Design and Development of Micro controller Based Temperature and Humidity Controller for Infant Incubator

A THESIS

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BY

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ABSTRACT

Infant incubator provides a controlled environment for newborns needing special care, such as those born prematurely. By placing an infant in an incubator, doctors and nurses can set and monitor different aspects of the child's environment in order to create ideal conditions for survival and moreover it protect infants from pollutants and infection. Infant incubators and other advances in medical technology have made it possible for small or premature babies to survive in higher numbers than they did in the middle of the 20th century.

Design and development of microcontroller based temperature and humidity controller for an infant incubator monitors and controls these two parameters constantly which are very critical for the normal growth of the new born (premature) babies

In this thesis work, focus has been to develop:

1. Hardware for temperature and humidity control
2. Compatible software

This system can automatically control the infant's temperature at optimum level using PID concept and to maintain high relative humidity so as to minimize the thermal loss. The developed system must be user friendly, cost effective and accurate.

ACKNOWLEDGEMENT

Words are often to less to revel one's deep regards. An understanding of the work like this is never the outcome of the efforts of a single person. I take this opportunity to express my profound sense of gratitude and respect to all those who helped me through the duration of this thesis.

First of all I would like to thank the Supreme Power, one who has always guided me to work on the right path of the life. Without his grace this would never come to be today's realty.

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No words of thanks for my dear parents, my brother Viejendera Singh whose support and care makes me stay on earth. Thanks to be with me.

At last, I would like to thank to all the members of Electrical Instrumentation Department whose love and affection made my stay at TIET campus a memorable.

Varuninder Singh

CLAIM OF ORIGINALITY

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*I, Varuninder Singh hereby certify that the work which is being presented in this thesis entitled "**Design and development of microcontroller based temperature and humidity controller for infant incubator**" by me in partial fulfillment of requirement for the award of degree of Master of Engineering (Electronics Instrumentation and Control) at Thapar Institute of Technology, Patiala, is an authentic record of my own work carried under the supervision of Mr. Sunil Kumar Singla.*

The matter presented in this thesis has not been submitted in any other University/ Institute for the award of Master of Engineering.

(Varuninder Singh)

Signature of the Student *Date…………..*

This is certified that the above statement made by the candidate is correct to the best of my knowledge.

(Sunil Kumar Singla) *(Mrs Manbir Kaur)*

Supervisor *Head of the Department*

Date………….. *Date………………...*

(Dr. T. P. Singh)

Dean Academic Affairs

Date………………

Chapter 1

Introduction

"Perhaps the most important conclusion from recent research into the effects of the physical environment on preterm infants is that each infant should have a 'microenvironment', which can be individualized to needs that are specific to that child's gestational age and medical condition. To some extent, the incubator can serve as this microenvironment, controlling light, sound, smell, and protecting from infection [1]."

Figure 1: Infant Incubator

1.0 Infant Incubator

An incubator is an infant-stimulating system used for intensive care of the new born, premature or sick baby. It provides a safe and clean environment, which has fresh air, clean and sterile ambient conditions for the babies. In addition to these, the incubator environment provides a homogeneous and stable temperature, a relative humidity (RH) level and oxygen gas concentration that are needed especially for intensive care of the premature baby. Since the incubator is a medical device and has a lot of limitations as other medical equipment, the most suitable humidity measurement and humidifying method have to be used. For continuous recording and control of the RH level, many kinds of electrical transducers can be employed such as resistive, capacitive, lithium chloride, electrolytic and integrated circuit (IC) type RH sensors which measure the RH level in the air. Owing to the suitable electrical characteristics for the measurement and control process, capacitive and IC types RH sensors are more suitable than the others [2].

Infant incubator is used mainly to keep a baby's core temperature stable at 37 degrees Celsius. The core temperature of the human body needs to be kept at a constant temperature of 37 degrees Celsius because the temperature goes too high or too low, then the organs can be damaged and illness or death can result. Premature babies (babies born before they are due to be born) have undeveloped nervous systems and also lack the energy to regulate their own temperature, which drop significantly because of heat loss from conduction (heat loss to cooler surfaces in direct contact with the infant), convection (heat loss to air moving past the infant), radiation (heat loss to cooler objects not in direct contact with the infant), and water evaporation (heat loss from the infant's lungs and skin surface). Whereas term neonates naturally regulate their body temperature to some extent, premature infants have thinner skin, which allows surface blood vessels to more readily lose heat to the environment; a large ratio of surface area to volume, resulting in greater heat losses from radiation and convection; and there is no subcutaneous fat to either metabolize into heat or act as an insulator. Prolonged cold stress in neonates can cause oxygen deprivation, hypoglycemia, metabolic acidosis, and rapid depletion of glycogen stores; therefore, energy conservation provided by thermal support is critical and hence their temperature needs to be maintained by an incubator [3]. We can only give small babies a small amount of food for growing. We want them to use all of their energy for growth rather than wasting it on keeping warm, so sometimes we use the incubator to help them grow faster. Every year, about 1 million infants in the developing world die due to heat loss and dehydration that can be prevented by an intensive care unit. Thus the function of the incubator is to compensate for these disadvantages and provide a congenial atmosphere for the infants [4].

1.1 Principles of Operation

The neonate lies on a mattress in the infant compartment, which is enclosed by a clear plastic hood. Most incubators have hand access ports with doors that permit the infant to be handled while limiting the introduction of cool room air. The clinician can raise or remove the plastic hood or open a panel to gain greater access to the infant. Some units feature an air curtain that causes warm air to sweep past the opening. Most incubators warm the infant by a forced or natural flow of heated air. At least one unit supplements air convection by actively warming the incubator walls to reduce radiant heat loss. Another unit uses a mattress of warm water, rather than a convective airflow, to warm the infant. Heating and humidification systems are located beneath the infant compartment. A fan or natural flow circulates air past the heater and the temperature measuring device, over a water reservoir used to humidify the air (if desired), and up into the infant compartment. Most incubators are equipped with proportional heating controls that provide electrical power to the heating coil in response to the difference between the actual temperature and the desired temperature.

Most units have two modes of operation:

a) Air-temperature control: With the air-temperature (manual) control, the operator sets the temperature of the air in the incubator; changes in infant body temperature are usually measured periodically with a thermometer, and adjustments in air temperature are made accordingly.

b) Skin-temperature control: In the skin temperature control mode, also called the servo (automatic) mode, a sensor is taped to the infant's skin, and the heater responds to changes in the sensor to keep the skin temperature at the preset level.

Most units allow the user to vary relative humidity from either a built-in reservoir or an outside source (e.g., a humidifier that attaches to one of the inlet ports). Although increasing the relative humidity in an incubator can reduce evaporative heat loss, many clinicians avoid supplemental humidification because of concern that infectious organisms may proliferate in the water reservoir. Many incubators have one or two oxygen inlet ports and can be equipped with optional oxygen controllers. These incubators can also provide support and protection for oxygen cylinders when oxygen must be delivered to the infant in the incubator. Because the room temperature of the nursery is nearly always lower than the temperature inside the incubator, radiant heat loss through the incubator walls accounts for as much as half the infant's total heat loss. In some nurseries, a plastic heat shield is placed over the infant inside the incubator to minimize radiant heat loss. In addition, some incubators have double walls separated by an air space to prevent excessive heat loss. However, in a study comparing heat loss from servo-regulated single- and double walled incubators, Bell and Rios (1983) reported that although the double-walled incubator decreased radiant heat loss, it increased convective heat loss; total heat loss and metabolic heat production were the same as in single-walled incubators [3].

1.2 Basic Biomedical Instrumentation System

The primary purpose of medical instrumentation system is to measure or determine the presence of some physical quantity that may some way assist the medical personnel to make better diagnosis and treatment. The basic block diagram is shown in figure below:

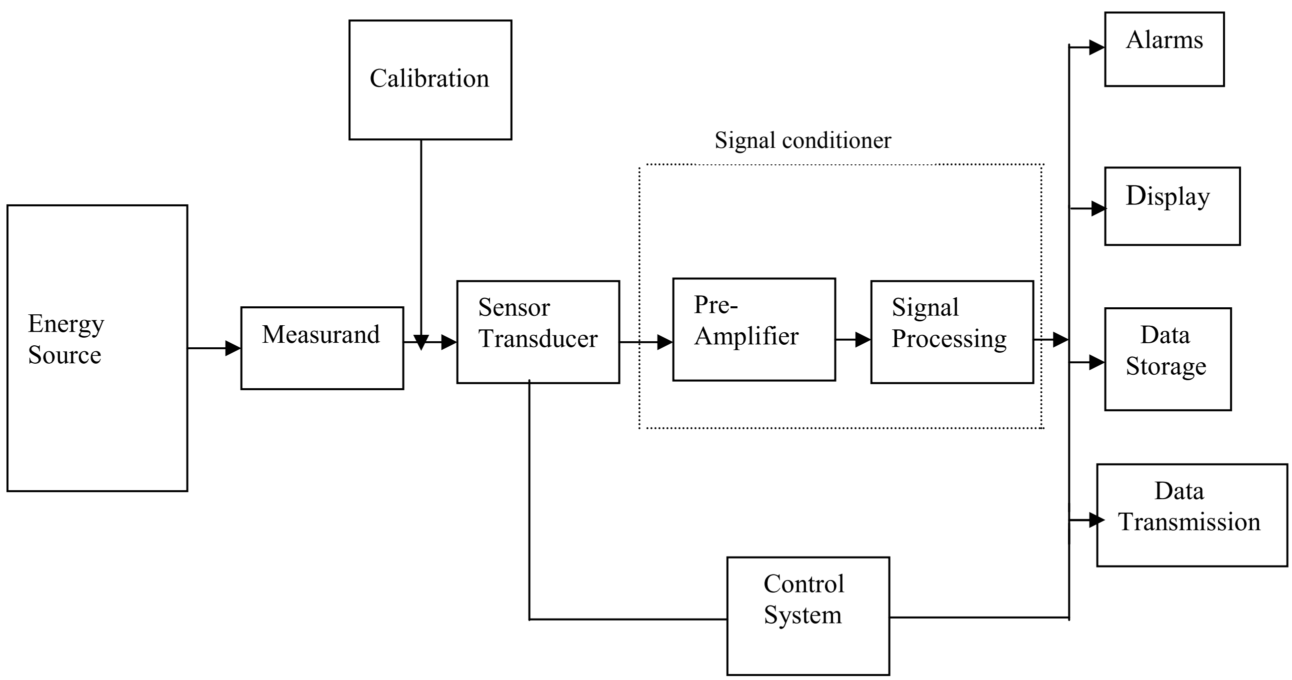


Figure2: Block Diagram of Bio-Medical Instrumentation System

Any medical instrument would comprise of the following:

1. **Measurand:** The physical quantity or condition that the instrumentation system measure is called measurand. The source for the measurand is the human body, which generates a variety of signals.
2. **Transducer/Sensor:** A transducer convert's one form of energy to another. The primary function of the transducer is to provide a usable output in response to the measurand, which may be a specific physical quantity, property or condition. Basically, a sensor converts a physical measurand to an electrical signal. Depending on the transducer, the output produced is in the form of voltage, current, resistance, or capacitance. The sensor should be minimally invasive and interface with the living system with minimum extraction or energy. The primary function of the transducer is to provide a usable output in response to the measurand.
3. **Signal Conditioner:** For interfacing analog signals to the microprocessor or microcontroller, use is made of some kind of data acquisition system. The function of the system is to acquire and digitize data, often from hostile clinical environments, without any degradation in the resolution or accuracy of the signal. Signal conditioner converts the output of the transducer into an electrical quantity suitable for operation of the display or recording system or control purposes. Signal conditioning usually includes functions such as amplification, conversion analog to digital or signal transmission circuitry. Buffer amplifier help in increasing the sensitivity of instruments by amplification of the original signal or its transduced form. The A/D converter carries out the process of the analog to digital conversion. The higher the no of bits, the higher the precision of conversion. Since software costs generally far exceed the hardware costs, the analog or digital interface

structure must permit software effective transfers of data and command and status signals to avail of the full capability of the micro controller.

The key parameters in A/D converters are:

- **Resolution** of the A/D converter is a measure of the number of discrete digital code that it can handle and is expressed as number of bits (binary). For example, for an 8- bit converter the resolution is 1 part in 256.
- **Accuracy** is expressed as either a percentage of full scale or alternatively in bits of resolution.
- **Integral non-linearity** is a measure of the deviation of the transfer function from a straight line.
- **Speed** of an A/D converter is generally expressed as its conversion time i.e. the time elapsed between application of a convert command and the availability of data at its outputs.

4. **Display System**: Provides a visible representation of the quantity. It may be on the chart recorder, or on the screen of a cathode tube or in numeric form or LCD display.
5. **Alarm System**: With upper and lower adjustable thresholds to indicate when the measurand goes beyond present limits.

6. **Data transmission**: Standard interface connections can be used so that the information obtained may be carried to other parts of an integrated system or to transmit from one location to another.
7. **Data Storage**: To maintain the data for future reference. It may be a hard copy on a paper or on magnetic or semiconductor memories.

8. **Control System**: It controls all the operations of the instrument. It consists of a microprocessor or a micro-controller and software stored inside it to provide the necessary controls. The control logic provides the necessary interface between the microcontroller system and the elements of the acquisition unit in providing the necessary timing control. It has to ensure that the correct analog signal is selected, samples data at correct time, initiate the A/D conversion process and signals to the microcontroller or microprocessors on completion of conversion.

1.3 Problem Definition

Baby Incubator is one of the quite essential life supportive equipment for the premature babies in the hospitals. Unfortunately, there is a lack of low cost infant incubators in the developing world.

"*The aim of the thesis is to design and develop a microcontroller based temperature control using PID concept and humidity control in an infant incubator*". Advances in electronic techniques coupled with economical prices make humidity and temperature control cost-effective with highly accurate and stable performance. In this work main focus will be to:

1. Design and develop hardware for temperature and humidity control.
2. The development of software using AT89C52 microcontroller.

The developed system should be accurate, economical, user friendly and must provide the required environment for the growth of the premature baby.

Chapter 2

Literature Survey

Infant incubator is a device in which preterm infants are placed so as to reproduce the similar environment to that baby was developing in mother's womb. This section gives the reader a general background of physiology of preterm newborn and how the environment control can make a difference in the life of an infant. This investigation will be based on theoretical study on whose basis a prototype has been built.

2.0 Premature Infant Physiology

Premature infants are babies born prior to the normal 36 or 37 weeks of gestation within the womb. As a result, their physiological systems are underdeveloped making the infant vulnerable to a number of health complications. Some common problems include jaundice caused by an immature liver, respiratory complications caused by fragile, underdeveloped lungs, and hypoglycemia, hypoxia and even death caused by an immature response of the nervous system to cold stress. These inadequate thermoregulations, wherein their physiology is not able to compensate for the heat they lose from the body are by far the leading causes of death in premature infants. Heat is lost via evaporative, conductive, convective and radiative means. Premature infants lack muscle mass, which allows adults to shiver and produce heat when necessary, as well as heat generating brown fat, which makes up about 5% of the body weight in preterm infants. This heat loss is enhanced by their large surface area to volume ratio (about 4 times the adult ratio). Furthermore, their immature skin allows for excessive water loss from the body causing a considerable evaporative heat loss and a potentially fatal imbalance of salts and acids in the infant's system. In evaporative heat loss, moisture from the body first diffuses across the epidermis (general outer layer of skin). Then it evaporates off from the skin's surface cooling the infant.

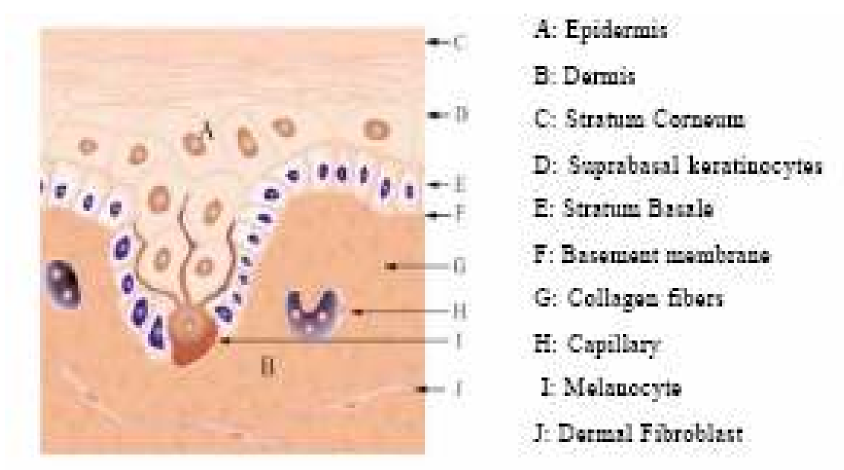


Figure 3: Skin surface

Premature infants have a thin, underdeveloped stratum corneum, or the rough, outer layer of the epidermis which protects the skin from external agents, that enables excess of water to diffuse out. Evaporative heat losses make up a significant fraction of the total heat loss of a premature infant [6].

2.1 Thermal Protection in New Born

Thermal protection of the newborn is the series of measures taken at birth and in the first days of life to ensure that the newborn does not become either cold or overheated and maintains a normal body temperature of 36.5-37.5°C (97.7-99.5°F). Since the consequences of an environment that is too cold or too warm are serious, it is important to know what is the optimal — i.e. the most suitable — thermal environment for the new born baby. This is the range of thermal conditions under which a new born baby can maintain normal body temperature. The range is narrow, especially in low birth weight or sick babies. Basically speaking, the smaller and more premature the new born is, the less it tolerates cold and heat. Thus there is no single environmental temperature that is appropriate for all sizes, gestational ages and conditions of new born babies. What is appropriate for a healthy baby is too cold for a preterm baby, and what is appropriate for the preterm baby is too hot for the preterm infant. The newborn cannot regulate its temperature as well as an adult. It therefore cools down or heats up much faster and is able to tolerate only a limited range of environmental temperatures. The smaller the new born, the greater the risk. Thermal stability improves gradually as the baby increases in weight. The table 1 below shows relation between age, weight and corresponding range of temperatures.

Table 1: Neutral Thermal Environment Temperatures

Age and Weight	Starting Temperature (^{0} C)	Range of Temperature (^{0} C)
0-6 hours		
Under 1200g	35.0	34.0-35.4
1200-1500 g	34.1	33.9-34.4
1501-2500 g	33.4	32.8-33.8
Over 2500g (> 36 weeks)	32.9	32.0-33.8
6-12 hours		
Under 1200g	35.0	34.0-35.4
1200-1500 g	34.0	33.5-34.4
1501-2500 g	33.1	32.8-33.8

Over 2500g (> 36 weeks)	32.8	31.4-33.8
12-24 hours		
Under 1200g	34.0	34.0-35.4
1200-1500 g	33.8	33.3-34.3
1501-2500 g	32.8	31.8-33.8
Over 2500g (> 36 weeks)	32.2	31.0-33.7
24-36 hours		
Under 1200g	34.0	34.0-35.0
1200-1500 g	33.6	33.0-34.1
1501-2500 g	32.6	31.4-33.5
Over 2500g (> 36 weeks)	32.1	30.5-33.3
36-48 hours		
Under 1200g	34.0	34.0-35.0
1200-1500 g	33.5	33.0-34.1
1501-2500 g	32.5	31.4-33.5
Over 2500g (> 36 weeks)	31.9	30.5-33.3
48-72 hours		
Under 1200g	34.0	34.0-35.0
1200-1500 g	33.5	33.0-34.0
1501-2500 g	32.3	31.1-33.2
Over 2500g (> 36 weeks)	31.3	29.8-32.9
72-96 hours		
Under 1200g	34.0	34.0-35.0
1200-1500 g	33.5	33.0-34.0
1501-2500 g	32.2	31.1-33.2
Over 2500g (> 36 weeks)	31.3	29.8-32.9
4-12 days		
Under 1500g	33.5	33.0-34.0
1501-2500g	32.1	31.0-33.2
Over 2500g (>36 weeks)		
4-5 days	31	29.5-32.6
5-6 days	30.9	29.5-32.3
6-8 days	30.6	29.0-32.2
8-10 days	30.3	29.0-32.8
10-12 days	30.1	29.0-31.4
12-14 days		
Under 1500g	33.5	32.6-34
1501-2500g	32.1	31.0-33.2

Over 2500g (>36 weeks)		
2-3 weeks		
Under1500g	33.1	32.2-34.0
1501-2500g	31.7	30.5-33.0
Over 2500 g		

The temperature inside the mother's womb is 38°C (100.4°F). Leaving the warmth of the womb at birth, the wet new born finds itself in a much colder environment and immediately starts losing heat thus the thermal protection of newborns is very important but not difficult. The basic principles are the same whether the baby is born at home or in an institution. As most cooling of the newborn occurs during the first minutes after birth, it is important to act quickly to prevent heat loss. The new born baby loses heat in four different ways. Heat loss is mainly due to evaporation of amniotic fluid from the baby's body. But loss of body heat also occurs by conduction if the baby is placed naked on a cold surface (e.g. a table, weighing scale or cold mattress); by convection if the naked new born is exposed to cooler surrounding air; and by radiation from the baby to cooler objects in the vicinity (e.g. a cold wall or a window) even if the baby is not actually touching them.

