Design and Development of an Infant Incubator for Controlling Multiple Parameters”

Article in Journal of Electrical and Electronics Engineering · September 2012

Ashish Gupta
ABES Engineering College

Design and Development of an Infant Incubator for Controlling Multiple Parameters

Hitu Mittal 1 , Lini Mathew 1 , Ashish Gupta 2

ABSTRACT :The preterm infant care is one of the mostimportant, delegate and sensitive area in the Bio-medicalfield. Somenew-born’s are at a higher risk of mortality andare called high risk infants, because the gestational age ortheir birth weight put them at a higher-than-average risk of disease and death. Since most infants hospitalized in NICUare born preterm, the problems of high risk infants aremainly related to prematurity. Thirty eight percent of mortalities in the first 5 years of age belong to prenatalperiod and out of these, 28% is related to preterm birth. Theresults of statistics in Iran show that in 1980,13% of new-born were preterm, while in 2006 more than 30% of birthswere preterm[3]. Preterm baby requires surroundingexactly similar as in the womb to cope with the externalenvironment. Perhaps the most important conclusion fromrecent research into the effects of the physical environmenton preterm infants is that each infant should have a ‘microenvironment’, which can be individualized to needsthat are specific to that child’s gestational age and medical condition. To some extent, the incubator can serve as thismicroenvironment, controlling light, sound, smell andprotecting from infection [3][5]. An infant incubatorprovides stable levels of temperature, relative humidity, lightcondition and oxygen level up to an extent in which thepreterm have same condition as in the womb. Airtemperature has to be maintained around 35ºC[1]. Thepurpose of this project is to design and implement a closedloop control system to regulate the temperature, humidity, light intensity by using LED’s to avoid jaundice condition and the proper amount of oxygen level inside a neonatalincubator[2]. Microcontroller and PID controller will beused for implementing the hardware. The closed loop controlsystem is a combination of sensors and actuators thatoperates synchronously to provide a stable thermal environment inside the incubator [3].Keywords: Incubator, Temperature, Humidity, Oxygen,Light, LED, Microcontroller, PID Controller.

INTRODUCTION

Infants who born before 37 weeks of the gestation periodare known aspreterm or premature babies. Preterm babyrequires surrounding exactly similar as in the womb tocope with the external environment. In fact mammalshave the advantage of being homoeothermic,i.e.theyhave a nearly uniform body temperature, regulatedindependent of theenvironmentaltemperature. Vitalorgans or enzymes of premature babies grow to the verylesser extent and thus requires special attention to copewith external physical condition like temperature,humidity, light and oxygen level. The infant has severaldisadvantages in terms of thermal regulation. An infanthas a relatively large surface area, poor thermal insulation and a small amount of mass to act as a heat sink. The new-born has little ability to conserve heat by changing postureand no ability to adjust their own clothing in a response tothermal stress. Responses may also be hindered by illnessor adverse conditions such as hypoxia (below normallevels of oxygen). To provide the similar environment asin the womb infants have to be kept in a device known asincubator. An infant incubator is a device consisting of arigid box-like enclosure in which an infant may be kept ina controlled environment for medical care. An infantincubator provides stable levels of temperature, relativehumidity and oxygen concentration [28]. Air temperaturehas to be maintained around 37ºC. The relative humidityshould follow set values according to the number of incubation days [18].

