hygrometer, measures and regularly reports the relative humidity in the air. Relative humidity (RH), expressed as a percent, is the ratio of actual moisture in the air to the highest amount of moisture air at that temperature can hold. After the sensor detects the humidity level, it sends a signal to the microcontroller. The microcontroller analyzes this signal and will then turn on or off the mister or exhaust fan to bring the conditions back to the preset levels.

Conventional sensors determine relative air humidity using resistive measurement technology. For this principle, the sensor consists of noble metal electrodes either deposited on a substrate by photo-resist techniques or wire-wound electrodes on a plastic or glass cylinder. The substrate is coated with a salt or conductive polymer. When it is dissolved or suspended in a liquid binder it functions as a vehicle to evenly coat the sensor. Alternatively, the substrate may be treated with activating chemicals such as acid. The sensor absorbs the water vapor and ionic functional groups are dissociated, resulting in an increase in electrical conductivity. [12].

2.3 Microcontroller

The microcontroller of PIC will be programmed in the C language and will be capable of comparing the input signals from the sensors to the preset values. The appropriate signal will then be output and used to either turn on or off the devices.

PICs are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability. The name PIC initially referred to "Programmable Interface Controller" [5].

Below are the special features for the well-known PIC16F877A:

- Operating speed:20Mhz, 200ns instruction cycle
- Operating voltage:4.0-5.5volts
- Industrial temperature range(-40 to +85 degrees)
- Self-reprogrammable under software control
- Programmable code protection
- Power-saving code protection

Basically, PIC16F877A is the advance PIC of PIC16F877 as the masking is different in both the microcontrollers. In addition, while burning the code in PIC microcontroller there is an acknowledgement received for each code word written in PIC's memory. In the case of PIC16F877A, the code word is written in blocks. An acknowledgement is required only for the block of code word and hence speed of writing is more when compared to that of PIC16F877A [9].

2.4 Environment Maintaining Devices

2.4.1 Temperature Controllers Devices

Heating and cooling in greenhouse are important for plant growth. Due to the amount of energy consumed for these operations, their control is critical. Electrical heaters are used when it is necessary to specifically heat the local part of the greenhouse. The cooling part is also necessary as the radiation in greenhouse that use sunlight can cause high air temperature. Generally, curtain, watering on the glass roof, fan and pad system, fan and mist system and other methods are employed.

In order to reduce the temperature maintaining devices cost, a cooling fan is used to ensure that the greenhouse is in not too hot or too cold. If the surrounding temperature exceeds the preset level, the cooling fan will be turned on. However, if the surrounding temperature is below the preset level, the cooling fan will be turned off.

2.4.2 Humidity Controllers Devices

Humidity in greenhouse is influence by air temperature control, transpiration from plants, water evaporation from soil and other effects [7]. Usually, to reduce humidity, an exhaust fan or electric cooling machine is used, while air ventilation is the simplest method.

Due to the cost constrain, the cooling fan is also used to replace the pricey electric cooling machine. If the surroundings are too humid, the cooling fan will be turned on while if the surroundings are too dry, the cooling fan will be turned off.

2.5 Liquid Crystal Display (LCD)

A liquid crystal display (LCD) is a thin, flat panel used for electronically displaying information such as text, images, and moving pictures. Many microcontroller devices use LCD displays to output visual information. LCD displays designed around Hitachi's LCD HD44780 module, are inexpensive and easy to use. They have a standard ASCII set of characters and mathematical symbols.

The HD44780 character LCD is one of the industry standard liquid crystal display (LCD) display device designed for interfacing with embedded systems. These screens come in a variety of configurations including 8x1, 16x2, and 20x4 characters, where for instant, 8x1 characters define that the LCD could have one row of eight characters [16].

In this project, the HD44780 Character LCD with 16x2 characters is included to display the temperature and humidity reading of this Automated Greenhouse.

Based on the above readings and findings made, the following components and devices had been used as a framework for this project of Automated Greenhouse.

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

This Figure 1 shows the summary of the project procedure for this 2-Semester Final Year Project. This project covers starting from the title selection to the working prototype.

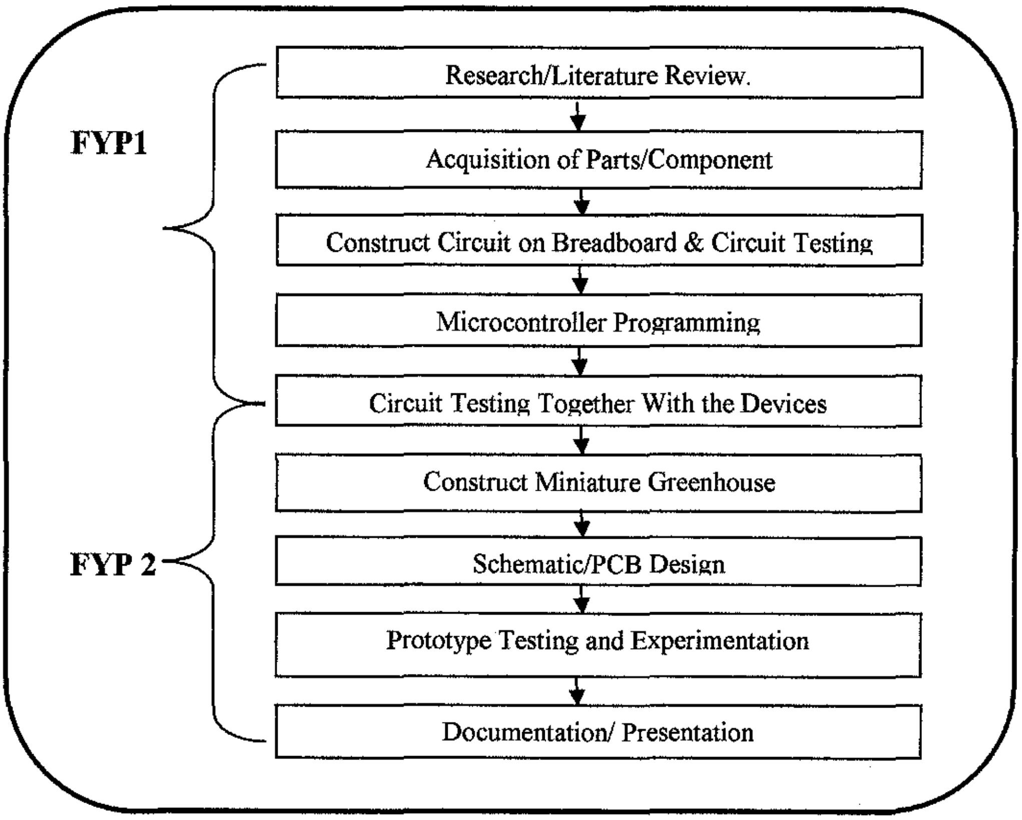

Figure 1: Workflow Project

The flow chart above illustrates the general progression of the project. The methodology is divided into two parts which are FYP1 and FYP2. This section briefly show the paths to ensure that all activities are done along with the development of the system would be accomplished on time.

The research stage is where all related information for this project was collected in order to get the better idea on the construction of this Automated Greenhouse. The identification on the component was done together with the designing circuit in order to get the most suitable component. The acquisition phase continued based on the circuit that had been designed in the previous stage. After all the components were obtained, the circuit was constructed on the breadboard and the testing stage is carried on.

During the microcontroller programming stage, the circuit is tested and it managed to show the output based on the input of temperature and humidity using LEDs. Furthermore, the programming code in PIC16F877A also managed to display the actual temperature and humidity reading of greenhouse via the LCD.

The next stages proceed with the circuit testing together with the actual devices and the LEDs are removed. In the mean time, the miniature of greenhouse is constructed using Perspex. Once all the circuits were tested and worked well, all the devices were mounted properly into the greenhouse and the overall prototype experimentation was held. The last stage was preceded with the documentation and presentation part after the overall experimentation achieved a successful result.

