# DEVELOPMENT OF PORTABLE TESTER FOR NEONATAL INCUBATOR WITH MULTIPARAMETER MEASUREMENT

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# DEVELOPMENT OF PORTABLE TESTER FOR NEONATAL INCUBATOR WITH MULTIPARAMETER MEASUREMENT

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**THESIS SUBMITTED IN PARTIAL FULFILMENT FOR THE DEGREE OF BACHELOR OF ELECTRONIC ENGINEERING TECHNOLOGY ( MEDICAL TECHNOLOGY) WITH HONOURS**

**DEPARTMENT OF ELECTRICAL ENGINEERING**
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**2019**

# DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

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# ABSTRACT

Neonatal incubators were made for survival of newborns. They regulate temperature, humidity and oxygen concentration, providing the perfect environmental conditions for the newborn improvement. The incubator analyzer used to test the performance of the incubator. The incubator analyzer simplifies testing and ensures proper performance and safety of newborn incubators and transport incubators. The biomedical staffs faces difficulties in lifting heavy safety analyzer from one place to another and the misplacement of external probes may disrupt the process flow of safety test. In this research, a portable infant incubator tester is developed. Temperature, humidity, noise level, and oxygen concentration are the main parameters that is measured in the infant incubator. The 4 parameters readings will be detected and measured from the infant incubator. The data will be transmitted and processed into Arduino Uno and the result will be displayed on the LCD screen. The data also will be stored in the SD card. In addition , the usability of the tester also has been compared with the incubator analyzer. The invention of the light-weight portable tester for neonatal incubator will help to reduce the burden of technician by bringing around the tester. It will also increase the efficiency of the staffs to perform better at workplace with user-friendly tester.

**Keywords-** Neonatal Incubator, Multiparameter Sensor, Portable, Tester

# ABSTRAK

Inkubator bayi dibuat untuk bayi yang baru lahir. Mereka mengawal suhu, kelembapan dan kepekatan oksigen, menyediakan keadaan persekitaran yang sempurna untuk peningkatan bayi baru lahir. Instrument yang dipanggil 'incubator analyzer' digunakan untuk menguji prestasi inkubator. Incubator analyzer memudahkan ujian dan memastikan prestasi dan keselamatan yang betul bagi inkubator bayi. Kakitangan bioperubatan menghadapi masalah dalam mengangkat incubator analyzer yang berat dari satu tempat ke tempat yang lain dan penyelewengan wayar dapat mengganggu proses ujian keselamatan. Dalam kajian ini, tester inkubator bayi mudah alih direka bentuk. Suhu, kelembapan, paras bunyi, dan kepekatan oksigen adalah parameter utama yang diukur dalam inkubator bayi. Bacaan 4 parameter akan dikesan dan diukur dari inkubator bayi. Data akan dihantar dan diproses oleh Arduino Uno dan hasilnya akan dipaparkan pada skrin LCD. Data ini juga akan disimpan dalam kad SD. Di samping itu, kegunaan tester juga telah dibandingkan dengan incubator analyzer. Penciptaan alat yang mudah alih dan juga ringan untuk inkubator bayi akan membantu mengurangkan beban juruteknik semasa melakukan proses ujian keselamatan. Ia juga akan meningkatkan kecekapan kakitangan untuk melakukan memberi perkhidmatan yang lebih baik di tempat kerja dengan penguji mesra pengguna.

**Kata Kunci-** Inkubator Bayi, Suhu, Analyzer, Mudah Alih, Tester

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| CPU | Central Processing Unit |
| RAM | Random Access Memory |
| ROM | Read Only Memory |
| PCB | Printed Circuit Board |
| LED | Light Emitting Diode |
| LCD | Liquid Crystal Display |
| VOC | Volatile Organic Compound |
| CMOS | Complimentary Metal Oxide Semiconductor |
| ICD | Integrated Circuit Design |
| PWM | Pulse Width Modulation |
| USART | Universal Synchronous/Asynchronous Receiver/Transmitter |
| SD | Secure Digital(Memory Card) |

# CHAPTER 1

# INTRODUCTION

## 1.1 INTRODUCTION

The incubator analyzer is the analyzer that shows the performance of the incubator. Knowing how close the values of a medical device are to the actual values is very important in the treatment process. Considering the importance of the baby incubators, keeping the equipment underneath continuous tracking, periodic maintenance, repair and calibration is incredibly necessary. The health of the babies is risked with faulty incubator controls. This case concerning the incubator may be exposed with an incubator analyzer. this incubator is connected to the test unit (analyzer) that has standard values belong to the measurement parameter. This test method permits United States of America to examine this values in the incubator accordance with the standards or not. It is claimed within the interview with Dr. Uğur Dilmen that the calibration tests are performed in an annual amount and there area unit 2 kinds of brooder analyzers [1]. One among them is meeting the necessities of the IEC Standards for incubators (IEC 60601-2-19) and refulgent heaters (IEC 60601-2-21) [2].

## 1.2 PROBLEM STATEMENT

The incubator analyzer simplifies testing and ensures proper performance and safety of newborn incubator. If the temperature level, humidity level, oxygen level and noise level are measured incorrectly, it would gives effect to neonates life. Some hospitals had issues in purchasing the infant incubator analyzer because it is high in cost.

The biomedical staffs face challenges in lifting heavy analyzer from one spot then onto the next and the misplacement of external probes may disrupt the process flow of safety test. Biomedical team from hospital had requested a prototype that can be a model for the incubator analyzer.

Beside that, basic infant incubator problem according to the report of WHO (World Health Organization), are caused by uncontrolled oxygen saturation and uncontrolled temperature [3]. Pretend infants usually have to spend long time incubator, excessive noise in which can adverse physiological effect on neonates [4].

## 1.3 OBJECTIVE

There are several objectives involved in this project that we need to achieve in order to design the project.

1. To identify the infant incubator analyzer usability.
2. To develop a portable infant incubator analyzer.
3. To assess temperature, humidity, noise and gas concentration in an incubator.

## 1.4 BLOCK DIAGRAM

The system of the project starting from input, process and output. Input consists of 4 main parameter which is processed by microcontroller and gives output in form of displaying the reading, blinking of Led light, buzzer and store data.


**Figure 1.1 : Block Diagram Of The Tester**

## 1.5 PROJECT SCOPE

The scope of this project is categorized into three parts such as software, hardware and mechanical design.