II. INCUBATOR

The first official neonatal intensive-care unit (NICU) forneonates was established in 1961 at Vanderbilt University.Incubator is a device in which premature or unusuallysmall babies are placed and which provides a controlledand protective environment for their care[4]. Every year,about 1 million infants in the developing world die due toheat loss and dehydration that can be prevented by anintensive care unit i.e. incubators[3]. Thus incubatorsprovides congenial atmosphere for the infants, whichhelps in thermoregulation. The incubator is considered asan air conditioned room with special specification whichwe can be control with respect to the condition of baby inincubator. Incubators are designed to provide an optimalenvironment for new born babies with growth problems(premature baby) or with illness problems[4]. Theincubator is an isolated area environment with no dust,bacteria, and has the ability to control temperature,humidity, and oxygen to remain them in acceptable levels.Incubator is designed to keep baby warm, to monitormany of their vital body functions like heart rate, bloodpressure, oxygen saturation and to support their breathingif necessary. Regarding the temperature and humiditycontrol, incubators should minimize heatloss from theneonate and eddies around him/her. The main physicalvariables affecting the incubator environment aretemperature, humidity, oxygen saturation andlight

II. PARAMETERS AFFECTING THEINCUBATORS3.1TEMPERATURE

The infants have very lowthermal regulation andtemperature regulation is one of the most importantfactors which affect the preterm. One of the majorproblems that new-born's face is improper

thermoregulation. The temperature inside the mother's womb is 38ºC (100.4ºF). Leaving the warmth of thewomb at birth, the wet new born finds itself in a muchcolder environment and immediately starts losing heat. If heat loss is not prevented and is allowed to continue, the baby will develop hypothermia and is at increased risk of developing health problems and of death[6].Avoiding hypothermia (rectal temperature less than 36.5°C or 96.8°F) is important for new-born health outcomes because hypothermia increases morbidity and mortality. A baby can lose one degree of body temperature per minute when wet, even in a room that is not obviously cold. To prevent heat loss, it is necessary to dry up the baby and wrap the baby in a clean, dry cloth and to make sure the baby's head is covered (WHO, 1977).

3.2HUMIDITY

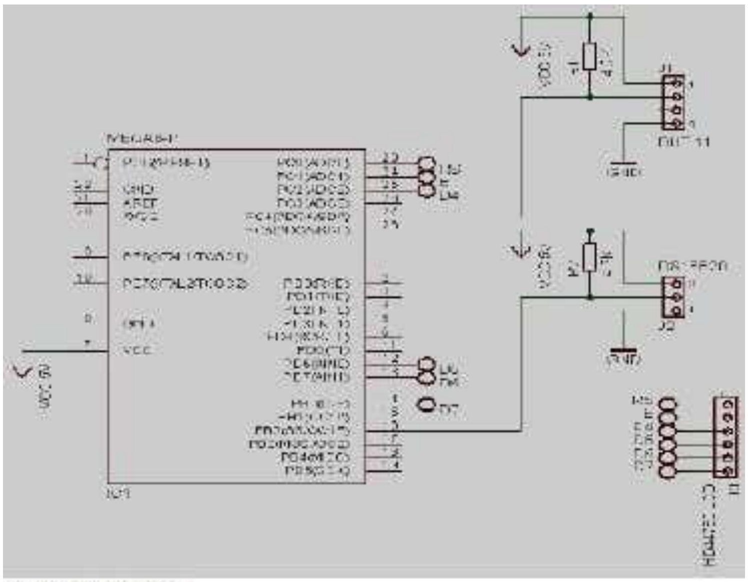
Low relative humidity of a servo controlled incubatorincreases the temperature of the incubator itself and theoxygen consumption of premature infants accordingly.This causes an increase in the insensible water losses. Inaddition, premature infants with small weight or illnessesaresusceptible to unfavorable incidents such as apneicspells. However, insensible water losses under radiantwarmers are higher than conventional incubators.Apparently, small variations in relative humidity insideincubators with skin servo control do notinfluence theinsensible water loss; however significant fluctuations inrelative humidity would vary the amount of insensiblewater losses. Few investigations have shown that the bodyweight and insensible water loss is inversely proportionalto the waterloss. The humidity of the shell environmentcan negatively affect the patient if it is not at a healthylevel. Infants can lose moisture and heat by evaporation if humidity is too low, while higher levels of humidityincrease the likelihood for germs andbacteria to bepresent. The ability to control or at least monitor humidityis beneficial[4].