3.2 Functional Block Diagram

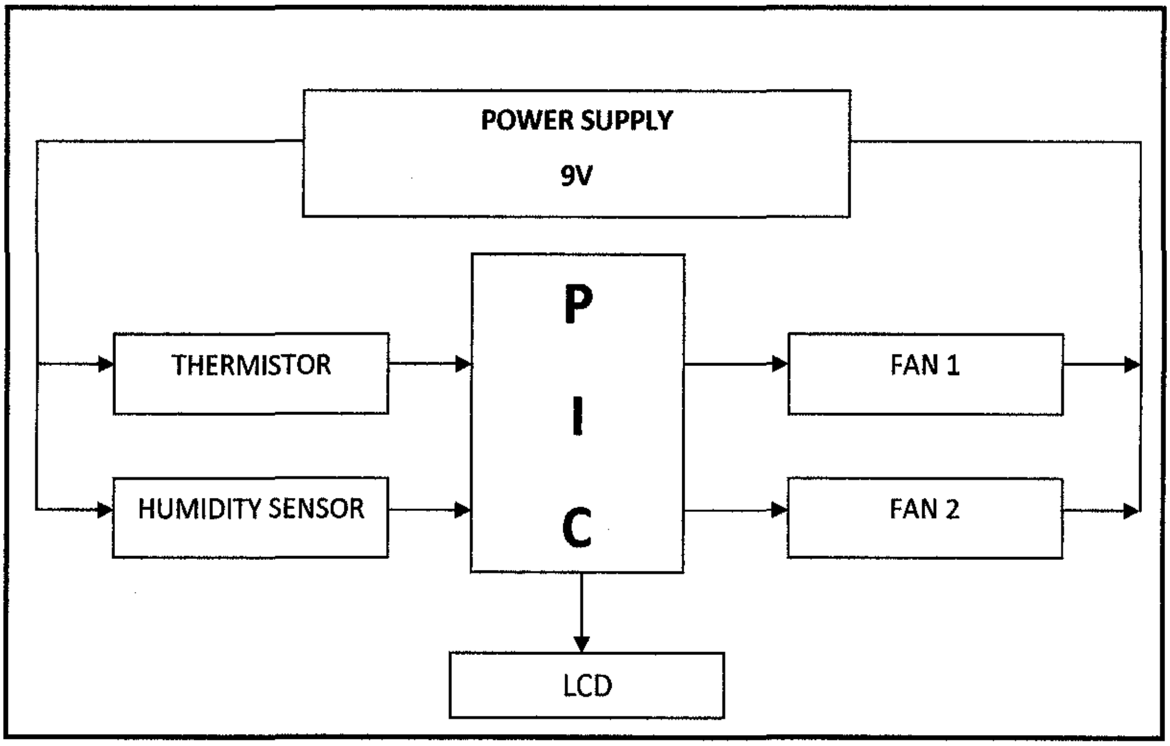

Figure 2: Functional Block Diagram

3.2.1 Block Descriptions

The Automated Greenhouse has five main parts which are power supply of 9V, sensors, microcontroller, devices and liquid crystal display (LCD). There are two types of environmental sensors that will be implemented in this project.

These sensors will be connected to a microcontroller which will function as the main control unit. The sensors will send signals to the microcontroller and the microcontroller will translate the signals, determine if the input is within the preset range and turn on or off the necessary devices to maintain the climate in the greenhouse.

For instance, if the preset temperature range is 35°C, the microcontroller will make sure that the greenhouse temperature is within this value. If the temperature exceeds this value, the microcontroller will then turn on the fan 1. If the temperature drops below this value, fan 1 will off.

As for the humidity sensor, it will detect a change in humidity levels and send a signal to the microcontroller. If the humidity level is not within the required preset value, fan 2 will be turned on or off.

A miniature greenhouse was constructed and power supply, sensors, microcontroller, fans and LCD were placed by a box made out of Perspex.

3.3 Tools and Equipment

Table 1: List of Hardware and Software Used

Hardware	Software
i. Power Supply ii. Digital Multi Meter iii. Thermistor iv. Humidity Sensor v. Cooling Fans vi. LCD	i. Microsim Eval 8,Pspice Schematic and Capture - This software is needed to simulate the circuitry designed for the device. It can be used for error checking to identify week points of the circuit. ii. AutoCAD - This software is particularly important for the design of the prototype. The initial design should be done using this software to get a visual representation of how the final product should look like. iii. MPLAB IDE - This software is used to program the instructions for PIC and stimulate the correct output of PIC, so that the devices can either on or off, respectively according to the necessary condition of the plant.

3.4 Process Flow Chart

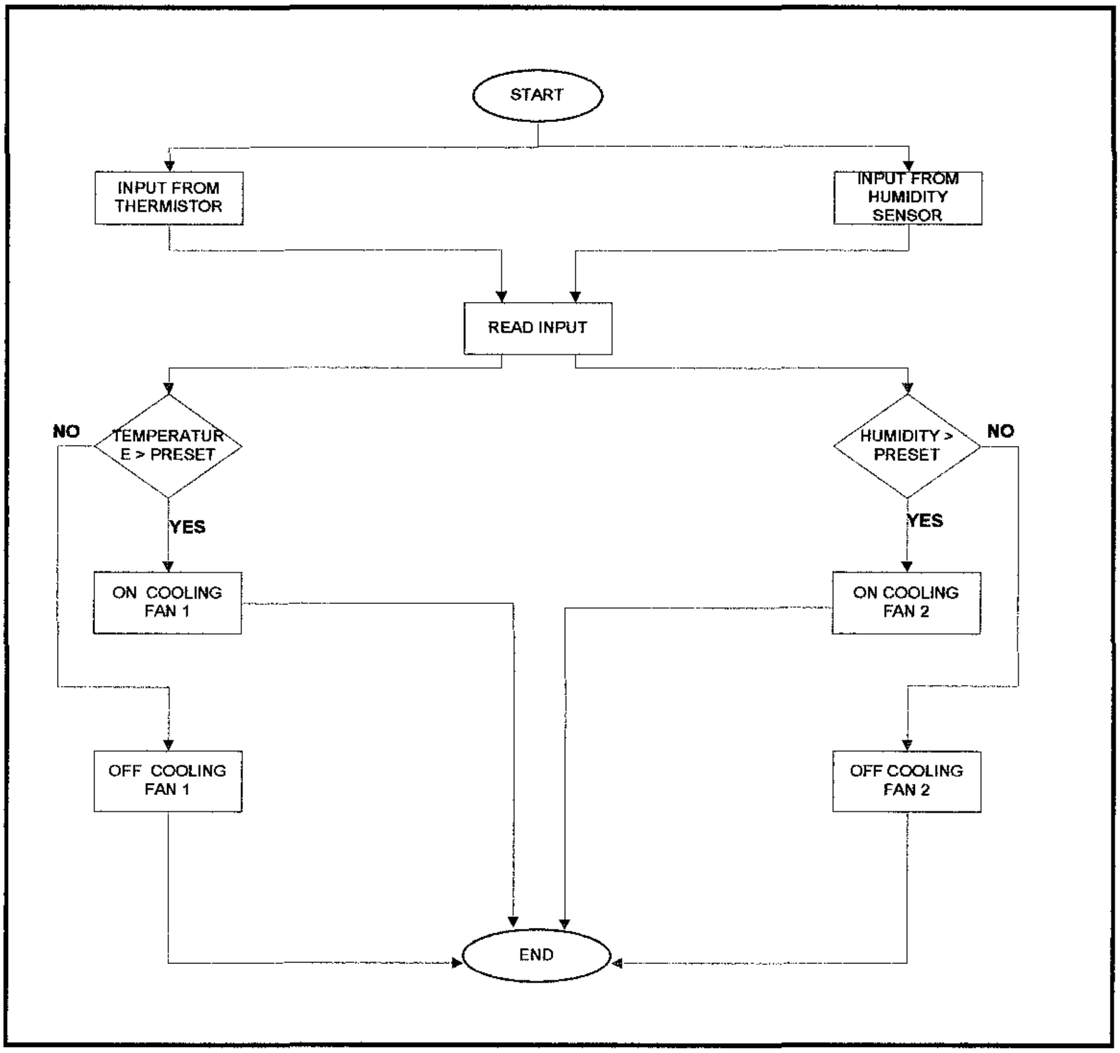

Figure 3: Flowchart for Project

3.4.1 Flow chart Descriptions

In general, the microcontroller works by reading the analog inputs (from the sensors), converts the analog signals to digital signals, processes the inputs and generates a 1-bit output. There are two inputs from the two sensors and there are two outputs signals produced by the PIC16F877A. These outputs are used as a switch to turn on or off the environment maintaining devices.

The PIC reads the analog inputs from both sensors; thermistor and humidity sensor. These analog inputs are then converted to digital values using the PIC's in-built analog-to-digital converter.

After the input is read, the counter will begin to count. The input values are then compared to the preset values. For the input from thermistor, it is compared to the preset values.

i. If the ADC value is equal and greater than preset values, the first cooling fan will be turned on to cool the greenhouse down, which indicates that the temperature is greater than the preset maximum temperature.
ii. If the ADC value is less than preset values, the first cooling fan will be turned off, which means the temperature is below the preset minimum temperature.

As for the humidity sensor, the input is compared to preset values, as well.

i. If the ADC value is equal and greater than preset values, the second cooling fan (which act as exhaust fan) will turn on to reduce the relative humidity level. This indicates that the humidity level is greater than the preset maximum humidity level.
ii. If the ADC value is less than preset values, the second cooling fans will turn on, which indicates the relative humidity is below the preset minimum humidity level.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Design Procedure

This project involves a construction of a prototype that can constantly monitor the natural environmental conditions in the greenhouse. Before acquisition of any parts or component, the design of circuit for sensors, PIC and devices is required either suitable to work on together on one same circuit board or not. Thus, a simple calculation is needed and the equation that will be used is Ohm's Law, where:

$$\text{Voltage [V]} = \text{Current [A]} \times \text{Resistance } [\Omega] \quad (1)$$

4.1.1 Environmental Sensors

4.1.1.1 Temperature Sensor

The amount power supply that will be channeled into the circuit board is 9V. Consequently, a sensor that could operate within 5V voltage supply will be used. After analyzing the specifications, the thermistor of MCP9700A-E/TO is selected. This sensor is able to measure the surrounding temperature with a very high accuracy, and has a wide temperature measurement range.