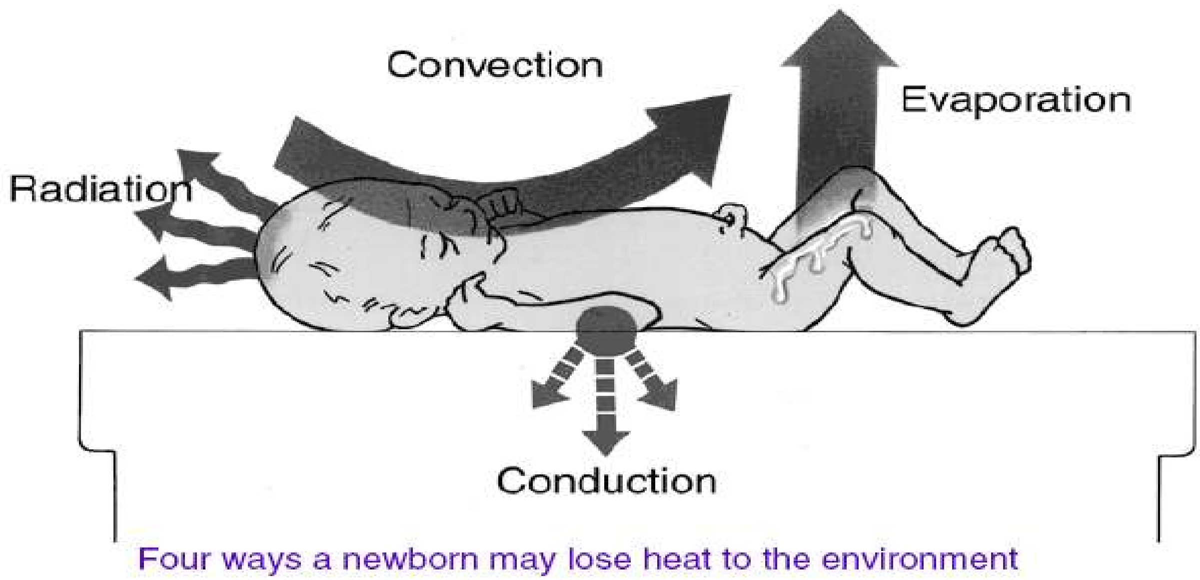


Figure 4: Heat Losses

Heat loss increases with air movement, and a baby risks getting cold even at a room temperature of 30°C (86°F) if there is a draught. Most cooling of the new born occurs during the first minutes after birth. In the first 10-20 minutes, the new born who is not thermally protected may lose enough heat for the body temperature to fall by 2-4°C (3.6-7.2°F), with even greater falls in the following hours if proper care is not given. If heat loss is not prevented and is allowed to continue, the baby will develop hypothermia, i.e. a body temperature below normal. A hypothermic baby, especially if it is small or sick, is at increased risk of developing health problems and of dying. However, if heat loss is prevented, the new born will stay warm and will have a much better chance of remaining healthy, or of surviving if it is already sick. In trying to keep babies warm, it is important to make sure they do not become overheated. The mechanisms described above may act in reverse and cause hyperthermia, i.e. a body temperature above normal. Although less common, hyperthermia is as dangerous as hypothermia [7].

2.2 Cold Stress or Hypothermia

Cold stress in the neonatal period can be defined as a body temperature measurement less than 36.5° C (97.6° F) rectally with system wide associated. The normal responses to cold stress for the adult are either not present or not adequately effective for the neonate. Full term neonates have a very limited ability to shiver to produce heat and preterm infants have none. Additionally, preterm neonates have unstable vasomotor responses and therefore cannot vasoconstrict adequately to slow down heat losses. Preterm infants have limited stores of brown fat and therefore inadequately produce heat metabolically.

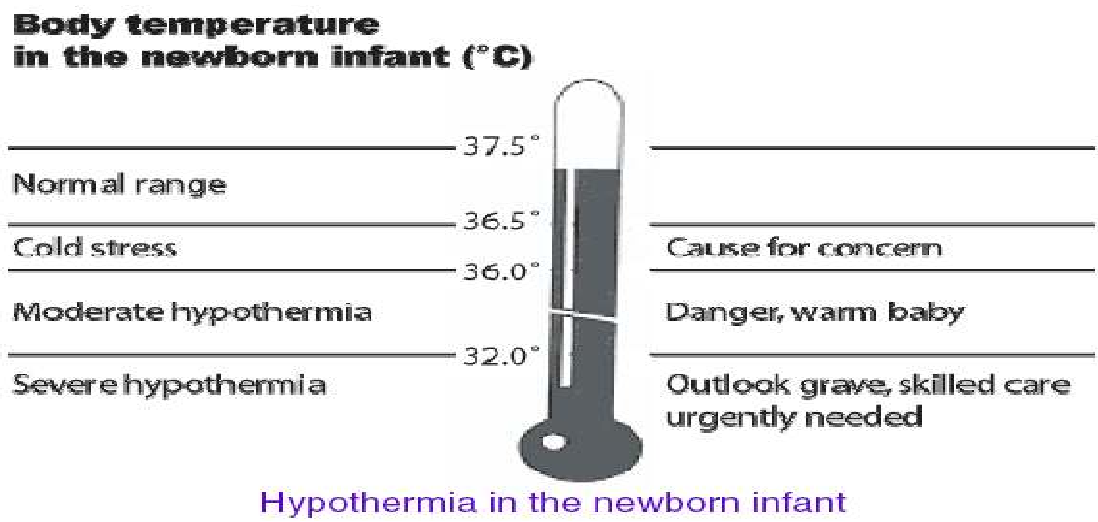


Figure 5: Temperature ranges in Hypothermia

While in the adult model, control of body temperature is achieved by a complex system which via negative feed-back basically creates a balance between heat production, heat gain and heat loss. The key of this system is a central controller located in the hypothalamus and limbic system, which based on information from central and peripheral thermo receptors (multiple-input), controls the action of the so-called effectors: thermo genesis, the vasomotor system, sweat secretion and thermoregulatory behavior, through the efficient nervous system. Body temperature therefore is the result of the combined action of the detectors, controller system and the effectors. In the case of newborn infants, especially preterm infants, immaturity of the thermoregulatory system makes the infant more vulnerable to changes of environmental temperature. In the infant model, the physiology of the response to cold stress is related to the oxidation of brown fat or brown adipose tissue. In full term newborn infants, non-shivering thermogeneisis (oxidation of brown adipose tissue) is the major route of a rapid increase of heat production in response to cold exposure. The figure 6 represents the metabolic response to cold stress [8]:

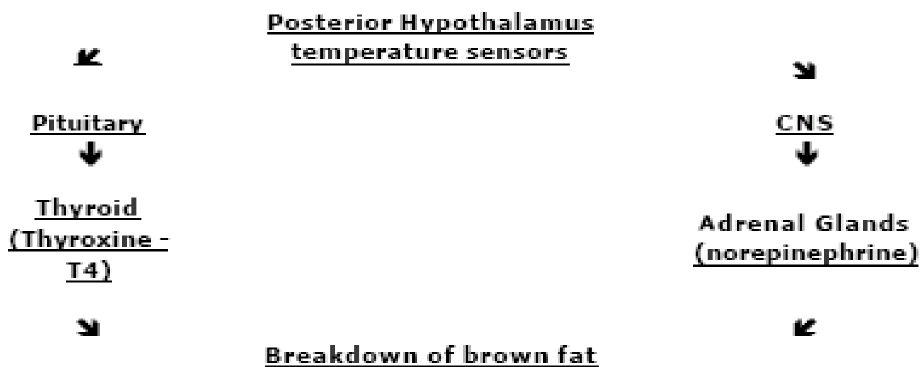


Figure 6: Metabolic response to cold stress

The consequences of cold stress can be quite severe. As the body temperature decreases, the baby becomes less active, lethargic, hypotonic, sucks poorly and their cry becomes weaker. Respiration becomes shallow and slow and the heart-beat decreases. Sclerema – hardening of skin with redness – develops mainly on the back and the limbs. The face can also become bright red. As the condition progresses it causes profound changes in body metabolism resulting in impaired cardiac function, hemorrhage (especially pulmonary), jaundice and death [9].

2.2.1 *Management of Cold Stress*

Newborns found to be hypothermic must be rewarmed as soon as possible. The temperature of the room where the rewarming takes place should be at least 25°C (77°F). Cold clothes should first be removed and replaced with pre-warmed clothes and a cap. The newborn should be quickly rewarmed; if a warming device is used, the baby should be clothed and its temperature should be checked frequently during the rewarming process. It is very important to continue feeding the baby to provide calories and fluid. Breast-feeding should resume as soon as possible. If the infant is too weak to breast feed, breast milk can be given by nasogastric tube, spoon or cup. It is important to be aware that hypothermia can be a sign of infection. Every hypothermic newborn should therefore be assessed for infection. In hospital a diagnosis of hypothermia is confirmed by measuring the actual body temperature with a low-reading thermometer, if available. The method used for rewarming depends on the severity of the hypothermia and the availability of staff and equipment. In cases of mild hypothermia (body temperature 36.0-36.4°C/96.8-97.5°F), the baby can be rewarmed by skin-to-skin contact, in a warm room (at least 25°C/77°F). In cases of moderate hypothermia (body temperature 32-35.9°C/89.6-96.6°F) the clothed baby may be rewarmed:

- under a radiant heater;
- in an **incubator**, at 35-36°C (95-96.8°F);
- by using a heated water-filled mattress;
- in a warm room: the temperature of the room should be 32-34°C/89.6-93.2°F(more if the baby is small or sick);

- in a warm cot: if it is heated with a hot water bottle or hot stone, these should be removed before the baby is put in;
- If nothing is available or if the baby is clinically stable, skin-to-skin contact with the mother can be used in a warm room (at least 25°C/77°F).

The rewarming process should be continued until the baby's temperature reaches the normal range. The temperature should be checked every hour, and the temperature of the device being used or the room adjusted accordingly. The baby should continue to be fed.

In cases of severe hypothermia (body temperature below 32°C/89.6°F), studies suggest that fast rewarming over a few hours is preferable to slow rewarming over several days. Rapid rewarming can be achieved by using a thermostatically controlled heated mattress set at 37-38°C (98.6-100.4°F) or an air-heated incubator, with the air temperature set at 35-36°C (95-96.8°F). If no equipment is available, skin to- skin contact or a warm room or cot can be used. Feeding should continue, to provide calories and fluid and to prevent a drop in the blood glucose level which is a common problem in hypothermic infants. If this is not possible, monitoring blood glucose becomes important and an intravenous line

should be set up to administer glucose if needed. Once the baby's temperature reaches 34°C (93.2°F), the rewarming process should be slowed down to avoid overheating. The temperature of the incubator and the baby's body temperature should be checked every hour [7].

2.3 Hyperthermia

Hyperthermia can be defined as a rectal temperature greater than 37.0°C (98.6°F). Determination of an external source of heat gain versus an actual febrile state can be made by observing for peripheral vasoconstriction as demonstrated by a higher rectal temperature versus a distal temperature of the foot. In the presence of over heating, the opposite would occur [8]. Hyperthermia should not be confused with fever, which is a raised body temperature in response to infection with microorganisms or other sources of inflammation. However, it is not possible to distinguish between fever and hyperthermia by measuring the body temperature or by clinical signs, and when the newborn has a raised temperature it is important to consider both causes. Infection should always be suspected first, unless there are very obvious external reasons for the baby becoming overheated [7].Hyperthermia can cause increased metabolic demands for the neonate. The neonate may have increased oxygen requirements, apnea, dehydration, metabolic acidosis and in worse case scenarios heat stroke, brain damage, shock and death [8].

2.3.1 Management of Hyperthermia

The baby should be moved away from the source of heat, and undressed partially or fully, if necessary. If the baby is in an incubator, the air temperature should be lowered. It is important that the baby be breast-fed more frequently to replace fluids. Every hyperthermic baby should be examined for infection. When hyperthermia is severe i.e. body temperature above 40°C(104°F°) the baby can be given a bath. The water should be warm. If it is possible to measure the water temperature, it should be about 2°C (3.6°F) lower than the baby's body temperature. Using cooler or cold water is dangerous. It may not achieve the desired effect and the baby may very quickly become hypothermic. If the baby cannot breast-feed extra fluids should be given intravenously or by tube.

2.4 Measurement of Body Temperature

Obtaining a body temperature is the only reliable method available to evaluate thermal stability. Accepted temperature ranges for the neonate are dependent upon the site from which the body temperature is obtained.

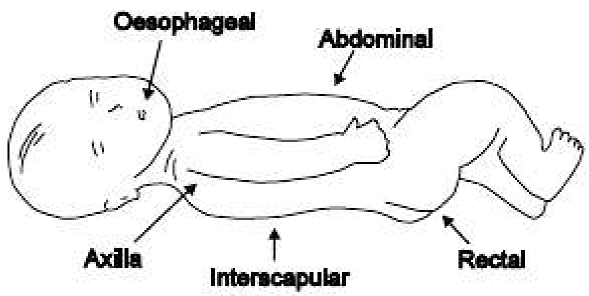


Figure 8: Temperature measurement points

2.4.1 Rectal Temperature

Traditionally the rectum has been used as a measure of the core temperature. However taking a rectal temperature is an invasive procedure and the measurement is not always reliable. The rectal temperature depends on the depth to which the probe is inserted as shown in figure 9.

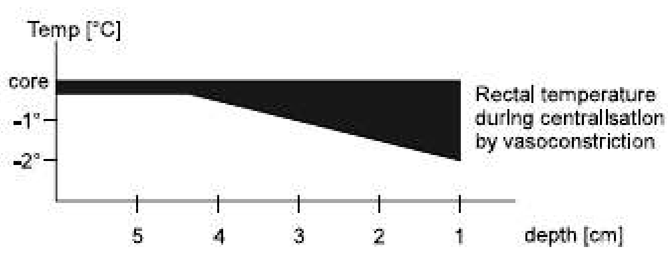


Figure 9: Rectal Temperature

Rectal temperature is also affected by the temperature of the blood returning from the lower limbs. If there is peripheral vasoconstriction, and the baby is centralizing its circulation, the cold blood returning from the legs will significantly lower the measured rectal temperature. *From a practical point of view, it is impossible to keep a rectal probe in the same position for any length of time and so this is not a suitable site for continuous temperature monitoring.*

2.4.2 Axilla and Abdominal Skin Temperatures

The Axilla and the abdomen (over the area of the liver) are alternative sites commonly used to represent central temperature. In the newborn baby these sites, although on the skin, do not appear to react to lower temperatures with vasoconstriction. This means that, although the temperature measurements in the axilla or on the abdomen are slightly lower than the true central temperature, they will change in the same way as the central temperature. Monitoring the trends in the axilla or abdominal skin measurements will therefore give information on the way the central temperature is changing. The axilla is a good site for a probe as it is not easily affected by changes in environmental temperature and the position of the probe does not interfere with X ray fields

2.4.3 Zero Heat Flux Temperature

If the baby is lying on a non-conducting mattress, the skin adjacent to the mattress will be unable to lose heat and will therefore warm up to the temperature of the body's core. This is called the Zero Heat Flux Temperature. With the baby on its back on a non conducting mattress, this temperature can be measured by a probe placed in the interscapular region. It is important to use small, flat probes that will not cause pressure damage to the baby's skin.

2.4.4 Oesophageal Temperature

Oesophageal temperature, with the probe positioned close to the heart, is possibly the closest we can get to a true core temperature. This probe gives a measurement of the temperature of the blood in the great vessels. This is however an invasive procedure and there are currently no probes that can be used for long periods of time in the newborn baby. Zero heat flux temperature has been shown to be closely correlated with oesophageal temperature.

2.4.5 Peripheral Temperature

Peripheral temperature is usually measured from the sole of the foot. In the newborn baby, the foot has been shown to respond to lower temperatures with vasoconstriction [9].

2.5 Devices for Thermal Protection in Preterm Infants

Low birth weight or sick newborns are at greater risk of developing hypothermia or hyperthermia than normal weight babies because they regulate body temperature even less well. To keep low birth weight or sick newborn babies warm, the same principles apply as for other newborns, but these babies require extra warmth over a longer period of time. Moreover the baby's temperature and the temperature inside the device should be monitored frequently. No heating device can function efficiently in a cold room, because heat loss by radiation to the cold environment may exceed heat generated by the device. All equipment should therefore be used in room temperatures of at least 25°C (77°F). The method used to keep the baby warm will depend on its weight, gestational age, and health, which can be taken care by various devices such as:

1. Infant Incubators
2. Radiant Warmers

Note: Even Kangaroo-mother care can be used for clinically stable low birth weight newborns which is continuous skin-to-skin contact.

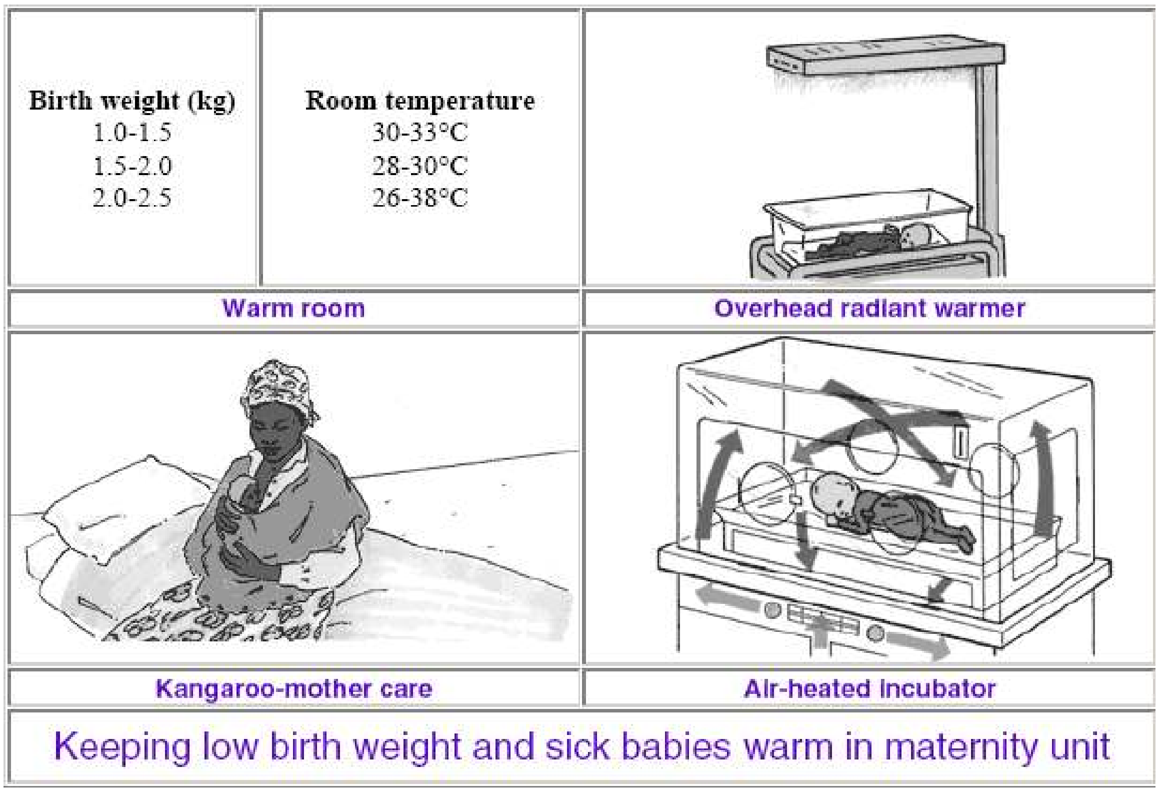


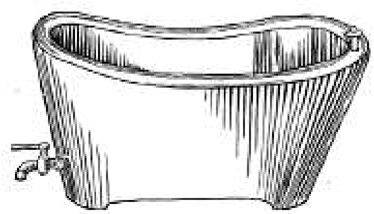
Figure 10: Thermal Protection in New Borns

Different devices serve different purposes: Radiant heaters are best used for resuscitation and interventions while ***Infant incubators are the proper choice for the care of very small newborns during the first days or weeks [7].***

2.5.1 Background of Infant Incubators

Stories differ regarding the invention of the infant incubator,it seems that the Imperial Foundling Hospital in Moscow had been using a double-walled warming tank invented by

Carl Credé since at least 1874, while the first published account of a similar open, double-walled tank came in 1857 from French pediatrician Denucé. This device, called a warmwännen, consisted of a large metal tub into which was set a smaller metal tub. They were welded at the top edges, with an opening near the top to pour in warm water and a faucet near the bottom to drain it. By filling the space between the tubs with warm water, an infant placed in the inner tub could be kept warm.



Denuce/Crede *Warmwännen*, from Julius Hess, *Premature and congenitally diseased infants*. Philadelphia: Lea and Febiger, 1922.