3.3LIGHT

The physical environments of hospitals are critical to goodpatient care. High light levels (e.g. phototherapy) the lack of regular light/dark cyclesmay also adversely affect new-born patients. The level of ambient light should be flexibleto allow day-night cycling[5]. The technique to controlthe jaundice in the neonates is also comprises of lighttherapy. Phototherapy is the best solution to control the jaundice in the premature babies placed in babyincubators. Babies with jaundice will usually receive thetreatment of phototherapy for 4 to 7 days. When ill infantswith low birth weight receive phototherapy in incubators,their insensible water losses are significantly doubled ortripled. This is attributed to the heat source placed insidethe incubator for the purpose of phototherapy. It may alsobe attributed to the delay in time until the effectiveness of phototherapeutic processes is reached. In a radiant heatwarmer, the exposure to non-ionizing radiant energycauses several changes in infants who requiredphototherapy (such as, changes in body temperature,higher insensible water loss and fluid intakes) [6].Although it can be necessary to useradiant heat warmer tonurse premature infants with low birth weight instead of incubators, this causes an increase of insensible waterlosses. Thus, the smaller the infant (small body weight)the higher the insensible water losses and the fluid intakesaccordingly.

3.4OXYGENATION

Oxygenation is a therapeutic process in which oxygen isadministered directly to facilitate breathing. If a baby bornmore than two months early, her breathing difficulties cancause serious health problems because other immatureorgans in her body may not get enough oxygen.Ventilation is necessary to provide the patient with freshair and sufficient oxygen. Flowing air is also necessary toprovide sufficient transfer of heat from the heat source tothe shell environment and the patient. The ventilationneeds to be carefully managed so that there is enoughfresh air and convective heat transfer over the heatexchanger, but the flow is not so fast that it makes thepatient uncomfortable and causes an increase in heat lossof theincubation system to the outside environment [26].Incubator oxygen treatments have been used to preventnew-born respiratory distress. The oxygen concentrationof inhalation is fixed at a rather high level to improve thedistress and the anoxia, while the arterial oxygen partialpressure $PaO_2$of new-born infants sometimes becomesextremely high and brings about retrolental fibroplasia inthe worst case. It is hence desired that the oxygen pressureof inspired gas in an incubator should be adjustedadequately in accordance with the monitored PaO_2output[31].The block diagram of the project is shown in Fig.1. Itmainly consists of the temperature sensor, humiditysensor, light sensor, carbon di-oxide sensor, PIDcontroller and Microcontroller



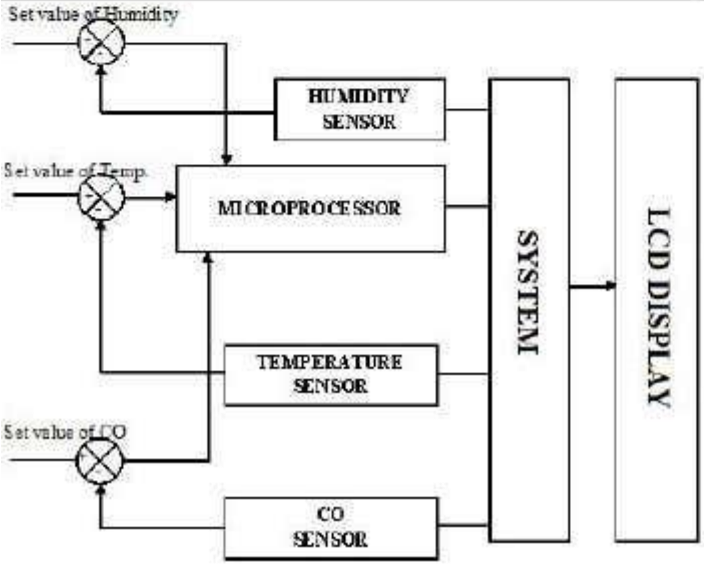


Fig1. Block Diagram of the HardwareIV. DESIGN COMPONENTS4.1TEMPERATURE SENSOR DS18B20