As specified in the datasheet, this sensor needs 5V voltage supply with an operating current that ranges from 6μA to 12 μA. To convert the output voltage to the equivalent temperature measurement, the datasheet provides the necessary equations. The equation is as follows [13]:

$$V_{OUT} = T_C \, . T_A + V_{0°C} \tag{2}$$

Where: V_{OUT} = Sensor Output Voltage

T_C = Temperature Coefficient (10.0mV/°C)

T_A = Ambient Temperature

$V_{0°C}$ = Voltage at 0°C (500mV)

A design of current limiting circuit is required to control the input current of the sensor. As mentioned before, the operating current have ranges from 6μA to 12 μA. Thus, Eq.1 needs to be applied to obtain the necessary current limiting resistor.

$$R = \frac{V}{I}$$

For a current of 6μA :

$$R = \frac{5\,V}{6\,\mu A}$$

$$= 833\,k\Omega$$

For a current of 12μA :

$$R = \frac{5\,V}{12\,\mu A}$$

$$= 416.7\,k\Omega$$

Therefore, any resistor between 833kΩ and 416.7kΩ is preferred. From the average of these both values and thus, 680kΩ resistor had been chosen. Hence the exact value of the operating current is limited to:

$$I_{DD} = \frac{V}{R}$$

$$= \frac{5\,V}{680\,k\Omega}$$

$$= 7.35\ \mu A$$

As for the output voltage of the sensor, the datasheet stated that it ranges from 0V to 3V. Thus, to calculate the equivalent temperature reading, Eq.2 had been applied, which is given in the datasheet:

$$V_{OUT} = T_C \,.\, T_A + V_{0°C}$$

$$T_A = \frac{V_{OUT} - V_{0°C}}{T_C}$$

$$= \frac{V_{OUT} - 500\ mV}{10mV/°C}$$

The datasheet stated that the sensor had a maximum output current of 100μA. Since the maximum current input of the PIC is 25mA, this output of the sensor can be connected directly to the input of the PIC.

A decoupling circuit, is also recommended by the datasheet, for the power supply to filter out the noise system. This switching noise compromises measurement accuracy. As recommended, to connect a decoupling circuit, a 1μF capacitor has to connect in series with a 200Ω from the Vcc connection of the sensor to ground.

Figure below shows the schematic design for thermistor circuit with the voltage output that will be connected to PIC16F877A.

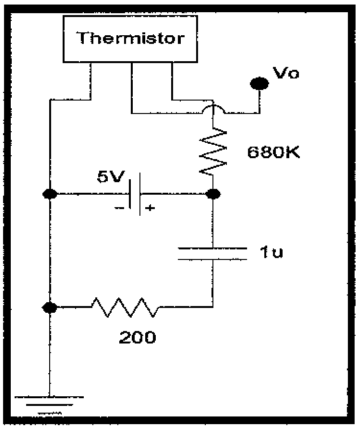

Figure 4: Thermistor Circuit.

4.1.1.2 Humidity Sensor

The humidity sensor is used to sense the humidity and delivers for instrumentation quality Relative Humidity (RH) sensing performance purpose. Relative humidity is a measure, in percentage, of the vapor in the air compared to the total amount of vapor that could be held in the air at a given temperature. Thus, the TDK CHS-GSS Humidity Sensor Unit was selected after considering the price and the reliability aspect. This humidity sensor is the most suitable as there is no hysteresis effect on the output readings.

This sensor also needs a 5V voltage supply and it will have the output with range of 0V to 1V. To determine the equivalent relative humidity level, the output voltage should be analyzed. From the datasheet, the output voltage changes linearly with the humidity level, where output 1V is at 100% RH .Thus, for every 0.01V is equivalent to 1%RH [14].

Subsequently the current going into the PIC has to be considered and a current of 20mA was chosen to minimize the risk of damaging the PIC. Thus, by applying Eq.1, the current limiting value is determined as following:

$$R = \frac{V}{I}$$

$$= \frac{1\,V}{20\,mA}$$

$$= 50\,\Omega$$

Figure below shows the schematic design for the humidity sensor circuit with the voltage output that will be connected to PIC16F877A.

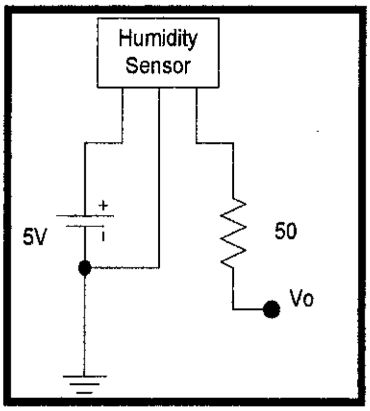

Figure 5: Humidity Sensor Circuit

4.1.2 Microcontroller

The well-known, PIC16F877A,is chosen as the microcontroller for this project as it has the capability to convert analog inputs into digital and also capable to produce digital output [8]. For this design, the PIC will read the analog inputs from both two sensors. These analog inputs are then converted to digital values before the digital values are then compared to the preset values of relative humidity range and temperature trigger voltage. Next, the appropriate signals will be the output to turn on or off the devices. This PIC is not complicated to use as it can be programmed in C to be utilized in processing the inputs and its corresponding outputs.

As mentioned in sensors part, PIC16F877A has several limitations such as the input current must not exceed 25mA. Hence, the sensors circuitry designs were then calculated for the current limitation so it will not exceed the current limit. The maximum output current from the PIC is 25mA but average output current from one pin is 10mA. This amount of output current is actually not sufficient to turn the devices on. So, the N-type of MOSFET will be used to amplify this small current.

4.1.3 Environment Maintaining Devices

4.1.3.1 Temperature Controllers Devices

The cooling fan will turn on to lower the temperature inside the greenhouse. In order to get a constant power supply, a fan with 12V at 18mA DC current is chosen as it would be sufficient enough to cool the greenhouse.

Since the output of the PIC controls the fan, the output needs to be considered. The PIC output is a digital 1 which means 5V or a digital 0 where voltage equal to 0V.Thus, an N-type of MOSFET is desired as switching and amplification. Basically, MOSFET has the same function as transistor yet MOSFET could flow out more power compared to the transistor [10]. Thus, MOSFET will be used again as a switch to open or close the power supply circuit by connecting the circuit to the ground. In order to increase the temperature, the PIC will give an output of a digital 0. Thus, the cooling fan will turn off.

4.1.3.2 Humidity Controllers Devices

If the surroundings are too humid, the second cooling fan (which act as exhaust fan) will be turned on. However, if the surroundings are too dry, the second fan will be turned off. The same concept applies to this humidity maintaining devices as it applied for the same type of cooling fan. The connections and specifications are similar to the first cooling fan design for the temperature maintaining device.

Figure below shows the general circuit for environment maintaining devices for both temperature and humidity.

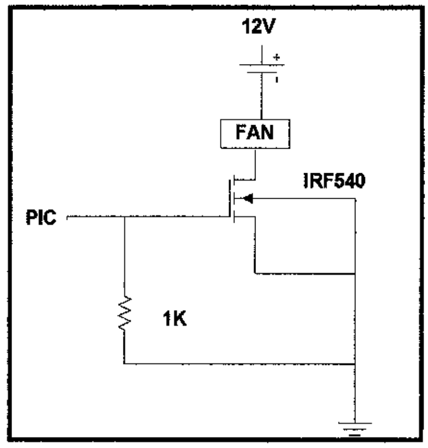

Figure 6: General Circuit for Devices

4.1.4 Liquid Crystal Display (LCD)

Signals from environmental sensors are input into the PIC and processed. The PIC then sends a signal to the Liquid Crystal Display (LCD) to display the current climate inside the greenhouse.

The HD44780 Character LCD with 16x2 characters has 16 pins. The transistor is connected together with the nominal backlight voltage of 5V to the backlight connection in order to turn on and off the LCDs backlight [16].

The pin outs connection and descriptions are as in figure below:

Pin	Function	Description
1	VSS	Ground
2	VCC	+5V Supply
3	VEE	Contrast
4	RS	Register Select
5	R/W	Read/Write
6	E	Enable
7-14	DB0-DB7	8 Bit Data
15	LED+	Backlight Supply
16	LED-	Backlight Ground

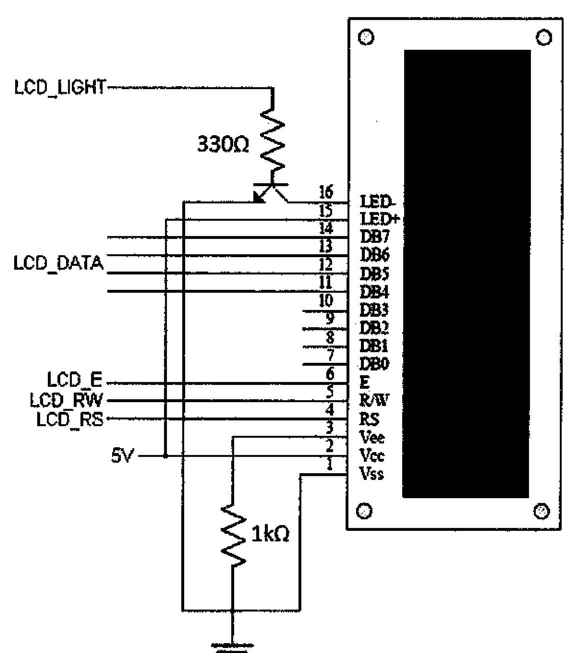

Figure 7: Connection and Descriptions of LCD HD44780

4.2 Prototype Design

The miniature greenhouse was constructed after all the components and devices were finally tested. Figure below show the layout drawing for the miniature of Automated Greenhouse. There is the body part that includes all the electrical components, devices, LCD and plant, itself.

Two fans and a LCD will be mounted respectively on each side of the box. The electrical component, thermistor and humidity sensor will be installed in a small circuitry box together with the power supply.

Figures below show the prototype design and actual Perspex box of the miniature of Automated Greenhouse with measurement of 40cm x 40cm x 60.