Figure 11: *warmwännen*

In 1883, Pierre-Victor-Adolph Auvard published an account of another incubator, developed by Etienne Stéphane Tarnier for use in the enormous Paris Maternité. Tarnier was visiting a poultry exhibit at the Paris zoo when struck with the idea to have a poultry incubator built with the purpose of warming premature infants. It seems that he came to this idea with little knowledge of the less-sophisticated Denucé/Credé device. Tarnier device, the couveuse, consisted of a double-walled wooden box, the space between the walls filled with sawdust for insulation. To prevent fumes from a gas or alcohol heater reaching the infant, Tarnier used a thermosiphon with a gas burner to heat a reservoir of water in the lower compartment of the box. The infant was placed in the upper compartment. Air would enter the box at the bottom, be warmed by the reservoir, and then pass upwards through vents to reach the baby above. It would then pass out the top of the incubator through vents in the double thick glass lid. A thermometer placed next to the baby allowed caretakers to monitor the incubator. temperature without opening the box. Tarnier recommended that the thermosiphon burner be lit three times a day for an hour at a time in winter, and twice a day in summer, with adjustments to be made as needed.

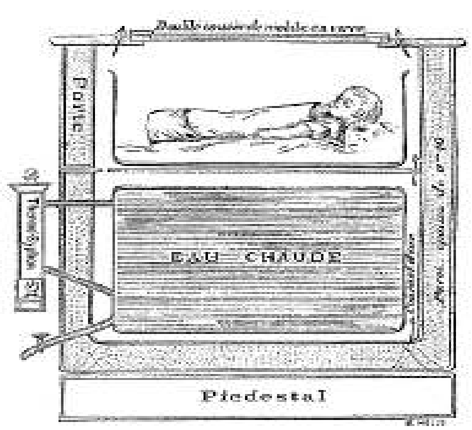


Figure 12: The Couveuse

However, this device was large, expensive, and conducted heat so efficiently that it risked cooking the infant. Two solutions were engineered to respond to these problems. One, designed by Tarnier student Budin, incorporated a mercury thermostat and a battery operated alarm to alert caregivers if the temperature rose too high or dropped too low. But the more popular design was in response to nurse behavior in the wards: viewing the thermosiphon as too risky, nurses began periodically filling the reservoir with hot water by hand two or three times daily. Tarnier and his intern Auvard developed a low-tech version of the incubator in response: a two-tiered, sawdust-insulated box heated by removable clay hot water bottles. It was this device that was produced on a large scale, and was the most popular model until the late 1890s.

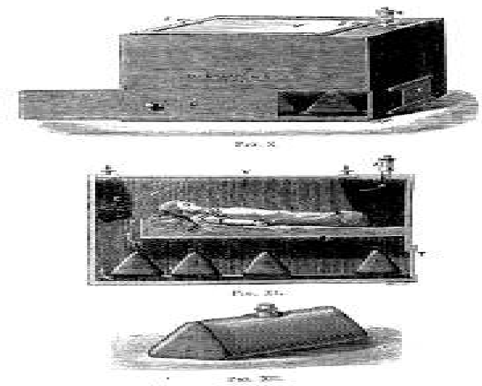


Figure 13: Two-tiered, sawdust-insulated box

The first report of the use of an incubator in an American journal came in 1887. As it was reported to the Chicago Medical Society, John Bartlett, a physician and Professor of Diseases of Women and Children at the Chicago Policlinic. The incubator he created was made of inset metal tubs, like the warmwännen, it also used a boiler attached to the side, like Tarnier original couveuse plan. It had a complicated thermosiphon arrangement intended to keep the water at a regular temperature throughout. It had no provisions for ventilation but also had no solid top: Bartlett recommended that a blanket big enough to cover the device be draped over it, except about the face of infant. In 1891 reports came of a new incubator design in France, designed by Alexander Lion of Nice. The Lion incubator was made all of iron, with glass doors in the front and hot water circulating through a spiral pipe in the bottom, warming the air within. It was ventilated by pipes which drew air from the outside, filtering it before delivering it to the base of the incubator. A fan at the top indicated the rate of air circulation. The infant was placed on a mattress in a basket which was suspended from the sides of the apparatus by springs. Lion indicated that the boiler, placed to the side of the device,could be heated with gas, oil, electricity, methylated spirits, or any other fuel. Temperature was automatically regulated via a thermostat. The device was large, heavy, complex, and expensive, requiring installation into buildings for proper use [11].

Figure 14: Lion Incubator

Hess's model, a double-jacketed warming tub after Credé's model, was introduced to little enthusiasm in 1915. In the 1930s the incubator as a means of introducing an artificially high level of oxygen along with warmth to the struggling infant gained again in popularity hence Julius Hess's pioneering oxygen therapy incubators were introduced in 1934.Since then technology has been frequently updated with parameters of control being the same such as temperature, humidity and oxygen in the baby incubator. The technology as has seen great development form manual control to automatic control which is still being worked upon. Hence till the world is here infant incubator technology will be developing to next stage. [12]

2.5.2 Types of Incubators

As mentioned in previous section, infant incubator has a rich background which has led to vast development in this technology on whose basis we have infant incubator such as:

1. *Manually controlled incubators*

2. *Servo-Controlled incubators*
3. *Transport Incubators*

These different incubators have same purpose of controlling the temperature of infants body but operational principle of these incubator differs from each other in certain respect.

2.5.2.1 Manually Controlled Incubator

The temperature in an incubator may be controlled by a thermostat. This keeps the environment at a set temperature and allows one to monitor the neonate's temperature. The temperature is set to provide a neutral thermal environment. Instructions should be followed.

1. Appropriate start temperatures and temperature ranges should be selected.
2. Neonates in manually controlled incubators shouldn't be wrapped in blankets except for weaning to an open crib.
3. Use closed sleeves in portholes to prevent heat loss.
4. Keep incubator away from cold walls, air currents, windows and other cold objects.
5. With neonates less than 1500 grams, use a heat shield over the neonate or a double-walled incubator to decrease radiant heat loss and oxygen consumption.
6. VLBW neonates may require use of a heating pad in conjunction with methods described above to maintain temperature ideally. The incubator's ambient temperature should be recorded simultaneously with the neonate's axillary or skin temperature so that changes in the neonate's temperature can be interpreted appropriately.

7. An increase or decrease in body temperature will not be masked if the manually controlled ambient temperature has been stable and set in the appropriate neutral thermal environmental range.
8. A change in a neonate's body temperature caused by a change in the manually controlled ambient temperature could be detected by noting both the neonate and ambient temperatures changing in the same direction [10].

2.5.2.2 Servo-controlled Incubators

The servo control system adjusts the environmental temperature to keep the skin temperature constant. Changes in incubator temperature must be observed since the neonate's skin temperature will not change. Air-heated incubators are widely used for the care of very small and sick newborns. They provide a clean, warm environment, where the temperature and humidity can be controlled and oxygen can be supplied if necessary. Incubators also allow easy observation of the naked infant if necessary, and isolation. Incubators have numerous advantages moreover nursing staff must regulate and record the incubator air temperature regularly. Even if the incubator has heat-sensitive probes that monitor skin temperature, nursing staff must take the baby's body temperature regularly (every 4-6 hours) and adjust the temperature of the incubator if necessary to ensure that the newborn maintains normal body temperature. It should be possible to regulate the air temperature inside the incubator between 30-37°C (86-98.6°F). Staff should make use of the port-holes and small inlets in the incubator as far as possible, because opening the main lid or canopy allows much of the warm air to escape and the baby will be exposed to cold. Nursing staff should follow instructions such as [10]:

1. Set the temperature control to maintain the neonate's temperature within the normal range. Usually a set point of 36.5 ^{0}C (97.7^{0}F) skin temperature will maintain a normal temperature.
2. Care should be taken to prevent the probe from coming off the skin. If this should occur, the unit will sense a lower temperature and increase the environmental temperature, possibly over-heating the neonate.
3. Use closed sleeves in portholes to prevent heat loss.
4. Keep incubator away from cold walls, air currents, windows and other cold objects.
5. With neonates less than 1500 grams, use a heat shield over the neonate or a double-walled incubator to decrease radiant heat loss and oxygen consumption.
6. VLBW neonates may require use of a Heating pad in conjunction with methods described above to maintain temperature ideally. These neonates should be cared for in a servo control incubator.
7. Both the ambient temperature and the neonate's temperature should be recorded and compared together, to avoid masking of the neonate's true condition.
8. Both these temperatures should be stable in order to state that the neonate's temperature is stable. If a neonate starts to become febrile, the incubator temperature drops, but there is no change in body temperature. Alternately, a decreasing body temperature would be corrected and held steady by an increase in the servo controlled ambient temperature. These changes in the neonate may be detected by noting changes in the environmental temperature.

2.5.2.3 Transport Incubators

During transport within a hospital or to another facility, infants require thermal support. Transport incubators can be operated on a variety of power sources found in hospitals or transport vehicles (e.g., 120 VAC, 12 VDC, and 24 VDC). Most units also carry their own backup power supplies (e.g., 12 VDC rechargeable nickel-cadmium [Ni-Cd], gel-cell, or lead-acid batteries) that power the unit for short periods in the absence or failure of other power sources. In addition to having a reliable portable power source, transport incubators also need to meet strength requirements for air and ground travel, provide isolation from external noise and vibration, and have limited electromagnetic emissions to allow for aircraft use. Transport incubators are typically smaller and lighter than mobile or stationary incubators, facilitating easy maneuvering in and out of emergency vehicles [3].

Figure 15: Transport Incubator

2.6. Radiant Warmers

Radiant heaters are overhead heating elements that provide warmth locally. The advantage of using this form of heating is that it allows for direct observation and free access to the baby. Radiant heaters can be used to produce a limited area of warmth where sick and low birth weight newborns can be rewarmed, given oxygen if needed and observed naked. A 400 watt radiant warmer placed 50 cm above the baby will be sufficient. This method is effective only if the room temperature is kept high (above 25°C/77°F). Spot lights or bulbs are dangerous because they focus the heat and may burn the baby. However radiant heaters have several disadvantages:

1. If a baby is left for a prolonged period under a radiant heater it risks becoming dehydrated if enough fluids are not given, especially if it is very premature.
2. If the temperature of the radiant heater is not monitored adequately, there is also a risk of overheating or first degree burns.
3. There should never be more than one baby under one lamp because of the risk of cross infection and of unequal heat distribution causing some babies to be too warm and others not warm enough.

Thus radiant heaters should only be used for short periods —for example, in the delivery room, for resuscitation or during procedures in intensive care units. This method of heating should be replaced by other alternatives as soon as possible. The equipment must have a temperature control that is either automatic or manual or both. It is essential that the newborn's axillary temperature be taken frequently to ensure that it is not becoming either cold or overheated, and the temperature of the radiant heater should be adjusted if necessary [7].

2.7 PID Control

PID controllers will automatically control process variables such as temperature, humidity, pressure, flow rate, level or in fact, almost any physical variable that can be represented as an analog signal. The example used assumes that the variable is temperature, which is the most common, but the principles are equally applicable to all analog variables.

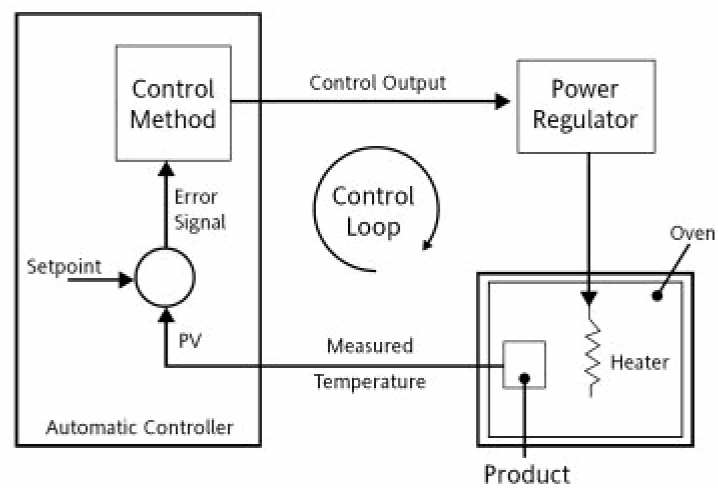


Figure 16: Diagram exhibiting PID Control

The figure 16 shows an automatic temperature control 'loop'. It consists of a sensor to measure the temperature, a controller and a power regulator.

1. The controller compares the measured temperature with the desired temperature, called the 'set point', and regulates the output power to make them the same.

2. The measured temperature is referred to as the Process Value or 'PV for short.
3. The difference between the set point and the measured value is called the 'error signal'

2.7.1 Input Sensors

An automatic controller requires some means of measuring the process value.PID controller will accept an input from almost any type of sensor. Linearisation of the measured value, if necessary, will be performed within the controller.In temperature applications, either a thermocouple or resistance thermometer is typically used. The type will depend on the temperature range and the environment in which it has to operate. In applications where it is difficult to attach a fixed temperature sensor, non-contact temperature measurement can be made using infra-red or optical pyrometers. In large process control applications, signal conditioners are normally used to convert the sensor measurement into a 4 to 20mA or 0 to 10Vdc signal for transmission to the controller.

2.7.2 Controller Outputs

An automatic controller requires some means of varying the heating power, or flow rate, or pressure, to the process under control.

The main output types are:

1. **Relay**: This is used to operate a contactor or solenoid valve in heating and cooling applications.
2. **Logic**: which is used to switch a solid state relay.The benefits are such as long life, no maintenance and the ability to rapidly switch heaters which have a small thermal mass.
3. **Triac**: Triacs are solid state switches primarily used to operate solenoid valves. They are also ideal for the positioning of motorized gas burner valves.
4. **DC milliamps or volts**, used for positioning control valves and to drive analogue input thyristors (used in phase angle and three phase heating applications).

2.7.2 On-Off Control

On/Off control action is shown in the figure below. The heating power is either fully On when the temperature is below set point or fully Off when it is above. As a result the temperature oscillates about the set point. The amplitude and time period of the oscillation is a function of the thermal lag between the heating source and the temperature sensor. To prevent the output 'chattering' as the measured temperature crosses the set point, the controller does not turn On and Off at precisely the same point. Instead a small differential known as the 'hysteresis' is applied. A typical value is 1°C.On-Off control is satisfactory for non-critical heating applications where some oscillation in the temperature is permissible.

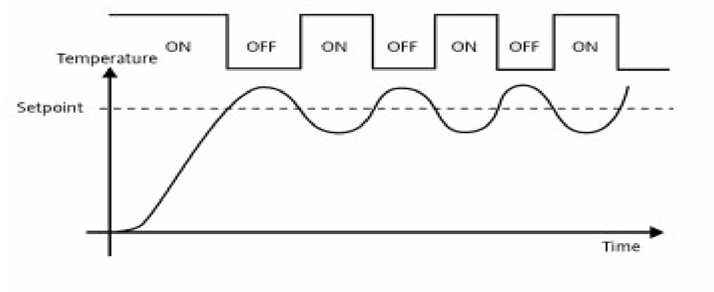


Figure17: ON-OFF Control

2.7.3 PID Control

Most industrial processes such as plastic extrusion, metals treatment or semiconductor processing require stable 'straight-line' control of the temperature. Mostly controllers employ advanced PID control algorithms to provide exactly that. PID control is also referred to as "Three-term" control. The three terms are:

1. P for Proportional
2. I for Integral
3. D for Derivative

The output of the controller is the sum of the above three terms.The combined output is a function of the magnitude and duration of the error signal, and the rate of change of the temperature or process value.

2.7.4 PID Terms

1. **The Proportional term** delivers an output which is proportional to the size of the error signal. In the example below, the proportional band is 10°C and an error of 3°C will produce an output of 30%.Proportional only controllers will not, in general, control precisely at set point, but with an offset corresponding to the point at which the output power equals the heat loss from the system.
2. **The Integral** term removes steady state control offsets by ramping the output up or down in proportion to the amplitude and duration of the error signal. The ramp rate (Integral time constant) must be longer than the time constant of the process to avoid oscillations.
3. **The Derivative** term is proportional to the rate of change of the temperature or process value. It is used to prevent overshoot and undershoot of the set point and to restore the process value rapidly to the set point if there is a sudden change in demand.

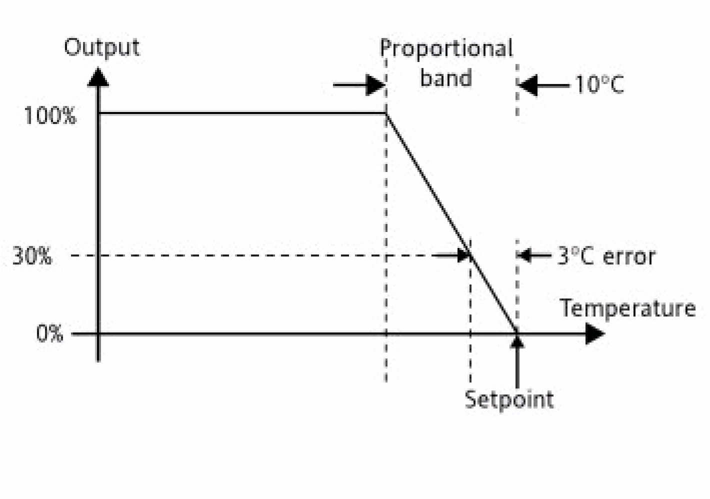


Figure18: Diagram representing PID Terms

2.7.5 High and Low Cutback

While the PID parameters are optimized for steady state control at or near the set point, high and low cutback parameters are used to reduce overshoot and undershoot for large step changes in temperature. They respectively set the number of degrees above and below set point at which the controller will start to decrease or cutback the output power.

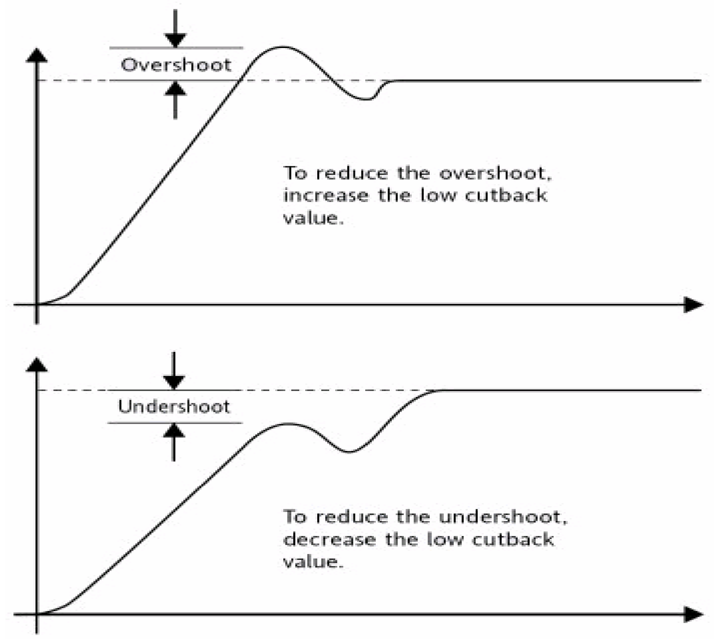


Figure19: High and Low Cutback

2.7.6 Time Proportioning Action

To obtain 'straight-line' temperature control, a PID controller requires some means of varying the power smoothly between 0 and 100%.Time proportioning varies the % on time of relay, triac and logic outputs to deliver a variable output power between 0 and 100%. The graphs below illustrate the principle. The cycle time must be short enough to allow the thermal mass of the load to smooth out the switching pulses.20 seconds is typical. Systems with a small thermal mass will need shorter cycle times than can be provided with a relay. In these cases, a solid state relay is typically used with cycle times down to 0.2 seconds. In practice Cycle Time may not be a constant, but vary with Power Demand, particularly at the extremes of the range 0-100% [13].

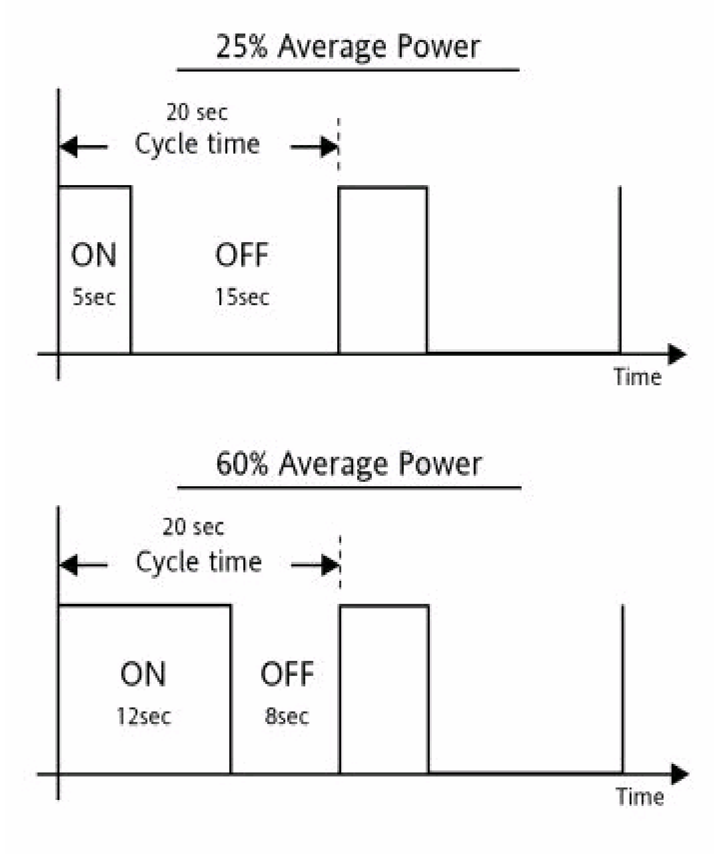


Figure 20: Time Proportioning Action

2.8 Summary

Hence above we discussed about that major parameters such as humidity, temperature and oxygen which need to be continuously monitored for preterm infant to live a life and how infant incubator as a device can take care of all these three major parameters in comparison to the other devices which cannot do so at one time. We also discussed how infant incubators have developed from a warm tub to an enclosed canopy with usage of electronics to control environment within the canopy so that small preterm baby can get a natural environment to get along in new life.