The DS18B20 Digital thermometer provides 9 to 12

–

bitcentigrade temperature measurements and has an alarmfunction with non-volatile user-programmable upper andlower trigger points as shown in Fig.2. The DS18B20communicates over a 1-Wire bus that by definitionrequires only one data line (and ground) forcommunication with a central microprocessor. It has anoperating temperature range of 55°C to +125°C and isaccurate to ±0.5°C over the range of   10°C to +85°C. Inaddition, the DS18B20 can derive power directly from the

data line ("parasite power"), eliminating the need for an external powersupply [6].The core functionality of theDS18B20 is its direct-to-digital temperature sensor. Theresolution of the temperature sensor is user-configurableto 9, 10, 11, or 12 bits, corresponding to increments of 0.5°C, 0.25°C, 0.125°C, and 0.0625°C, respectively. Thedefault resolution at power-up is 12-bit. The DS18B20powers up ina low-power idle state. To initiate atemperature measurement and A-to-D conversion, themaster must issue a Convert T command. Following theconversion, the resulting thermal data is stored in the 2-byte temperature register in the scratchpad memory andthe DS18B20 returns to its idle state. If the DS18B20 is powered by an external supply, the master can issue "readtime slots" (see the 1 -Wire Bus System section) after theConvert T command and the DS18B20 will respond bytransmitting 0 while the temperature conversion is inprogress and 1 when the conversion is done. If theDS18B20 is powered with parasite power, this notificationtechnique cannot be used since the bus must be pulledhigh by a strong pull up during the entire temperatureconversion.TheDS18B20 output temperature data is calibrated indegrees Celsius and for Fahrenheit applications, a lookuptable or conversion routine must be used. The temperaturedata is stored as a 16-bit sign-

extended two's complement

number in the temperature register.For designing ourincubator we have used temperature sensor DS18B20,which is then interfaced with microcontroller (ARDUINOMEGA 2560). The interfacing of both temperature andhumidity sensor with microcontrolleris shown in fig. 2

Fig. 2Interfacing of DS18B20 and DHT-11 withMicrocontroller4.2HUMIDITY SENSOR

Humidity sensor should provide humidity level in theincubator in terms of relative humidity (%RH) in therange of 0-100%RH. The humidity sensor chosen for thepresent work is DHT11.Application of a dedicated digitalmodules collection technology and the temperature andhumidity sensing technology, to ensure that the producthas high reliability and excellent long-term stability. Thesensor includes a resistive sense of wet components andan NTC temperature measurement device, and connectedwith a high-performance 8-bit microcontroller[8].DHT11uses a simplified single-bus communication. Single busthat only one data line, the system of data exchange,control by a single bus to complete.Device (master orslave) through an open drain or tri-state port connected tothe data line to allow the device does not send data torelease the bus,while other devices use the bus,single bus

usually require an external one about 5.1kΩ pull

-upresistor, so that when the bus is idle, its status is high.Because they are the master-slave structure, and onlywhen the host calls the slave, the slave can answer, thehost access devices must strictly follow the single-bussequence, if the chaotic sequence, the device will notrespond to the host.Its connection diagram withmicrocontroller ATMEGA 2560 is also shown in fig.2.

