

**DESIGN AND DEVELOPMENT OF A NOVEL  
HUMIDEX BASED AIR CONDITIONER  
CONTROLLER**

*A Thesis*

*Submitted in the partial fulfillment of requirement for the award of the degree of*

**Master of Engineering  
in  
Electronic Instrumentation and Control Engineering**



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## **CERTIFICATE**

I hereby certify that the work, which is being presented in the thesis, entitled “**Design and Development of a Novel Humidex based Air Conditioner Controller**” in partial fulfillment of the requirements for the award of degree of Master of Engineering in Electronic Instrumentation and Control Engineering at Thapar Institute of Engineering and Technology (Deemed University), Patiala, is an authentic record of my own work carried out under the supervision of Assistant Professor Mandeep Singh and Lecturer Nirbhowjap Singh.

I have not submitted the matter presented in the thesis for the award of any other degree of this or any other university.

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**“DEDICATED TO”  
MY PARENTS  
AND  
\*\*\* TO ALL THOSE GREAT SOULS WHO SHAPED  
MY FUTURE \*\*\***

## **ABSTRACT**

In present era, to maintain certain level of physical comfort, use of air conditioner is becoming more and more popular. However conventional air conditioners are not energy efficient as they operate mostly described by a band of temperature limits. Human comfort, on the other hand is dependent not only on temperature but also on relative humidity i.e. at the same temperature say 30<sup>o</sup>, if humidity is low, discomfort is less as compared to if humidity is high. To incorporate this factor of humidity, an index known as humidex was proposed

**[“[http://www.wul.qc.ec.gc.ca/meteo/documentation/Humidex/humidex\\_a.html](http://www.wul.qc.ec.gc.ca/meteo/documentation/Humidex/humidex_a.html)”]**

and operating air conditioners in the prescribed humidex zone is not only more comfortable but also economical. The present work revolves around microcontroller based intelligent air conditioning control system that takes inputs in the form of temperature and humidity, computes the humidex and gives user a choice to operate in “comfort” or “economy” mode.

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## Chapter 1: Introduction

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Humidex, meaning humidity extraction, is today's ultimate home dehumidifier, and air quality management equipment. Humidex is the chart, which comes from the values of temperature and relative humidity. Humidex is the Canadian way to describe what the temperature feels like when it's very hot and very humid. For example, the air temperature on a hot summer day might be 30°C (86°F). But if it's muggy, and the relative humidity is, say, 80%, the temperature is going to feel more like 43°C (110°F), according to the humidex.

The body attempts to maintain a constant temperature of 37°C at all times. In hot weather, the body produces sweat, which cools the body as it evaporates. As the humidity or the moisture content in the air increases, sweat does not evaporate as readily. Sweat evaporation stops entirely when the relative humidity reaches about 90 percent. Under these circumstances, the body temperature rises and may cause illness. Comfort has been divided in many parts i.e. no discomfort, some discomfort, great discomfort, dangerous and heat stroke.

In this thesis, the objective of the project is to achieve the Humidex value (which comes from the chart between Temperature and Relative Humidity) suitable in 2 aspects i.e. human comfort and economy. Here the decided values for comfort and economy are 28 and 34 respectively. If the Humidex value is below 28, then there is no requirement to turn on the A.C. because this value suits the human comfort and it can be seen from the humidex chart. Between 28 and 34 humidex value, little bit discomfort is felt but humidex value more than 34, results in great discomfort, so at this value A.C. is required to turn ON.

In the present work, humidex indicated by the hardware is compared with standard humidex chart. An extremely high humidex reading can be defined as one that is over 40<sup>o</sup> Celsius. In such conditions, all unnecessary activity should be reduced. If the reading is in the mid to high 30s, then certain types of outdoor exercise should be toned

down or modified, depending on the age and health of the individual, physical shape, the type of clothes worn, and other weather conditions.

## Chapter 2: Literature Review

---

This chapter describes the review of Introduction to Humidex and its basic components in detail.

### 2.1 Humidex

Humidex is a measure of how hot one feels. It is an equivalent temperature intended for the general public to express the combined effects of warm temperatures and humidity. It provides a number that describes how hot, people feel much in the same way the equivalent chill temperature, or "wind chill factor," describes how cold, people feel. Humidex is used as a measure of perceived heat that results from the combined effect of excessive humidity and high temperature. It

- restores dryness after flooding cleanup
- dries up damp drywall, wood, concrete, etc.
- solves condensation problems on windows, sills, walls and pipes
- prevents dampness and rot, removes musty basement odor

#### 2.1.1 Humidex Formula

The formula is not for the faint of heart -- those who are faint of heart should be indoors where there's air conditioning sipping iced tea when it's so humid anyway. It uses the dew point temperature and is concerned with the molecular weight of water, among other things. Fortunately there is a simplified formula:

$$\text{Humidex} = T + \frac{5 \times ((6.112 \times 10^{(7.5 \times T / (237.7 + T))} \times H) - 10)}{9}$$

where H is the percentage of humidity in the air and T is the temperature in degrees Celsius. Humidity is the amount of moisture in the air. Relative humidity is the ratio of water vapour in the air at a given temperature to the maximum amount, which could exist at that temperature. On hot summer days, the higher the relative humidity, the greater the discomfort, since perspiration evaporates less readily and the body feels more hot and sticky. The humidex is the scale describing how hot, humid weather feels to the average person.

The humidex combines the temperature and humidity into one number to reflect the perceived temperature. Because the humidex takes into account the two most important factors that affect summer comfort, it can be a better measure of how stifling the air feels than either temperature or humidity alone.

Temperature In Degrees	C <input type="text" value="45"/> F <input type="text" value="113"/>
Relative Humidity In Percent	<input type="text" value="70"/> %
<input type="button" value="Calculate"/> <input type="button" value="Clear Values"/>	
Humidex Factor In Celsius	<input type="text" value="76"/> Degrees
Humidex Factor In Fahrenheit	<input type="text" value="169"/> Degrees
<pre>The humidex factor is 76 C The humidex factor is 169 F Heat stroke probable.</pre>	

**Table-2.1. Humidex Calculation**

In summer, hot or very warm means more than 7 Celsius above normal; warm, 4 to 7 Celsius above normal; cool, 4 to 7 Celsius below normal; and very cool, more than 7 Celsius below normal. In winter, very mild means more than 7 Celsius above normal; mild, 4 to 7 Celsius above normal; cold, 4 to 7 Celsius below normal; and bitterly cold or very cold, more than 7 Celsius below normal. Normal refers to a long-term average, usually over 30. [22]

### 2.1.2 Reasons to Be Called Humidex

The name is sort of a meld of the words "humidity" and "index". Sometimes Canadian governmental agencies will invent their own words for things to make translation easier between the two official languages. The wind chill index is sometimes called the "chilldex".

### 2.1.3 Humidity History

The humidex was introduced in 1965 by what is now the Meteorological Service of Canada. The formula currently used to determine the humidex has been in use since 1979. The humidex is a Canadian innovation, first used in 1965. It was devised by Canadian meteorologists to describe how hot, humid weather feels to the average person. The humidex combines the temperature and humidity into one number to reflect the

perceived temperature. Because it takes into account the two most important factors that affect summer comfort, it can be a better measure of how stifling the air feels than either temperature or humidity alone.

The purpose was to create an easily understood method of describing how very hot and humid weather feels to the average person. The humidex combines the temperature and humidity into one number to reflect the perceived temperature. Because it takes into account the two most important factors that affect summer comfort, it can be a better measure of how uncomfortable the air feels than either temperature or humidity alone. The humidex is similar to the heat index but is widely used in Canada. It equals  $H = T + (0.5555 * (e - 10))$ , where T is the temperature in Celsius and e is the vapor pressure in millibars (mb). This is the Canadian formula but there are variations of humidex throughout the world, of both the exact formulae and of interpretation of the results. Temperature is entered in either scale though the actual calculation is done in degrees Celsius. Here the conversion is done from Celsius temperature to Fahrenheit by way of the formula,

$$T_f = (9/5) \times T_c + 32$$

### 2.1.4 Use of Humidex

If the temperature and relative humidity is known, the following chart can be used to determine the humidex rating. If the temperature is 30°C and the relative humidity is 70%, the humidex rating is 41°C. This level is considered a level of "great discomfort" and exertion should be avoided.

Under certain workplace conditions, the humidex may serve as an indicator of discomfort resulting from occupational exposures to heat. For when humidity is high, but when work load, wind speed and radiant heat sources do not significantly contribute to the heat burden, humidex may be useful.

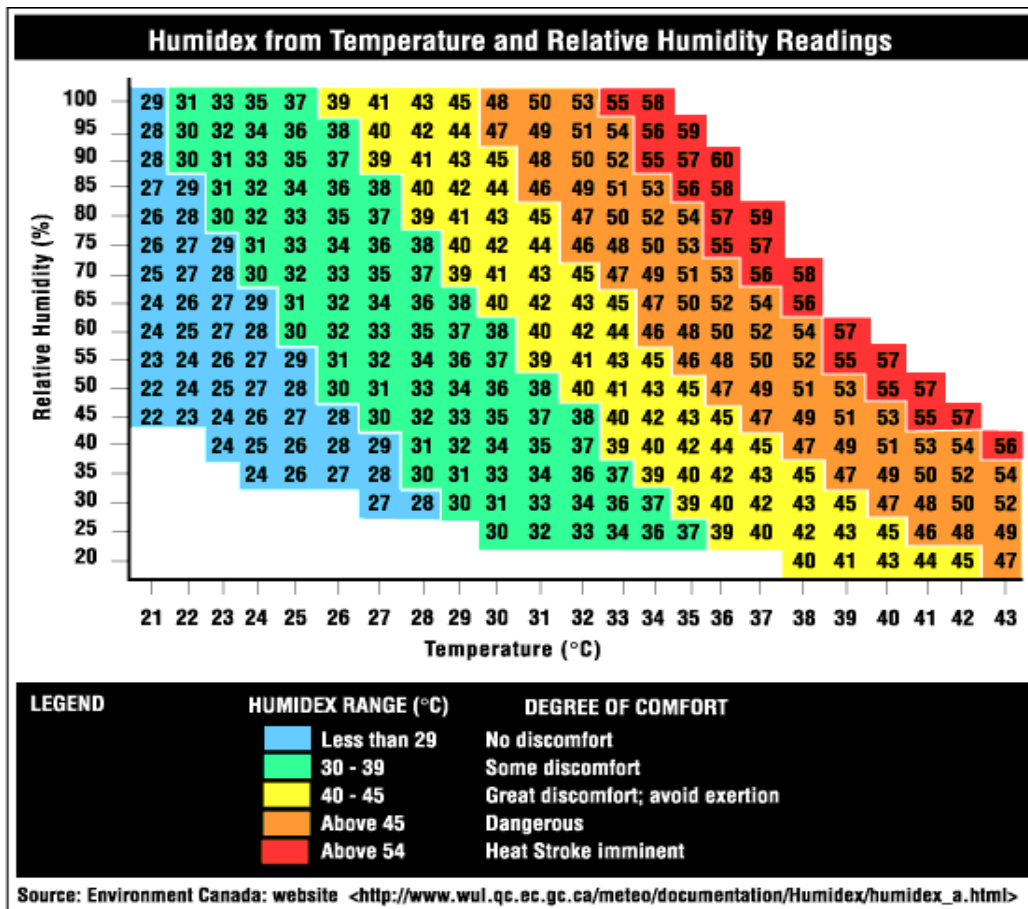


Table-2.2. Humidex Chart

Offices are typical of workplaces where humidex could be used. It is important to use the values of the temperature and relative humidity obtained by actual measurements taken in the workplace. Conditions inside the workplace may significantly differ from those given by the Weather Service.