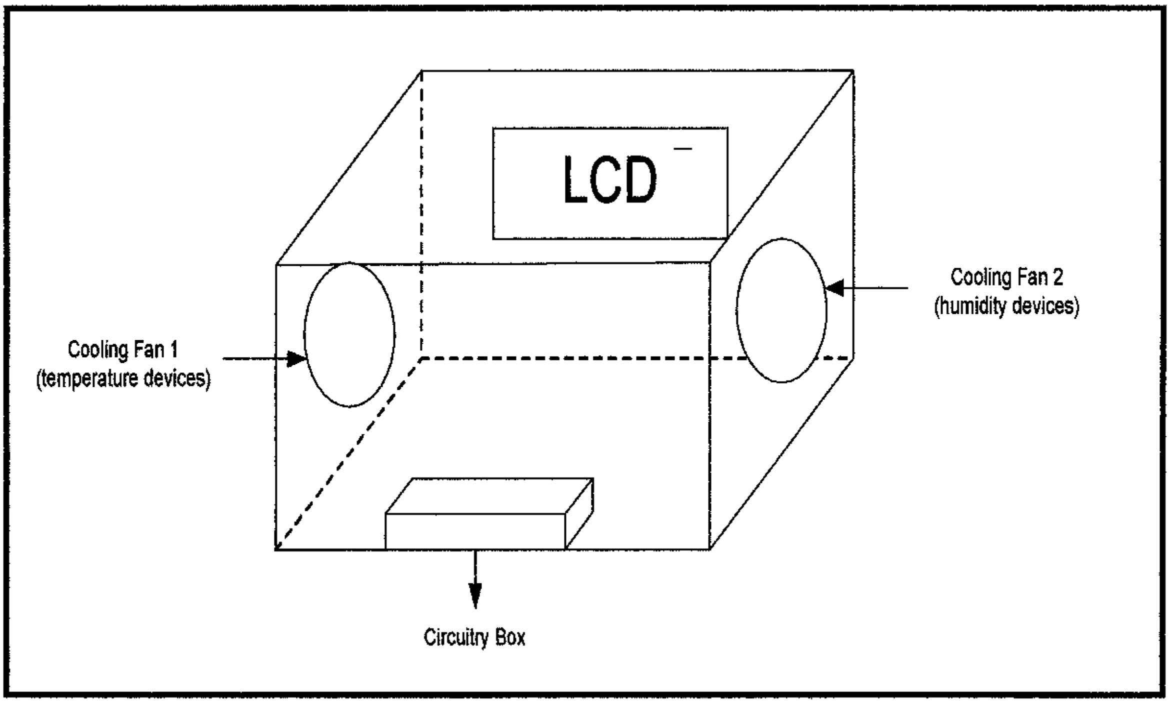

Figure 8: Miniature Greenhouse

Figure 9: Laboratory Greenhouse Model Used in Experiments.

4.3 Acquisition Procedure

With the circuit design done and tested, this project step forward to the acquisition stage. At this stage, the components were bought based on the calculation that had been made in the previous design procedure. This kind of workflow could be a cost and timesaving as all the required components are completely identified. The table of sensors' requirement had been included in the Appendix C.

4.4 Environmental Sensor Testing Procedures

The sensors, PIC and devices are needed to be tested individually to ensure that they could operate successfully. This is to make sure that this greenhouse monitoring system could function automatically without any human intervention at all.

4.4.1 Temperature Sensor

The main goal was to test the output voltage of the thermistor towards the decreasing and increasing of temperature. The voltage changes at the output of sensor is tested using a multi-meter by different surrounding, for instant in the cold, normal and warm condition.

The sensor will run using a 5V DC power supply. The datasheet suggested to use a decoupling circuit to reduce noise. The noise-reduction circuit was shown in the datasheet [13]. Then 1μF capacitor is connected in series with a 200Ω from the Vcc connection of the sensor to ground. A thermometer was also used to reconfirm the actual temperature reading with the readings output by the sensor and the output voltage of the thermistor is measured using a multi-meter.There is a set of conditions - 20°C, 27°C and 35°C. The results are recorded and shown in the table below.

Table 2 : Voltage Output for Different Temperature.

Thermometer reading (°C)	**Sensor Voltage output (V)**	**Sensor Temperature Equivalence (°C)**
20	0.704	20.4
27	0.769	26.9
35	0.852	35.2

The relationship between the temperature and voltage is:

$$T_A = \frac{V_{OUT} - V_{0°C}}{T_C} \quad (2)$$

Where, V_{OUT} = Sensor Output Voltage

T_C = Temperature Coefficient (10.0mV/°C)

T_A = Ambient Temperature

$V_{0°C}$ = Voltage at 0°C (500mV)

The result of the test was good as results obtained is in the range of ±1°C accuracy and the sensor was very sensitive and had a time response of less than 1 second. Moreover, the time response of the sensor towards temperature also changed instantly. Thus, the circuit will be use as the temperature sensor.

4.4.2 Humidity Sensor

The main goal was to test the reliability of the sensor by comparing the voltage output using a multi-meter to the humidity meter reading. As stated in the datasheet, when the sensor is connected to the power supply, the voltage output reading will start at a voltage of 1V and decreases to the actual humidity level of the surrounding. The sensor also needs 5V DC power supply and a resistor of 50Ω to connect in series.The result was reliable and matched the actual reading from the humidity meter. The result of the test is shown in the table below.

Table 3 : Voltage Output for Different Relative Humidity.

Humidity meter reading (%RH)	**Sensor Voltage Output (V)**	**Sensor Humidity Equivalence (% RH)**
72	0.722	72.2
65	0.647	64.7
51	0.525	52.5

The sensor outputs an analog voltage output which follows a relatively linear response function of 0.05V at 5% RH and 0.90V at 90% RH, which is given by the following response function [14] :

$$\% RH = \frac{V_{OUT} - V_{0\% RH}}{0.01} \quad (3)$$

where, $V_{0\%RH} = 0V$

The accuracy of the humidity sensor was in the range of ±2%RH whereas the responsiveness of the sensor is very good with an average speed of 0.01V/s. Therefore, it had been finalized to be a circuit for the humidity sensor.

4.5 Microprogramming Testing Procedure

The main goal was to verify the function of the programming code of PIC 16F877A. The software of MPLAB IDE is used with the HI-TECH ANSI C compiler to program the codes. The source code for the climate control and LCD display could be tested when the programs has been successfully compiled, simulated and downloaded into the PIC.

The result was accurate and reliable as the LEDs turn on and off accordingly as compared to the actual and preset value. Besides, the real time display of LDC obtained the range of ±2°C accuracy when compared to the temperature and humidity meter. Additionally, the time response of the LCD towards temperature and humidity also changed instantly. Thus, this could be concluded that the microprogramming testing was successful. The figure below shows the snapshot of the result from this testing.

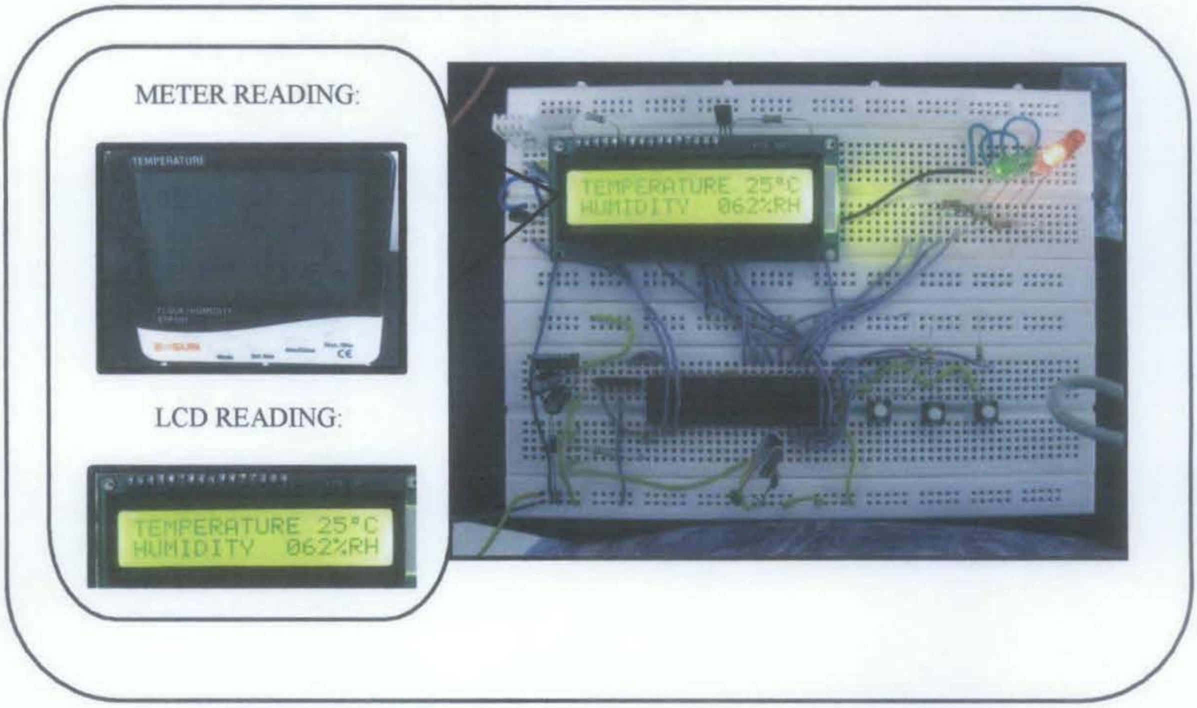

Figure 10: Snapshot of the LCD Display Compared with the Meter Reading and the Functioning Output of LEDs.