4.3LIGHT SENSOR

Light Dependent Resistor (LDR) is used for detecting theintensity of light in the incubator. For controlling the

jaundice in infants the LED PT series will be used. Itdelivers a blue light with the peak intensity of 455nm. Thelight is free of unwanted UV and IR radiations. LEDmaintains the intensity of light level for 20,000 hrs. In thisproject we have made the array of LED. LED's are opto-semiconductors that convert electrical energy into lightenergy. LED's offer the advantages of low cost and a longservice life compared to laser diodes. LED's are broadlygrouped into visible LED's and invisible

LED's . Visible LED's are mainly used for display or illumination, where LED's are used individually without photo sensors.Invisible LED's are mainly used with photo sensors suchas photodiodes or CMOSimage sensors. In the categoryof visible LED, red LED's are used in combination withphoto sensors for applications such as optical switches.These red LED's have high emission power that allowsphoto sensors to generate a large photocurrent. In thecategory of invisible LED infrared LED's are alsoavailable. These red LED's and infrared LED's are usedin a wide range of applications including optical switches,optical communications, analysis and CMOS imagesensor lighting. Advances in crystal growth technologyand wafer process technology led to develop high-output,long-life

LED’s (operable for ten years or longer underthe optimal drive conditions).

4.4CARBON MONO-OXIDE SENSOR (MQ-7)

MQ-7 sensor is mainly used to determine the Carbonmonoxide gas detection[9].As the concentration of bothcarbon di oxide and carbon mono oxide are same, so wecan use CO sensor as well to measure the CO2gas. Thecost of CO sensor is really low as compared to that of CO2sensor and while designing a low cost infantincubator the cost parameter plays a major role.Measurement of gas pollutants in atmosphere is always achallenging job due to the accuracy required in itsmeasurement. The unprecedented growth in moderntechnologies and the continued development of industrialization has made the issue of environmentalpollution increasingly Carbon monoxide serious andalarming.Among the various gas sensors available in themarket, semiconductor sensors are considered to have fastresponse, high stability, low dependency onhumidity, lowcost, long life, low power consumption, and small size etc.The semiconductor sensor consists of one or more metaloxides such as tin oxide, aluminum oxide etc. MQ-7 is thesemiconductor sensor mainly used to detect Carbonmonoxide gas at theambient atmosphere by using itssensing layer whichis consisted of aluminum oxide.When heated to a high temperature an N typesemiconducting material decreases its resistance while Ptype increases its resistance in the presence of a reducinggas. Therefore, a semiconductor sensor produces a strongsignal at high gas concentrations. MQ-7 is also produce astrong signal so that it can detect CO from any of theambient atmospheres which contain Carbon monoxide gasin hazardous level.Itscircuit diagram isshown in Fig 3and interfacing of MQ-7 sensor with microcontrollerATmega 2560 is shown in Fig.4

4.5MICROCONTROLLER

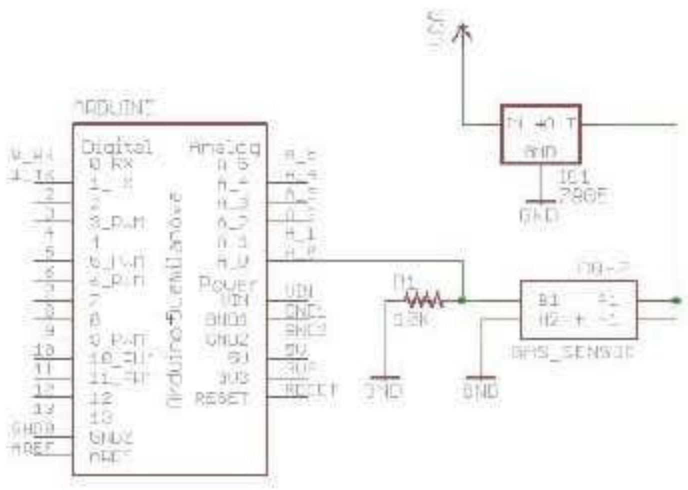
The microcontroller usedis Arduino mega2560. TheArduino Mega 2560 is a microcontroller board based onthe ATmega2560 (datasheet). It has 54 digital input/outputpins (of which 14 can be used as PWM outputs), 16analog inputs, 4 UARTs (hardware serial ports), a 16MHz crystal oscillator, a USB connection, a power jack,an ICSP header, and a reset button. It contains everythingneeded to support the microcontroller; simply connect it toa computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. TheMega iscompatible with most shields designed for the ArduinoDuemilanove or Diecimila. The Arduino Mega2560 can be powered via the USB connection or with an externalpower supply. The power source is selected automatically.External (non-USB) power can come either from an AC-to-DC adapter (wall wart) or battery. The adapter can beconnected by plugging a 2.1mm center-positive plug intothe board's power jack. Leads from a battery can beinserted in the GNDand VINpin headers of the POWERconnector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the5V pin may supply less than five volts and the board maybe unstable. If using more than 12V, the voltage regulatormay overheat and damage the board. The recommendedrange is 7 to 12 volts.TheATMega2560 differs from all preceding boards inthat it does not use the FTDI USB-to-serial driver chip.Instead, it features the Atmega8U2 programmed as aUSB-to-serial converter. The ATmega2560 has 256 KB of flashmemory for storing code, 8 KB of SRAM and 4 KBof EEPROM (which can be read and written with theEEPROM library).TheATMega2560 has 16 analoginputs, each of which provides 10 bits of resolution (i.e.1024 different values).They measure from ground to 5volts, though is it possible to change the upper end of theirrange using the AREF pin and Analog Reference function.It controls the operation of sensors and gives the outputthrough LCD display as shownin the circuitry shown inFig5.