### **2.1.5 Temperature Ranges**

Range of humidex defines degree of comfort or discomfort.

- 20-29°C - Comfortable
- 30-39°C - some discomfort
- 40-45°C - great discomfort; avoid exertion
- Above 45°C - Dangerous
- Above 54°C - heat stroke imminent

### **2.1.6 Humidex Operation**

The amount of water removed by your Humidex will vary according to the model selected and the conditions in which it is operating. During very cold weather the performance of your Humidex is reduced. No domestic dehumidifier is capable of completely eliminating condensation from single glazed windows, but the Humidex will significantly reduce it and prevent damp and mould growth. The time it takes to do this depends upon the size of the home and level of moisture within it. The reduction in

Condensation and damp within the first few days or alternatively, may take several weeks. To achieve the maximum benefit from the Humidex, it should ensure that:

- a) It is permanently connected to the mains and controlled via the adjustable humidistat.
- b) The Humidex is not switched off for long periods of time due to an incorrect setting of the humidistat or because the container is full.
- c) Internal doors are left ajar.
- d) External doors and windows are kept closed as much as possible.

This also saves wasting heat from the home. Since water is heavier than air, moisture and humidity naturally gravitate towards the basement of the home. When a HUMIDEX unit is installed and operating in the basement, the moist and stale air is drawn to the unit by a quiet and powerful fan and then expelled to the outside of the house through the funnel system. This then creates an area of decreased pressure at the lower level and causes the warmer, drier air from the upper levels to be drawn

downstairs. In this manner, the house achieves more effective air stratification throughout all levels.

In the summer, the effect is that the temperature at the lower level has been raised when the upper air has been drawn downwards, thereby creating a more even temperature level throughout. When the temperature at the lower level has risen, the dew point has risen as well, which translates into lower relative humidity and less condensation.

In the winter, before using the Humidex the relative humidity in the basement is higher than the cold air outside, and in actuality contains a greater quantity of water particles. Water will condense in the basement at about 50% - 60% relative humidity. After the Humidex is operational, the air downstairs with the greater amount of water is expelled outside; the warmer and drier air from upstairs flows down, raising the temperature, and lowers the relative humidity, and lowers the condensation. The drier air is easier to heat than the heavy moist air, thereby saving money in heating bills. The Humidex works well set at 50% year round.

All Humidex units are controlled by an adjustable dehumidistat, and will automatically go to a lower speed, once it reaches the desired level of humidity; using a minimal amount of electricity. As opposed to a conventional dehumidifier, which will run constantly, recirculation the same heavy stale air, and letting the water sit unemptied. The latter requires a compressor with high wattage, and several units for an area of 2,400 square feet. One Humidex unit will do the job, more efficiently for a fraction of the cost and requires no maintenance or attention to its operation.[21]

## **2.2 Air Conditioning**

The air conditioning is that branch of engineering science which deals with the study of conditioning of air i.e. supplying and maintaining desirable atmospheric conditions for human comfort, irrespective of external conditions. The human comfort depends upon physiological and psychological conditions. Thus it is difficult to define the term 'human comfort'. There are many definitions given for this term by different bodies. But the most accepted definition, from the subject point of view, is given by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) which states: human comfort is that condition of mind, which expresses satisfaction with the thermal environment. [19]

### **2.2.1 Factors Affecting Comfort Air Conditioning**

The four important factors for comfort air conditioning are discussed as below:

#### **➤ Temperature**

In air conditioning, the control of temperature means, (the maintenance of any desired temperature within an enclosed space even though the temperature of the outside air is above or below the desired room temperature. This is accomplished either by the addition or removal of heat from the enclosed space as and when demanded. It may be noted that a human being feels comfortable when the air is at 21°C with 56% relative humidity.

#### **➤ Humidity**

The control of humidity of air means the increasing or decreasing of moisture contents of air during summer or winter respectively in order to produce comfortable and healthy conditions. The control of humidity is not only necessary for human comfort but it also increases the efficiency of the workers. In general, for summer air conditioning, the relative humidity should not be less than 60% whereas for winter air conditioning it should not be more than 40%.

#### **➤ Purity**

It is an important factor for the comfort of a human body. It has been noticed that people do not feel comfortable when breathing contaminated air, even if it is within acceptable temperature and humidity ranges. It is thus obvious that proper filtration, cleaning and purification of air is essential to keep it free from dust and other impurities.

#### **➤ Motion**

The motion or circulation of air is another important factor, which should be controlled, in order to keep constant temperature throughout the conditioned space. It is, therefore, necessary that there should be equi-distribution of air throughout the space to be air-conditioned

### **2.2.2 Air Condition Working**

The essential ingredients in an air conditioning system are a fan to blow air around, a cold surface to cool and dehumidify the air, a warm surface and a source of water vapour. In a large system there will also be a tangle of tubes to distribute the air and collect it again. Notice that the cold surface has two independent jobs to do: it is used to cool the air and it is also used to dehumidify, by condensing water from the air. This means that

the air is cooled more than is necessary for temperature control, so that it must be heated again afterwards.

Air conditioning wastes energy. It also wastes space, because air has to be pumped around in quite large tubes, so that it doesn't make a rushing noise. It does, nevertheless, generate a disturbing background noise if the room is otherwise quiet.

**VAGLICA and GILMOUR [1]** gave a set of guidelines for the designer to use as a checklist for evaluating candidate devices is given. The first decision examined is the level of performance required, that is, on the word size of the controller. The second step is to identify the quantity, frequency, and type of all input/output (I/O) signals, as well as any other special requirements, including those imposed by mechanical aspects of the system. The third consideration is the application's memory requirements, which should be further broken down into program memory and data memory. Mapping I/O peripherals and the choice of single-chip or expanded are discussed. The feature-selection process is addressed, stressing that an absolute match between requirements and features is not necessary, since minor alterations to the requirements or the addition of a peripheral chip could create the most cost-effective solution from a less-than-perfect pairing.

**SAILOR and PAVLOVA [2]** in existing state-level models relating climate parameters to residential electricity consumption indicate a nominal sensitivity of 2–4% for each degree celsius increase in ambient temperatures. Long-term climate change will also impact electricity consumption through corresponding increases in the market saturation of air conditioning. In this paper we use air conditioning market saturation data for 39 US cities to develop a generalized functional relationship between market saturation and cooling degree days. The slope of this saturation curve is particularly high for cities that currently have low to moderate saturation. As a result, the total response of per capita electricity consumption to long-term warming may be much higher than previously thought. A detailed analysis of 12 cities in four states shows that for some cities changes in market saturation may be two to three times more important than the role of weather sensitivity of current loads. While actual behavioral response to climate change will be more complicated than that captured in our model of market saturation, this approach provides a new perspective on the sensitivity of space conditioning electricity consumption in the US to climate change.

**DIAZ, MARTIN-RAMOS, PRIETO, FERNANDEZ and NUNO [3]** proposed a system controls the speed of a winding machine in order to obtain the optimum stop point in terms of security and fast production. The system is based on a microcontroller and an

extremely simple hardware. The system has been tested for two years and results evince a very good mean time between failures.

**DUROVIC and KOVACEVIC [4]** The HVAC (heating ventilation and air conditioning) car unit may be considered as a very complex multiple-input multiple-output system with the basic target to make the car passengers feel comfortable. The system inputs are: air temperature, actual temperature in the passenger compartment, sun load, vehicle speed, desired temperature set by the driver or co-driver, air recirculation request and defrost request. The last two inputs are binary signals. The system outputs are defined by the actuators located in the HVAC unit: defrost door position (it controls the air distribution between the defrost registers and penal-feet registers), mode door position (it controls the air distribution between the penal and feet registers), blend door position that mixtures hot and cold air, recirculation door position that makes a difference between the fresh air input and recirculation and the last output is the blower speed. The system that has to be controlled is quite nonlinear and non-stationary and there are two important criteria that have to be fulfilled. The first of them is the passengers' comfort and this criterion is vague, hardly defined numerically. In order to acquire some training sets many test trips have been made. Car companies usually organize three test trips trying to cover extreme temperature and weather environments. One of them is during summer choosing some hot destinations in Spain, Portugal or North Africa. The second trip is during the winters with the destinations in North Europe and the third trip is the so-called 'mild' trip usually organized in Middle Europe. The set of characteristic training values that may be collected during these trips is usually not enough for training of neural networks. This paper presents an algorithm to design the simulator in order to generate enough data necessary to train the networks. These data must be consistent with the data collected during the trips. Also, the paper proposes architecture and a training algorithm for the neural networks that control the actuators in the HVAC unit. The obtained results demonstrate the accuracy and the simplicity of the proposed solutions.

**NITTA, TERADA and FUKUSHIMA [5]** Two types of multifunctional ceramic sensors have been developed in response to strong demands for automatic control systems in cooking ovens, air conditioners, etc. The first sensing device can detect both humidity and particular reducing agents, such as alcohols and smokes, with a high

sensitivity and selectivity. This novel ceramic sensor utilizes gas chemisorption at 400°-500°C as well as water physisorption at <150°C on the grain surface of MgCr<sub>2</sub>O<sub>4</sub>-TiO<sub>2</sub> ceramic with a porous structure and p-type semiconduction. The other sensor is composed of a porous dielectric Ba<sub>0.5</sub>Mg<sub>0.5</sub>TiO<sub>3</sub> ceramic characterized by a high temperature dependence of the dielectric constant. The sensing device can independently detect simultaneously and rapidly both temperature and humidity.

**ALONSO, VILLEGAS, DIAZ, BLANCO and RICO [6]** have presented new emergency ballast for fluorescent lamps. The fundamental block is the microcontroller-based control circuit, which performs the supervision and control function. High-frequency electronics techniques are proposed for the high power factor battery charger and the lamp driver, which provides high luminous efficacy. In this way, size and weight have been minimized for the whole system. With the introduction of the microcontroller, the system has the capability of testing itself, checking its functional state, and displaying internal faults. Thus, the reliability of the system is improved and, concurrently, maintenance cost is decreased.

**JACHOWICZ [7]** Many different measurement methods, depending on the humidity range and required accuracy, are used for humidity sensors. The author reviews the properties of some of these sensors, considering the potential advantages of computer control and the requirements such control imposes on the sensor element itself.

**XIAOHONG<sup>1</sup>, LI, WANG, ZHAO, LISA and CHEN** In this research, high voltage static electricity and ultraviolet technologies were integrated to an air purifying device which can be used to trap and kill airborne bacteria and viruses in central air-conditioning systems. An experimental platform was built to mimic the central air system, in which the efficacy of the newly built device was examined. In addition to the standard physical and chemical tests, bacteriophages were used to simulate airborne viruses in the experimental system. The bacteriophage suspension was aerosolized into the air with ultrasonic wave atomization. The result showed that more than 86% removal efficiency of micro-particles (<10 micron in diameter) were removed after the device was in operation in a building and more than 95% of bacteriophages in the experimental system. It is concluded that the integrated air purifier is suitable for controlling air quality and preventing virus transmission through the central air system.

**BAYNDR and KAHRAMAN** have described that most people living in large cities have lived indoors. Especially in summer, high relative humidity, elevated air temperatures and bright sunshine can sometimes combine to produce an uncomfortable indoor environment. Therefore, people want to increase the quality of indoor environment. An air conditioning system can provide comfort for occupants by lowering both the air temperature and the humidity level in the closed area. The aim of the present study is to design and construct PIC controlled air conditioner system and compare them to other systems.