4.6 Overall Prototype Testing.

The system is represented by a prototype where the circuits were placed in a miniature of greenhouse by a box made out of Perspex. The LEDs from the previous breadboard were taken out and had been replaced with the environment maintaining devices which are cooling fans. Also, all the components have been soldered onto the vera board, rather than assemble them onto breadboard, in order to have a smaller size of circuit. The circuit schematic diagram is attached in the Appendix H.

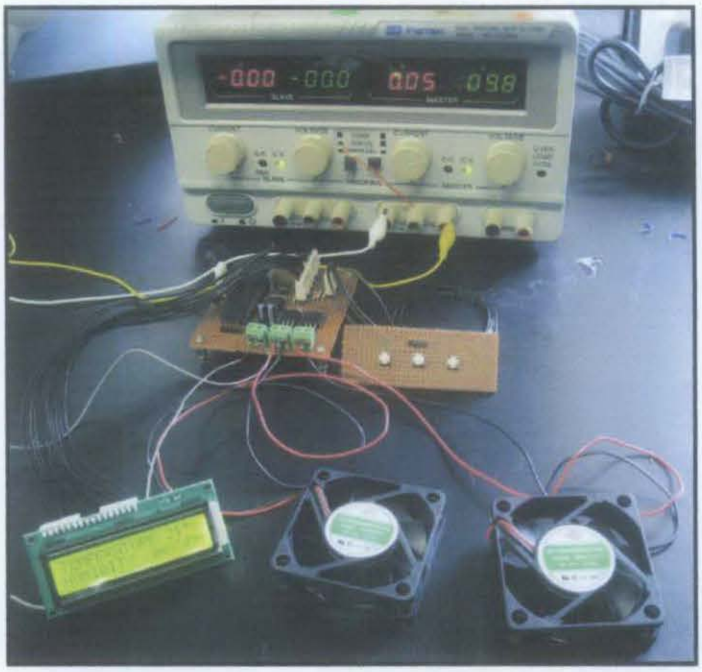

Figure 11: Circuit Implemented on Vera Board

The circuit board, devices and LCD display are all gathered and assembled into one system and tested. In order to test the functionality of this prototype, chilli plant had been chosen as an experimental purpose. Since chilli has the average temperature of 25°C and average air humidity of 75%RH, the preset value of temperature and air humidity were inserted, as the figures from the LCD below.

Figure 12: Actual Reading of Temperature and Air humidity

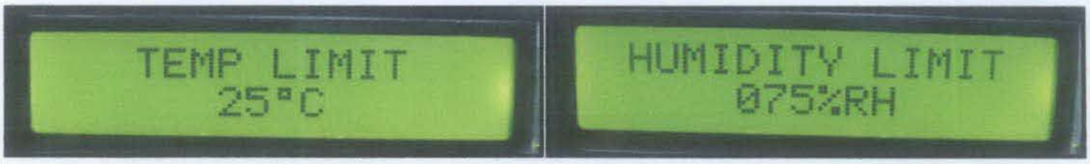

Figure 13: Temperature and Air Humidity Preset Value

Then, the devices will turn on and off respectively, depends on the preset value which had been set before. If actual temperature higher than 25°C, fan 1 (which act as cooling fan) will turn on, whereas if temperature lower than 25°C fan 1 will turn off. For the humidity part, when the actual air humidity is higher than 75%RH, fan 2 (which act as exhaust fan) will turn on, and if air humidity lower than 75%RH, fan 2 will turn off.

Besides that, the characteristic of the sensors also could be checked and both characteristic of the sensors are linear when compared to the output voltage (mV). For the temperature reading, every 0.01V is equivalent to 10°C. The graph in figure below shows the characteristic of the temperature sensor together with the snapshot of LCD that showed the temperature output voltage.

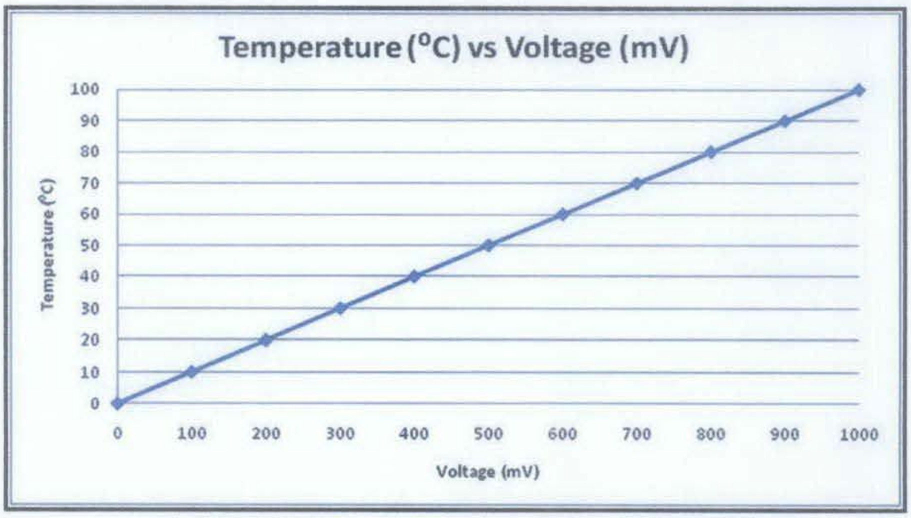

Figure 14: Characteristic of Temperature Sensor

Figure 15: Output Voltage for the Actual Temperature Reading of 21°C

The same characteristic also applied to the air humidity sensor. The output voltage changes linearly with the humidity level, where output 1V is at 100% RH .Thus, for every 0.01V is equivalent to 1%RH [14]. The graph below shows the characteristic of the humidity sensor together with the snapshot of LCD that display the air humidity output voltage.

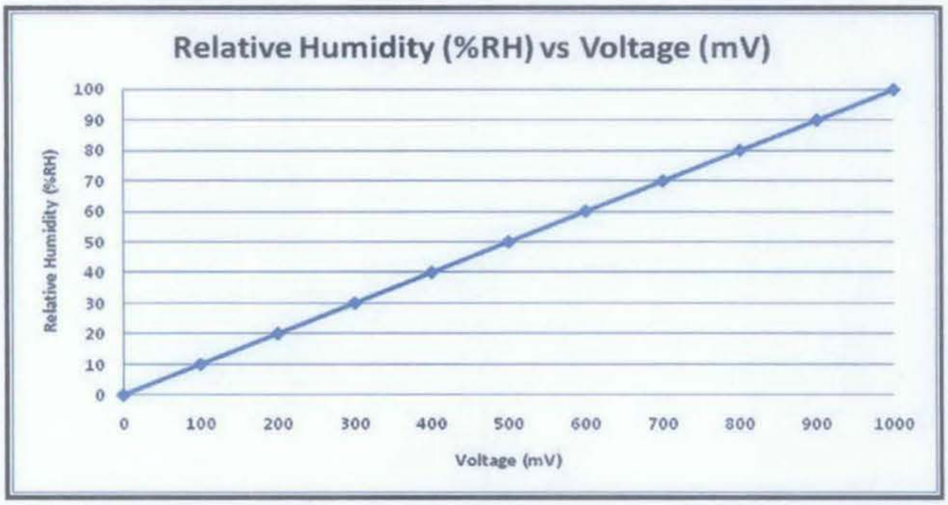

Figure 16: Characteristic of Humidity Sensor

Figure 17: Output Voltage for the Actual Air Humidity Reading of 69%RH

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Although the traditional way is widely used to grow and manage the crops, it has certain drawback regarding the quality of the crops. It is hard for farmers to maintain the quality of their crops and as the result; their harvest comes in various size and weight. Thus, it is hard for the farmers to compete in export market.

In conclusion, this project was successfully conducted as it met all the objectives that were set forth. This study allowed the detail analysis of the technical and feasibility for the implementation of Automated Greenhouse. By using controlled environment using microcontroller of PIC16F877A, this Automated Greenhouse can give better results compared to the work which is done manually and the labor cost also could be reduced. Moreover, it could bring out positive effect and can be applied in real life in order to improve the standard of local agriculture industry in Malaysia.