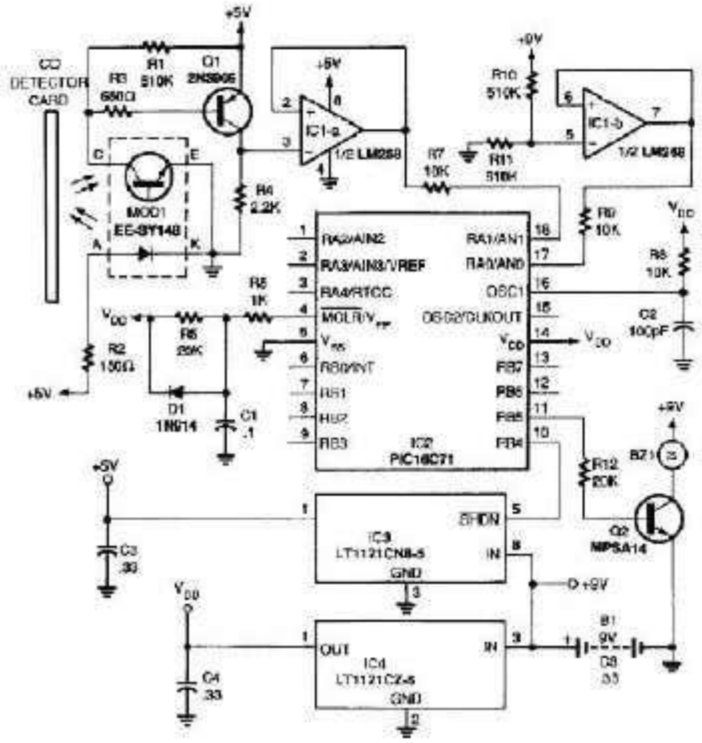
Using DS18B20 we found that the time response is reallyfast as 1±1 sec (We have put a delay of 1 sec in acomplete loop to match the LCD responses). If weincrease the delay of the loop more than 1 sec, there willbe a garbage value. In Table 5.1, we have given thechange in temperature with respect to time by the study of temperature sensor DS18B20.

Table1 Time vs Incubator TemperatureTime (seconds)IncubatorTemperature (°C)

033.25533.481033.861534.132034.192534.253034.313534.384034.464534.545034.615534.76034.816534.8870357535.58035.2

In Table1, we had given the temperature change withrespect to time by the study of temperature sensorDS18B20. The maximum temperature range set for theinfant in this incubator is 35°C. Initially when incubator isturned ON then the initial temperature is found to be at33.75°C. As the time increases differentvalues of temperatures have been recorded. As a result we haveseen that due to the heat produced by the bulb, thetemperature gradually increase and attains the set valuei.e. 35°C.Now if the temperature of the incubatorincreases more than 35°C temperature sensor will sense itand turn ON the Fan which in turn cools itdown to thegiven temperature.The graph between time andtemperature of incubator, obtained by the results is shownin Fig.