Chapter 3

System Design and Implementation

Temperature and humidity are two very important parameters that need to be monitored continuously in the infant incubator chamber so that similar environment can be replicated for the pre-term infant or new born baby. Temperature can be displayed in terms of degree Celsius (^{0}C) and humidity in terms of relative humidity which is expressed as % Relative Humidity (%RH).

3.1 Importance of Temperature and Humidity Control in Infant Incubator

Thermal stress in neonates has been associated with increased mortality and morbidity. The preterm baby is particularly vulnerable because of increased heat loss and immature or absent thermoregulatory mechanisms. Even with modern methods of temperature control the increased metabolic demands caused by thermal stress can result in insufficient energy left over for good growth. The body attempts to maintain a constant central temperature within narrow limits. To do this there must be a balance between heat production and heat exchange with the environment. This exchange with the surroundings occurs by conduction, convection, radiation and evaporation. The effect of these four modes will depend on gestation, postnatal age, the characteristics of the environment such as temperature and humidity. The importance of high humidity to prevent evaporative heat losses, thereby maintaining the required body temperature of infant's body [14].

3.2 Design Requirements of the System

The various design requirements of the system are given in Table 2:

Table 2: Design Requirements of the System

Mode of System Operation	Automatic Control
Temperature Range	28 ^{0}C-38 ^{0}C or User requirements
Relative Humidity	>70 % R.H or User Requirements
Mode of input of parameters	User Friendly
Temperature of water reservoir	42 ^{0}C-45 ^{0}C
Mode of Temperature Control	Skin-Temperature Control
Display	LCD

3.3 Hardware Details of the System

The block diagram of microcontroller based temperature and humidity controller in the infant incubator is shown in figure 21.

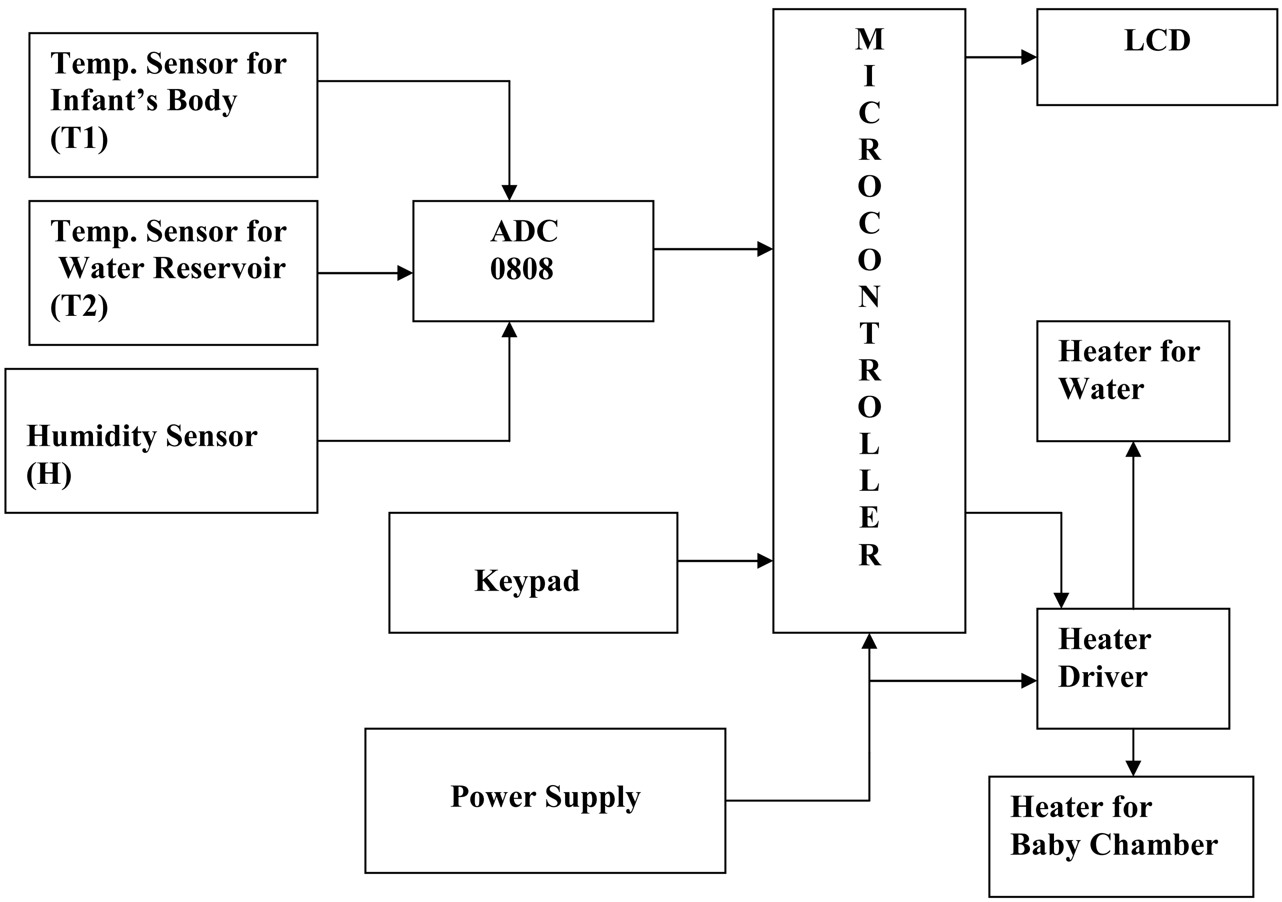


Figure 21: Block diagram of microcontroller based temperature and humidity controller

The details of the various components are given below:

3.3.1 Sensor

Sensor is the front end device which comes directly in contact with the quantity being measured. In microcontroller based infant incubator, the choice of transducer or sensor to measure the temperature of baby, temperature of water reservoir and humidity of baby chamber is very critical [15].So we require two types of sensors:

1. Temperature Sensor
2. Relative Humidity Sensor

3.3.1.1 Temperature sensor

The requirements of the temperature measurement are given below:

- **Temperature Sensor (T1)** for measurement of body temperature of an infant in the range of 28 ^{0}C-38 ^{0}C.
- **Temperature Sensor (T2)** for measurement of temperature of water reservoir should measure temperature within range of 42 ^{0}C-45 ^{0}C.

Despite being capable of measuring temperature in the range of 28 ^{0}C-38 ^{0}C and 42 ^{0}C-45 ^{0}C, the transducer should have following properties:

i) Accuracy

ii) High Output

iii) Repeatability

iv) Long term stability

v) High Input Impedance

vi) Linearity

vii) Self Heating

viii) Temperature Compensation

ix) Small Size

For present work LM35 is selected as temperature sensor. The sensor has been chosen on basis of comparative study of various sensors. The sensors selected on basis of study have temperature range of -55 ^{0}C-150 ^{0}C. The technical specification for LM35 has been mentioned below in table 3 [17].

Table 3: Technical Specification of LM35

Scale	**Calibrated directly ^{0}Celsius**
Scale Factor	+10.0 mV/^{0}C
Accuracy	0.5 ^{0}C
Range	-55 ^{0}C to +150 ^{0}C
Operating Voltage	4-30 volts
Self Heating	Low, 0.08 ^{0}C in still air
Nonlinearity	Only $\pm\frac{1}{4}{}^0C$
Impedance Output	0.1 ohm for 1mA load
Current Drain	< 60uA
Applications	Suitable for remote application also

The temperature sensor is chosen on basis of its characteristics of nonlinearity, accuracy, low self heating capability, range as required for application and lastly it gives output in terms of degree Celsius (^{0} C).The specifications stated above fulfills the requirement that was required for the temperature sensors needed for the measurement of temperature from infant's body and measurement of temperature of water reservoir, hence for both purposes

LM35 has been used as our temperature sensor in comparison to the other sensors available.

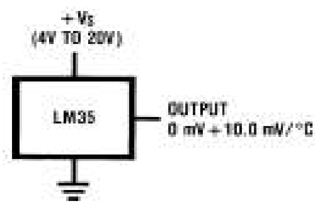


Figure 22: Basic Centigrade Temperature Sensor

3.3.1.2 Humidity Sensor (H)

Humidity sensor should provide humidity level in the incubator in terms of relative humidity (%RH) in the range of 0-100%RH.The humidity sensor must have the following properties:

i) Accuracy

ii) Temperature Range

iii) Repeatability

iv) Long term stability

v) High Input Impedance

vi) Linearity

vii) Humidity Range

The Humidity Sensor chosen for the present work is HIH 3310.The technical specifications of relative humidity sensor are given in table 4 [18].

Table 4: Technical Specification of Humidity Sensor

RH Accuracy	±2% RH, 0-100% RH non-condensing
RH Interchangeability	± 5% RH, 0-60% RH
RH Linearity	± 0.5% RH typical
RH Hysterisis	± 1.2% RH span maximum
RH Repeatability	± 0.5% RH
RH Response time	15 sec in slowly moving air at 25 ^{0}C
RH Stability	± 1% RH typical at 50% RH in 5 years
Power Requirement	4 Vdc-5.8 Vdc, sensor calibrated at 5Vdc,200uA at 5 Vdc
Voltage Output	0.8 Vdc to 3.8 Vdc output at 25 ^{0}C
Temperature Range	-40 ^{0}C to +85 ^{0}C
Humidity Range	0-100 % RH

The humidity sensor is chosen on basis of accuracy, linearity, low power design, workable within required temperature range, repeatability and stability. The specifications stated above fulfills the requirement that was required for the measurement of relative humidity in infant incubator hence capacitive type relative humidity sensor was used in comparison to other humidity sensors.

3.3.2 Microcontroller (ATMEL AT89C52)

The AT89C52 is a low-power, high-performance CMOS 8-bit microcomputer with 8K 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 80C51 and 80C52 instruction set and pin out. 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 AT89C52 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications [21].

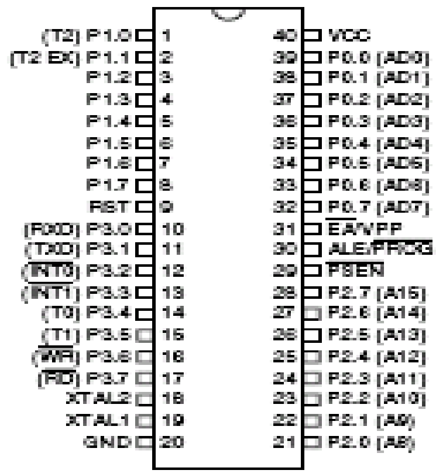


Figure 23: Pin Configurations of AT89C52

3.3.2.1 Block Diagram of ATMEL AT89C52

The block diagram of Microcontroller AT89C52 is shown in figure 24.

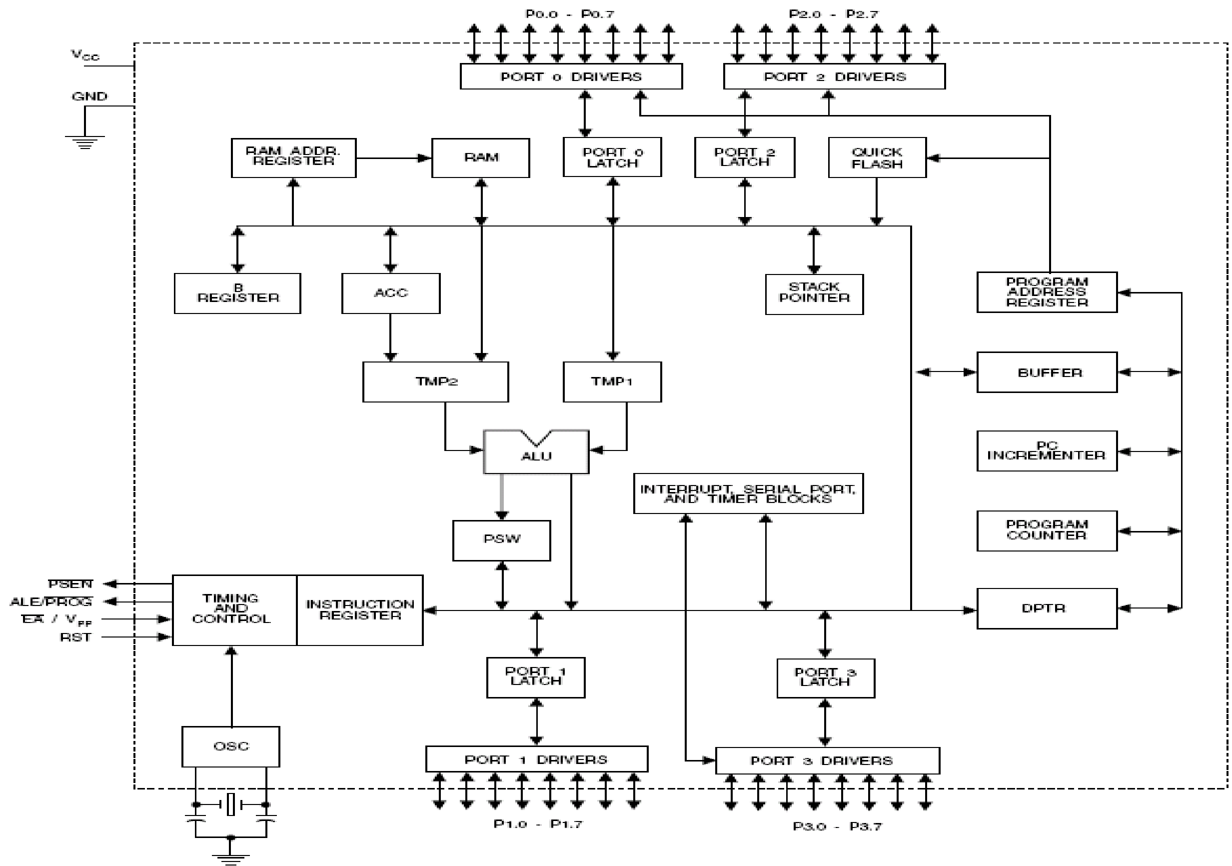


Figure 24: Block Diagram of AT89C52

3.3.2.2 Features of AT89C52

Various features of Microcontroller AT89C52 are given in Table 5.

Table 5: Features of AT89C52

Compatibility	MCS-51 Products
In System Reprogrammable Flash Memory	8K Bytes
Endurance	1000 Writes/Erase Cycles
Fully Static Operation	0 Hz – 24 MHz
Internal RAM	256×8 Bit
I/O Lines	32
Timers/Counters	3, 16 Bit
Interrupt Sources	8

3.3.2.3 Pin Connection for Application

AT89C52 microcomputer is the heart of the system, hence all the components interact with the chip microcontroller and hence pins of AT89C52 has to be divided among various components which has been shown in the Table 6.

Table 6: Pin Classification of AT89C52

AT89C52 Pins	Pins of other Components
Port 0 (pin 39,38,37,33,32)	S1,S2,S3,bch,wch respectively
Port 1 (pin 1 – pin 8)	LCD Data (pin 7 – pin 14)
Port 2 (pin 21 – pin 28)	ADC Data (pin 21,20,19,18,8,15,14,17)
Port 3 (pin 11,12,14,15,16,17)	ADC (pin 25,24,[6,22]), LCD (4,5,6)

Abbreviation Used:

- S1: Switch 1 (Increment)
- S2: Switch 2 (Decrement)
- S3: Switch 3 (Enter)
- Bch: Baby Chamber Heater
- Wch: Water Chamber Heater

3.3.3 Analog to Digital Converter (ADC)

As it is clear from the block diagram (Figure 21) that there are three inputs given to ADC. The three inputs are:

i) Temperature of the chamber

ii) Temperature of water reservoir

iii) Humidity of the chamber

These three inputs are analog in nature and are required to be converted into digital signals for further processing. For this purpose ADC 0808 is used.

3.3.3.1 ADC 0808

ADC0808 data acquisition component is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8-channel multiplexer can directly access any of 8-single-ended analog signals. The device eliminates the need for external zero and full-scale adjustments. Easy interfacing to microcontrollers is provided by the latched and decoded multiplexer address inputs and latched TTL TRI-STATEÉ outputs. The design of the ADC0808 has been optimized by incorporating the most desirable aspects of several A/D conversion techniques. ADC0808 offers high speed, high accuracy, minimal temperature dependence, excellent long-term accuracy and repeatability, and consumes minimal power. These features make this device ideally suited to applications from process and machine control to consumer and automotive applications. The block diagram of ADC 0808 is shown in figure 25.

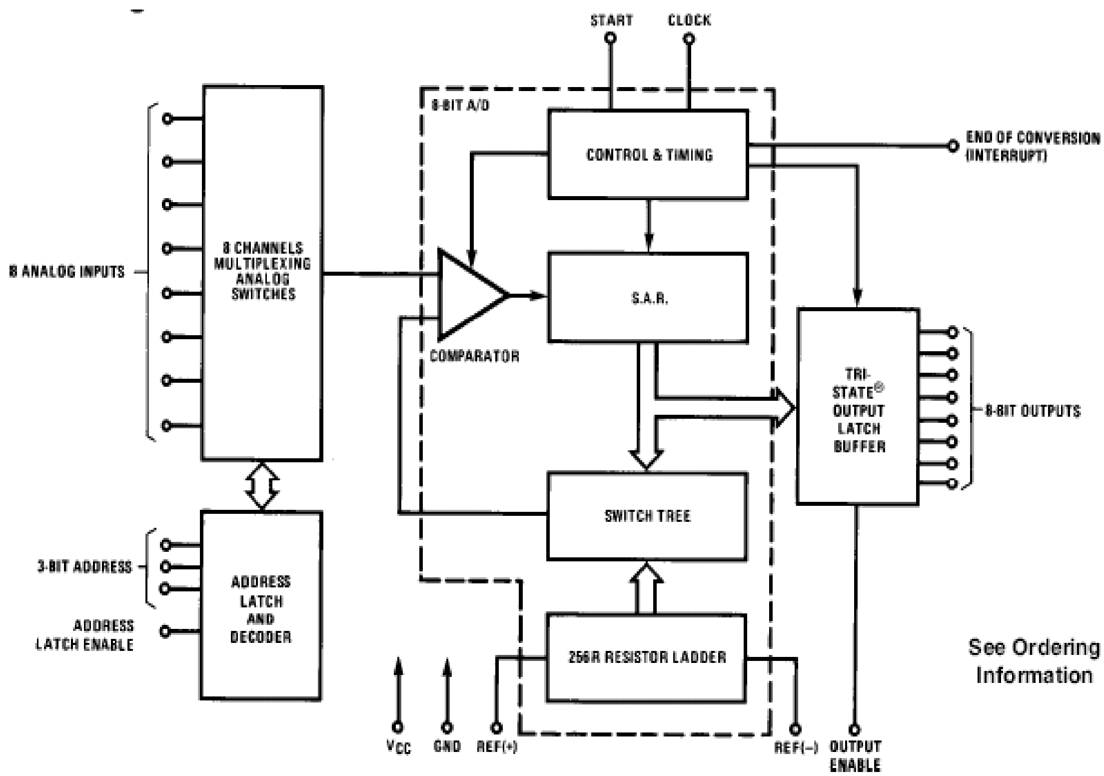


Figure 25: Block Diagram of ADC 0808

3.3.3.2 Functional Description

- **Multiplexer**: The device contains an 8-channel single-ended analog signal multiplexer. A particular input channel is selected by using the address decoder. Table 7 shows the input states for the address lines to select any channel. The address is latched into the decoder on the low-to-high transition of the address latch enable signal.

Table 7: Selection of Analog Channel

Selected Analog Channel	ADDRESS LINE		
	C	B	A
IN0	L	L	L
IN1	L	L	H
IN2	L	H	L
IN3	L	H	H
IN4	H	L	L
IN5	H	L	H
IN6	H	H	L
IN7	H	H	H

- **Converter Characteristics:** The heart of this single chip data acquisition system is its 8 bit analog-to-digital converter. The converter is designed to give fast, accurate, and repeatable conversions over a wide range of temperatures. The converter's digital outputs are positive true and it is partitioned into 3 major sections [19]:
- The 256R ladder network
- The successive approximation register
- The comparator.