## Chapter 3: Hardware Implementation

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### 3.1 Component Selection

Selection of components is the major issue to be considered in making a project. One must have the knowledge of proper specifications, requirements and the use of the component. Humidex based Air Conditioner system includes the following components:

- (1) Temperature Sensor (LM35)
- (2) Power Supply (9-0-9 V)
- (3) Analog to Digital Converter (ADC 0809)
- (4) Microcontroller (8051)
- (5) Liquid Crystal Display (HD 44780)

### 3.2 Component Description

This section gives the brief description of every component used in the system.

#### 3.2.1 Temperature Sensor

➤ **Selection of Suitable Transducer:**

For measuring the temperature, the choice of sensor is of utmost importance. The sensors are used in many fields includes Thermocouples, Resistive temperature devices (RTDs and thermistors), and bimetallic devices. The factors for the selection of sensor that we take into account includes the inherent accuracy for durability, range of operation ,susceptibility to external noise influences, ease of maintenance and installation, Handling during installation (delicacy), Ease of calibration, and type of environment it will be used in.

Temperature sensor used in this project is LM35. It is an precision integrated-circuit temperature sensor, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 does not require any external calibration or trimming to provide typical accuracies of  $\pm 1/4^{\circ}\text{C}$  at room temperature and  $\pm 3/4^{\circ}\text{C}$  over a full  $-55$  to  $+150^{\circ}\text{C}$  temperature range. The LM35's low output impedance, linear output and precise inherent calibration make interfacing to readout or control circuitry especially easy. [22]



**Figure-3.1. LM35 Temperature Sensor**

➤ **Features**

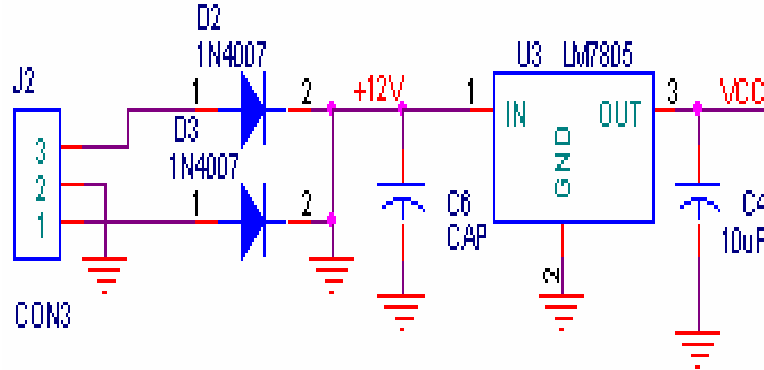
- Easy interface to all Microprocessors
- No zero or full scale adjustment required
- Operates ratiometrically or with 5 V dc or analog span adjusted voltage reference
- 8 channel multiplexer with address logic
- ADC 0808 equivalent to MM74C949
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guarantee able (at +25°C)
- Rated for full -55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60  $\mu$ A current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only  $\pm 1/4^\circ\text{C}$  typical
- Low impedance output, 0.1 W for 1 mA load

### **3.2.2 Humidity Sensor**

Humidity sensors are more costly than temperature sensors. Also these are not so easily available. There are many humidity sensors that can be used at different places according to the requirement, cost and availability. Some of the most commonly used humidity sensors are listed below:

- SHT11
- HIH-3610

### 3.2.3 Power Supply Unit



**Figure-3.2. Circuits showing positive supply generation**

The regulated DC power supply of +5 Volts and +12 Volts (Unregulated) required for various units. +5 volt is generated using LM7805 fixed voltage regulator. Rectification of the AC supply is carried out using centre-tap full wave rectifier using two 1N4007 diodes. The output of this section is free from ripples and distortions.

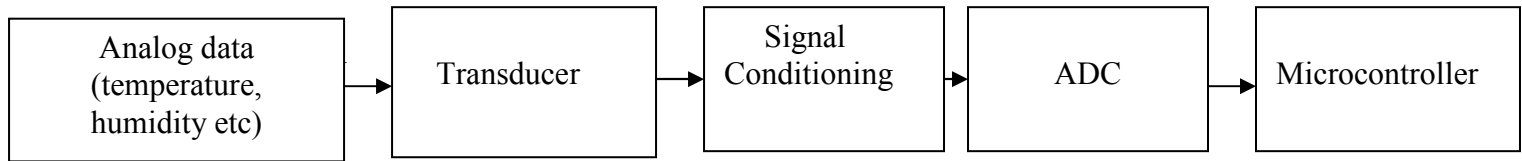
Three different power supplies are required in our project namely  $V_{cc}$  (+5V),  $V_{ss}$  (+12V).  $V_{cc}$  &  $V_{ss}$  are regulated using LM7805 (U1) & LM7812 (U2) respectively.

DC Input to these regulators is fed through full wave rectifier's made using diodes D1, D2 & D3 and D5. A step down transformer (12-0-12) is used for stepping down the voltage from 220 Volts AC. C1, C2 & C3, C4 are filter capacitors for  $V_{cc}$  &  $V_{ss}$  respectively. These capacitors remove ripples from the unregulated rectified power supply. Electrolytic filter capacitors are unable to remove this high frequency noise because of their poor response at high frequency.  $V_{cc}$  feeds all IC's and serves as a positive supply for MCU and display driver IC,  $V_{ss}$  gives supply to relay and buzzer.

### 3.2.4 Analog to Digital Converter (ADC)

The function of an analog-to-digital converter is to produce a digital word which represents the magnitude of some analog voltage or current. In physical world parameters such as temperature, pressure, humidity, and velocity are analog signals. A physical quantity is converted into electrical signals. An analog to digital converter is needed to translate the analog signals to digital numbers so that microcontroller can read

them. Thus, an analog-to-digital converter (ADC) is an electronic circuit that converts continuous signals to discrete digital numbers.



**Figure-3.3. ADC Functional Block Diagram**

The ADC 0804 is most widely used chip. For this work, the analog to digital converter chosen is ADC 0809. Because ADC 0804 has only one analog input, this chip has 8 of the analog inputs. This chip allows us to monitor up to 8 different transducers using only a single chip. The 8 analog input channels are multiplexed and selected according to the requirement. In ADC 0808/0809,  $V_{ref (+)}$  and  $V_{ref (-)}$  set the reference voltage. If  $V_{ref (-)} = Gnd$  and  $V_{ref (+)} = 5V$ , the step size is  $5V/256=19.53$ . Therefore to get a 10 mV step size we need to set  $V_{ref (+)} = 2.56 V$  and  $V_{ref (-)} = Gnd$ .

➤ **Selection of channels**

Any combination of analog channels with 3 bits can be chosen. The selection of analog channels of ADC 0808/0809 according to the values, 000-111 is given as:

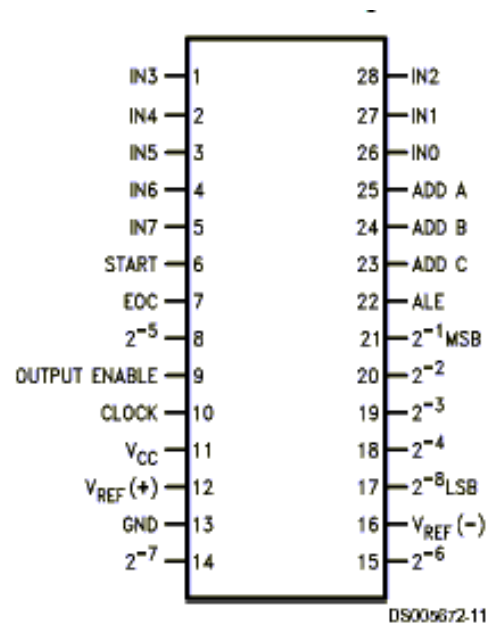
Channel	C	B	A
IN0	0	0	0
IN1	0	0	1
IN2	0	1	0
IN3	0	1	1
IN4	1	0	0
IN5	1	0	1
IN6	1	1	0
IN7	1	1	1

**Table-3.1. Selection of channels**

➤ **Pin Diagram of ADC 0808/0809**

Here A, B, C addresses are used to select IN0-IN7 and activate Address latch enable (ALE) to latch in the address. SC is for Start Conversion. EOC is for End of Conversion,

and OE is for Output Enable. The output pins D0-D7 provides the digital output from the chip



**Figure-3.4. Pin Diagram of ADC 0808/0809**

$V_{ref(-)}$  and  $V_{ref(+)}$  are the reference voltages. Since there is no self clocking in this chip so the clock must be provided from an external source to the Clock (CLK) pin. From the pin diagram, the input, output, and the control signals to the chip are clear.

➤ **Steps to program the ADC 0808/0809**

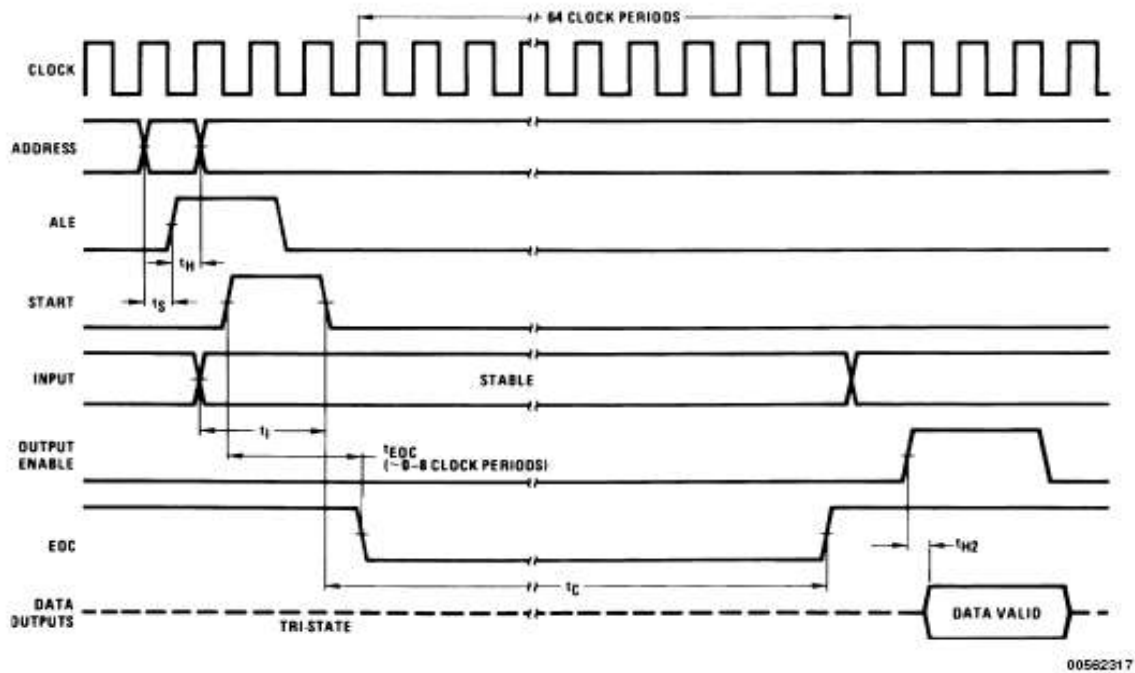
The following are the steps to get data from analog input of ADC 0808/0809 into the microcontroller:

1. Select an analog channel by providing bits to A, B, C addresses.
2. Activate the ALE (address latch enable) pin. It needs an L-to-H pulse to latch in the address.
3. Activate SC (start conversion) by an H-TO-L pulse to initiate conversion.
4. Monitor EOC (end of conversion) to see whether conversion is finished H-to-L output indicates that the data is converted and is ready to be picked up.
5. Activate OE (output enable) to read data out of the ADC chip. An H-to-L pulse to the OE pin will bring digital data out of the chip.