Infant incubator tester is a biomedical equipment that used in neonatal in hospital. Used for perform preventative maintenance, repair verification and routine verification of baby incubators. In this respect, the micro-controlled structure facilitates the programming of correction functions that can be modeled from the calibration points.

The software which used in circuit configuration is Arduino Pro software and Proteus 7.2. Proteus 7.2 software is used to design the circuit to be produced on PCB board. MicroC Pro software is used to install the program code regarding the process in the system of the project. Then, the tester casing is designed 3D using SOLIDWORKS software.

There is several hardware components and circuit used in this project. Temperature sensor is used to detect the temperature and humidity. Gas sensor is used to measure air quality in environment of the incubator. Then, sound sensor is used to detect noise inside the infant incubator. Buzzer, LED indicator, LCD screen display,data logger will be used in part of output.

The mechanical design is referred to casing of the tester. The casing was printed in 3D. The casing is printed using PLA material.

## 1.6 ORGANIZATION

a) Chapter 1(Introduction)

Introduction of main purpose and aim for this project. Other than that discussion about objective of this project, design of block diagram and scope of the project.

b) Chapter 2(Literature review)

It's about literature review of some similar or related project based on this project. Discuss about how it's functioning and components used.

c) Chapter 3(Methodology)

This chapter contain full solution for components used with descriptions, also explanation of why this components are use in this circuit. Furthermore this chapter contain program simulation details and how it's works in this project. The mechanical design design also included.

d) Chapter 4(Results & Discussion)

Chapter 4 contain evidence for this project and some photos with descriptions. Data for some components and project results also combined in this chapter

e) Chapter 5(Conclusion & Recommendation)

This chapter will conclude all the results, data and will let know whether this project is successful or not. Moreover will pin point some idea to implement in future.

f) References

References is about source taken from where as an additional notes or information gathered for this project

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INCUBATION BASICS

Infant incubator system is a vital and critical area because it deals with premature infant or illness baby. It is essential to detect any abnormal conditions occur in the infant incubator system as soon as possible [5]. Temperature, humidity, and oxygen concentration are the main parameters must be control in the infant incubator system. This paper deals with the measurement of temperature inside the incubator as temperature is one of the most-measured process variables in human body. Most commonly, a temperature sensor is used to convert temperature value to an electrical value. Temperature sensors are the key to read temperatures correctly and to control temperature in biomedical applications [6]. The current incubator is connected to the test unit (analyzer) which has standard values belong to the measurement parameter. This test process allows us to see the current values in the incubator accordance with the standards or not.

## 2.2 INCUBATOR ANALYZER

The INCU Incubator Analyzer is a device designed to verify the proper operation and environment of infant incubators. This unit records parameters important to the care of infants over time, such as airflow, sound level, temperature (four individual measurement probes), and relative humidity. Event markers can be placed on the recording to identify certain activities or periods. The rechargeable battery allows the unit to be placed within the incubator chamber for up to 24 hours without compromising the integrity of the environment.

The INCU can operate stand-alone or with the use of a personal computer. With a PC, the user selects the desired record time/interval via the software, and then initiates the start of the test from the INCU. After completion of the test, the user uploads the data collected by INCU into the PC software for display and analysis. The user may store the recorded data in a file or print the data to a report. In stand-alone mode, the unit displays all measured parameters repeatedly in cycle fashion, and no data is recorded [7].

## 2.3 PARAMETER

There are some important parameter that had been in analyzed the incubator for the performance.

### 2.3.1 TEMPERATURE

The infants have very low thermal regulation and temperature regulation is one of the most important factors which affect the preterm. One of the major problems that newborns face is improper regulation. 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.

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 [8]. 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.

### 2.3.2 HUMIDITY

Low relative humidity of a servo controlled incubator increases the temperature of the incubator itself and the oxygen consumption of premature infants accordingly. This causes an increase in the insensible water losses. In addition, premature infants with small weight or illnesses are susceptible to unfavorable incidents such as apneic spells.

However, insensible water losses under radiant warmers are higher than conventional incubators. Apparently, small variations in relative humidity inside incubators with skin servo control do not influence the insensible water loss; however significant fluctuations in relative humidity would vary the amount of insensible water losses. Few investigations have shown that the body weight and insensible water loss is inversely proportional to the water loss. The humidity of the shell environment can negatively affect the patient if it is not at a healthy level. Infants can lose moisture and heat by evaporation if humidity is too low, while higher levels of humidity increase the likelihood for germs and bacteria to be present. The ability to control or at least monitor humidity is beneficial [9].

### 2.3.3 OXYGENATION

Oxygenation is a therapeutic process in which oxygen is administered directly to facilitate breathing. If a baby born more than two months early, her breathing difficulties can cause serious health problems because other immature organs in her body may not get enough oxygen. Ventilation is necessary to provide the patient with fresh air and sufficient oxygen. Flowing air is also necessary to provide sufficient transfer of heat from the heat source to the shell environment and the patient.

The ventilation needs to be carefully managed so that there is enough fresh air and convective heat transfer over the heat exchanger, but the flow is not so fast that it makes the patient uncomfortable and causes an increase in heat loss of the incubation system to the outside environment [10].

Incubator oxygen treatments have been used to prevent new-born respiratory distress. The oxygen concentration of inhalation is fixed at a rather high level to improve the distress and the anoxia, while the arterial oxygen partial pressure PaO2 of new-born infants sometimes becomes extremely high and brings about retrolental fibroplasia in the worst case. It is hence desired that the oxygen pressure of inspired gas in an incubator should be adjusted adequately in accordance with the monitored PaO2 output [11].

### 2.3.4 AIR QUALITY

Passive monitors and summa canisters were used for close air sampling in the ICU and detection of VOCs within infant incubators [12]. Excrement samples from neonates housed within the incubators were analyzed for urinary markers of aerophilic stress. Separately, a neonatal apparatus was crammed with generated smoke and an optical device was accustomed to verify air movement at intervals the apparatus below varied care conditions [13]. One-sided paired t-tests of the log transformations were accustomed to compare VOC concentrations within and outdoors infant incubators within the varied conditions examined.

### 2.3.5 NOISE

Exposure of infants to excessive noise is a concern which has more recently been realized. Newborns are sensitive to noise and excessively loud and prolonged noise can potentially cause adverse impacts on hearing, brain development, and sleep[14]. Standards from organizations including the American Academy of Paediatrics and the World Health Organization state that the sound pressure level to a patient in a neonatal care unit should not exceed 45 dB A (A-weighted decibels, which are decibels adjusted to account for the way the human ear perceives loudness) [15]. However, this can be difficult to achieve in practice even with modern incubators under normal hospital conditions [16].