3.3.3.3 Connection Diagram of ADC0808

The pin out diagram of ADC 0808 is shown in figure 26.

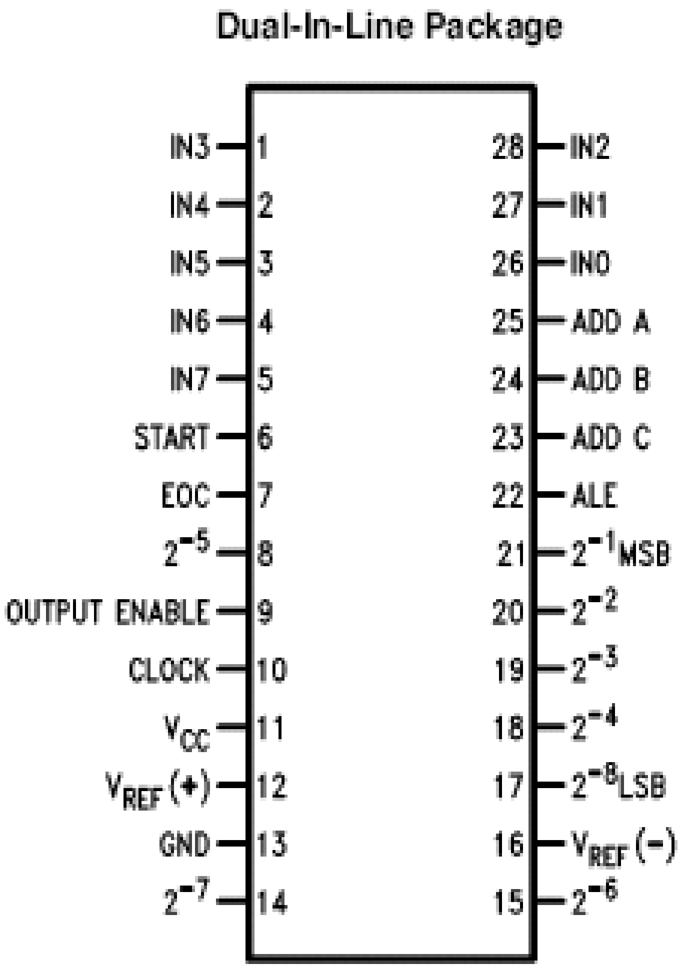


Figure 26: Pin out Diagram of ADC 0808

3.3.3.4 Interfacing of ADC 0808 to Microcontroller AT89C52

The interfacing of ADC 0808 and LM555 with microcontroller AT89C52 is shown in figure 28. The schematic can be divided in three parts:

1) **Analog Signals** which are the real world signals is captured by the sensors i.e. LM35 (temperature) which provide the temperature of infant and temperature of the water reservoir respectively. While the third humidity sensor measures the relative humidity in the infant incubator. Hence these three analog signals are further processed by ADC 0808. By using select lines pin numbers 23, 24 and 25, 8 analog signals can be processed. For our Application we need to process three analog signals hence we selected three analog channels (IN0-IN2) by grounding ADD C and connecting ADD A and ADD B to microcontroller pin 10 and pin 11 of port 3 as per selection chart discussed in section 3.3.3.2.
2) **LM 555 circuit** is introduced here to provide accurate time delays to ADC0808 because ADC 0808 doesn't have internal clock. Hence output (pin3) of LM 555 is provided to clock pin (pin 10) of ADC 0808. In the time delay mode of operation, the time is precisely controlled by one external resistor and capacitor. In this system the LM555 has been used in astable mode where it operates as an oscillator, the free running frequency and duty cycle are accurately controlled with two external resistors and one capacitor. The circuit may be triggered and reset on falling waveforms, and the output circuit can source or sink up to 200mA or drive TTL circuits [20]. The schematic is as shown in figure 27 :

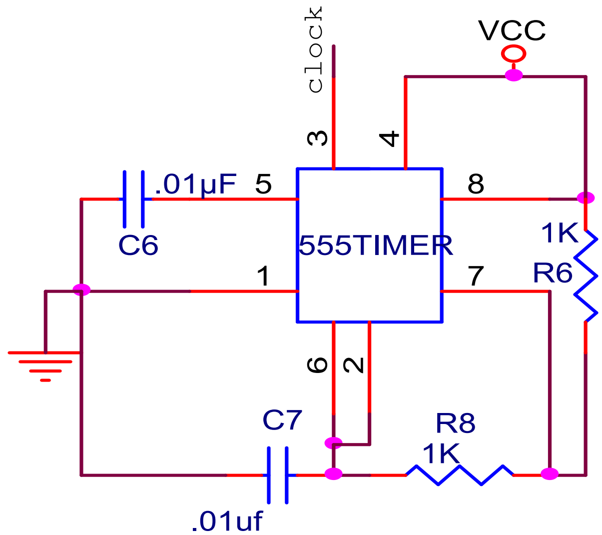


Figure 27: Schematic of LM 555

3) **ADC 0808 and AT89C52** communication is one of the most important part of this application because the real world analog signals are captured and provided to ADC 0808 which digitizes the signals and these signals are provided through data pins 2^{-1} (M.S.B) - 2^{-8} (L.S.B) to the microcontroller port 2 (pin 20 to pin 27) which process these signals to implement the control of the measured parameters. The other pins such as start (pin6), ALE (pin 22), A0 (pin25), A1 (pin 24), A2 (pin25) are controlled by the software instructions stored in AT89C52 as shown in figure 28.

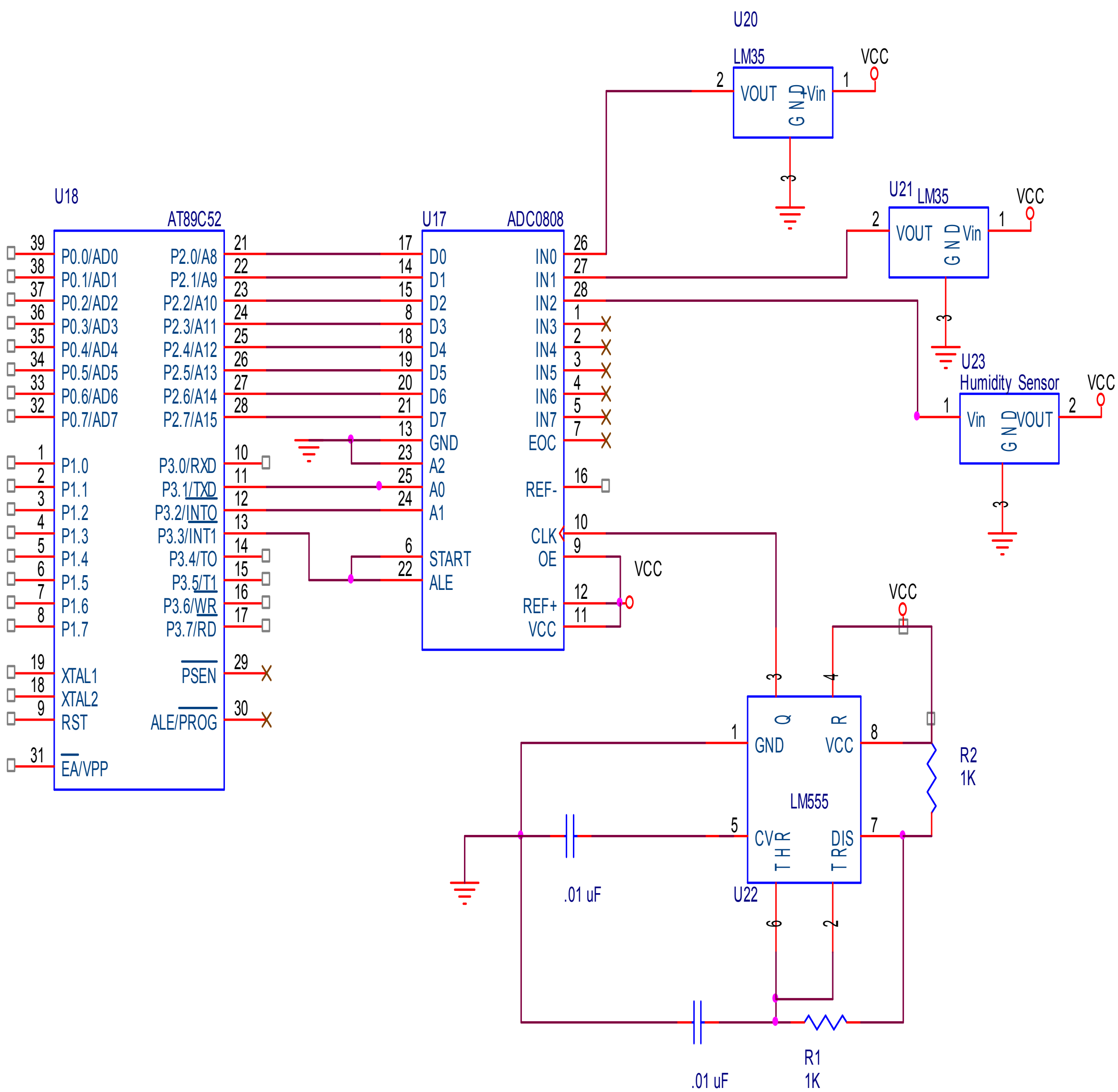


Figure 28: Interfacing of ADC0808 with AT89C52

3.3.4 Power Supply

This part of the hardware provides the required energy for working of the various integrated circuits that has been developed. The schematic of power supply circuit is as shown figure 29.

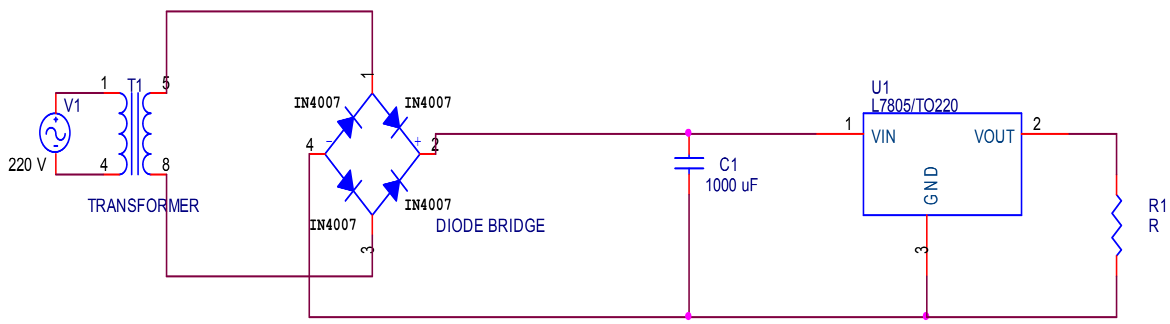


Figure 29: Power Supply Schematic

The power supply circuit converts the 220 V AC into 5 V DC at which various integrated circuits can work efficiently. Hence it can be achieved by using various components such as:

i. **Transformer** which step down the voltage level from 220 V AC to required voltage level. Here 9-0-9 rating transformer has been used.

ii. **Full Wave Rectifier** is composed of four diodes (IN4007) which are placed as shown in figure 29. It converts the alternating voltage to a unidirectional voltage.

iii. **Capacitor** of 1000 µF is used for ripple rejection of the unidirectional voltage obtained at rectifier end.

iv. **LM 7805** is a regulator which regulates the voltage to constant supply which is 5 V DC in this case. It has three pins i.e. Vin, GND, Vout as as shown in figure 29.

3.3.5 Interfacing of ATMEL AT89C52 to various Components

The connection of microcontroller with various components of temperature and humidity control in baby chamber is shown below in detail in figure 30.

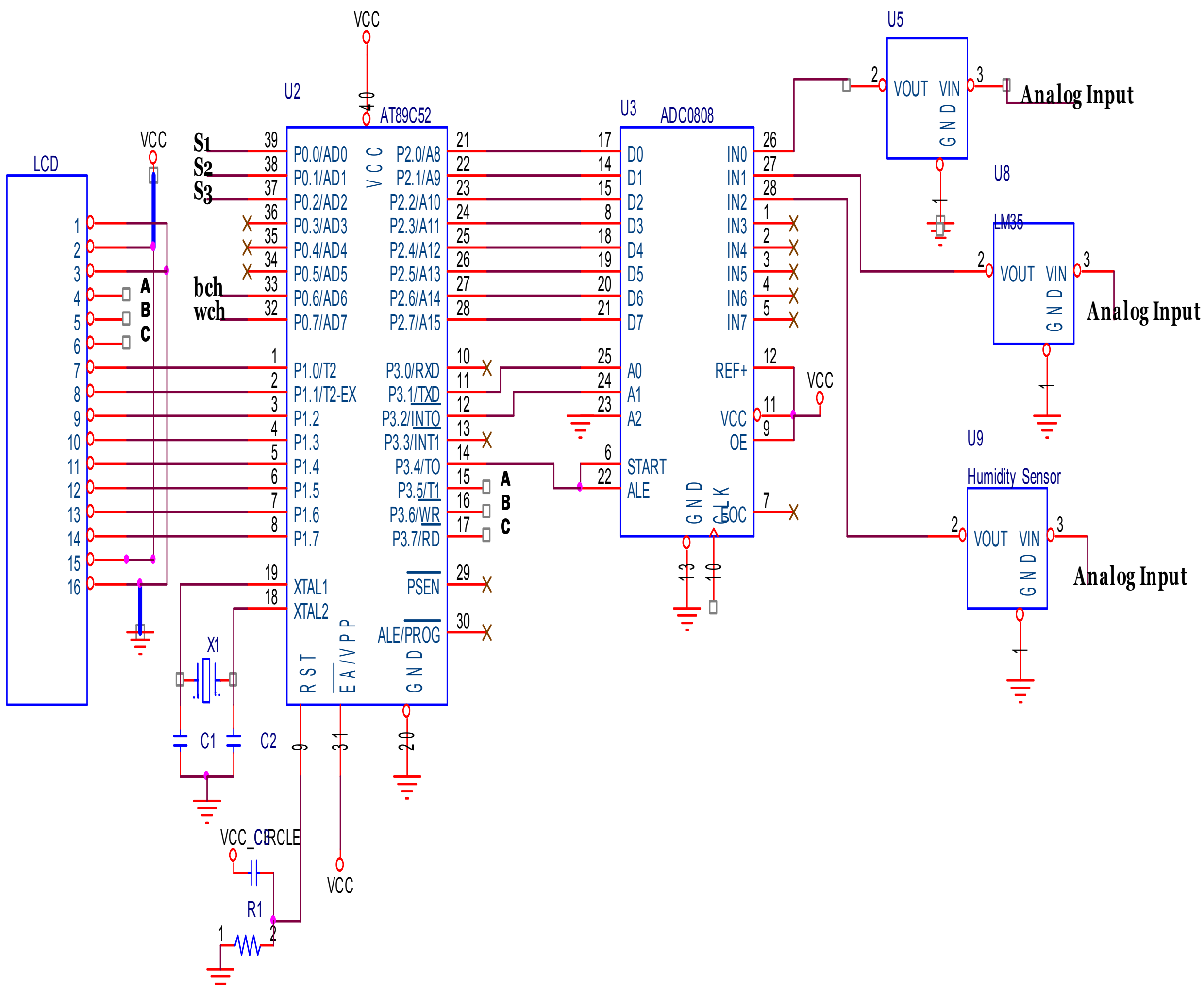


Figure 30: Interfacing of AT89C52

It is clear from above schematic that AT89C52 is the heart of the system as it interacts with all the components with ports dedicated to a particular component. This interaction takes place through the software instructions stored in the microcontroller. Now monitoring of parameters can be divided in three parts:

1) **Acquiring Analog Signals** which are the real time signals i.e. temperature of the infant, temperature of water reservoir and the humidity of the chamber. These signals being the input has to be very accurate for monitoring of parameters, hence sensors play an important role and are carefully chosen so as to get accurate results. Sensors form part of system at pin number 28, 27, 26 respectively of ADC0808.

2) **Processing of signals** is composed of two stages:
    a. *Analog to Digital Conversion:* Firstly analog channels IN0, IN1, IN2 are selected by software instructions which are provided at pin 25, 24 of ADC0808 by pin 11, 12 of AT89C52. The signals acquired by the sensors are analog in nature and hence for further processing they need to be converted to digital form by successive approximation method by the circuitry in ADC0808 Integrated Chip. ADC0808 get start pulse for processing at pin 6, 22 of ADC 0808 from pin 14 of AT89C52.When equivalent digital signal is achieved its sent to AT89C52 at port 2 through pin D0-D7 (pin21, 20, 19, 18, 8, 15, 14, 17) of ADC0808.
    b. *Logical processing:* The real time signals once converted to its equivalent digital form can be further processed or logically operated by software instructions to maintain baby temperature between 20 ^{0}C-38 ^{0}C and humidity level between 0-100 %RH as per the requirement of nursing staff. If the parameters maximum-minimum limit is crossed, heaters (bch-33, wch-32) are switched OFF or switched ON respectively. As our system is user-friendly the required values are entered by S1 (Increment), S2 (Decrement), S3 (Enter) at pins 39, 38, 37 of AT89C52.Hence after logical processing values are displayed and accordingly controls the respective

heater responsible for maintaining chamber temperature and humidity respectively.

3) **Display of parameters** is important part of system as we can monitor real time parameters. Firstly the maximum and minimum values for temperature and humidity are input which we can see on LCD. Then the real time values can be displayed on LCD. This happens by sending data by AT89C52 (port1) to LCD (pin 7-14).The data to be read or to be written is decided by control lines (pin 4,5,6) of LCD which gets its signal from software instructions of AT89C52.

3.3.6 PID based Heater Circuit for Baby Chamber

Temperature of infant is the most important parameter which is maintained by switching ON and OFF of the heater at desired temperature level and hence for this purpose the concept of PID has been developed in the software. This concept switches the heater On and OFF for particular time intervals by calculating the error and hence requires high speed switching ON and OFF and heater which cannot be achieved by devices such as relay because it can give away at such high speed and hence TRIAC has been used. The implementation of this concept requires a compatible hardware which can be seen in the figure 31.

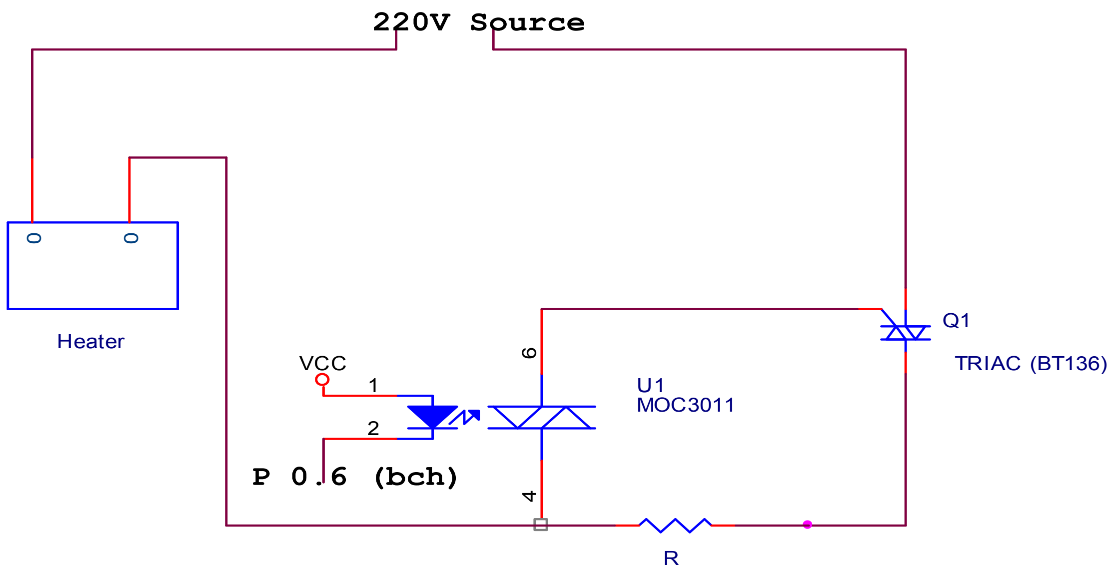


Figure 31: Heater Circuit for Baby Chamber

This circuit has two main components

1. **BT 136 or TRIAC** or bidirectional triode thyristor is a solid-state device that acts like two SCRs that have been connected in parallel with each other (inversely) so that one SCR will conduct the positive half-cycle and the other will conduct the negative half-cycle. This means that the triac can be used for control in ac circuits which is required in our circuit so that we can get optimum automatic control of infant's temperature. The description of various pins used in triac is given below in the table 8 [22].