5.2 Recommendation

As the system has few limitations in term of time and cost of hardware constraints, here are some recommendations that could enhance this Automated Greenhouse:

i. Include others parameter for environmental control such as light and CO_2concentration
ii. Construct the real miniature of greenhouse to apply the principle in order to test the applicability in real life (either practical or not)

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APPENDICES

APPENDIX A

GANTT CHART FOR FINAL YEAR PROJECT 1

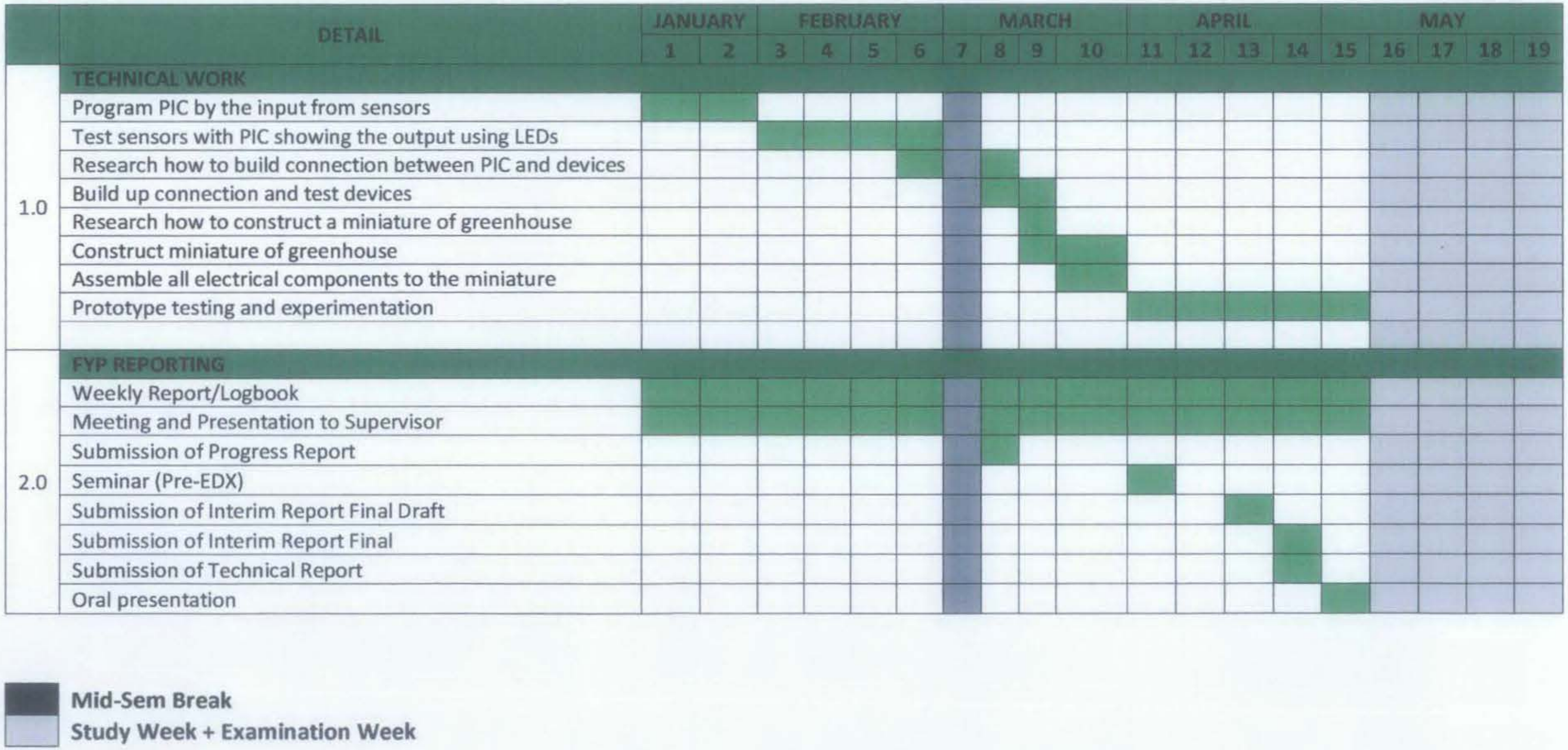
	DETAIL	JULY	AUGUST				SEPTEMBER					OCTOBER				NOVEMBER					DECEMBER	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1.0	Selection of Project Topic																					
	TECHNICAL WORK																					
	Research specifications for a greenhouse																					
	Research on components (Sensors,PIC,devices)																					
	Survey and buy sensors and other component																					
	Research how to program basic functions on PIC																					
2.0	Research how to build connection between sensors and PIC																					
	Build up connection and test sensors																					
	Program PIC by the input from sensors																					
	Test sensors with PIC showing the output using LEDs																					
	Research how to build connection between PIC and devices																					
	Build up connection and test devices																					
	Assemble all electrical components. Test and troubleshoot																					
	FYP REPORTING																					
	Weekly Report/Logbook																					
	Meeting and Presentation to Supervisor																					
	Submission of Preliminary Report				19/8																	
3.0	Submission of Progress Report								22/9													
	Seminar									TBA	TBA											
	Submission of Interim Report Final Draft													18/10								
	Submission of Interim Report Final															2/11						
	Oral presentation																				TBA	TBA

Mid-Sem Break

Study Week + Examination Week

APPENDIX B

GANTT CHART FOR FINAL YEAR PROJECT 2



APPENDIX D

PIC16F877A DATASHEET

40-Pin PDIP

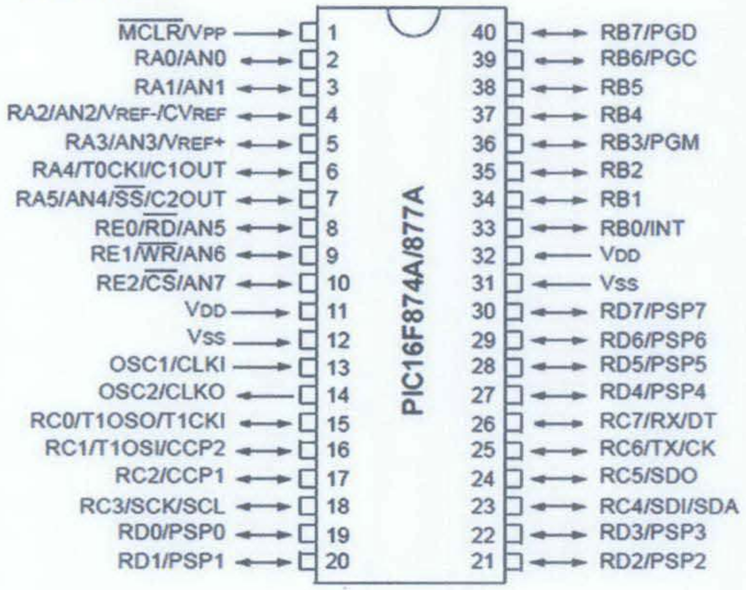


TABLE 1-1: PIC16F87XA DEVICE FEATURES

Key Features	PIC16F873A	PIC16F874A	PIC16F876A	PIC16F877A
Operating Frequency	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory (bytes)	128	128	256	256
Interrupts	14	15	14	15
I/O Ports	Ports A, B, C	Ports A, B, C, D, E	Ports A, B, C	Ports A, B, C, D, E
Timers	3	3	3	3
Capture/Compare/PWM modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Analog Comparators	2	2	2	2
Instruction Set	35 Instructions	35 Instructions	35 Instructions	35 Instructions
Packages	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

APPENDIX E

MCP9700A-E/TO DATASHEET

MCP9700/9700A and MCP9701/9701A

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin No. SC-70	Pin No. SOT-23	Pin No. TO-92	Symbol	Function
1	—	—	NC	No Connect
2	3	3	GND	Power Ground Pin
3	2	2	V_{OUT}	Output Voltage Pin
4	1	1	V_{DD}	Power Supply Input
5	—	—	NC	No Connect

3.1 Power Ground Pin (GND)

GND is the system ground pin.

3.2 Output Voltage Pin (V_{OUT})

The sensor output can be measured at V_{OUT}. The voltage range over the operating temperature range for the MCP9700/9700A is 100 mV to 1.75V and for the MCP9701/9701A, 200 mV to 3V .

3.3 Power Supply Input (V_{DD})

The operating voltage as specified in the **"DC Electrical Characteristics"** table is applied to V_{DD}.

4.0 APPLICATIONS INFORMATION

The Linear Active Thermistor™ IC uses an internal diode to measure temperature. The diode electrical characteristics have a temperature coefficient that provides a change in voltage based on the relative ambient temperature from -40°C to 125°C. The change in voltage is scaled to a temperature coefficient of 10.0 mV/°C (typical) for the MCP9700/9700A and 19.5 mV/°C (typical) for the MCP9701/9701A. The output voltage at 0°C is also scaled to 500 mV (typical) and 400 mV (typical) for the MCP9700/9700A and MCP9701/9701A, respectively. This linear scale is described in the first-order transfer function shown in Equation 4-1.

EQUATION 4-1: SENSOR TRANSFER FUNCTION

$$V_{OUT} = T_C \bullet T_A + V_{0°C}$$

Where:

T_A = Ambient Temperature

V_{OUT} = Sensor Output Voltage

$V_{0°C}$ = Sensor Output Voltage at 0°C

T_C = Temperature Coefficient

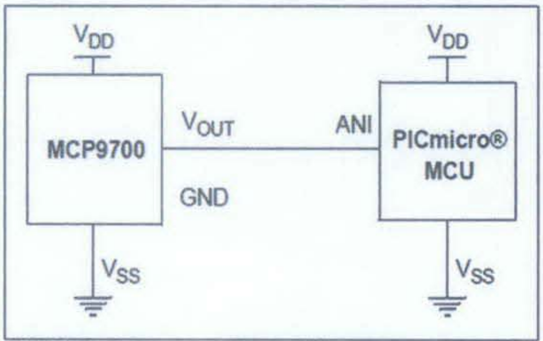


FIGURE 4-1: Typical Application Circuit.

4.1 Improving Accuracy

The MCP9700/9700A and MCP9701/9701A accuracy can be improved by performing a system calibration at a specific temperature. For example, calibrating the system at +25°C ambient improves the measurement accuracy to a ±0.5°C (typical) from 0°C to +70°C, as shown in Figure 4-2. Therefore, when measuring relative temperature change, this family measures temperature with higher accuracy.