## 2.4 PROGRAMMING

Microcontrollers are typically programmed in higher-level languages such as C++ or Java. One of the essential tools needed to program a microcontroller is an integrated development environment (IDE). microcontroller has a CPU, in addition with a fixed of RAM, ROM and other peripherals all embedded on a single chip.

### 2.4.1 PIC MICROCONTROLLER - PIC 16F877A

The microcontrollers played revolutionary role in embedded industry and other place after the invention of 89C51. The steady and progressive research in this field gave the hospital, industry and other place more efficient, high-performance and low-power consumption microcontrollers [17]. PIC 16F877 is one of the most advanced microcontroller from Microchip.

This controller is widely used for experimental and modern applications because of its low price, wide range of applications, high quality, and ease of availability. It is ideal for applications such as machine control applications, measurement devices, study purpose, and so on.

The PIC16F877A CMOS FLASH-based 8-bit microcontroller is upward compatible with the PIC16C5x, PIC12Cxxx and PIC16C7x devices. It features 200 ns instruction execution, 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, a synchronous serial port that can be configured as either 3-wire SPI or 2-wire I2C bus, a USART, and a Parallel Slave Port. [18]

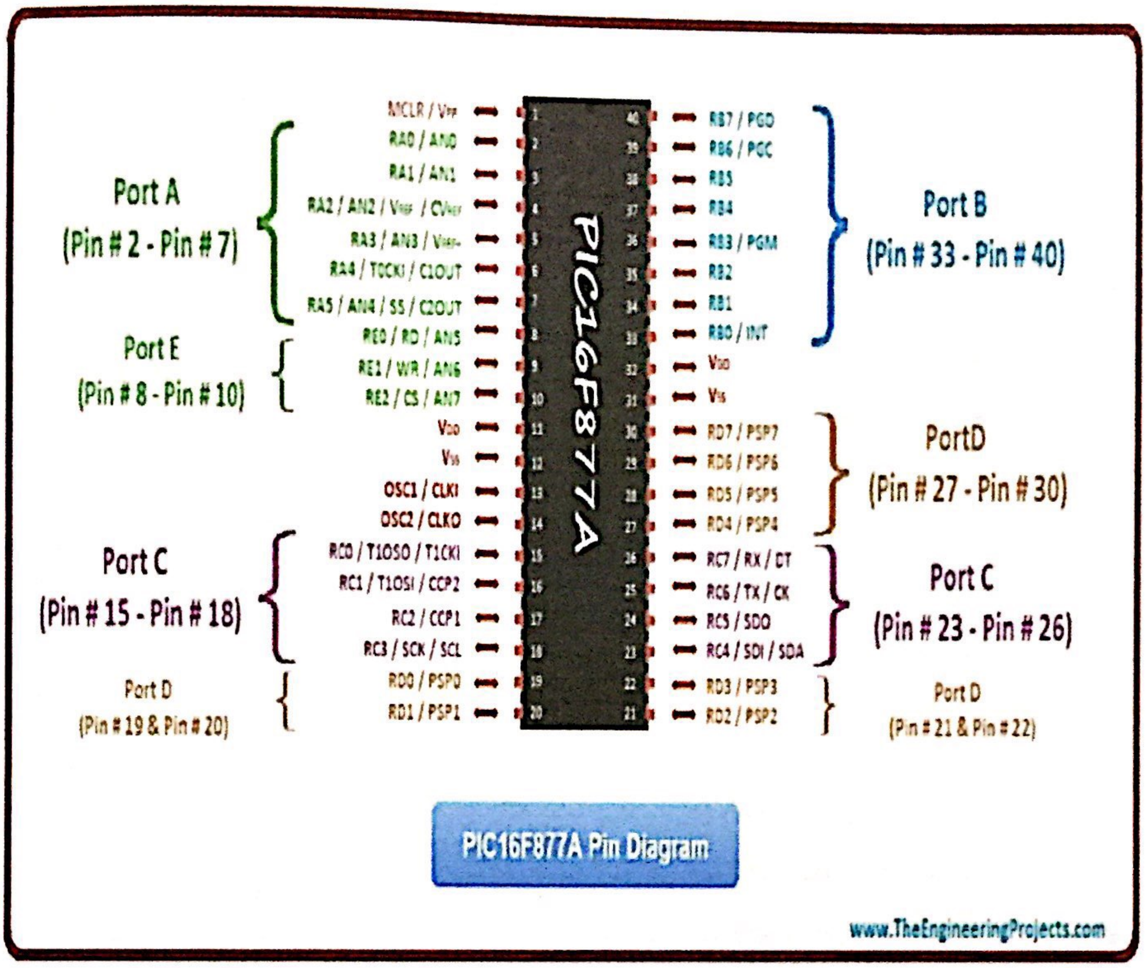


**Figure 2.1 : PIC16F877A Pin Diagram**

## 2.5 RESEARCH OF JOURNAL

There are some journal has been refereed in order to study the incubator analyzer.

TABLE 2.5 : Journal List With Keywords

| TYPES | TITTLE OF JOURNAL | KEYWORDS |
|---|---|---|
| *Incubator* | INFANT INCUBATOR WITH NON-CONTACT SENSING AND MONITORING | The infant incubator having means for controlling the environment in which the infant resides disclosed herein includes an infant support surface disposed within an enclosure having a canopy, a sensor spaced apart from the infant to sense a physiological condition and provide a sensor output, and a controlling means responsive to the sensor output to change the environment. |
| | INFANT INCUBATOR | Purpose,terminology,design , safety features |
| | DESIGN OF WIRELESS SMART SENSOR MODULE FOR INFANT INCUBATOR TEST | Infant incubator; IEEE 1451; Zigbee; smart sensor |
| | INFANT INCUBATOR PROJECT | Maintaining incubator air temperature, air flow and relative humidity |