In ADC 0808/0809 there is no self clocking and the clock must be provided from an external source to the CLK pin.

➤ **ADC Timing Diagram**

There are 8 clock periods per approximation. Even though there is no conversion in progress the ADC0808/ADC0809 is still internally cycling through these 8 clock periods. A start pulse can occur any time during this cycle but the conversion will not actually begin until the converter internally cycles to the beginning of the next 8 clock period sequence. As long as the start pin is held high no conversion begins, but when the start pin is taken low the conversion will start within 8 clock periods. The EOC output is triggered on the rising edge of the start pulse. It, too, is controlled by the 8 clock period cycle, so it will go low within 8 clock periods of the rising edge of the start pulse. One can see that it is entirely possible for EOC to go low before the conversion starts internally, but this is not important, since the positive transition of EOC, which occurs at the end of a conversion, is what the control logic is looking for. Once EOC does go high this signals the interface logic that the data resulting from the conversion is ready to be read. The output enable (OE) is then raised high.



**Figure-3.5. ADC Timing Diagram**

### 3.2.5 Microcontroller chip

#### ➤ **Criteria for choosing a microcontroller**

There are four major 8-bit microcontrollers. They are Motorola's 6811, Intel's 8051, Zilog's Z8, and PIC 16 X from microchip technology. Each of the above microcontrollers has a unique instruction set and register set therefore they are not compatible with each other. Programs written for one will not run on the others. There also exist 16-bit and 32-bit microcontrollers, manufactured by different chip manufacturers. With all these different microcontrollers, what criteria do designers consider in choosing one.

Three main points are as follows:

- (1) Meeting the computing needs of the tasks at hand efficiently and cost effectively.
- (2) Availability of software development tools such as compilers, assemblers and debuggers.
- (3) Wide availability and reliable sources of microcontrollers.

Thus the microcontroller AT89C51 satisfying this entire criterion is chosen for this work.

#### ➤ **AT89C51 Microcontroller**

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

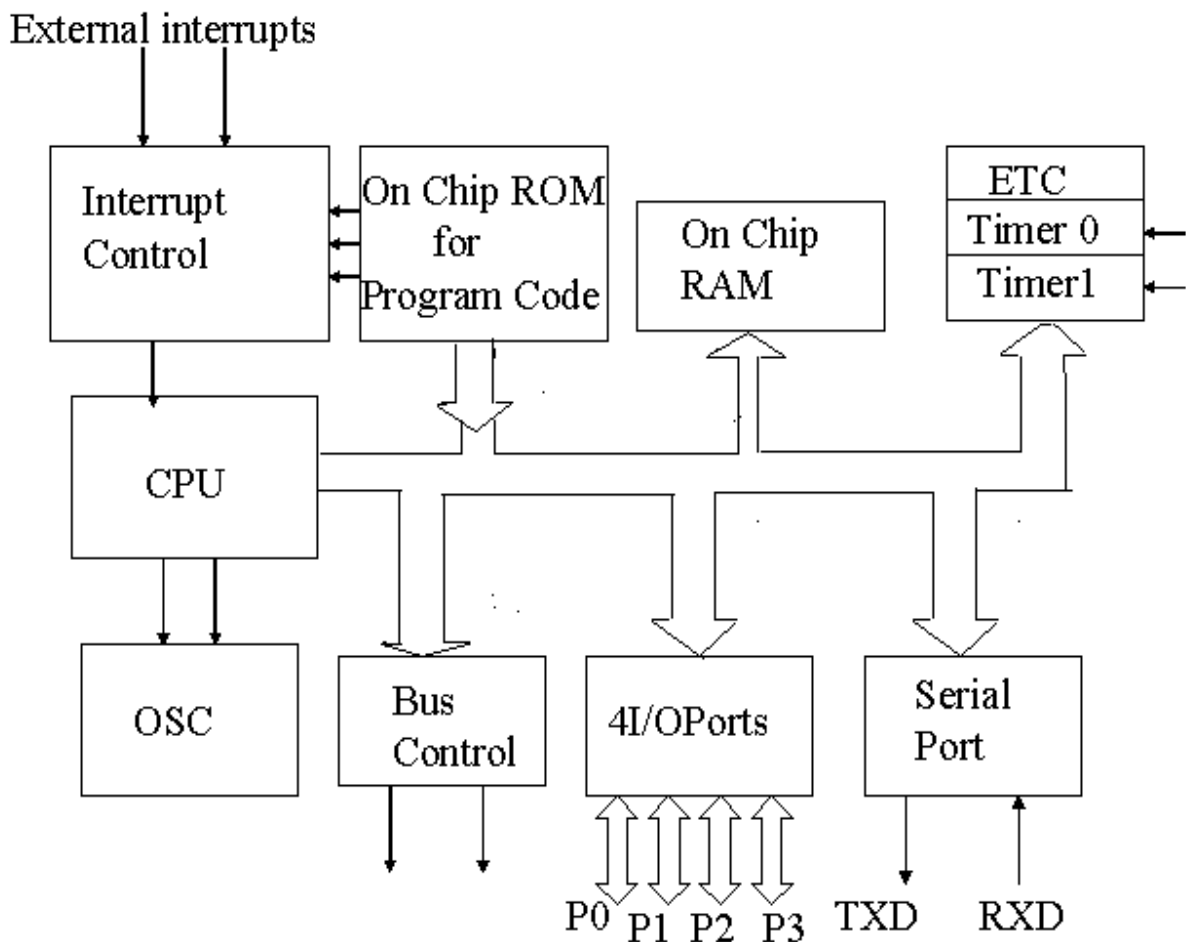
The basic architecture of AT89C51 consists of the following features:

- An eight bit ALU
- 32 discrete I/O pins (4 groups of 8) which can be individually accessed
- Two 16 bit timer/counters
- Full duplex UART
- 6 interrupt sources with 2 priority levels
- 128 bytes of on board RAM

- Separate 64K byte address spaces for DATA and CODE memory

One 8051 processor cycle consists of twelve oscillator periods. Each of the twelve oscillator periods is used for a special function by the 8051 core. The time required for any 8051 instruction can be computed by dividing the clock frequency by 12, inverting that result and multiplying it by the number of processor cycles required by the instruction in question.

➤ **Block Diagram of Microcontroller**



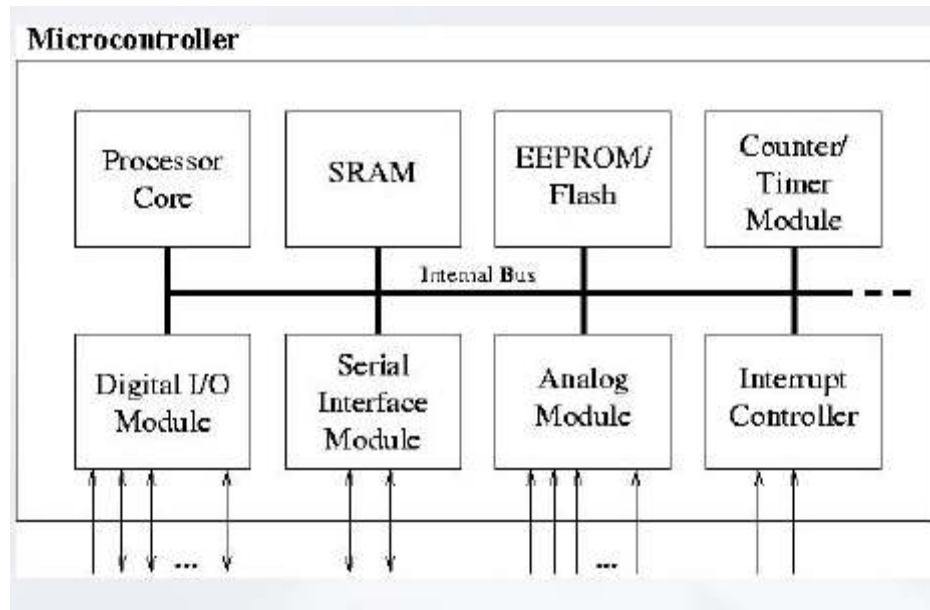
**Figure-3.6. Block diagram of AT89C51**

➤ **Components of Microcontroller**

Microcontroller integrates several components:

- CPU
- Memory

- Digital I/O lines
- Analog I/O lines
- Interrupt controller
- Counter/timer
- Serial interface(s)

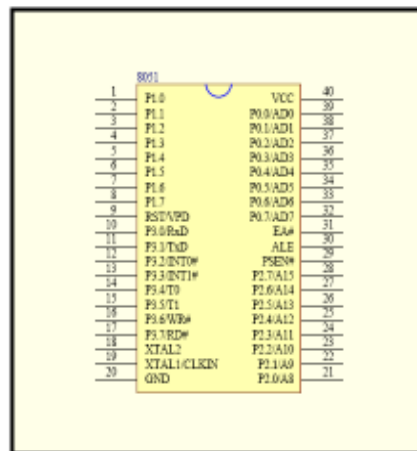


**Figure-3.7. Components of Microcontroller**

➤ **Types of Microcontroller**

- Many different controllers from many different vendors  
(e.g. PIC, ATmega16, HC11, 8051)
- controller family:
  - same CPU
  - different peripherals (number of I/Os, timers, ...)  
e.g.: Atmel AVR ATmega family
- controllers are (4), 8, 16, 32 bit
- we concentrate on small 8bit controllers
- no MMU (memory management unit)
- no DMA (direct memory access)
- no Cache

- clocking frequency about 1.25 MHz
- **Features of Microcontroller (8051)**
- 8051 has 40 pins
- 32 pins function as I/O port lines, 24 of them are dual purpose (each can operate as I/O or as a control line or part of address or data bus)
- Eight lines in each port can be treated as a unit in interfacing to parallel devices (e.g., ADC) or each line can operate Independently in interfacing to single bit devices (e.g. switches)
- Port 0: a dual purpose port on pins 32-39
- Port 1: a dedicated I/O port on pins 1-8
- Ports 2: dual purpose ports on pins 21-28 (could be a general purpose I/O or high byte of the address bus for external memory)
- Ports 3: dual purpose ports on pins 10-17
- **Pin Description of Microcontroller (8051)**



**Figure-3.8. Pin out of the 8051 Microcontroller (NC stands for No Connection)**

- **V<sub>CC</sub>** - Pin no.40. Power Supply (4 - 6V)
- **GND** - Pin no.20.Negative supply pole (ground)
- **Port 0 (P0.0 - P0.7)** - Pin no's. 31-39. If designated as output, each of these pins can be connected up to 8 TTL input circuits. If designated as input, they are high impedance inputs as their potential is undefined with respect to the ground. If external memory is used, these pins are used for alternate transfer of data and

addresses (A0-A7) for accessing the extra memory chip. Signal on ALE pin determines the mode of transfer on port.

- **Port 1 (P1.0 - P1.7)** - Pin no's 1-8. If designated as output, each of these pins can be connected up to 4 TTL inputs. If designated as input, these pins act like standard TTL inputs (that is, they have an internal resistor connected to the positive supply pole and a +5V voltage). Also, pins of Port 1 have alternate functions according to the following table:

Pin	Alternate function
P1.0	T2 (Timer 2 input)
P1.1	T2EX (Timer 2 control input)
P1.4	SS (SPI control input)
P1.5	MOSI (I/O of SPI system)
P1.6	MISO (I/O of SPI system)
P1.7	SCK (SPI clock signal)

**Table-3.2. Port 1**

- **Port 2 (P2.0 - P2.7)** - Pin no's 21-28. If designated as input or output, this port is identical to Port 1. If external memory is used, Port 2 stores the higher address byte (A8-A15) for addressing the extra memory chip.
- **Port 3 (P3.0 - P3.7)** - Pin no's 10-17. Similar to Port 1, Port 3 can also be used as universal I/O, but pins of Port 3 also have alternate functions. Each of the functions will be explained in detail later.