Table 8: Pin Connection of TRIAC in the Circuit

PIN	Description	Circuit Connection
1	Main Terminal 1	Pin 4 of MOC 3011
2	Main Terminal 2	220 V Source
3	Gate	Pin 6 of MOC 3011

2. **MOC 3011 or Optotriac** family of non-zero crossing triac drivers consist of an aluminum gallium arsenide infrared LED, optically coupled to a silicon detector chip these two chips are assembled in a 6 pin DIP package, providing 7.5 KV ac(peak) of insulation between the LED and the output detector. These output detector chips are designed to drive triac controlling loads on 115 and 220 V AC power lines the detector chip is a complex device which functions in the same manner as a small triac, generating the signals necessary to drive the gate of a larger triac. Basically, MOC30XX family of opto-isolators is capable of controlling large power triacs with a minimum number of additional components [23].

3.3.6.1 Operation of Heater Circuit

This circuit makes the monitoring of infants temperature in the incubator much more precise and accurate based on PID concept employed in the software thereby taking care of:

i. Overshoots

ii. Reduce energy wastage.

As seen in figure 31 one terminal of heater is connected to 220V source directly while the other terminal is connected to this source through MOC 3011 and BT136.The current from source to terminal 2 of triac doesn’t reach MOC 3011 till gate pin of BT 136 gets high which is connected to pin6 of MOC 3011 and this high pulse is received according to software instructions from pin 0.6 (bch) of microcontroller. When high pulse is received gate gets into active mode and current blocked at pin 2 of BT136 is passed on to pin1 of BT136 and hence circuit gets completed and heater is switched ON and similarly according to pulse it gets switched OFF. This switching time (ON – OFF) depends on the error (maximum temperature – body temperature) × millisecond delay. This time based switching action yields an optimum automatic control of baby temperature.

3.3.7 Heater Circuit for Water Chamber

Temperature-controlled water reservoir (wch) humidification system is used to increase the relative humidity inside the infant's compartment. The active humidification system actively heats water to provide precise control and monitor the humidity level in the incubator and provides a feedback mechanism to correctly adjust and control to a user-selected set point. The temperature at which the water in the reservoir of the active system is heated depends on the humidity required inside the compartment. The water temperature is normally kept above 42 ^{0}C. Pseudomonas auerogenosa a kind of bacteria does not survive in water above 42 ^{0}C [24].The heater for water chamber (wch) is connected to P 0.7 (pin32) of AT89C52. . As there are always some chances of high voltage spikes back from the switching circuit i.e. heater so an optocoupler or isolator MCT2e is used. It provides and electrical isolation between the microcontroller and the heater. MCT2e is a 6-pin IC with a combination of optical transmitter LED and an optical receiver as phototransistor. Microcontroller is connected to pin no 2 of MCT2e through a 470-ohm resistor. Pin number 1 is given +5V supply and pin number 4 is grounded. To handle the current drawn by the heater a power transistor BC-369 is used as a current driver. Pin no.5 of optocoupler is connected to the base of transistor. It takes all its output to V_{cc} and activates the heater through relay circuit. The electromagnetic relay consists of a multi-turn coil, wound on an iron core, to form an electromagnet. When the coil is energized, by passing current through it, the core becomes temporarily magnetized. The magnetized core attracts the iron armature. The armature is pivoted which causes it to operate one or more sets of contacts. When the coil is de-energized the armature and contacts are released. Relays can generate a very high voltage across the coil when switched off. This can damage other components in the circuit. To prevent this, diode is connected across the coil. Relay has five points. Out of the two operating points one is permanently connected to the ground and the other point is connected to the collector side of the power transistor. When V_{cc} reaches the collector side i.e. signal is given to the operating points the coil gets magnetized and attracts the iron armature. The iron plate moves from normally connected (NC) position to normally open (NO) position. Thus the heater gets the phase signal and is ON. To remove the base leakage voltage when no signal is present a 470-ohm resistance is used. The heater driver circuit for water reservoir is shown in figure 32.

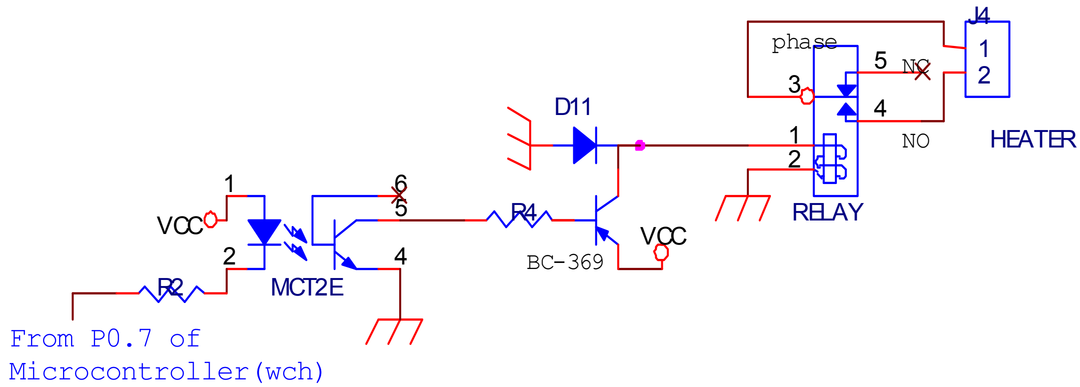


Figure 32: Heater Driver Circuit for water chamber heater

3.3.8 Keypad

To make the system user friendly three push buttons are provided on the control unit namely:

i. **S1 or Increment**
ii. **S2 or Decrement**
iii. **S3 or Enter**

The doctors can feed the values of parameters according to their requirement S1 or increment switch as name implies increases the value of parameter and similarly S2 or decrement switch is used to decrement the parameter value that has already been input.S3 or enter switch is used so that a new value for new parameter can be fed in the system. When values of all parameter have been fed, on pressing S3 LCD displays the real time value of parameters. Moreover S1 comes with additional function to display the temperature of water reservoir if required by user. Hence whenever user presses this switch S1 it displays water reservoir temperature. Hence their connection with AT89C52 is as follows:

i. S1- P3.8
ii. S2- P3.7
iii. S3- P3.6

3.3.9 Display

The system has been designed to monitor the temperature of infants body and humidity of the chamber so that the new born baby can get similar environment as it get when its in mothers womb. To display the parameters LMB162A is used. The block diagram of Liquid Crystal Display (LCD) is shown in figure 33.

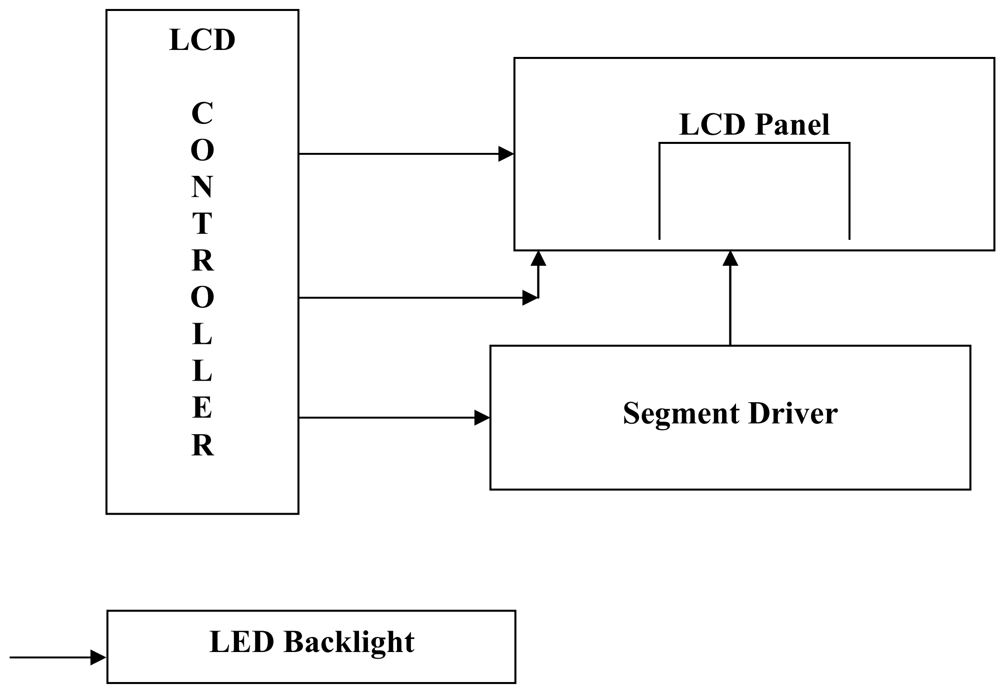


Figure 33: Block Diagram of LMB162A

The LCD Controller has two 8-bit registers, the Instruction register (IR) and the data register (DR). The Instruction register (IR) is a write only register to store instruction codes like display clear or cursor shift as well as addresses for the Display Data RAM (DD RAM) or the Character Generator RAM (CG RAM). The data register (DR) is a read or write register used for temporarily storing data to be read or written from the DD RAM or CG RAM. Data written into the DR is automatically written into DD RAM or CG RAM by an internal operation of the display controller. The DR is also used to store data when reading out data from DD RAM or CG RAM. When address information is written into IR, data is read out from DD RAM or CG RAM to DR by an internal operation. Data transfer is then completed by reading the DR. After performing a read from the DR, data in the DD RAM or CG RAM at the next address is sent to the DR for the next read cycle. The register select (RS) signal determines which of these two registers is selected is shown in table 9.

Table 9: Selection of Registers

RS	RW	Function
0	0	Instruction write operation(MPU write instruction code to IR)
	1	Read busy flag (DB7) and Address counter(DB0 ~ DB6)
1	0	Data write operation (MPU writes data to DR)
	1	Data read operation (MPU reads data from DR)

Busy Flag (BF): When the busy flag is high or “1” the module is performing an internal operation and the next instruction will not be accepted. The busy flag outputs to DB7 when RS = 0 and a read operation is performed. The next instruction must not be written until ensuring that the busy flag is low or “0”.

Address Counter (AC): The address counter (AC) assigns addresses to the DD RAM and the CG RAM. When the address of an instruction is written into the IR, the address information is sent from the IR to the AC. The selection of either DD RAM or CG RAM is also determined concurrently by the same instruction. After writing into or reading from the DD RAM or CG RAM the address counter (AC) is automatically increased by 1 or decreased by 1(determined by the I/D bit in the “Entry Mode Set” command). AC contents are output to DB0 - DB6 when RS = 0 and a read operation is performed [25].

3.3.9.1 Terminal Functions

The pin description is given in table 10.

Table 10: Pin description

Pin	Symbol	I/O	Description
1	VSS	-	Ground
2	VCC	-	+5V power supply
3	VEE	-	Power supply to control contrast
4	RS	I	RS=0 to select command register, RS=1 to select data register.
5	R/W	I	R/W=0 for write, R/W=1 for read
6	E	I/O	Enable
7	PB0	I/O	The 8 bit data bus
8	PB1	I/O	The 8 bit data bus
9	DB2	I/O	The 8 bit data bus
10	DB3	I/O	The 8 bit data bus
11	DB4	I/O	The 8 bit data bus
12	DB5	I/O	The 8 bit data bus
13	DB6	I/O	The 8 bit data bus
14	DB7	I/O	The 8 bit data bus
15	LED A	-	Led Power Supply (+5V)
16	LED B	-	Led power Supply (0 V)

3.3.9.2 Interfacing of LCD with AT89C52

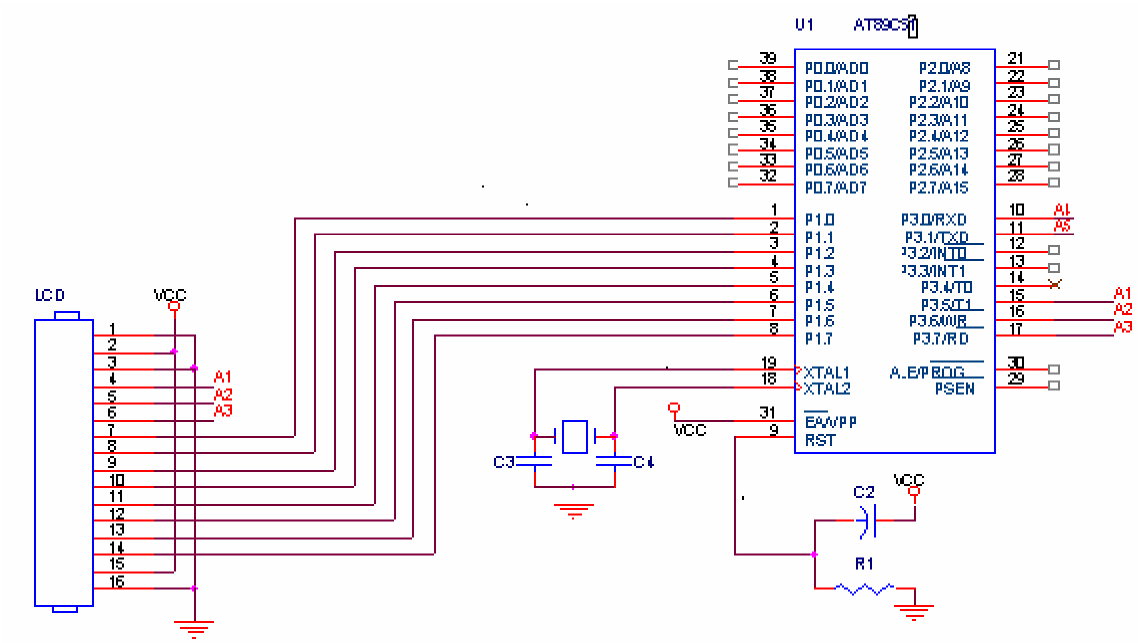


Figure 34: Interfacing of LCD withAT89C52

From above schematic it’s clear that port 1 of AT89C52 is dedicated for LCD data (pin7-pin14). Pins 4, 5, 6 of LCD are control pins which have dedicated functions and are responsible for display of data. These are connected to 15, 16, and 17 of AT89C52.These pins have been discussed in detail in table 10.

Chapter 4

Software Implementation

This chapter deals with developing of software for the control of parameters such as temperature of newborn baby and relative humidity in the chamber of the baby to maintain the thermal balance, so that baby gets the similar environment as in the mother's womb which is very important for preterm baby for their growth.

4.1 Introduction

Software is an integral part of any control system; it interacts with hardware to carry out different functions which are responsible for the control of parameters. In the given problem the software can be divided into following subparts:

i. To assign different ports (pins) of microcontroller (AT89C52) to different components of the system.
ii. To display different input values.
iii. To accept the maximum-minimum input value of temperature of infant's body and relative humidity in infant chamber.
iv. To compare the real time values to input values and perform necessary control action.
v. To display the results

Firstly when the system is switched ON the LCD displays "Bio-Environment Control System" and then asks for "Maximum Temp." which is entered with help of keypad and then the system ask for "Minimum Temp." which is again entered by the user with the help of keypads. Similarly it's done for relative humidity. Then the real time values of temperature of infant's body and relative humidity in baby chamber are displayed which is being controlled internally within the specified limits by the software instructions. In the design and development of microcontroller based temperature and humidity controller for infant incubator, KIEL µVision2 software has been used

4.2 KEIL µVision2 Software

KIEL µVision2 software is an Integrated Development Environment (IDE) that encapsulates a project manager, make facility, tool configuration, editor and a powerful debugger. It is used to write and compile the programs using different tools. It can transfer the assembly language as well as C code into the hex file. KIEL software consists of the following:

i. **Linker control file** is a text file that uVision2 passes to the linker. The control file contains all directives. The names of the input list and the name of the output file are still derived from the project. Therefore the linker control file must not include the object files and library files of your project.

ii. **Map File** is a listing file generated by the linker.

iii. In **Project** a target is an executable program that is generated. A project may generate a target that runs on an 8051. Targets may be created for builds with no optimization and for builds with full optimization.

iv. In a project **Source File Group** is a number of source files that compose the project target. Although you may individually specify the toolset options for a file, a group lets you apply the same options to a group of source files. The options for a group may be different from the options for the target.

v. A **Toolset** include an assembler, compiler, linker, HEX converter, debugger, and the other associated tools for a particular device family like the 8051.All of the tools or programs in a toolset are dedicated for generating target code for a specific family of chips. [26].

To evaluate the software for correct operation the file was programmed into the microcontroller on the relevant development board. Programming of the microcontroller was achieved using the VPL-SPROG programmer. It is a handy serial programmer. This permits hexadecimal files to be loaded into the microcontroller. Initially the microcontroller was programmed by removing it from the socket on the board and inserting it into the multi-pin socket on the programmer.

4.3 Microcontroller

The microcontroller is a collection of 8 bit and 16 bit registers and 8-bit memory locations. These registers and memory locations can be made to operate using the software instructions that are incorporated as part of the design. The program instructions communicate with the registers and data paths that are physically contained inside the microcontroller, as well as memory locations that are physically located outside the microcontroller. Most of the registers perform specific functions such as function of a accumulator (A) is to carry out the processing in the microcontroller and program counter (PC) performs the function of pointing towards next memory location to be executed. Others, which are generally indistinguishable from each other, are grouped in a large block, such as internal ROM or RAM memory. Each register, with the exception of the program counter, has a 1-byte address assigned to it. Some registers are both byte and bit addressable [27].

4.3.1 Microcontroller Programming

The programming of the 8051 is done in embedded C language. It is used because of the following advantages:

i. To speed up computer operation.
ii. To reduce the size of the program.
iii. To write programs for special situations.
iv. To have better understanding of the computer operation.

The instruction set for Microcontroller is described as:

1. Data movement instructions

Moving data from one location in the memory to another forms one of the most basic and important operations of the micro controller. Data is stored at the source address and moved to the destination address. The ways these address are specified are called addressing modes. The following four addressing modes are used to addressing data:

- Immediate addressing mode
- Resister addressing mode
- Direct addressing mode
- Indirect addressing mode

2. Logical level instructions

A main application of micro controller is single point sensing and control, which implies a need of byte and bit opcodes that operate on data using Boolean operators. All 8051 RAM areas may be manipulated by using byte opcodes. Many of the special function register (SFR's) and a special Random Access Memory (RAM) area that is bit addressable may be operated upon at the individual bit level. Bit operators are efficient when speed response is needed.

- Byte level operations
- Bit level operations

3. Arithmetic operations instructions

Applications involve performing mathematical calculations on data in order to alter program flow and modify program actions. There are 24 opcodes, which are grouped into the different types

4. Jump and Call instructions

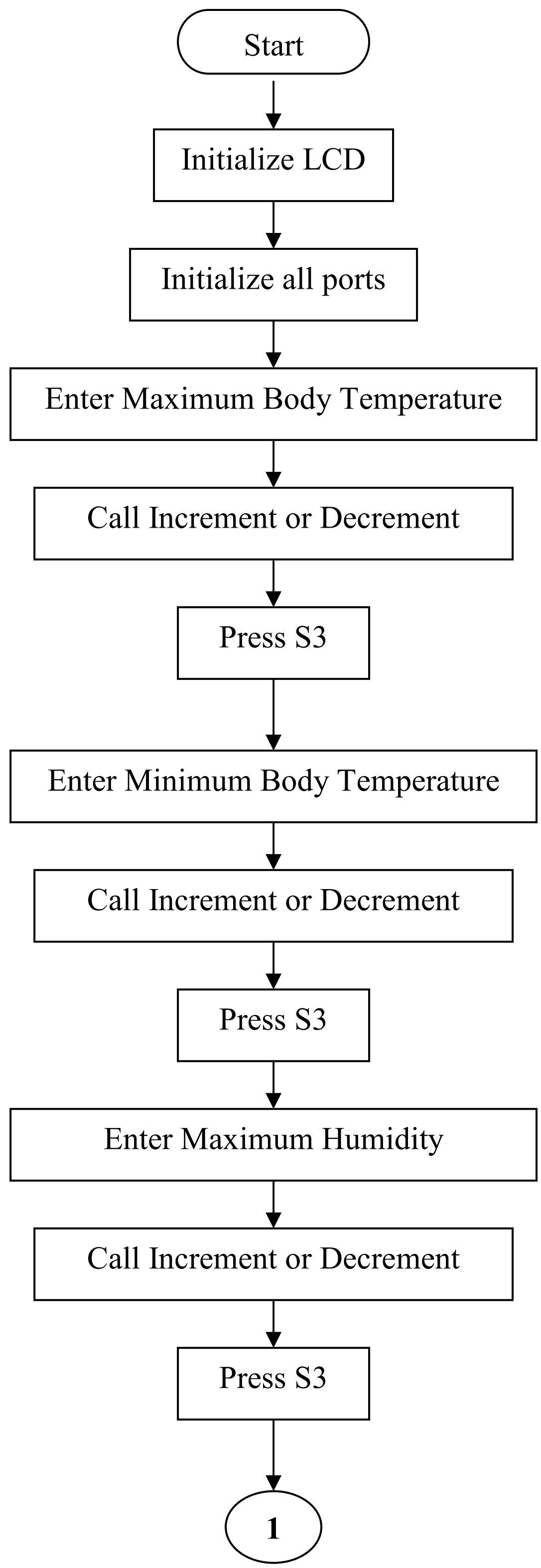
The jump and call instructions are decision codes that alter the flow of the program by examining the results of the action codes and changing the contents of the program counter. Decisions can be made using the different types of decision opcodes.