| | | |
|---|---|---|
| *Analyzer* | PERFORMANCE ANALYSIS FOR MEDICAL DEVICES | Performance test; preventive maintenance; quality management; risk analysis |
| | INFANT INCUBATOR WITH NON-CONTACT SENSING AND MONITORING | Portable incubator analyzer that verifies the operation and environment of baby incubators, transport incubators, and radiant warmers. |
| | NEONATAL TEST SOLUTIONS NEONATAL QUALITY ASSURANCE SOLUTIONS FROM AN ISO 13485 MEDICAL DEVICE COMPANY. | Incubator analyzer |
| *Temperature and humidity* | THE ACCURACY OF TEMPERATURE MONITORING OF INCUBATOR FOR NEWBORNS | Neonatal incubator,performance test,temperatures |
| | 8051 - TEMPERATURE AND HUMIDITY CONTROLLER FOR INFANT INCUBATOR \| FREE MICROCONTROLLER PROJECTS - 8051-AVR-PIC | Temperature and humidity controller for infant incubator |
| | CONTROLLING OF TEMPERATURE AND HUMIDITY FOR AN INFANT INCUBATOR USING MICROCONTROLLER | Incubator, temperature, humidity, microcontroller, PID controller |

| | | |
|---|---|---|
| | DESIGN AND DEVELOPMENT OF AN INEXPENSIVE TEMPERATURE CONTROLLER FOR AN INFANT INCUBATOR | Incubator, adt7410 digital temperature sensor and pic18f8720 microcontroller |
| | TEMPERATURE DETECTOR FOR PREMATURE INFANT INCUBATOR USING AVR MICROCONTROLLER | Incubator, sensor lm35, at mega 32 |
| | PIC MICROCONTROLLER BASED BABY INCUBATOR USING SENSORS | Microcontroller, temperature sensor, humidity sensor |
| | FPGA-BASED TEMPERATURE MONITORING AND CONTROL SYSTEM FOR INFANT INCUBATOR | Temperature sensor, field programmable gate array, temperature measurement, infant incubator, control system. |
| | NOVEL TECHNIQUE TO CONTROL THE PREMATURE INFANT INCUBATOR SYSTEM USING ANN | (36°c-38°c) for temperature, (70%-75%) for humidity |
| *Sound* | SOUND ENVIRONMENTS SURROUNDING PRETERM INFANTS WITHIN AN OCCUPIED CLOSED INCUBATOR | Noise level effects neonates. |
| | NOISE CHARACTERISTICS IN THE BABY COMPARTMENT OF INCUBATORS | The noise is especially loud in the baby compartment, and its intensity appears influenced by other sound sources in the rooms. |

| | | |
|---|---|---|
| | NOISE LEVELS IN INFANT INCUBATORS (ADVERSE EFFECTS?) | The sound measuring instrument was a br#{252}eland kjaer sound level meter, |
| | NOISE LEVEL IN NEONATAL INCUBATORS: A COMPARATIVE STUDY OF THREE MODELS | Noise levels, incubators, neonates. |
| | SOUNDTRANSMISSIONINTOINCUBATORSINTHENEONATALINTENSIVE CAREUNIT | Attenuation of sound by modern incubators. |
| | INCUBATOR NOISE AND VIBRATION - POSSIBLE IATROGENIC INFLUENCE ON NEONATE | Identify and measure the levels of excessive noise and vibration present in children incubators |
| | WIRELESS COMMUNICATION INTEGRATED HYBRID ANC SYSTEM WITH IMPULSIVE NOISE CANCELLATION CAPABILITY FOR INFANT INCUBATOR | Noise influences on infants |
| *Oxygen* | NOVEL TECHNIQUE TO CONTROL THE PREMATURE INFANT INCUBATOR SYSTEM USING ANN | (25%-60%) for oxygen concentration |

| | | |
|---|---|---|
| | DESIGN AND DEVELOPMENT OF AN INFANT INCUBATOR FOR CONTROLLING MULTIPLE PARAMETERS | Incubator, temperature, humidity, oxygen, light, led, microcontroller, pid controller. |
| | INCUBATOR WITH OXYGEN METERING | Fresh air delivering means providing a fresh gas flow to the incubator. |

# CHAPTER 3

# METHODOLOGY

## 3.1 RESEARCH

For this aspect that characterizes a good research methodology, indicate how the research approach fits with the general study, considering the literature review outline and format, and the following sections. The methods you choose should have a clear connection with the overall research approach and you need to explain the reasons for choosing the research techniques in your study, and how they help you towards understanding your study's purpose. A common limitation of academic articles found in research papers is that the premises of the methodology are not backed by reasons on how they help achieve the aims of the article.

## 3.2 OBSERVATION

Observation, as the name implies, is a way of collecting data through observing. Observation data collection method is classified as a participatory study, because the researcher has to immerse herself in the setting where her respondents are, while taking notes and/or recording. Observation as a data collection method can be structured or unstructured. In structured or systematic observation, data collection is conducted using specific variables and according to a pre-defined schedule. Unstructured observation, on the other hand, is conducted in an open and free manner in a sense that there would be no pre-determined variables or objectives.

## 3.3 INTERNET

Online research methods (ORMs) are ways in which researchers can collect data via the internet. They are also referred to as Internet research, Internet science or iScience, or Web-based methods. Many of these online research methods are related to existing research methodologies but re-invent and re-imagine them in the light of new technologies and conditions associated with the internet. The field is relatively new and evolving. With the growth of social medias a new level of complexity and opportunity has been created. Inclusion of social media research can provide unique insights into consumer and societal segments and gaining an "emotional" measure of a population on issues of interest.

## 3.4 DESIGN

Design methods are procedures, techniques, aids, or tools for designing. They offer a number of different kinds of activities that a designer might use within an overall design process. Conventional procedures of design, such as drawing, can be regarded as design methods, but since the 1950s new procedures have been developed that are more usually grouped together under the name of "design methods". What design methods have in common is that they "are attempts to make public the hitherto private thinking of designers; to externalize the design process". Research design can be thought of as the logic or master plan of a research that throws light on how the study is to be conducted. It shows how all of the major parts of the research study– the samples or groups, measures, treatments or programs, and work together in an attempt to address the research questions.

## 3.5 PROJECT MILESTONE

TABLE 3.1 : Gantt Chart of Overall Semester

| Activities | 2018 | | | | | 2019 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
| Topic Selection / Project Briefing | | | | | | | | | |
| Proposal | | | | | | | | | |
| Block Diagram Development | | | | | | | | | |
| Circuit Designing | | | | | | | | | |
| Software/ Hardware Development | | | | | | | | | |
| Testing | | | | | | | | | |
| Final Report | | | | | | | | | |

### 3.6. SYSTEM

A proper firmware is programmed for temperature, humidity, noise and oxygen sensors. The measured data will be transmitted, processed by microprocessor, uploaded into Arduino Uno and the result will be displayed on the LCD screen. During measurements, the sensor has taken a measurement per minutes. In order to ensure the values shown on the display do not change too much, the average values of each of the ten readings of the sensor are taken.