Pin	Alternate function
P3.0	<b>RXD</b> (Serial input)
P3.1	<b>TXD</b> (Serial output)
P3.2	<b>INT0</b> (External interrupt 0)
P3.3	<b>INT1</b> (External interrupt 1)
P3.4	<b>T0</b> (Timer 0 external input)
P3.5	<b>T1</b> (Timer 1 external input)
P3.6	<b>WR</b> (Signal <b>write</b> to external memory)
P3.7	<b>RD</b> (Signal <b>read</b> from external memory)

**Table-3.3. Port 3**

- **RST** - Pin no.9. Positive voltage impulse on RST pin resets the MCU. In order to be detected, this impulse needs to have duration of at least two operating cycles (this cycle represents the time necessary to execute one instruction and lasts for 12 oscillator signals).
- **ALE/PROG** - Pin no.30. This pin emits an impulse sequence with a frequency equal to 1/6 of the frequency generated by the main oscillator. If external memory is used, signal from this pin controls the additional register for temporary storage of the lower address byte (A0 - A7). This pin also serves as a control input during the writing of program to MCU.
- **PSEN** - Pin no.29. Signal of this pin is used for reading from external program memory (ROM).
- **EA/VPP** - Pin no.31. When this pin is connected to the ground, MCU gets program instructions from external program memory. In case that internal program memory is used (common case), this pin should be connected to the

positive supply pole (VCC). During the loading of program to internal Flash memory, this pin is at +12 V.

- **XTAL 1** - Pin no.19. This is the input part of internal oscillator. It is used for synchronizing the MCU with another circuit. Also, if there is need to use an external oscillator, it connects to this pin.
- **XTAL 2** - Pin no.18. Input of internal oscillator connects to this pin. In case external oscillator is used, this pin is without a function. [26]

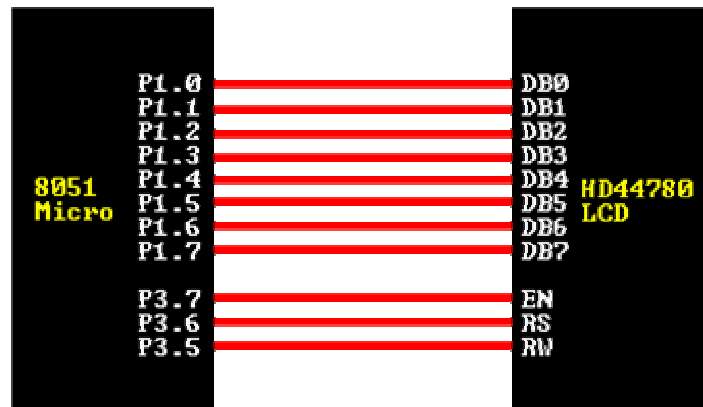
### **3.2.6 Liquid Crystal Display**

A liquid crystal display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. It is prized by engineers because it uses very small amounts of electric power, and is therefore suitable for use in battery-powered electronic devices. Each pixel consists of a column of liquid crystal molecules suspended between two transparent electrodes, and two polarizing filters, the axes of polarity of which are perpendicular to each other. Without the liquid crystals between them, light passing through one would be blocked by the other. The liquid crystal twists the polarization of light entering one filter to allow it to pass through the other [22].

More microcontroller devices are using 'smart LCD' displays to output visual information. LCD displays designed around Hitachi's LCD HD44780 module, are inexpensive, easy to use, and it is even possible to produce a readout using the 8x80 pixels of the display. Hitachi LCD displays have a standard ASCII set of characters plus Japanese, Greek and mathematical symbols.

For an 8-bit data bus, the display requires a +5V supply plus 11 I/O lines. For a 4-bit data bus it only requires the supply lines plus seven extra lines. When the LCD display is not enabled, data lines are tri-state which means they are in a state of high impedance (as though they are disconnected) and this means they do not interfere with the operation of the microcontroller when the display is not being addressed.

➤ **Interfacing the LCD to Microcontroller**



**Figure-3.9. LCD Interfacing with Microcontroller 8051**

Following table gives pin structure of LCD module. LCD modules without backlight will have only 14 pins. If you are using such LCDs, simply ignore 15th and 16th pins. [27]

Pin No	Symbol	Details
1	GND	Ground
2	Vcc	Supply Voltage +5V
3	Vo	Contrast adjustment
4	RS	0->Control input, 1-> Data input
5	R/W	Read/ Write
6	E	Enable
7 to 14	D0 to D7	Data
15	VB1	Backlight +5V
16	VB0	Backlight ground

**Table-3.4. LCD Pin Arrangement**

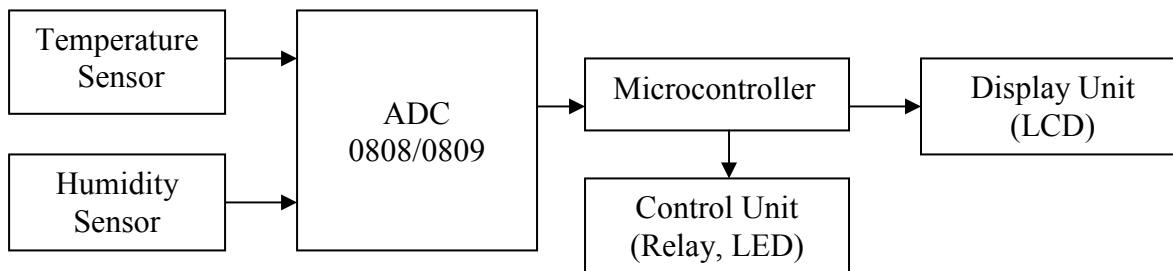
LCD modules are available in a wide range like 8x1, 8x2, 16x1, 16x2, 20x2, 20x4, and 40x5. Here 16x2 LCD module is used- that means 2 rows of 16 characters. It is a Hitachi HD44780 compatible module, having 16 pins including 2 pins for backlight.

To program the LCD module, first task is to initialize the LCD by sending some control words. RS should be low and E should be high when control is sent. R/W pin 0 mean write data or control to LCD and R/W pin 1 means read data from the LCD. To send a data to LCD, make RS high, R/W low, place the data in pins 7 to 14 and make pin E high and low once. R/W is connected to ground directly.

An 8051 program must interact with the outside world using input and output devices that communicate directly with a human being. One of the most common devices attached to an 8051 is an LCD display. Some of the most common LCDs connected to the 8051 are 16x2 and 20x2 displays. This means 16 characters per line by 2 lines and 20 characters per line by 2 lines, respectively. [25]

### 3.2.7 Operational Blocks

The basic functional block diagram for is as shown in figure 3.2. it can be seen that the components used here are temperature sensor, ADC 0809, Microcontroller 8051 and control and display unit which is taken as LCD here. A brief description of all its functional blocks is given below:



**Figure-3.10. Block Diagram of the System**

The hardware details of the project are given below. It consists of the following main parts:

- Power supply
- Microcontroller 8051
- ADC 0809

- LCD
- LM 35
- Relay

### 3.2.8 Hardware Details

The hardware details of the present system has been compiled in the table 3.1. The table also gives an overview of the number of components being used in the present system.

Component	Qty
AT89C51 Microcontroller (IC2)	1
ADC 0809	1
12 MHz Crystal -1	1
Capacitors 33pF (for crystal circuitry)	2
Capacitor (power circuitry) 1000 $\mu$ F	1
Capacitor (power on reset circuit) 10 $\mu$ F	1
Resistor 10 k	1
Regulator IC7805 (IC1)	1
LCD 5 $\times$ 7 matrix, 16 $\times$ 2	1
Relay	1
Transformer (9-0-9)	1
LM35 (temperature sensor)	1
SIP	1
POT	2

**Table-3.5. Component Details**

The schematic diagram of the system showing all its parts is shown here. From the schematic it can be seen that the main components used in the system are Microcontroller (8051), ADC (0809), LCD (HD 44780), LM35. A brief description of all these parts mentioning its connections is given here. It is quite easy to understand the connection arrangement from the schematic shown in fig- 3.1.