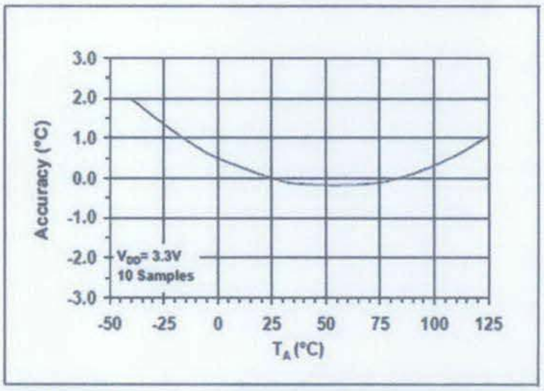


FIGURE 4-2: Relative Accuracy to +25°C vs. Temperature.

The change in accuracy from the calibration temperature is due to the output non-linearity from the first-order equation, as specified in Equation 4-2. The accuracy can be further improved by compensating for the output non-linearity.

For higher accuracy using a sensor compensation technique, refer to AN1001 *"IC Temperature Sensor Accuracy Compensation with a PICmicro® Microcontroller"* (DS01001). The application note shows that if the MCP9700 is compensated in addition to room temperature calibration, the sensor accuracy can be improved to ±0.5°C (typical) accuracy over the operating temperature (Figure 4-3).

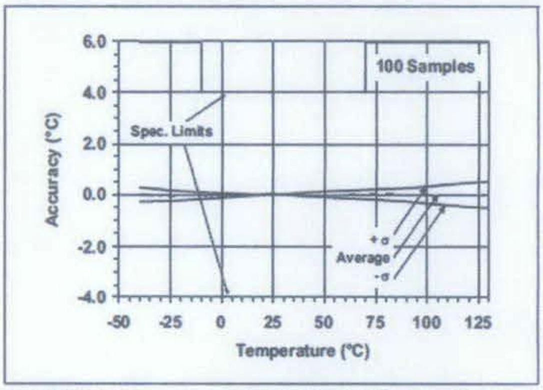


FIGURE 4-3: MCP9700/9700A Calibrated Sensor Accuracy.

The compensation technique provides a linear temperature reading. A firmware look-up table can be generated to compensate for the sensor error.

4.2 Shutdown Using Microcontroller I/O Pin

The MCP9700/9700A and MCP9701/9701A family of low operating current of 6 µA (typical) makes it ideal for battery-powered applications. However, for applications that require tighter current budget, this device can be powered using a microcontroller Input/Output (I/O) pin. The I/O pin can be toggled to shut down the device. In such applications, the microcontroller internal digital switching noise is emitted to the MCP9700/9700A and MCP9701/9701A as power supply noise. This switching noise compromises measurement accuracy. Therefore, a decoupling capacitor and series resistor will be necessary to filter out the system noise.

4.3 Layout Considerations

The MCP9700/9700A and MCP9701/9701A family does not require any additional components to operate. However, it is recommended that a decoupling capacitor of 0.1 µF to 1 µF be used between the V_{DD} and GND pins. In high-noise applications, connect the power supply voltage to the V_{DD} pin using a 200Ω resistor with a 1 µF decoupling capacitor. A high frequency ceramic capacitor is recommended. It is necessary for the capacitor to be located as close as possible to the V_{DD} and GND pins in order to provide effective noise protection. In addition, avoid tracing digital lines in close proximity to the sensor.

4.4 Thermal Considerations

The MCP9700/9700A and MCP9701/9701A family measures temperature by monitoring the voltage of a diode located in the die. A low-impedance thermal path between the die and the PCB is provided by the pins. Therefore, the sensor effectively monitors the temperature of the PCB. However, the thermal path for the ambient air is not as efficient because the plastic device package functions as a thermal insulator from the die. This limitation applies to plastic-packaged silicon temperature sensors. If the application requires measuring ambient air, consider using the TO-92 package.

The MCP9700/9700A and MCP9701/9701A is designed to source/sink 100 µA (max.). The power dissipation due to the output current is relatively insignificant. The effect of the output current can be described using Equation 4-2.

EQUATION 4-2: EFFECT OF SELF-HEATING

$$T_J - T_A = \theta_{JA}(V_{DD}I_{DD} + (V_{DD} - V_{OUT})I_{OUT})$$

Where:

T_J = Junction Temperature

T_A = Ambient Temperature

θ_{JA} = Package Thermal Resistance (331°C/W)

V_{OUT} = Sensor Output Voltage

I_{OUT} = Sensor Output Current

I_{DD} = Operating Current

V_{DD} = Operating Voltage

At T_A = +25°C (V_{OUT} = 0.75V) and maximum specification of I_{DD} = 12 µA, V_{DD} = 5.5V and I_{OUT} = +100 µA, the self-heating due to power dissipation ($T_J - T_A$) is 0.179°C.

APPENDIX F

CHS-GSS DATASHEET

TDK

Humidity Sensor Units
CHS Series CHS-U, -SS, -C Types

TDK's CHS series humidity sensors are compact and extremely simple to apply. Because they contain the necessary circuitry, there is no need to provide additional control circuitry or perform time-consuming calibration. With simple connection to a power supply, they will output DC at 100% relative humidity. This makes it possible to read RH directly with a voltmeter.

CHS-U TYPE

For industrial use and measuring equipment

FEATURES

- These sensors can measure a wide range of humidity – from 5(%) to 95(%)RH.
- They are highly accurate. The nominal accuracy for the CHS-UPR and CHR-UPS is within ±3(%) RH.

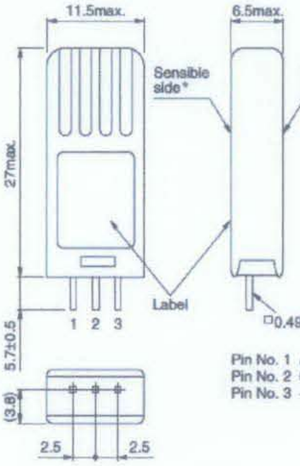
Type	CHS-UGS CHS-UGR	CHS-UPS CHS-UPR
Nominal accuracy(%)RH	±5	±3
Measuring range(%)RH	5 to 95	5 to 95

- Characteristics are stable over a wide temperature range.
- Humidity sensing characteristics exhibit virtually no hysteresis.
- Highly cost-effective and compact, requiring extremely little mounting space.
- Low current consumption.
- Outputs DC.1V at 100(%)RH; relative humidity can be read directly with a voltmeter.
- All-in-one construction integrates sensor with support circuitry. The entire module operates off a 5V power supply.
- Generated ripple at low humidity levels will not exceed 2.5mV.

SHAPES AND DIMENSIONS

SQUARE TYPE

CHS-UGS, -UPS

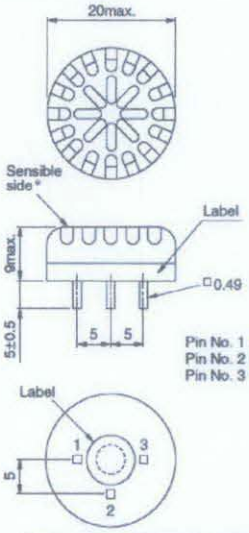


Pin No. 1 Analog output voltage
Pin No. 2 GND
Pin No. 3 +Power supply voltage

Weight: 1.38g typ.

ROUND TYPE

CHS-UGR, -UPR



Pin No. 1 Analog output voltage
Pin No. 2 GND
Pin No. 3 +Power supply voltage

*When installing the device, ensure that the humidity sensing surface is not obstructed.

Weight: 1.68g typ.

Dimensions in mm
Tolerance: ±0.2

MAXIMUM RATINGS (Ta=25°C)

Power supply voltage Edc	7V max.
Operating conditions	0 to +50°C, power supply voltage 5V, without dewing
Storage conditions	−20 to +60°C, without dewing

CHS-U TYPE

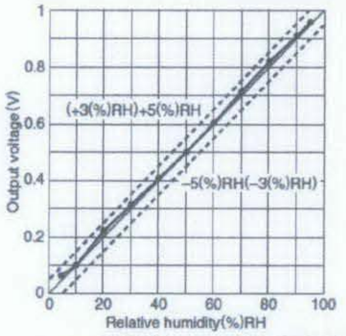
ELECTRICAL CHARACTERISTICS

Item		Specifications			Conditions
		Minimum	Standard	Maximum	
Operating voltage Edc (V)		4.75	5	5.25	
Operating current(mA)				0.6	Edc=5V, 25°C
Output voltage(mV)/(%)RH			10		Edc=5V, 25°C, 5 to 95(%)RH
Output impedance(kΩ)			(200)*		at DC
Accuracy(%)RH	CHS-UPS, -UPR	–3		+3	Edc=5V, 25°C, 5 to 95(%)RH
	CHS-UGS, -UGR	–5		+5	(For details, please refer to typical characteristics)
Hysteresis(%)RH			≈0		Stable time: 20min
Temperature dependency(%)RH		–5		+5	Edc=5V, 25°C standard, +5 to +45°C, 5 to 95(%)RH
Response time(min)			1		Response time to reach 90% of actual humidity as for from : 85(%)RH
Recommended operating temperature(°C)		+5		+45	Edc=5V

*( ): Reference value

TYPICAL CHARACTERISTICS

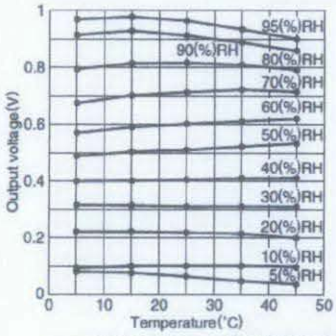
SENSOR LINEARITY CHARACTERISTICS (Ta=25°C Edc=5V)