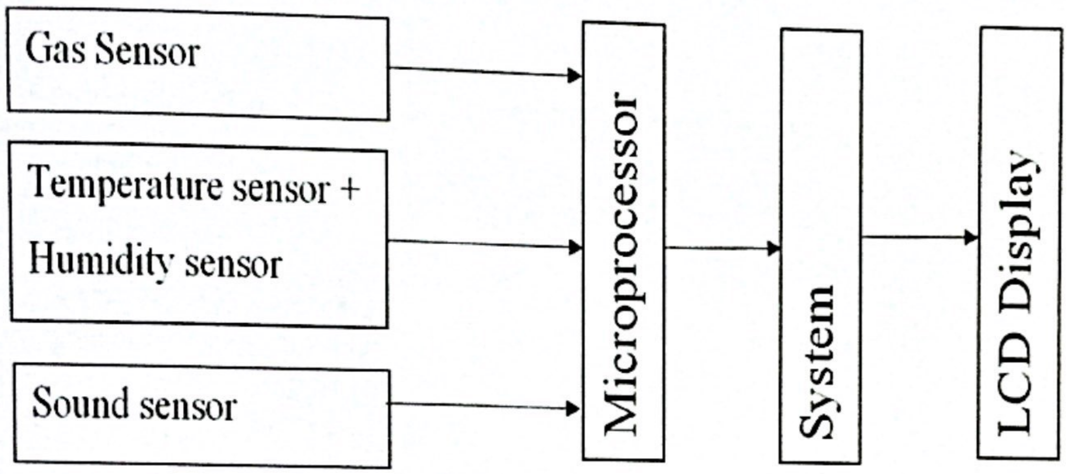


**Figure 3.1 : System Of The Project**

### 3.7 HARDWARE

There are some component has been used in order to built the tester.

### 3.7.1 DHT11 SENSOR

The DHT11 is a temperature and humidity sensor. The sensor comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data. The sensor is also factory calibrated and hence easy to interface with other microcontrollers. The sensor measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of ±1°C and ±1%.

DHT11 is a Humidity and Temperature Sensor, which generates calibrated digital output. DHT11 interface with any microcontroller like Arduino, Raspberry Pi, etc. And get instantaneous results. DHT11 is a low cost humidity and temperature sensor which provides high reliability and long term stability. This digital signal can be read by any microcontroller or microprocessor for further analysis.

- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3ma (measuring) 60ua (standby)
- Output: Serial data
- Temperature Range: 0°C to 50°C
- Humidity Range: 20% to 90%
- Resolution: Temperature and Humidity both are 16-bit
- Accuracy: ±1°C and ±1%

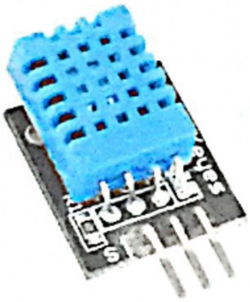

**Figure 3.2 : Temperature Sensor**

### 3.7.2 KY-SOUND SENSOR MODULE

The sensor has 3 main components on its circuit board. First, the sensor unit at the front of the module which measures the area physically and sends an analog signal to the second unit, the amplifier. The amplifier amplifies the signal, according to the resistant value of the potentiometer, and sends the signal to the analog output of the module. The third component is a comparator which switches the digital out and the LED if the signal falls under a specific value. The sensitivity is controlled by adjusting the potentiometer.

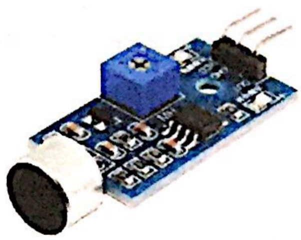

**Figure 3.3 : Sound Sensor Module**

### 3.7.3 MQ-135 SENSOR

The incubator will have continuous supply of oxygen and other supporting gases. There may be presence of some toxic gases which may cause threat to the life of neonates. Hence, the gas sensor are used to measure the presence of gases. In the proposed system the MQ135 gas sensor is used. This sensor used in air quality control equipment. MQ-135 gas sensor applies SnO2 which has a higher resistance in the clear air as a gas-sensing material. When there is an increase in polluting gases, the resistance of the gas sensor decreases along with that.

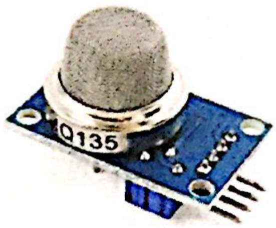


**Figure 3.4 : MQ135 Gas Sensor**

### 3.7.4 LIQUID-CRYSTAL DISPLAY (LCD) SCREEN DISPLAY

LCD(liquid crystal display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment leds. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this lcd each character is displayed in 5x7 pixel matrix.

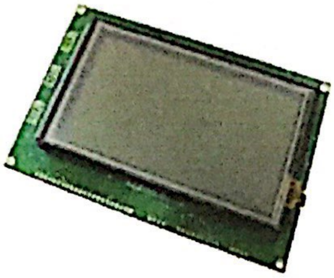

**Figure 3.5 : LCD Screen Display**

### 3.7.5 DATA LOGGER

A data logger (also data recorder) is an electronic device that records data over time or in relation to location either with a built in instrument or sensor or via external instruments and sensors. Increasingly, but not entirely, they are based on a digital processor (or computer). There is a SD card used along with the data logger.

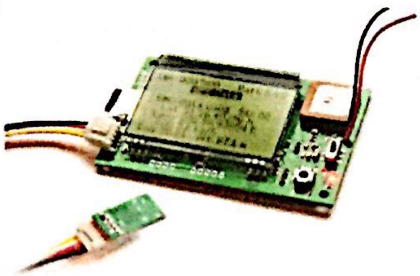

**Figure 3.6 : Data Logger**

### 3.7.6 BUZZER

A buzzer or beeper is an audio signalling device, which may be mechanical, electromechanical, or piezoelectric (piezo for short). Typical uses of buzzers and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke.