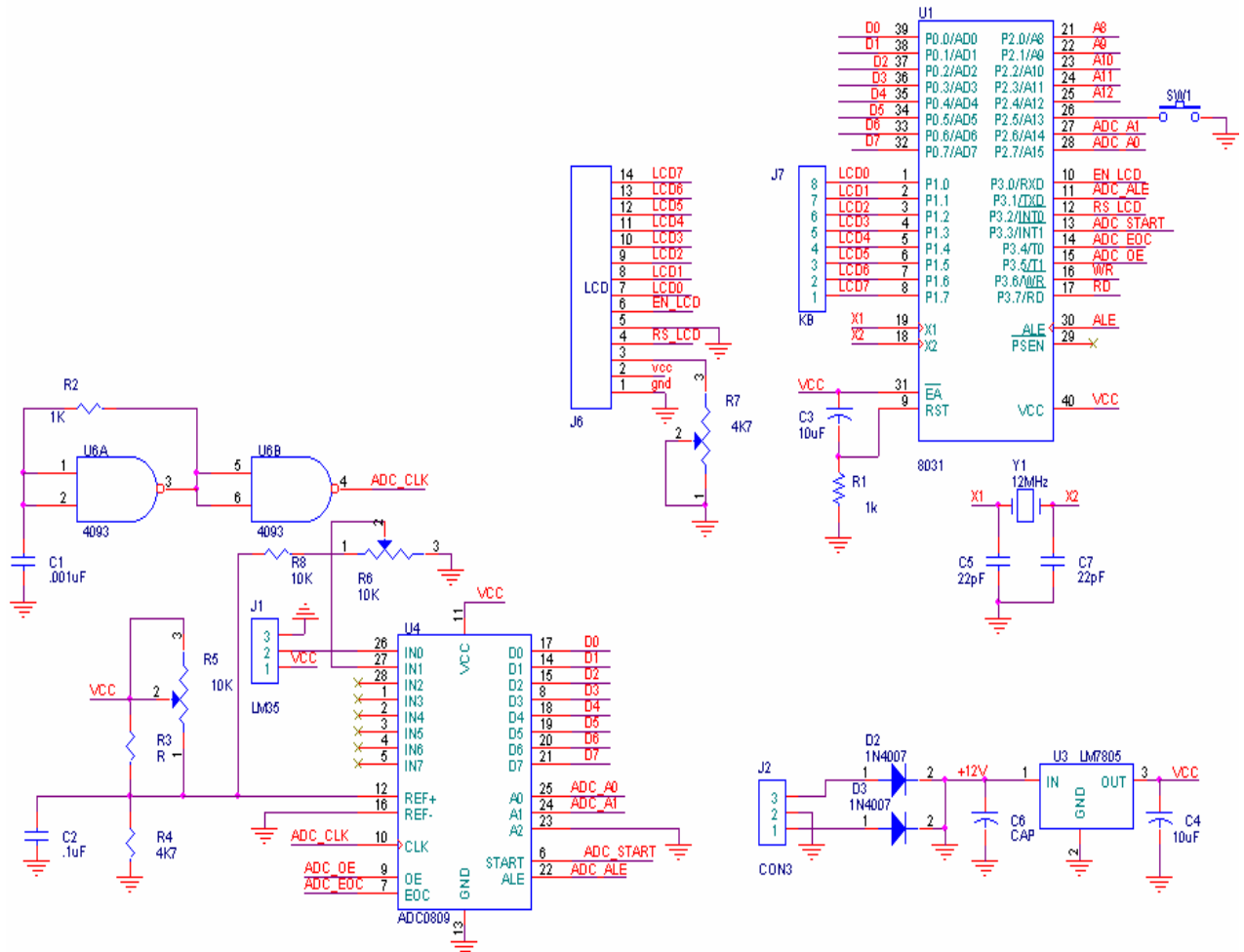


Figure-3.11. Schematic of the hardware

➤ **Power Supply**

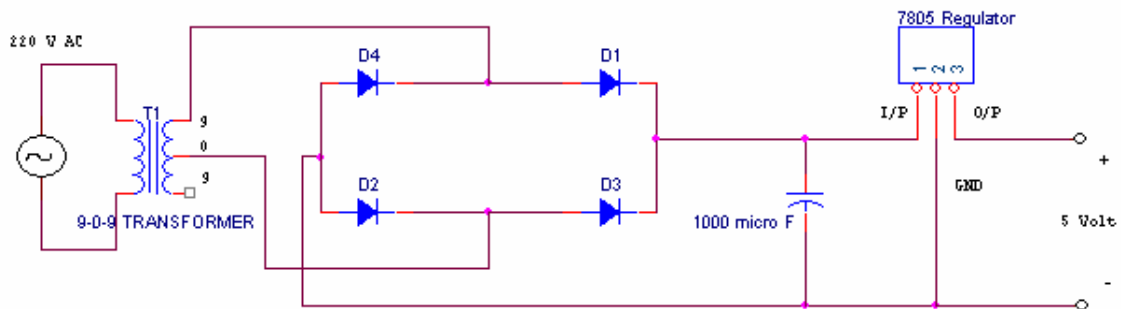


Figure-3.12. Power Supply Circuit

The regulator used here is LM 7805. It can be seen that from the schematic that the pin 1 is connected to gnd with a capacitor. Actually 12 V supply is given via this pin. It comes from the CON3 whose pin 3 is connected to pin I of the LM 7805 using a diode IN 4007. Pin 2 is gnd and pin 1 is also gnd having a capacitor IN 4007. Pin 3 is having a capacitor is gnd pin.

➤ **Microcontroller 8051**

Microcontroller 8051 is a 40 pin IC. The pin arrangement of the microcontroller 8051 is discussed below:

Pin no's 1-8 (port 1) of the microcontroller are designated as port 1 and connected to pin no's 8-1 of the LCD. Pin 9 is reset pin which is connected to ground. A resistance of 1 k is also connected at this pin. Pin no 10-17 are designated as port 3 (P 3.0- 3.7). Pin 10 (P 3.0) is connected to pin 6 (EN\_LCD) of the LCD. Pin 11(P 3.1) is connected to pin 22 (ADC\_ALE) of ADC. Pin 12 (P 3.2) is connected to pin 4 (RS\_LCD) of LCD. Pin 13 (3.3) is connected to pin 6 (ADC\_START) of ADC. Pin 14 (P 3.4) is connected to pin 7 (ADC\_EOC) of ADC. Pin 15 (P 3.5) is connected to pin 9 (ADC\_OE) of the ADC. Pin 18 and 19 are used for crystal operation and are used for frequency operations. Pin 20 is ground. Pin 21-28 are designated as port 2. These are address lines. Pin 21-25 (P 2.0- 2.3) are connected to A8-A12. Pin 26 (P 2.5) is grounded via a switch. Pin 27 and 28 (P 2.6- 2.7) are connected to pin 24 and 25 (A1 and A0) pins of ADC. Pin 29 is PSEN which is not being used here. Pin 30 is ALE pin. Pin 31 (EA) is connected to Vcc. Pin 39-32 (P 0.0-0.7) are designated as port 0 are connected through the SIP and are connected to data pins (17, 14, 15, 8, 18, 19, 20, 21) of ADC. Pin 40 is Vcc.

➤ **ADC 0809**

ADC 0809 is a 28 pin IC. The pin arrangement of the ADC 0809 is discussed below:

Pin no's 1-5 are input pins, but in this hardware these pins are not used because only 2 input signals are needed and here only pin no 26 and 27 are used. Pin 6 is a start pin and is connected to the pin 13 (P 3.3) of microcontroller. Pin 7 is the end of conversion (EOC) pin and is connected to the pin 14 (P 3.4) of the microcontroller. Pin 8 is a data pin and is connected to pin 36 (P 0.3) of the microcontroller. Pin 9 is the output enable (OE) pin and is connected to the pin 15 (P 3.5) of the microcontroller. Pin 10 is clock pin. Pin 11 is the Vcc pin. Pin 12 is Ref (+) pin. Pin 13 is ground pin. Pin 14 and 15 are data

(D1 and D2) pins and are connected to the pin 38 and 37 (P 0.1-0.2) of the microcontroller. Pin 16 is Ref (-) pin. Pin 17 is data (D0) pin and is connected to the pin 39 (P 0.0) of the microcontroller. Pin no's 18-21 are data (D4-D7) pins and is connected to the pin 35-32 (P 0.4-0.7) of the microcontroller. Pin 22 is ALE pin and is connected to the pin 11 (P 3.1) of the microcontroller. Pin no's 23-25 are used as selection lines. In this hardware use only 2 selection lines are used. Here pin no 23 (A2) is ground pin and pin 24 and 25 (A1-A0) are used as selection input pins. Pin 26 and 27 are used as input lines for temperature and humidity. Pin 28 is not used because only two input lines are needed here and that are taken as pin no's 26 and 27. Pin 12 is connected to ground with a capacitor. Pin no's 17, 14, 15, 8, 18, 19, 20 and 21 (D0-D7) of ADC are connected to the pin no's 39-32 (port 1) of the microcontroller.

➤ **HD44780 LCD**

LCD (Liquid Crystal Diode) is a 14 pin device used to display the readings. As shown in the schematic of the hardware, pin no's 7-14 are designated as LCD 0- LCD 7 and are connected at port 1 (P1.0-P1.7) of microcontroller via a sip. Pin 6 (EN\_LCD) is enable pin and is connected to pin 10 (P 3.0) of the microcontroller. Pin 5 is ground pin. Pin 4 is used for register select (RS\_LCD) and is connected to pin 12 (P 3.2) of the microcontroller. Pin 3 is connected to ground with a resistor. Pin 2 is Vcc pin and pin 1 is ground pin.

➤ **LM 35**

Temperature sensor used in this project is LM35. LM35 is an precision integrated-circuit temperature sensor, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 does not require any external calibration or trimming to provide typical accuracies of  $\pm 1/4^{\circ}\text{C}$  at room temperature and  $\pm 3/4^{\circ}\text{C}$  over a full  $-55$  to  $+150^{\circ}\text{C}$  temperature range.

It is a 3 pin sensor. Pin 3 of LM 35 is gnd. Pin 1 is Vcc. Pin 2 is used to select combination of inputs i.e. temperature and humidity. Pin 2 is connected at pin 26 as IN0.

➤ **Relay**

The function of the relay is to on/off a device. It is a mechanical switch. It is used as a control device in the system. The relay used in the system is connected to the pin 22

(P2.1) of the microcontroller. An LED (Light Emitting Diode) is connected with relay here to indicate the on/off operation of the relay.

# Chapter 4: Software Design and Development

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## 4.1 Software Design

The software of the project mainly having 3 main parts which are listed here:

1. Main program part
2. ADC part
3. LCD part

Each of the 3 parts has 3 different flowcharts and algorithms which are explained here as under:

### 4.1.1 Main Program

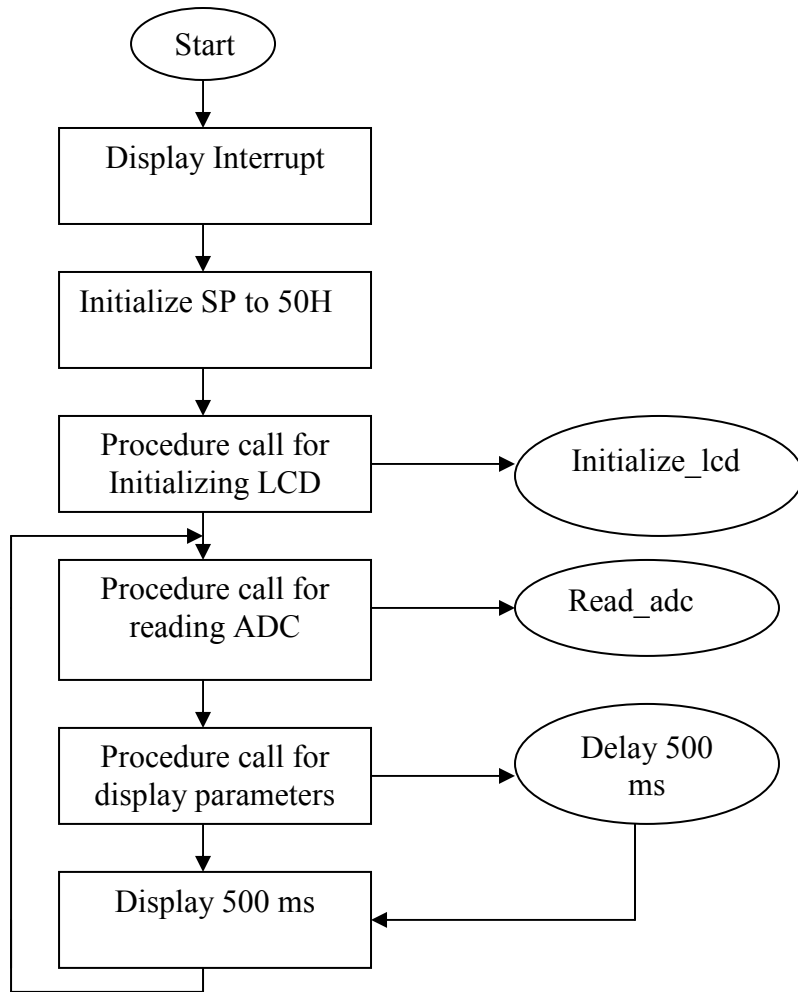
#### ➤ Algorithm

The complete algorithm of the system having interfacing of microcontroller with ADC 0809 and LCD is discussed below:

1. Start
2. Display the interrupt
3. Initialize stack pointer to 50h as the proceedings starts from here.
4. Call for initialize lcd.
5. Call for read adc.
6. Display the input parameters.
7. Display delay of 500 ms.
8. Go back to read another value of adc.

#### ➤ Flowchart

The flowchart for the main program showing interfacing with ADC 0809 and LCD is shown in the figure 4.1.



**Figure-4.1. Interfacing of Microcontroller with ADC and LCD**

### 4.1.2 LCD Program

#### ➤ Algorithm

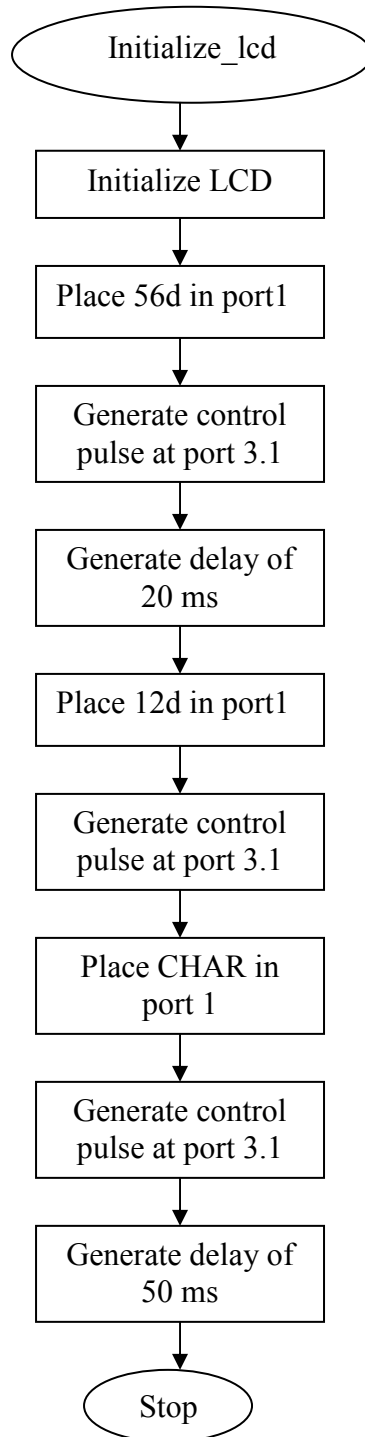
The algorithm for LCD interfacing to microcontroller is discussed here. The LCD is connected to port 1 of the microcontroller (refer to schematic of the system).