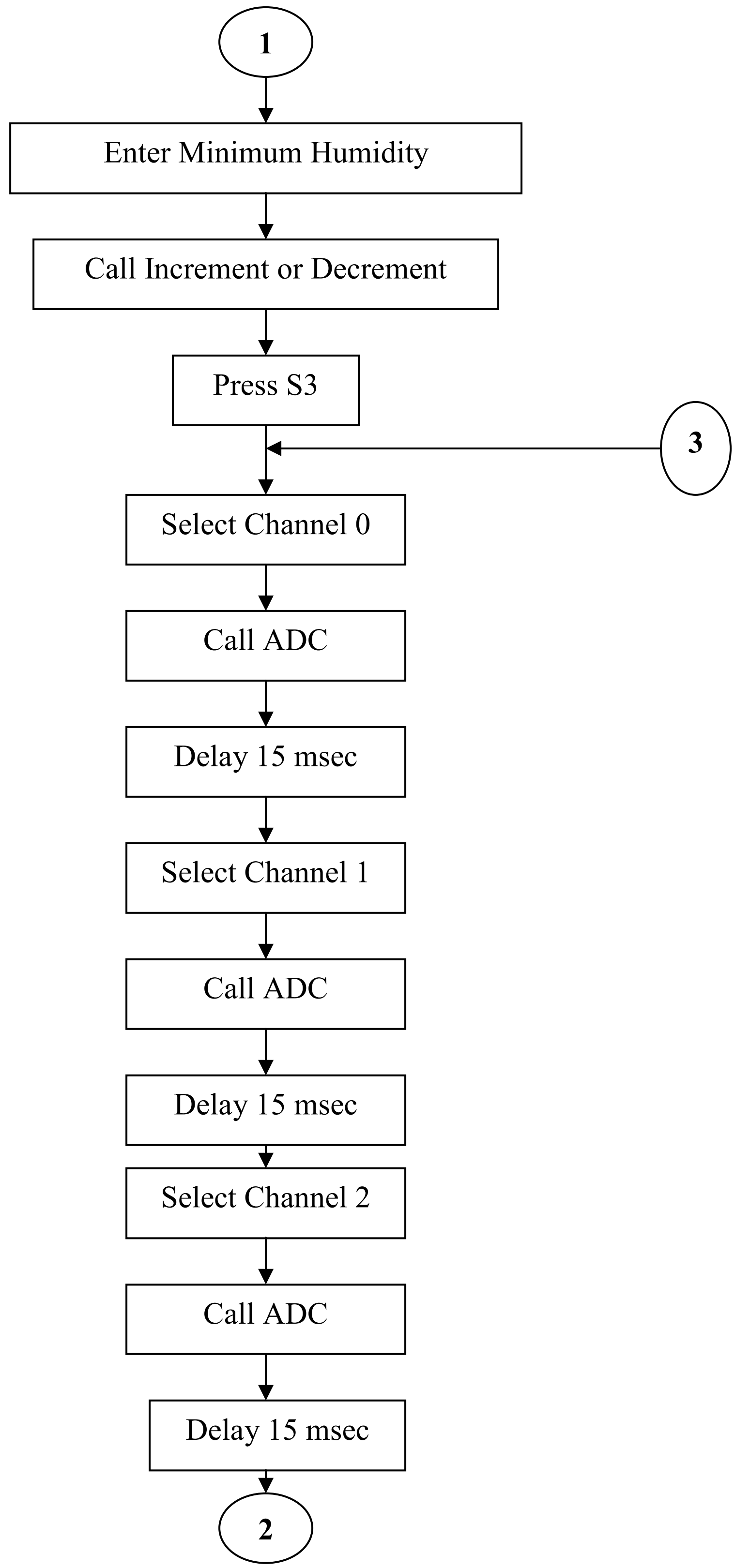
4.4 Flowcharts for Software Development

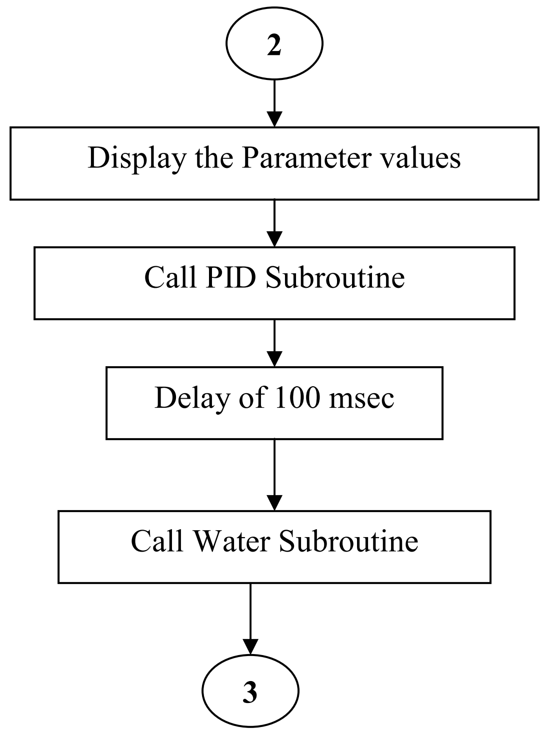
Flowcharts has been developed in this section depicting step by step development of the software which issue instructions to various components of the hardware thereby making monitoring and control of parameters efficient and automatic.

4.4.1 General Flowchart of the System

The flowchart of the design and development of microcontroller based temperature and humidity controller is shown in flowchart 1.


Start
Initialize LCD
Initialize all ports
Enter Maximum Body Temperature
Call Increment or Decrement
Press S3
Enter Minimum Body Temperature
Call Increment or Decrement
Press S3
Enter Maximum Humidity
Call Increment or Decrement
Press S3
1

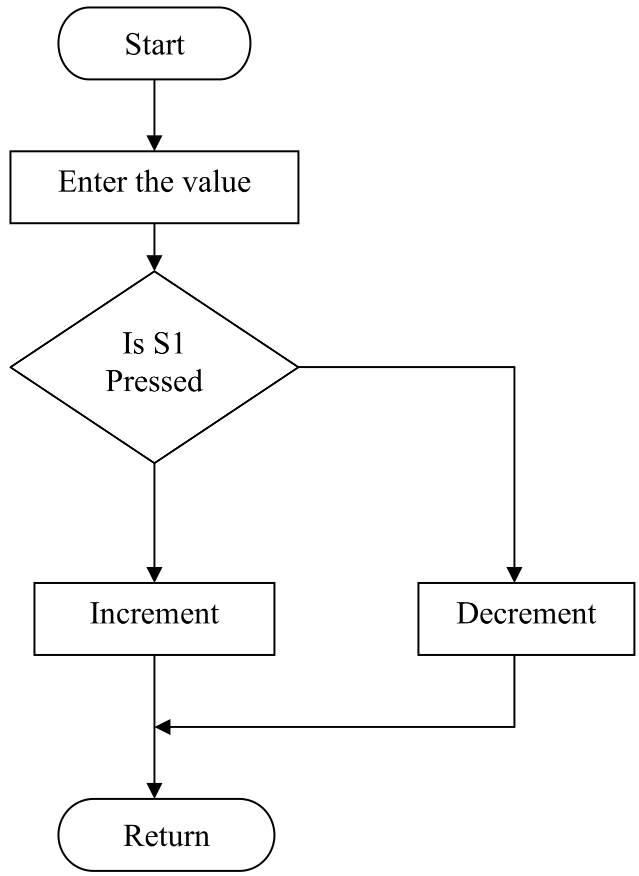

1
Enter Minimum Humidity
Call Increment or Decrement
Press S3
3
Select Channel 0
Call ADC
Delay 15 msec
Select Channel 1
Call ADC
Delay 15 msec
Select Channel 2
Call ADC
Delay 15 msec
2



Flowchart 1: General Flowchart of the system

4.4.2 Increment or Decrement subroutine

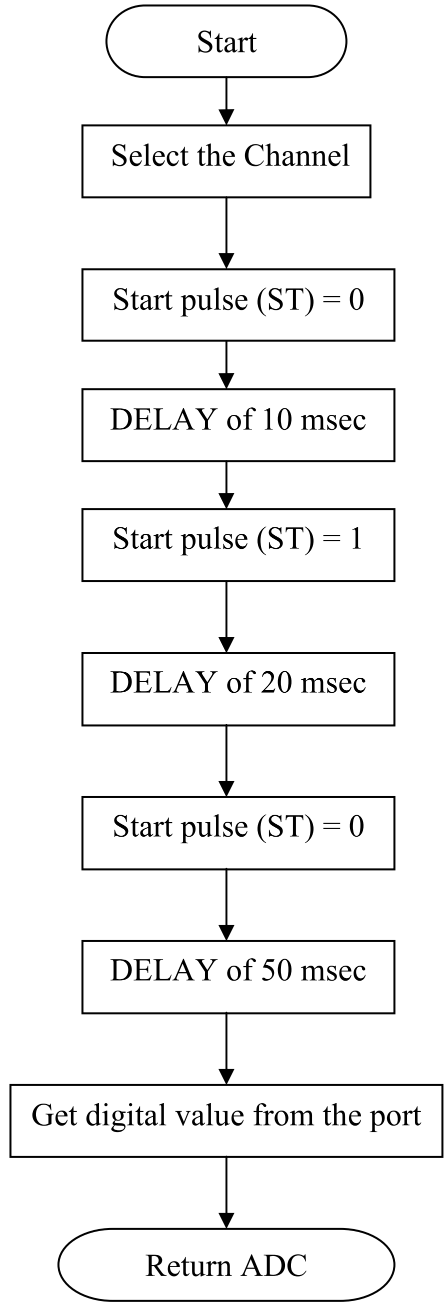
This subroutine is used to increment or decrement the value of parameters.



Flowchart 2: Increment or Decrement Subroutine

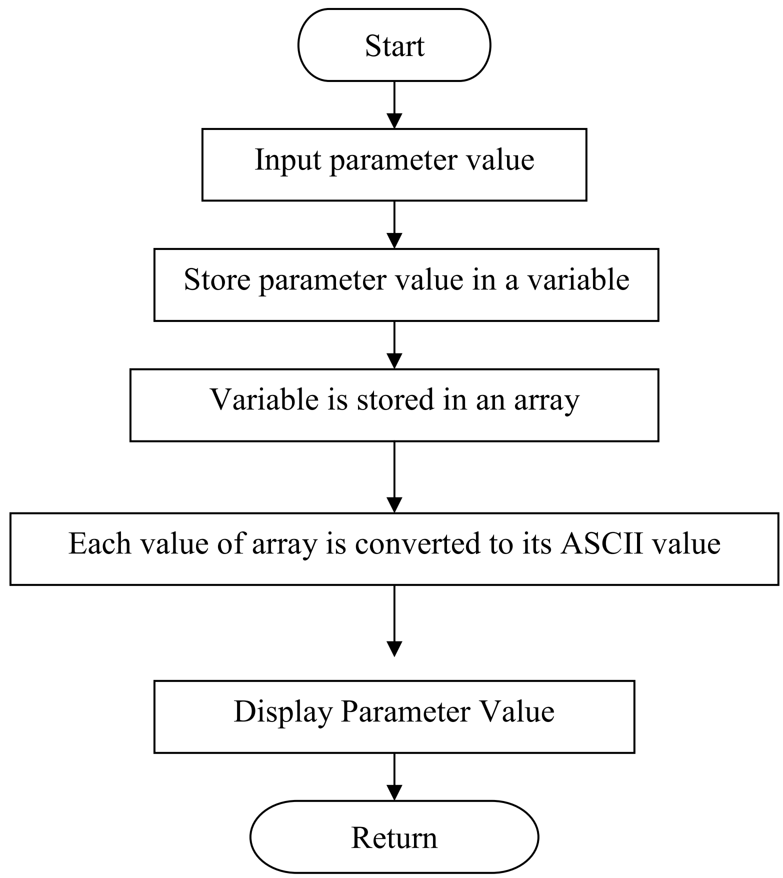
4.4.3 ADC Subroutine

This routine fetches analog signals from one of the 3 channels connected at input of ADC 0808 and converts it into digital signal.



Flowchart 3: Flowchart for ADC subroutine

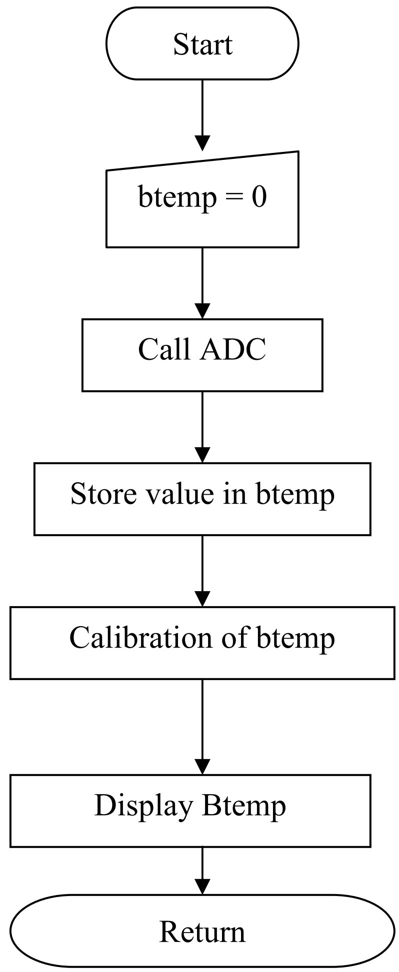
4.4.4 Display Routine



Flowchart 4: Display Routine

4.4.4.1 Btemp Subroutine

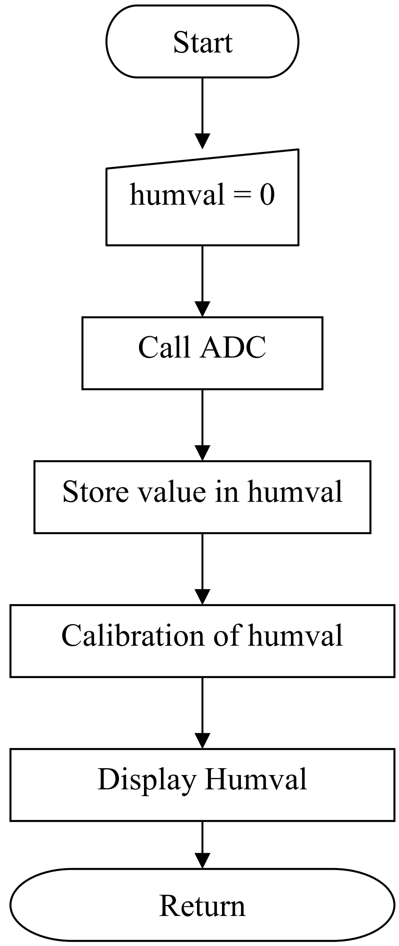
This subroutine gets the real time value from channel 0 and displays that value on the LCD.



Flowchart 5: btemp subroutine

4.4.4.2 Humval Subroutine

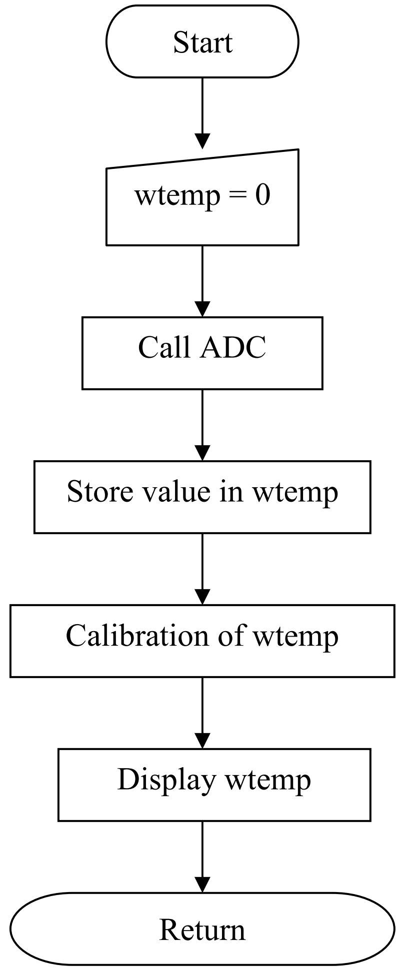
This subroutine gets the real time value from channel 2 and displays that value on the LCD.



Flowchart 6: humval subroutine

4.4.4.3 Wtemp Subroutine

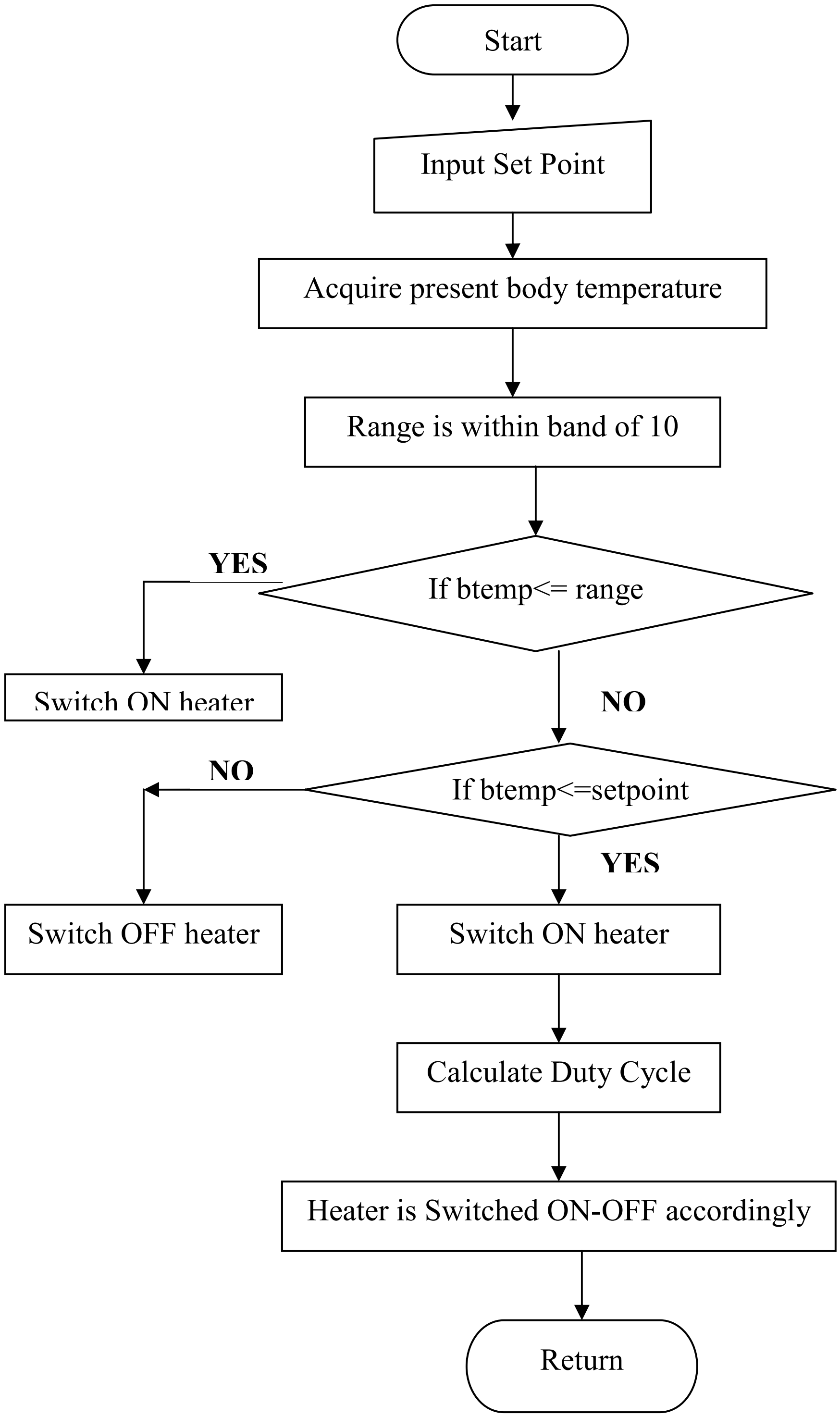
This subroutine gets the real time value from channel 2 and displays that value on the LCD.