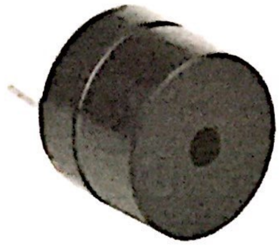

**Figure 3.7 : Buzzer**

### 3.7.7 LED

Light emitting diodes, commonly called LEDs, are real unsung heroes in the electronics world. LEDs were often used as indicator lamps, replacing small incandescent bulbs, and in seven-segment displays.

### 3.7.8 SWITCH

ON-OFF switch has been used for the tester. The power switch has two symbols on the face: "O" and "-". It is International Symbol for power "On" and power "Off". "O" means power is OFF and "-" means the power is ON. The on-off switch has a set of contacts,double pole and a switching position which conducts,single throw. It will switch live and neutral connections.

### 3.7.9 BATTERY

A lithium-ion battery is used along with additional buck converter circuit. The battery has two stages. First process is constant current charging. The charger will apply a steady current of electricity to battery  to get all electrons back to anode. The charger will decide how much power is coming out from firehouse and starts spraying. The higher the constant current, the faster the battery can charge. When the battery is charged 70%, the procedure will change to constant voltage charging. Once it reach 100%, the charge simple trickles in,just enough to account for the tiny bit of charge the battery loses naturally over time.

### 3.7.10 ARDUINO UNO

The Arduino Uno board is a microcontroller based on the ATmega328. It has 14 digital input/output pins in which 6 can be used as PWM outputs, a 16 MHz ceramic resonator, an ICSP header, a USB connection, 6 analog inputs, a power jack and a reset button.

## 3.8 SOFTWARE

Arduino Uno programming is used for programmed to firmware. The Arduino integrated development environment (IDE) is a cross-platform application written in Java, and derives from the IDE for the Processing programming language. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the boar Along with that, Proteus 7.2 is used for circuit simulation. The Proteus is a proprietary software tool suite used primarily for electronic design automation.

## 3.9 SCHEMATIC DIAGRAM

A schematic diagram is represents the components of a process, device, or other object using abstract, often standardized symbols and lines. Schematic diagram has been designed using Proteus software. The existing components are selected and their schematic view is modified. By using the 2D graphics mode, various blocks can be that are useful for presenting the prototypes. By using this simulation feature, the systems is developed within the software and all the features of the system were tested under design without using any hardware components. The system can be standardized by comparing the performance of various components.

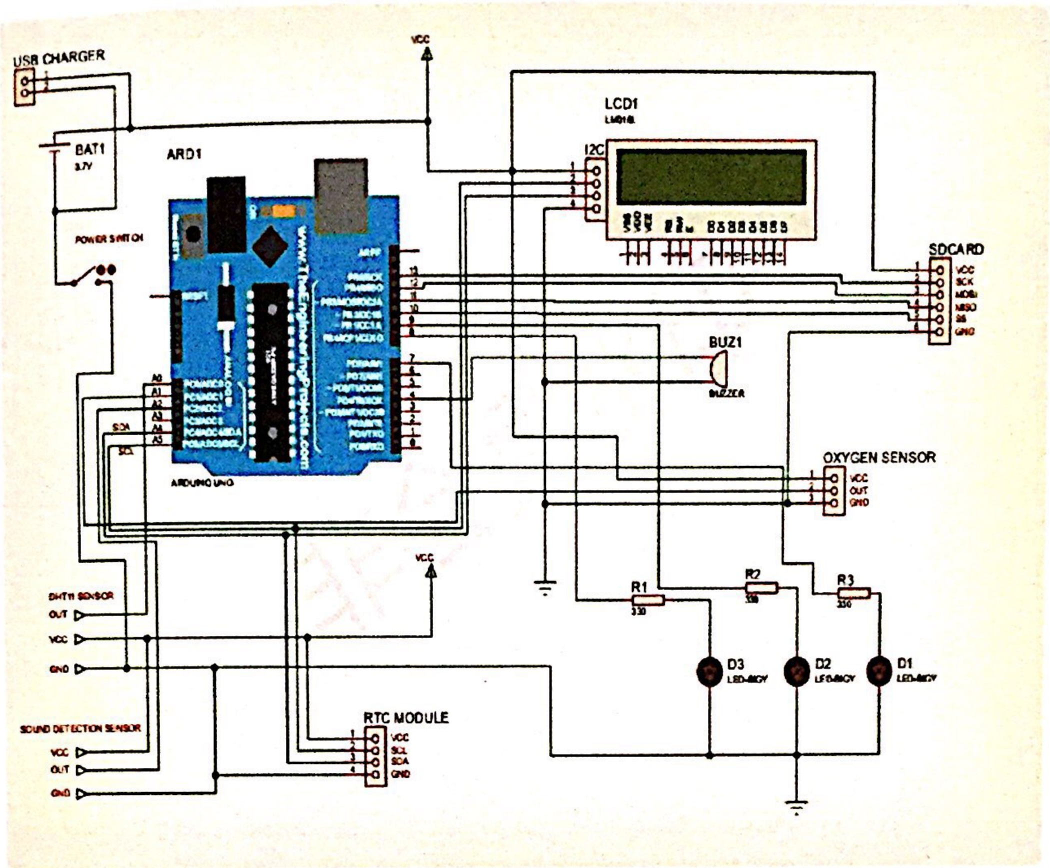


**Figure 3.8 : Schematic Diagram Of The Tester**

## 3.10 FLOWCHART

Flowchart is a step of conduction the project. It include how the system is working. The tester consists of battery circuit, data logger, a microcontroller, a liquid crystal display (LCD) screen, temperature sensor, humidity sensor, gas sensor and sound sensor. The DHT-11 temperature - humidity sensor was used to measure the temperature and humidity in the incubator. Humidity measurement performed within the scope of the project carried out between 30% and 95%. The MQ135 oxygen sensor was used to measure the amount of gas concentration in the incubator. A KY-sound module sensor is used to measure the noise level. A microcontroller is component that combines all the units that must be in a computer system into a single integrated circuit. As a microcontroller, Arduino Uno has been preferred because of the possibility to produce electronic solutions with a single microcontroller. It store the program in it and to work when required. Serial Peripheral Interface (SPI) communication is used in LCD - Ardunio communication.