1. Initialize lcd.
2. Place decimal value 56d in port 1.
3. Generate control pulse at port 3.1
4. Generate a delay of 20 ms.
5. Place decimal value 12d in port 1
6. Generate control pulse at port 3.1
7. Place character (CHAR) at port 1.
8. Generate control pulse at port 3.1
9. Generate a delay of 20 ms.

10. Stop

➤ **Flowchart**

The flowchart for the LCD interfacing to microcontroller is shown in figure 4.2. The LCD is connected to port 1 of the microcontroller (refer to schematic).



**Figure-4.2. Initialization of LCD with microcontroller**

### 4.1.3 ADC Program

#### ➤ Flowchart

The flowchart for the ADC interfacing to microcontroller is shown in figure 4.3. The ADC is connected to port 3 (P3.1, P3.3, P3.4, and P3.5) and port 2 (P2.6 and P2.7) of the microcontroller (refer to schematic of the system).

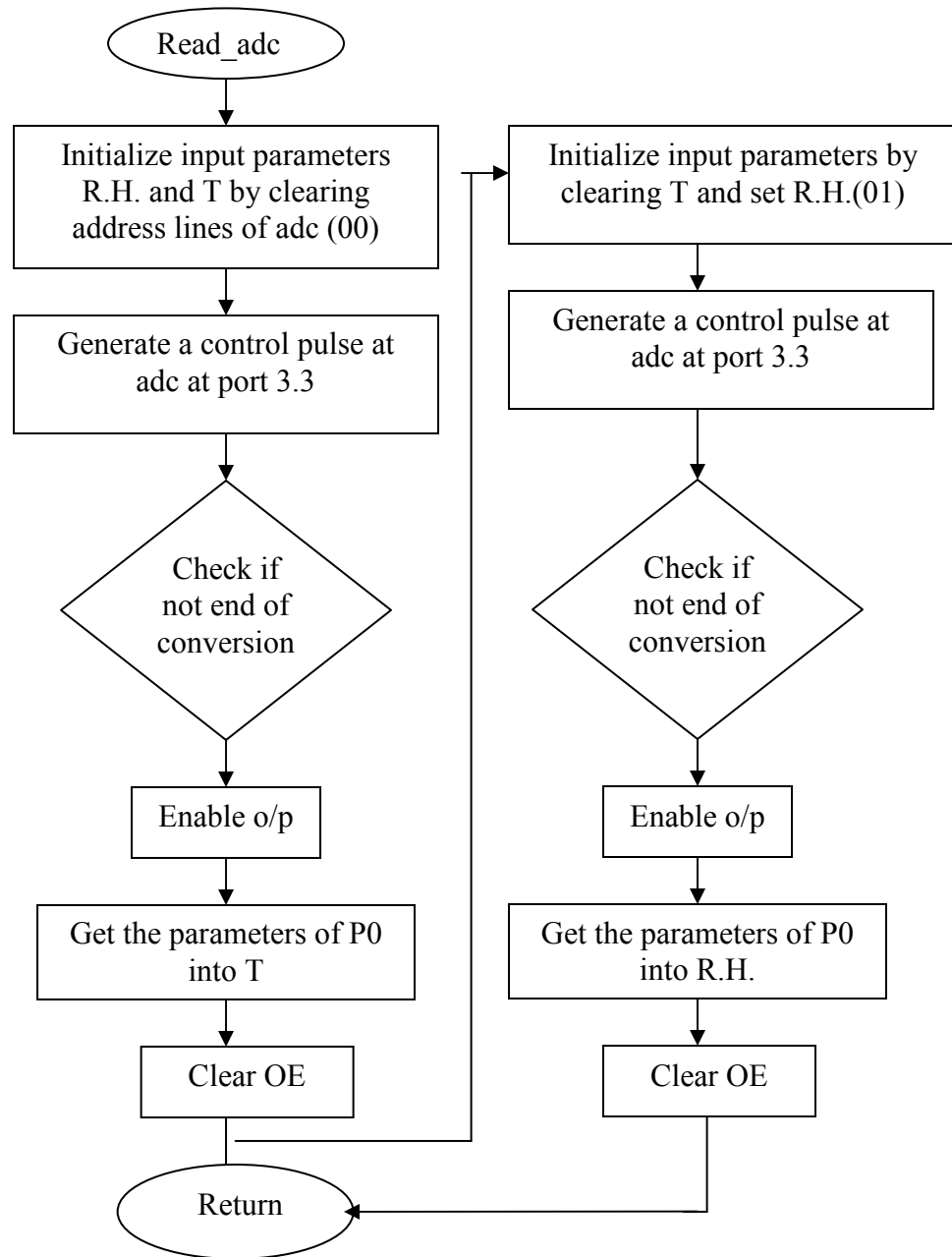


Figure-4.3. Initialization of ADC with microcontroller

➤ **Algorithm**

The algorithm for the ADC interfacing to microcontroller is shown in discussed below. The ADC is connected to port 3 (P3.1, P3.3, P3.4, and P3.5) and port 2 (P2.6 and P2.7) of the microcontroller (refer to schematic of the system).

1. Read the value of adc.
2. Initialize input parameters Relative Humidity (RH) and Temperature (T) by clearing address lines of adc (00).
3. Generate a control pulse at adc at port 3.3.
4. Check if not end of conversion otherwise it keeps working in the same loop until zero value is got.
5. If conversion ends, then go back to step 4.
6. If not end of conversion, then enable output.
7. Get the parameter of P0 into temperature.
8. Clear output enable.
9. Go back to initial input parameter by clearing temperature and set relative humidity value (01).
10. Generate a control pulse at adc at port 3.3.
11. Check if not end of conversion otherwise it keeps working in the same loop until zero value is got.
12. If conversion ends, then go back to step 4.
13. If not end of conversion, then enable output.
14. Get the parameter of P0 into relative humidity.
15. Clear output enable.
16. Return

## 4.1.4 Humidex Program

### ➤ Flowchart

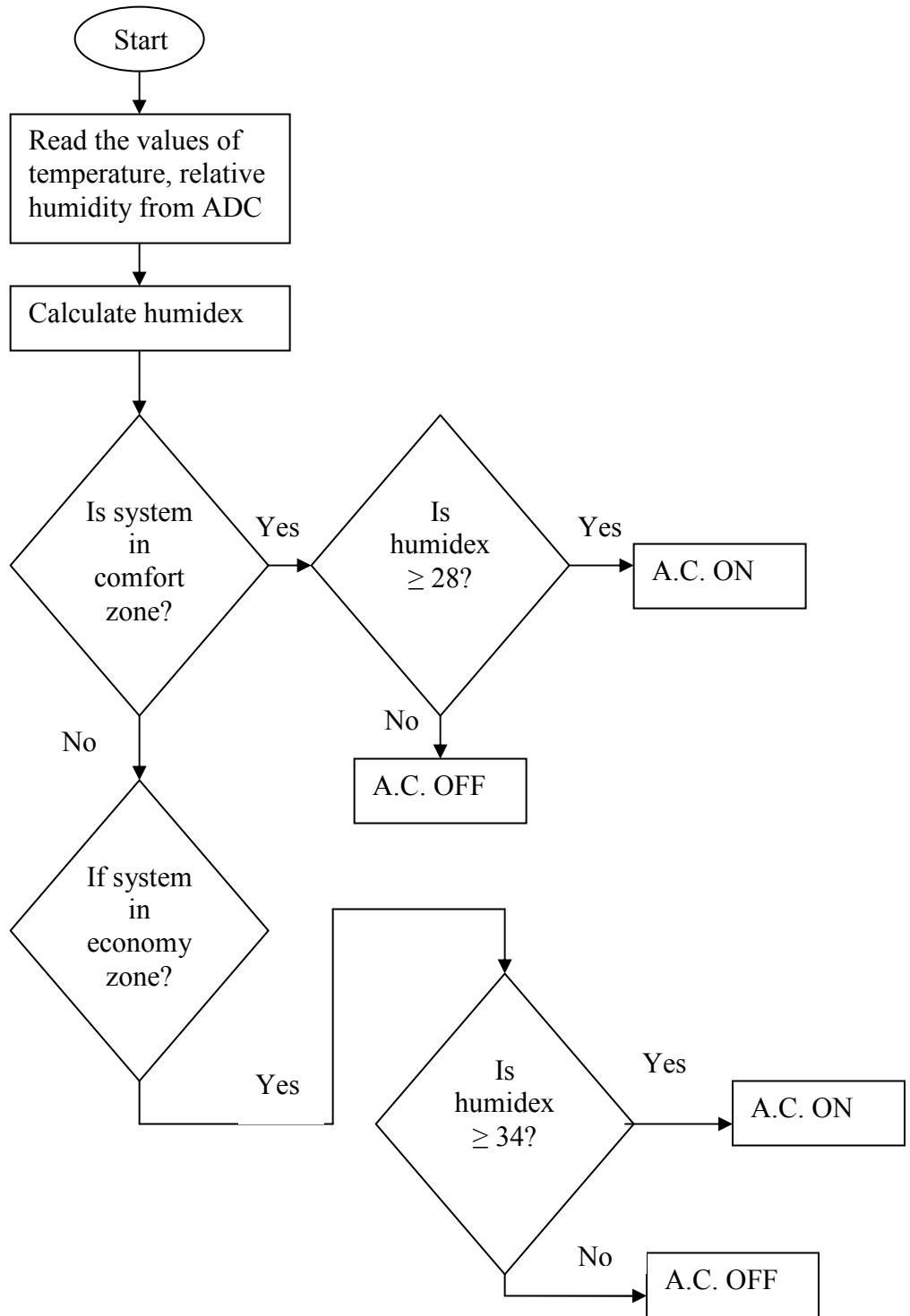


Figure-4.4. Flowchart to Calculate Humidex

➤ **Algorithm**

1. Start
2. Read the values of temperature and relative humidity from the ADC.
3. By using temperature and relative humidity, calculate humidex.
4. Check whether the system in comfort zone.
5. If yes, then check whether this value is greater than or equal to 28, if yes, A.C. will turn ON. If not, A.C. remains OFF.
6. If the system is in economy zone, check whether the value is greater than or equal to 34, if yes, A.C. will turn ON. If not, A.C. remains OFF.
7. Stop

## Chapter 5: Results and Discussions

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### 5.1 Results

The following values have been tabulated by varying the values of relative humidity and temperature and calculating the corresponding humidex value by the microcontroller system. The values have been tabulated on basis on comfort and economy zones and the status of the system corresponding to these zones.