5.2RelativeHumidity Achieved by the System

Relative humidity, an important factor in designing of anincubator to control thermal loss in an infant, is controlledby the heater of the water reservoir. The temperaturewhich is used to heat the water inside the incubatordepends on the maximum-minimum value of relativehumidity required in the chamber. Humidity can also beincreased and decreased by using water content in the air.Some observations are shown in the table 5.2 for thedifferent values of relative humidity with respect to watertemperature

5.3RESULT OF LED

Phototherapy should be started immediately if a rapidlyrising bilirubin is expected and with jaundice at less than24 hours. Light-emitting diode (LED) light sourcephototherapy is effective in bringing down levels of serumtotal bilirubin at rates that are similar to phototherapy withconventional (compact fluorescent lamp (CFL) orhalogen) light sources. According to level of disease

detecting by the doctor’s diagnosis we can manually

change (increase or decrease) the intensity of light usingpotentiometer. Potentiometer controls the current passing

through the LED’s which in turn results the change in

intensity of LEDshown in Fig.8. The light can be appliedwith overhead lamps, which means that the baby's eyesneed to be covered, or with a device called aBiliblanket,which sits under thebaby's clothingclose to its skin

5.4RESULT OF MQ-7 SENSOR

Sensor resistance varies a logarithmic function of gasconcentration, sensitivity characteristics to a certain gasdiffer with sensor type. When measuring a certain gas,possible interference of co-existing gases must always betaken into consideration. The curve for the variation of CO gas concentration with respect to the sensorresistanceis shown in Fig 9 and the concentration of CO2 ismeasured by using MQ-7 sensor has been explained inTable3

5.5INCUBATOR IN WORKING CONDITION

After designing the hardware when the project comes inworking condition then the different results will beobtained which are shown in theof Fig.10, showingdifferent values for two different time after switching ONthe incubator.In Fig 10(a) we have seen the values which we are gettingat the initial stage after switching ONthe incubator. Whilein Fig 10(b) we got the values of temperature andhumidity after 25 seconds of time.

(a)(b)Fig.10Values for Different parameters: (a) Values atTime = 0 Seconds(b) Values at Time = 25 Seconds.

From above Fig 10we have seen the difference intemperature as well as humidity with respect to timewhose graphs has been shown in Fig.8 and Fig.9simultaneously

VI.CONCLUSION

The objective of this project is to design and developmicrocontroller and closed loop control system basedtemperature, humidity, oxygen concentration and lightcontroller for infant incubator. To achieve this hardware isdesigned so that the above mentioned parameters can bemonitored for the normal growth of an infant.This system can provide optimum automatic control of temperature for the infant using closed loop controlsystem. Moreover it controls the heater of water reservoiraccording to relative humidity in the infant chamber. Thecontrol of relative humidity in chamber is required for

making the thermal losses lessen from the infant’s body.

Also controlling of light will provide proper growth ininfant. The controlling of the concentration of gas with theCO sensor is beneficial for infant to protect him fromvarious kinds of breath diseases.

VII.FUTURE SCOPE

Any work, whatsoever precise it may be, has always somescope of improvement. On the same lines the authorenvisages that there is lot of scope of improvement in thepresent work. Some ofthe future aspects of the work interms of its improvements are the parameters such aspulse measurement can also be introduced for closemonitoring and the response of the project can furtherimproved by using the different tuning techniques used forPIDcontrollers.The GSM technique canalsobe used toreduce the noise created by the alarms in the closemonitoring.