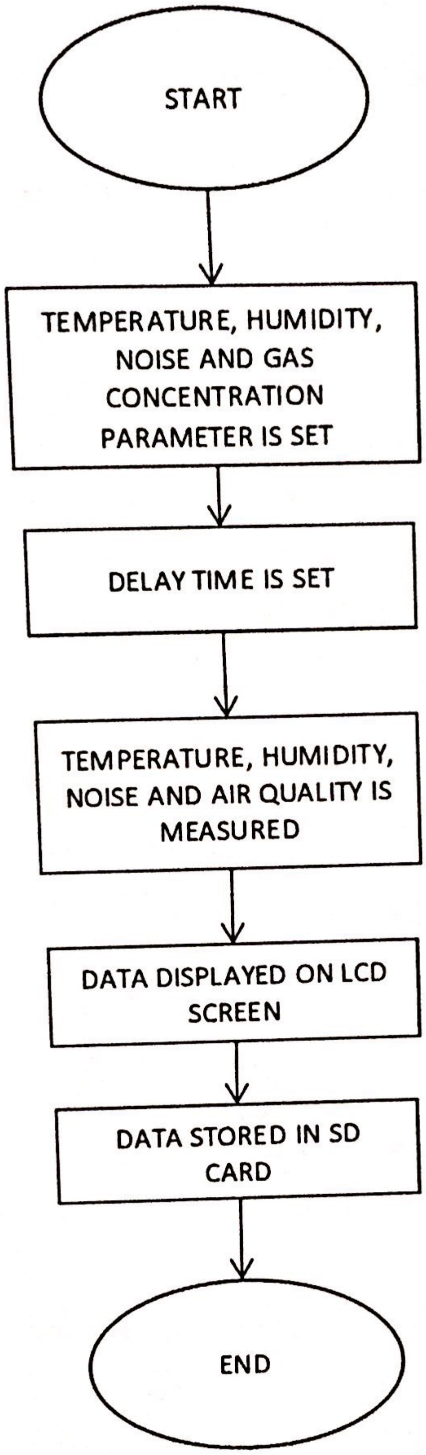


**Figure 3.10 : System Flow Chart**

### 3.11 PROJECT DEVELOPMENT

This part contain the information on how the project has been developed.

#### 3.11.1 HARDWARE CONNECTION

A proper firmware is programmed for temperature, humidity, noise and oxygen sensors. The measured data will be transmitted, processed into Arduino Uno and the result will be displayed on the LCD screen. During measurements, the sensor has taken a measurement per minutes. In order to ensure the values shown on the display do not change too much, the average values are taken. The sensor accuracy was also checked by compare incubator values and the tester value to standards, as a result the values were found to be appropriate. The measured data will be saved in the SD card.

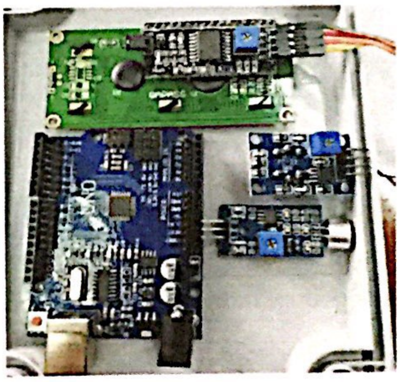

**Figure 3.11 : Components Of The Tester**

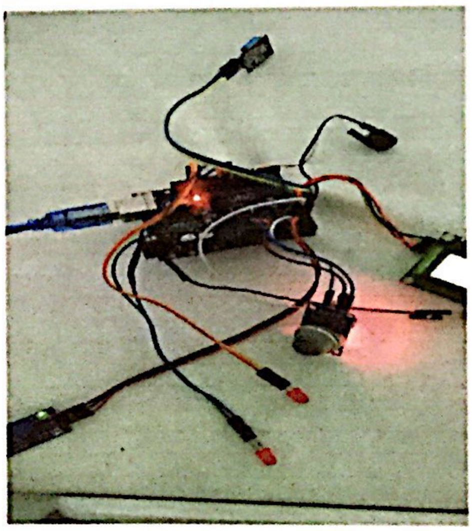

**Figure 3.12 : Circuit Connection**

### 3.11.2 CODING DEVELOPMENT

The firmware had been programmed using Arduino software. The coding compiling process id one before upload to the Arduino.