Flowchart 7: w-temp subroutine

4.4.5 PID Subroutine

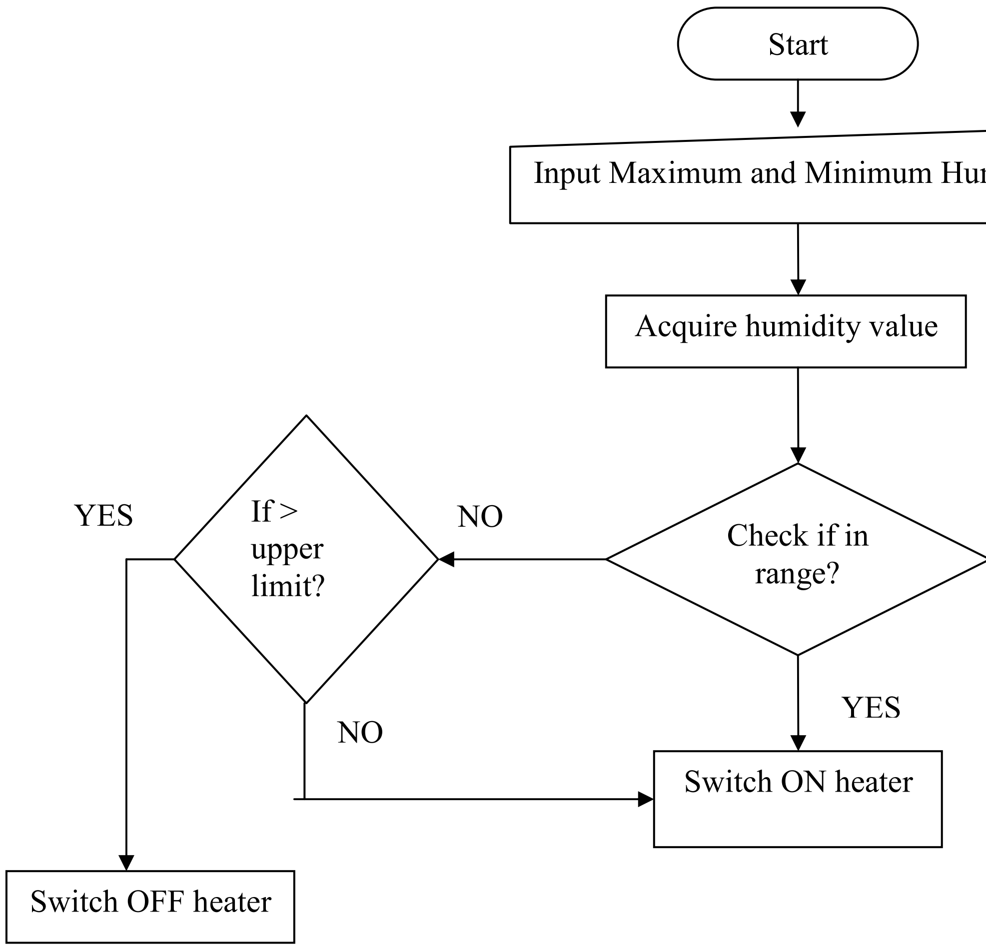
This flowchart depicts the PID control logic on baby chamber heater.



Flowchart 8: Flowchart for PID Control of heater

4.4.6 Water Reservoir Subroutine

As humidity is an important parameter which helps in maintaining heat loss to minimum at high relative humdidty level, hence its indirectly controlled by switching ON-OFF of heater of water reservoir which is responsible for humidity in baby chamber.



Flowchart 9: Flowchart for ON-OFF Control of heater of Water reservoir

CHAPTER 5

Results and Conclusions

The circuit shown in figure 30 of chapter 3 has been fabricated from various individual units. The performance of the system depends on working of each individual unit. Hence overall performance of the unit has been checked and which has been satisfactory. The details of results have been discussed in various paragraphs.

5.1 Results obtained from baby chamber heater

We have developed the system in such a way that it can be implemented in manually controlled systems so as to upgrade them to automatic control system and can also be used individually by constructing canopy and attaching suitable heaters, therefore for testing the system we have attached 100 Watt bulb to the point of baby chamber heater and kept the temperature sensor at distance of 5 inches from the bulb. The data recorded at different start temperatures has been shown in the table 11:

Table11: Data for Time Taken to Reach Desired Temperature

Desired Temperature (^{0}C)	Start Temperature (^{0}C)	Time taken (minutes)
44	30	11.15
44	32	9.03
44	34	7.40
44	36	5.53

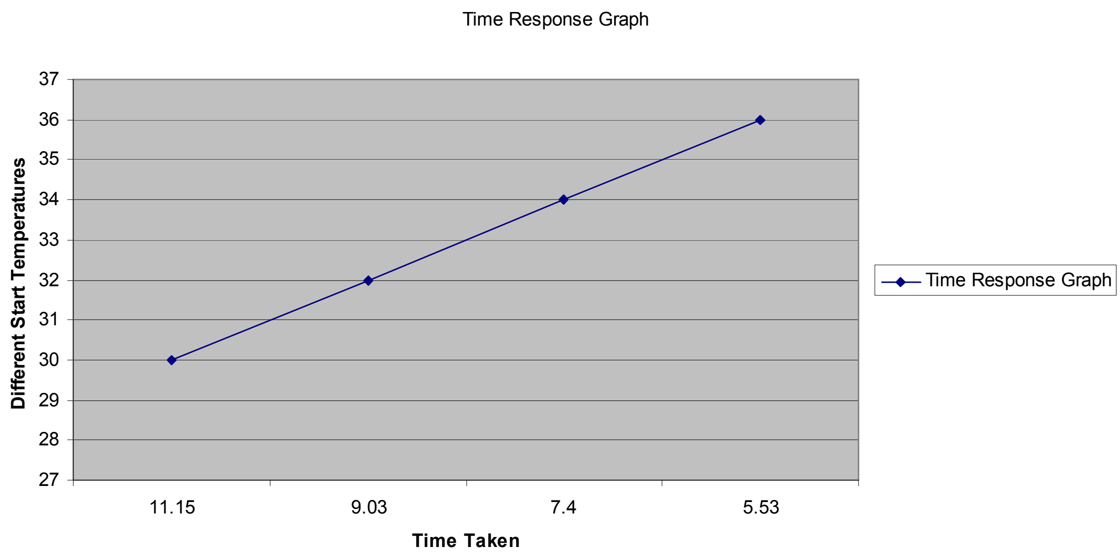


Figure 35: Graph for time to achieve different temperatures

Note: *The Desired temperature (44^0 C) has been assumed in accordance with present environmental conditions.*

5.1.1 Results depicting PID Control

Proportional-Integral-Derivative (PID) control is introduced in the software for more accurate control, hence a propotional band of 10 is chosen within which the ON-OFF time varies for the heater. It can also be known as time based control. The equation of PID controller is given by:

$U (t) =k[e (t) +1/Ti\int e (\tau) d\tau+Td\ de (t)/DT]$

Start Temperature = 34^0C

Desired Temperature = 44^0C

Error = Desired temp – Present temp.

Table 12: Error Vs ON-OFF Time

Present Temp	Desired Temp	Error	ON Time (msec)	OFF Time (msec)
34	44	10	1000	0
36	44	8	800	200
38	44	6	600	400
40	44	4	400	600
42	44	2	200	800
44	44	0	0	1000

Start Temperature : 34^{0}C

The graph below represents the behaviour of heater in achieving a particular temperature under PID Control.

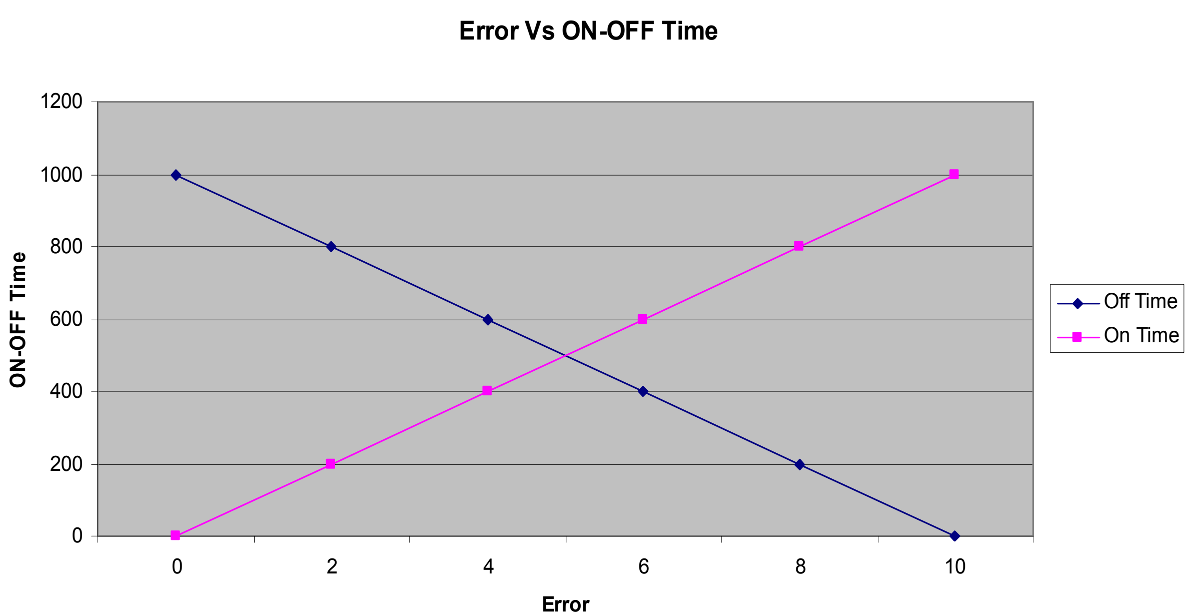


Figure 36 : Error Vs ON-OFF Time

5.1.2 PID Variations

In the above garph we tracked relation between Error Vs ON-OFF Time. Now we can elaborate the analysis and can see how PID results in variations of temeperatures for the given data in the table 13.

Start Temperature: 34^{0}C

Desired Temperature: 44 ^{0} C

Table 13 : Data of How 44 ^{0}C is Achieved

Present Temperature	Time at which change occurs
36	10 sec
38	20 sec
44	35 sec
42	50 sec
40	1.05
42	1.30
40	1.44
42	1.55
40	2.16
42	2.25
40	2.3
42	2.45
40	2.5
42	2.55
44	3.00
42	3.05
40	3.17
42	3.2
44	3.33
46	3.5
42	4.03
40	4.1
42	4.22
40	4.25
42	4.3
40	4.35
38	4.53
40	5.06
38	5.13
40	5.18

42	5.22
40	5.32
42	5.38
44	5.42
46	5.55
44	6
42	6.15
44	6.39
42	6.5
44	7.01
42	7.1

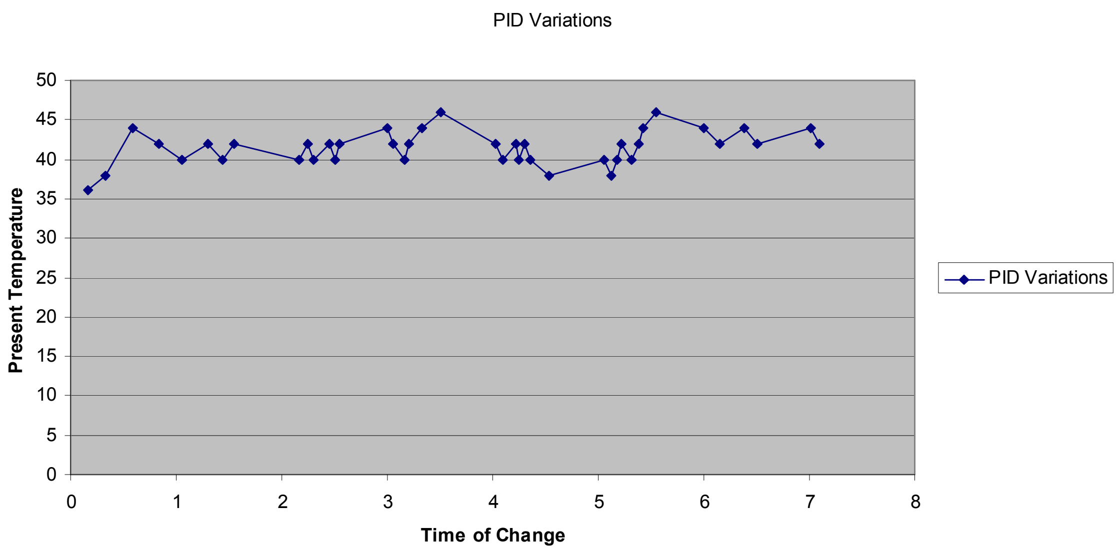


Figure 37: Graph of PID Variations

5.2 Relative Humidity Achieved by the System

Relative humidity which is an important factor in baby chamber to control thermal loss in an infant is controlled by the heater of the water reservoir. The temperature to which water is heated depends on the maximum-minimum value of relative humidity required in the chamber. Hence some normal observations are given in the table 14.

:

Table 14: Relative Humidity Vs Water Temperature

Temperature of water (^{0}C)	Relative Humidity(%RH)
28	36
32	48
36	68
40	76
46	88

This data given in the above table can be analysed much closely in graph below which gives general behaviour of the system.

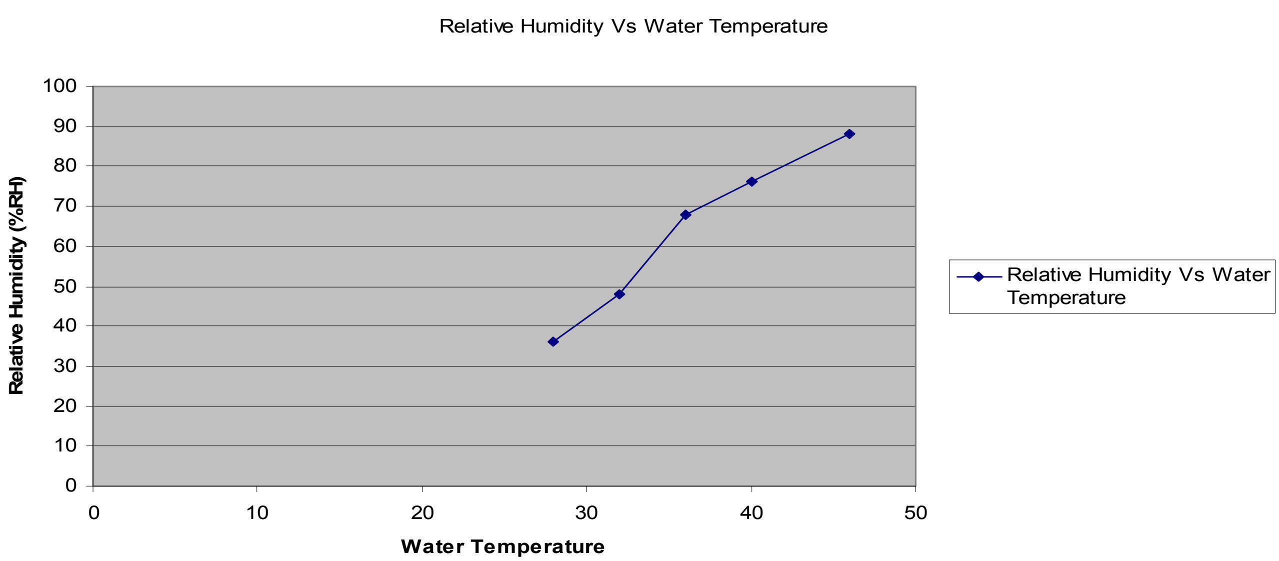


Figure 38: Relative Humidity Vs Water Temperature

5.3 Microcontroller Based Temperature and Humidity Controller

5.4 Circuit of The System

5.5 Sensors

5.6 Conclusion

The Goal of my thesis was to design and develop microcontroller based humidity and temperature controller for infant incubator.To achieve this a hardware was devloped with compatible software in KIEL so that the above mentioned parameters can be monitored for the normal growth of the infant.

This system can provide optimum automatic control of temperature of the infant using PID control technique which has been implemented in the software, moreover it controls the heater of water reservoir according to relative humidity in the infant chamber. The control of relative humidity in chamber is required for making the thermal losss lessen from the infants body.

The hardware with compatible software is of simple design, cost effective and accurate.

5.7 Future Scope Of work

Any work, whatsoever precise it may be, has always some scope of improvement.On the same lines the author envisages that there is lot of scope of improvement in the present work.Some of the future aspects of the work in terms of its improvements are discussed below:

1. Presently only skin temperature control mode which measures temperature from infant's body has been used.We can enhance the accuracy of system by introducing air temperature control mode in which temperature of the chamber environment can be measured.
2. Parameters such as pulse measurement can also be introduced for close monitoring.

3. Oxygen consumption which is necessity for human growth, hence if controlled consumption can be achieved it can increase the survival rate of sick babies.
4. Wireless transfer of data regarding parameters from infant's unit to the nurse monitoring station can be very benficial for the doctors and nurses in critical monitring of each infant in the nursery.
5. Introduction of motor for controlled humidity regulation using a flap can achieve better results for relative humidity in the chamber and can further lessen thermal loss.

APPENDIX 1

```
#define ADC P2

#define ST P34

#define CS1 P31
#define CS0 P30

#define bch P06
#define wch P07

#define DATA P1

#define RS P35
#define RW P36
#define E  P37

#define s1 P00
#define s2 P01
#define s3 P02

unsigned char getadc( unsigned char cs1,unsigned char cs0)
        {

                CS1=cs1;
                CS0=cs0;

                ST=0;
                ms_delay(10);
                ST=1;
                ms_delay(20);
                ST=0;
                ms_delay(50);
                return (ADC);

        }

void displaypval(unsigned char getval)
{
   unsigned char getvala;
        char val[3],count;
        getvala=getval;
```

```
        for(count=0; count<=2; count++)
        {
          val[count]=getvala%10;
    getvala=getvala/10;
        }

        for(count=2; count>=0; count--)
        {
                ACC=val[count]+48;
                lcd_datawrite();
        }

}



void main()

        {

                unsigned char wtemp,btemp,humval;
                unsigned char btempmax,humvalmax;
                unsigned char btempmin,humvalmin;
                unsigned char ton,error,toff;

                        bch=wch=0;
                lcd_initialize();

                        ACC=0x80;
                        lcd_cmd();

                        lcd_display("BIO_ENVIRONMENT",15);

                        ACC=0xc2;
                        lcd_cmd();

                        lcd_display("CONTROLLER",10);

                        secdelay(3);

                        ACC=0x01;
                        lcd_cmd();


        ACC=0x80;
        lcd_cmd();
```

```
	lcd_display("BODY-TEMP MAX",13);

	btempmax=0;
		while(s3==1)
			{
				if(s1==0)
					{
						btempmax++;
						if(btempmax==99)
						  btempmax=0;
					}
				if(s2==0)
					{
							btempmax--;
							if(btempmax==255)
							btempmax=0;
					}


			}


secdelay(1);

	ACC=0x01;
	lcd_cmd();


	ACC=0x80;
	lcd_cmd();
	lcd_display("BODY TEMP MIN",13);

	btempmin=0;
		while(s3==1)
			{
				if(s1==0)
					{
						btempmin++;
						if(btempmin==99)
						  btempmin=0;
					}
				if(s2==0)
```

```
                                        {
                                                btempmin--;
                                                if(btempmin==255)
                                            btempmin=0;
                                        }


                            }


secdelay(1);


                                ACC=0x01;
                                lcd_cmd();


        ACC=0x80;
        lcd_cmd();


lcd_display("HUMIDITY - MAX",14);

        humvalmax=0;
                while(s3==1)
                            {
                                if(s1==0)
                                        {
                                            humvalmax++;
                                            if(humvalmax==99)
                                              humvalmax=0;
                                        }
                                if(s2==0)
                                        {
                                                humvalmax--;
                                                if(humvalmax==255)
                                                humvalmax=0;
                                        }


                            }



        ACC=0x01;
        lcd_cmd();
```

```
        ACC=0x80;
        lcd_cmd();
        lcd_display("HUMIDITY - MIN",14);

        humvalmin=0;
while(s3==1)
                {
                                if(s1==0)
                                        {
                                                humvalmin++;
                                                if(humvalmin==100)
                                                  humvalmin=0;
                                        }
                                if(s2==0)
                                        {
                                                        humvalmin--;
                                                        if(humvalmin==255)
                                                  humvalmin=0;
                                        }


                        }



        ACC=0x01;
        lcd_cmd();

   secdelay(1);


                while(1)
                                {

        ACC=0x80;
        lcd_cmd();
        lcd_display("B-TEMP >>  ",12);

        ACC=0xC0;
        lcd_cmd();
        lcd_display("HUMIDITY >> ",12);


                                        btemp=humval=wtemp=0;
```

```
btemp=getadc(0,0);
        ms_delay(15);
btemp=btemp*2;

humval=getadc(1,0);
        ms_delay(15);



wtemp=getadc(0,1);
        ms_delay(15);
wtemp=wtemp*2;

        ACC=0x8c;
        lcd_cmd();
displaypval(btemp);

        ACC=0xcc;
        lcd_cmd();
displaypval(humval);


        if(s1==0)
                {


                                ACC=0x01;
                                lcd_cmd();




                                ACC=0x8c;
                                lcd_cmd();
                                displaypval(wtemp);


                                        secdelay(1);


                }



if(btemp<btempmax-10)
```

```
                    {
                        bch=0;
                    }

                else if(btemp<=btempmax)
                    {
                        bch=0;

                            {
                                ms_delay(100);
                            }

                        bch=1;


                            {
                                ms_delay(100);
                            }




                    }






            if(humval>=humvalmin && humval<humvalmax-2)
                    wch=0;
                    else
                    wch=1;


        }
    }
```

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