Sr. No.	Relative Humidity	Temperature	Humidex	Status(on/off) (Comfort)	Status(on/off) (Economy)
1.	20	21	-	off	off
2.	20	22	-	off	off
3.	20	23	-	off	off
4.	20	24	-	off	off
5.	20	25	-	off	off
6.	20	26	-	off	off
7.	20	27	-	off	off
8.	20	28	-	off	off
9.	20	29	-	off	off
10.	20	30	-	off	off
11.	20	31	-	off	off
12.	20	32	-	off	off
13.	20	33	-	off	off
14.	20	34	-	off	off
15.	20	35	-	off	off
16.	20	36	-	off	off
17.	20	37	-	off	off
18.	20	38	40	on	on
19.	20	39	41	on	on
20.	20	40	43	on	on
21.	25	21	-	off	off
22.	25	22	-	off	off
23.	25	23	-	off	off
24.	25	24	-	off	off
25.	25	25	-	off	off
26.	25	26	-	off	off
27.	25	27	-	off	off
28.	25	28	-	off	off
29.	25	29	-	off	off
30.	25	30	30	on	off
31.	25	31	32	on	off

32.	25	32	33	on	off
33.	25	33	34	on	on
34.	25	34	36	on	on
35.	25	35	37	on	on
36.	25	36	39	on	on
37.	25	37	40	on	on
38.	25	38	42	on	on
39.	25	39	43	on	on
40.	25	40	45	on	on
41.	30	21	-	off	off
42.	30	22	-	off	off
43.	30	23	-	off	off
44.	30	24	-	off	off
45.	30	25	-	off	off
46.	30	26	-	off	off
47.	30	27	27	off	off
48.	30	28	28	on	off
49.	30	29	30	on	off
50.	30	30	31	on	off
51.	30	31	33	on	off
52.	30	32	34	on	on
53.	30	33	36	on	on
54.	30	34	37	on	on
55.	30	35	39	on	on
56.	30	36	40	on	on
57.	30	37	42	on	on
58.	30	38	43	on	on
59.	30	39	45	on	on
60.	30	40	47	on	on
61.	35	21	-	off	off
62.	35	22	-	off	off
63.	35	23	-	off	off
64.	35	24	24	off	off
65.	35	25	26	off	off
66.	35	26	27	off	off
67.	35	27	28	on	off
68.	35	28	30	on	off
69.	35	29	31	on	off
70.	35	30	33	on	off
71.	35	31	34	on	on
72.	35	32	36	on	on
73.	35	33	37	on	on
74.	35	34	39	on	on
75.	35	35	40	on	on
76.	35	36	42	on	on
77.	35	37	43	on	on
78.	35	38	45	on	on
79.	35	39	47	on	on

80.	35	40	49	on	on
81.	40	21	-	off	off
82.	40	22	-	off	off
83.	40	23	24	off	off
84.	40	24	26	off	off
85.	40	25	27	off	off
86.	40	26	28	on	off
87.	40	27	30	on	off
88.	40	28	31	on	off
89.	40	29	32	on	off
90.	40	30	34	on	on
91.	40	31	35	on	on
92.	40	32	37	on	on
93.	40	33	39	on	on
94.	40	34	40	on	on
95.	40	35	42	on	on
96.	40	36	44	on	on
97.	40	37	45	on	on
98.	40	38	47	on	on
99.	40	39	49	on	on
100.	40	40	51	on	on
101.	45	21	22	off	off
102.	45	22	23	off	off
103.	45	23	24	off	off
104.	45	24	26	off	off
105.	45	25	27	off	off
106.	45	26	28	on	off
107.	45	27	30	on	off
108.	45	28	32	on	off
109.	45	29	33	on	off
110.	45	30	35	on	on
111.	45	31	37	on	on
112.	45	32	38	on	on
113.	45	33	40	on	on
114.	45	34	42	on	on
115.	45	35	43	on	on
116.	45	36	45	on	on
117.	45	37	47	on	on
118.	45	38	49	on	on
119.	45	39	51	on	on
120.	45	40	53	on	on
121.	50	21	22	off	off
122.	50	22	24	off	off
123.	50	23	25	off	off
124.	50	24	27	off	off
125.	50	25	28	on	off
126.	50	26	30	on	off

127.	50	27	31	on	off
128.	50	28	33	on	off
129.	50	29	34	on	on
130.	50	30	36	on	on
131.	50	31	38	on	on
132.	50	32	40	on	on
133.	50	33	41	on	on
134.	50	34	43	on	on
135.	50	35	45	on	on
136.	50	36	47	on	on
137.	50	37	49	on	on
138.	50	38	51	on	on
139.	50	39	53	on	on
140.	50	40	55	on	on
141.	55	21	23	off	off
142.	55	22	24	off	off
143.	55	23	26	off	off
144.	55	24	27	off	off
145.	55	25	29	on	off
146.	55	26	31	on	off
147.	55	27	33	on	off
148.	55	28	34	on	on
149.	55	29	36	on	on
150.	55	30	37	on	on
151.	55	31	39	on	on
152.	55	32	41	on	on
153.	55	33	43	on	on
154.	55	34	45	on	on
155.	55	35	46	on	on
156.	55	36	48	on	on
157.	55	37	50	on	on
158.	55	38	52	on	on
159.	55	39	55	on	on
160.	55	40	57	on	on
161.	60	21	24	off	off
162.	60	22	25	off	off
163.	60	23	27	off	off
164.	60	24	28	on	off
165.	60	25	30	on	off
166.	60	26	32	on	off
167.	60	27	33	on	off
168.	60	28	35	on	on
169.	60	29	37	on	on
170.	60	30	38	on	on
171.	60	31	40	on	on
172.	60	32	42	on	on
173.	60	33	44	on	on
174.	60	34	46	on	on

175.	60	35	48	on	on
176.	60	36	50	on	on
177.	60	37	52	on	on
178.	60	38	54	on	on
179.	60	39	57	on	on
180.	60	40	55	on	on
181.	65	21	24	off	off
182.	65	22	26	off	off
183.	65	23	27	off	off
184.	65	24	29	on	off
185.	65	25	31	on	off
186.	65	26	32	on	off
187.	65	27	34	on	on
188.	65	28	36	on	on
189.	65	29	38	on	on
190.	65	30	40	on	on
191.	65	31	42	on	on
192.	65	32	43	on	on
193.	65	33	45	on	on
194.	65	34	47	on	on
195.	65	35	50	on	on
196.	65	36	52	on	on
197.	65	37	54	on	on
198.	65	38	55	on	on
199.	65	39	55	on	on
200.	65	40	55	on	on
201.	70	21	25	off	off
202.	70	22	27	off	off
203.	70	23	28	on	off
204.	70	24	30	on	off
205.	70	25	32	on	off
206.	70	26	33	on	off
207.	70	27	35	on	on
208.	70	28	37	on	on
209.	70	29	39	on	on
210.	70	30	41	on	on
211.	70	31	43	on	on
212.	70	32	45	on	on
213.	70	33	47	on	on
214.	70	34	49	on	on
215.	70	35	51	on	on
216.	70	36	53	on	on
217.	70	37	56	on	on
218.	70	38	58	on	on
219.	70	39	55	on	on
220.	70	40	55	on	on
221.	75	21	26	off	off

222.	75	22	27	off	off
223.	75	23	29	on	off
224.	75	24	31	on	off
225.	75	25	33	on	off
226.	75	26	34	on	on
227.	75	27	36	on	on
228.	75	28	38	on	on
229.	75	29	40	on	on
230.	75	30	42	on	on
231.	75	31	44	on	on
232.	75	32	46	on	on
233.	75	33	48	on	on
234.	75	34	50	on	on
235.	75	35	53	on	on
236.	75	36	55	on	on
237.	75	37	57	on	on
238.	75	38	55	on	on
239.	75	39	55	on	on
240.	75	40	55	on	on
241.	80	21	26	off	off
242.	80	22	28	on	off
243.	80	23	30	on	off
244.	80	24	32	on	off
245.	80	25	33	on	off
246.	80	26	35	on	on
247.	80	27	37	on	on
248.	80	28	39	on	on
249.	80	29	41	on	on
250.	80	30	43	on	on
251.	80	31	45	on	on
252.	80	32	47	on	on
253.	80	33	50	on	on
254.	80	34	52	on	on
255.	80	35	54	on	on
256.	80	36	57	on	on
257.	80	37	59	on	on
258.	80	38	55	on	on
259.	80	39	55	on	on
260.	80	40	55	on	on
261.	85	21	27	off	off
262.	85	22	29	on	off
263.	85	23	31	on	off
264.	85	24	32	on	off
265.	85	25	34	on	on
266.	85	26	36	on	on
267.	85	27	38	on	on
268.	85	28	40	on	on
269.	85	29	42	on	on

270.	85	30	44	on	on
271.	85	31	46	on	on
272.	85	32	49	on	on
273.	85	33	51	on	on
274.	85	34	53	on	on
275.	85	35	56	on	on
276.	85	36	58	on	on
277.	85	37	55	on	on
278.	85	38	55	on	on
279.	85	39	55	on	on
280.	85	40	55	on	on
281.	90	21	28	on	off
282.	90	22	30	on	off
283.	90	23	31	on	off
284.	90	24	32	on	off
285.	90	25	35	on	on
286.	90	26	37	on	on
287.	90	27	39	on	on
288.	90	28	41	on	on
289.	90	29	43	on	on
290.	90	30	45	on	on
291.	90	31	48	on	on
292.	90	32	50	on	on
293.	90	33	52	on	on
294.	90	34	55	on	on
295.	90	35	57	on	on
296.	90	36	60	on	on
297.	90	37	55	on	on
298.	90	38	55	on	on
299.	90	39	55	on	on
300.	90	40	55	on	on
301.	95	21	28	on	off
302.	95	22	30	on	off
303.	95	23	32	on	off
304.	95	24	34	on	on
305.	95	25	36	on	on
306.	95	26	38	on	on
307.	95	27	40	on	on
308.	95	28	42	on	on
309.	95	29	44	on	on
310.	95	30	47	on	on
311.	95	31	49	on	on
312.	95	32	51	on	on
313.	95	33	54	on	on
314.	95	34	56	on	on
315.	95	35	59	on	on
316.	95	36	55	on	on
317.	95	37	55	on	on

318.	95	38	59	on	on
319.	95	39	55	on	on
320.	95	40	55	on	on

## 5.2 Discussion

It can be visualized that the readings i.e. temperature, relative humidity, status (on/off) and zone (comfort or economy) taken from the hardware of the system matches with the humidex chart which is taken as reference to control the conditions of the A.C.

The main purpose of the current work is to maintain the humidex value depending on temperature and relative humidity of surrounding conditions. The above results can be correlated on basis of two aspects which had been taken into consideration with respect to human perception. First of them is comfort level and the second is the economy. The humidex value for the human comfort and economy can be randomly chosen depending on various factors. The values that are taken here i.e., 28 for human comfort and 34 for economy has been based on a generalized system of measurements which have been accepted on basis of theoretical considerations.

The readings have been tabulated on basis of RH as a prima-facie condition and the temperature has been varied accordingly from a minimal value to a maximal value to analyze the above conditions i.e., comfort and economy zones. The value of temperature has been varied linearly calculating the humidex value with minimal gradation to avoid nonlinear discontinuities in the timing response of the system. Also the gradation of temperature will mimic the nature, constituting the temperature changes of a normal day.

## **Future Scope**

The present system has been formalized considering human comfort as prime condition. The system can be extended to be more vexatious including real time analysis on basis of seasonal changes. Also the economy zone can be subdivided to include different modes depending on power being used by the system and to enhance the system performance to include power saving features. Also the system can be implemented with a timer based control to make the AC work in an indigenous manner to effectively increase the net output of the system.

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## **Appendix**