Center line
Allowance
Typical value

Tolerance of each humidity
UP TYPE ±3(%)RH
UG TYPE ±5(%)RH

TEMPERATURE DEPENDENCY CHARACTERISTICS



Typical value

Specification temperature zone
+5 to +45°C(5 to 95(%)RH)
Tolerance of each humidity
±5(%)RH

APPENDIX G

PIC16F877A CODING

```
#include <pic.h>
#include <htc.h>
__CONFIG(0x3F32);
#define PB1           RC1
#define PB2           RC2
#define PB3           RC3
#define LED1          RC4
#define LED2          RC5
#define LED3          RC6
#define LED4          RC7
#define LCD_RS        RD0
#define LCD_RW        RD1
#define LCD_EN        RD2
#define LCD_LIGHT     RD3
#define LCD_DATA      PORTD         //D7-D4
#define LCD_PULSE() ((LCD_EN=1),(LCD_EN=0))
#define _XTAL_FREQ    20000000

void pic_init(void);
void lcd_init(void);
void lcd_write(unsigned char c);
void lcd_clear(void);
void lcd_goto(unsigned char pos);
void lcd_string(const char *s);
char read_button(void);
int read_a2d(unsigned char channel);
void convert(int no, char base);
void display(char number);

char di[10];

__EEPROM_DATA(1,244,1,244,0,0,0,0);

main()
{
int i,temperature[2],humidity[2];
char pb,mode=0;
pic_init();                                   //initialize PIC
```

```
lcd_init();                                              //initialize LCD
temperature[1]=256*eeprom_read(0)+eeprom_read(1);
humidity[1]=256*eeprom_read(2)+eeprom_read(3);
for(;;){
        pb=read_button();
        temperature[0]=(int)(4.888*read_a2d(0));
        humidity[0]=(int)(4.888*read_a2d(1));

        if(temperature[0]<temperature[1]){
                LED1=1;
                LED2=0;}
        else{
                LED1=0;
                LED2=1;}
        if(humidity[0]<humidity[1]){
                LED3=1;
                LED4=0;}
        else{
                LED3=0;
                LED4=1;}

        switch(mode){
        case 0:{
                lcd_goto(0x00);                          //select first line
                lcd_string("TEMPERATURE ");              //display string
                convert(temperature[0],10);
                for(i=2;i>=1;i--) display(di[i]);
                lcd_write(0);
                lcd_string("C");
                lcd_goto(0x40);                          //select second line
                lcd_string("HUMIDITY  ");                //display string
                convert(humidity[0],10);
                for(i=3;i>=1;i--) display(di[i]);
                lcd_string("%RH");
                switch(pb){
                case 1:{
                        mode++;
                        for(i=0;i<400;i++) __delay_ms(1);
                break;}
                case 2:{
                        mode=4;
                break;}
                case 4:{
                        mode=5;
                break;}}
        break;}
        case 1:{
                lcd_goto(0x00);                          //select first line
                lcd_string("   TEMP LIMIT   ");          //display string
                lcd_goto(0x40);                          //select second line
                lcd_string("     ");                     //display string
```

```
        convert(temperature[1],10);
        for(i=2;i>=1;i--) display(di[i]);
        lcd_write(0);
        lcd_string("C     ");                       //display string
        switch(pb){
        case 1:{
                mode++;
                for(i=0;i<400;i++) __delay_ms(1);
        break;}
        case 2:{
                if(temperature[1]<990) temperature[1]=temperature[1]+10;
                eeprom_write(0,temperature[1]>>8);
                eeprom_write(1,temperature[1]);
                for(i=0;i<200;i++) __delay_ms(1);
        break;}
        case 4:{
                if(temperature[1]>0) temperature[1]=temperature[1]-10;
                eeprom_write(0,temperature[1]>>8);
                eeprom_write(1,temperature[1]);
                for(i=0;i<200;i++) __delay_ms(1);
        break;}}
break;}
case 2:{
        lcd_goto(0x00);                             //select first line
        lcd_string(" HUMIDITY LIMIT ");             //display string
        lcd_goto(0x40);                             //select second line
        lcd_string("    ");                         //display string
        convert(humidity[1],10);
        for(i=3;i>=1;i--) display(di[i]);
        lcd_string("%RH     ");                     //display string
        switch(pb){
        case 1:{
                mode++;
                for(i=0;i<400;i++) __delay_ms(1);
        break;}
        case 2:{
                if(humidity[1]<1000) humidity[1]=humidity[1]+10;
                eeprom_write(2,humidity[1]>>8);
                eeprom_write(3,humidity[1]);
                for(i=0;i<200;i++) __delay_ms(1);
        break;}
        case 4:{
                if(humidity[1]>0) humidity[1]=humidity[1]-10;
                eeprom_write(2,humidity[1]>>8);
                eeprom_write(3,humidity[1]);
                for(i=0;i<200;i++) __delay_ms(1);
        break;}}
break;}
case 4:{
        lcd_goto(0x00);                             //select first line
        lcd_string("  TEMP VOLTAGE  ");             //display string
```

```
            lcd_goto(0x40);                                  //select second line
            lcd_string("    ");                              //display string
            convert(temperature[0],10);
            for(i=3;i>=0;i--) display(di[i]);
            lcd_string("mV    ");                            //display string
            if(pb!=2) mode=0;
        break;}
        case 5:{
            lcd_goto(0x00);                                  //select second line
            lcd_string("HUMIDITY VOLTAGE");                  //display string
            lcd_string("    ");                              //display string
            lcd_goto(0x40);                                  //select second line
            lcd_string("    ");                              //display string
            convert(humidity[0],10);
            for(i=3;i>=0;i--) display(di[i]);
            lcd_string("mV    ");                            //display string
            if(pb!=4) mode=0;
        break;}
        default:{
            mode=0;
        break;}}
}}

void pic_init(void)
{
TRISA=0b00000011;
TRISB=0b00000000;
TRISC=0b00001110;
TRISD=0b00000000;
TRISE=0b00000000;
ADCON1=0b00000110;
PORTA=0b00000000;
PORTB=0b00000000;
PORTC=0b00000000;
PORTD=0b00000000;
PORTE=0b00000000;
}
/* initialise the LCD - put into 4 bit mode */
void lcd_init(void)
{
__delay_ms(15);                                              //delay for LCD Power Up
lcd_write(0x28);                                             //function set
lcd_write(0x0C);                                             //display on/off control
lcd_clear();                                                 //clear screen
lcd_write(0x06);                                             //entry mode set
LCD_LIGHT=1;

LCD_RS=0;
lcd_write(0x40);
LCD_RS=1;
lcd_write(0b01110);
```

```
lcd_write(0b01010);
lcd_write(0b01110);
lcd_write(0b00000);
lcd_write(0b00000);
lcd_write(0b00000);
lcd_write(0b00000);
lcd_write(0b00000);
}
/* write a byte to the LCD in 4 bit mode */
void lcd_write(unsigned char c)
{
LCD_DATA=(LCD_DATA&0x0F)|(c&0xF0);
LCD_PULSE();
LCD_DATA=(LCD_DATA&0x0F)|((c<<4)&0xF0);
LCD_PULSE();
__delay_us(40);
}

/* clear LCD and goto home */
void lcd_clear(void)
{
LCD_RS=0;
lcd_write(0x1);
__delay_ms(2);
}
/* write a string of chars to the LCD */
void lcd_string(const char *s)
{
LCD_RS=1;                                   // write characters
while(*s)
lcd_write(*s++);
}
/* go to the specified position */
void lcd_goto(unsigned char pos)
{
LCD_RS=0;
lcd_write(0x80+pos);
}
char read_button(void)
{char i=0;
if(PB1==0) i=i+1;
if(PB2==0) i=i+2;
if(PB3==0) i=i+4;
return i;
}
int read_a2d(unsigned char channel)
{ADCON0=0b00000001;                         //Turn on A/D module
ADCON1=0b10000000;                  //configures analog and voltage reference
                pins
ADCON0=(ADCON0&0xC7)|(channel<<3);          //select analog input
channel
```

```
__delay_ms(2);
ADGO=1;                                         //initiate conversion on
the selected channel
while(ADGO==1) continue;                        //wait until conversion
done
return(256*ADRESH+ADRESL);}

void convert(int no, char base)
{char i;
for(i=0;i<=9;i++) di[i]=0;
i=0;
do{
        di[i]=no%base;
        no=no/base;
        i=i+1;}
while(no!=0);
}

void display(char number)
{switch(number){
case 0:{lcd_string("0");break;}
case 1:{lcd_string("1");break;}
case 2:{lcd_string("2");break;}
case 3:{lcd_string("3");break;}
case 4:{lcd_string("4");break;}
case 5:{lcd_string("5");break;}
case 6:{lcd_string("6");break;}
case 7:{lcd_string("7");break;}
case 8:{lcd_string("8");break;}
case 9:{lcd_string("9");break;}
case 10:{lcd_string("A");break;}
case 11:{lcd_string("B");break;}
case 12:{lcd_string("C");break;}
case 13:{lcd_string("D");break;}
case 14:{lcd_string("E");break;}
case 15:{lcd_string("F");break;}
default:{lcd_string("?");break;}
}}
```

APPENDIX H

SCHEMATIC DIAGRAM FOR AUTOMATED GREENHOUSE