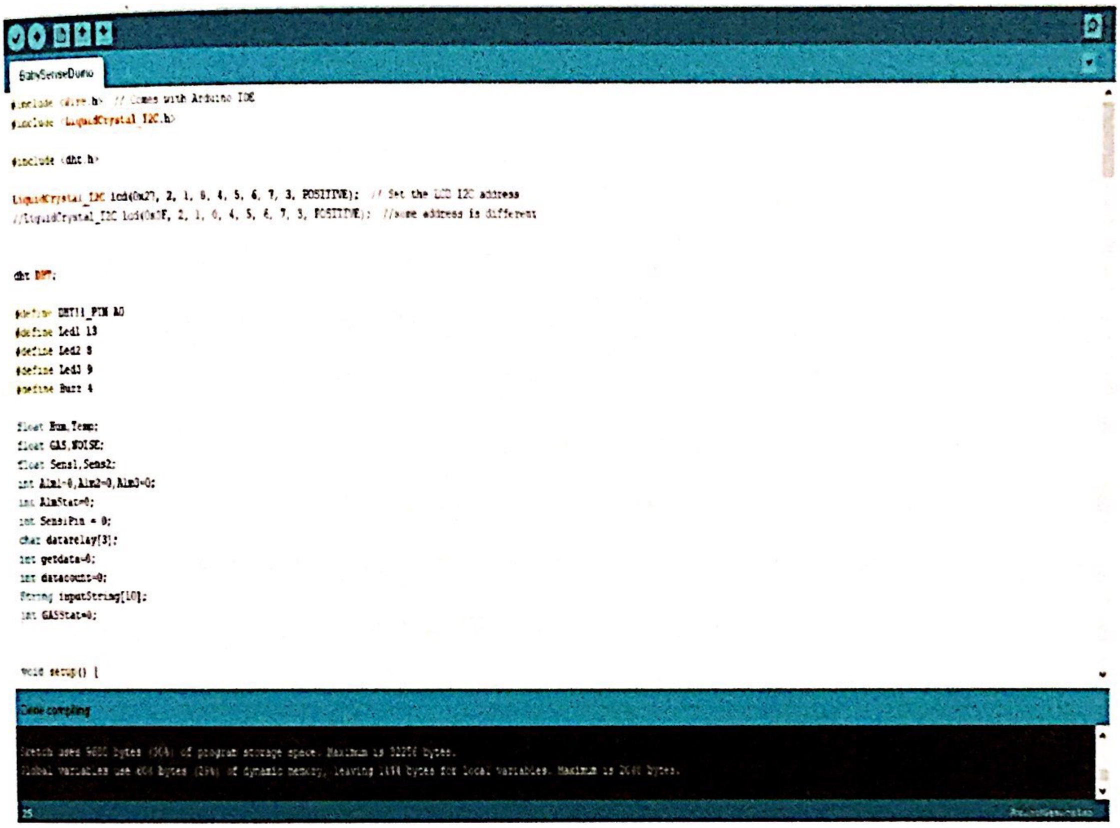

**Figure 3.13 : Coding Compiling Process**

## 3.12 MECHANICAL DESIGN

Mechanical design is to design elements, components, products, or systems of mechanical nature. Various criteria are planned in mechanical style processes, Some primary criterion embrace functions, safety, dependability, manufacturability, weight, size, wear, maintenance, and liability. In general, a mechanical design drawback ought to be developed with clear and complete statements of functions, specifications, and analysis criteria. The casing of the tester has been designed in 3D software and primted by 3D printer.The 3D design is based on the system size. The tester is designed by own creativity.

### 3.12.1 3D DESIGN

A. Design Sketching

For the sketching, we had used SOLIDWORKS software to design the tester in 3D. SOLIDWORKS simulation is an efficient analytical tool that allows the designer to visualize product behaviors under different operating situations and conditions. Simulation makes it possible to test designs in real time and under a number of different circumstances [19].

B. Cura-Printing Software

Cura is associate open supply 3D printer slicing application. Cura permits to remodel the STL file that represent the form of the half in g-codes which might be browse by the 3D printer. More precisely, the g-code is download on a SD card and then this SD card will be connected to the 3D printer to transfer the g-code to the 3D printer [20]. Cura also permits to configure some parameters, for examples the material used, the layer height, the infill, the heating temperature et cetera.

C. 3D Printer

Creality CR-10 printer has been used for the printing. CR-10 comes nearly assembled. Other kit printers take a couple of hours to complete from scratch, whereas the CR-10 takes only a few minutes. Second, it has a huge printing volume of 300mm x 300mm x 400mm. The printer came with plenty of stuff, lots of tools, usable spool of good quality PLA filament, roll of masking tape for bed adhesion, instructions, SD card and USB card reader, spare PTFE tube [20].

D. Polylactic Corrosive (PLA)

The materials used for 3D printing is Polylactic corrosive (PLA). It is a bioresorbable polymer that is utilized in various clinical circumstances [20]. Complex states of PLA are ordinarily machined for bone obsession and recreation. Strong free structure manufacture strategies, for example, 3D printing, can create complex-formed articles legitimately from a CAD show.

PLA is generally less susceptible to part warping than consumer or pro-sumer ABS machines and can be printed successfully on blue painter's tape. If it is actively cooled then parts are likely to have a nice sharp finish (less rounded corners without the risk of warping or cracking). PLA is a great choice for hobby shops or small production projects where high levels of detail are desired in the part [21].

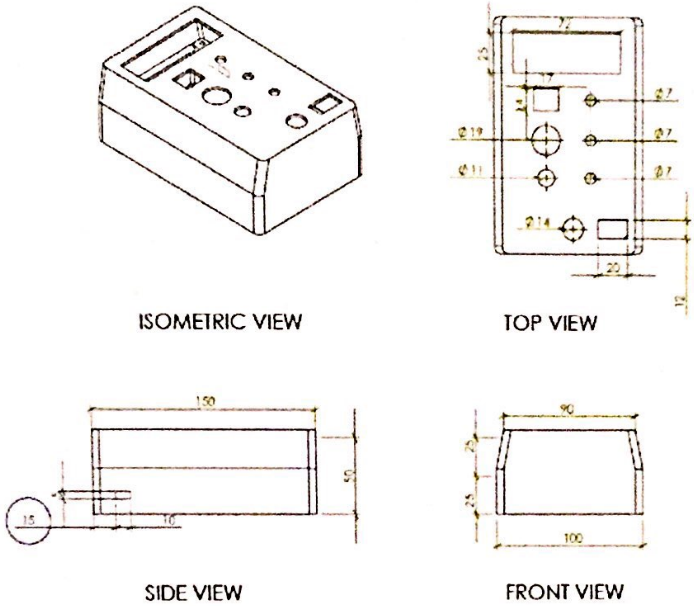


**Figure 3.14 : Isometric View Of The Tester**

**Figure 3.15 : Inside Plate Of The Tester**

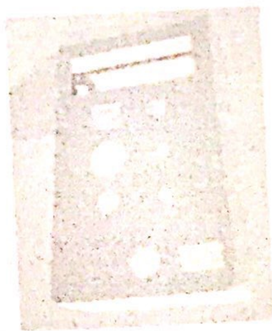

**Figure 3.16 : Main Body Of The Tester**

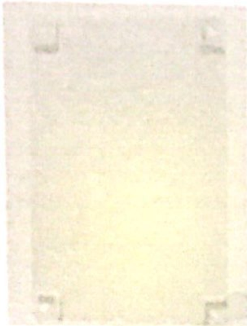

**Figure 3.17 : Back Plate Of The Tester**

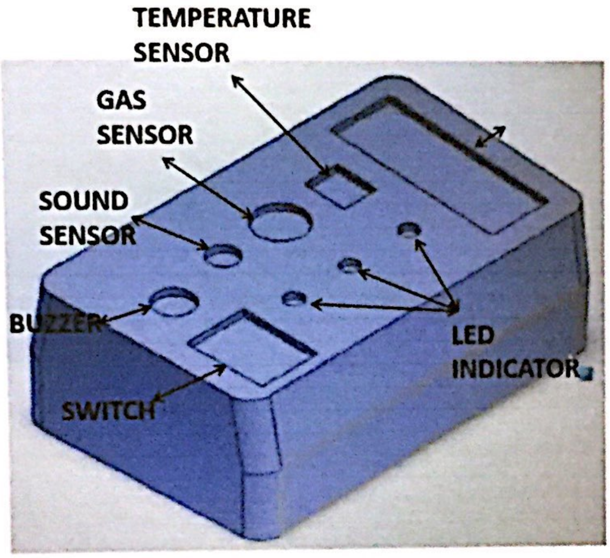


**Figure 3.18 : Complete Sketching Of The Hardware**

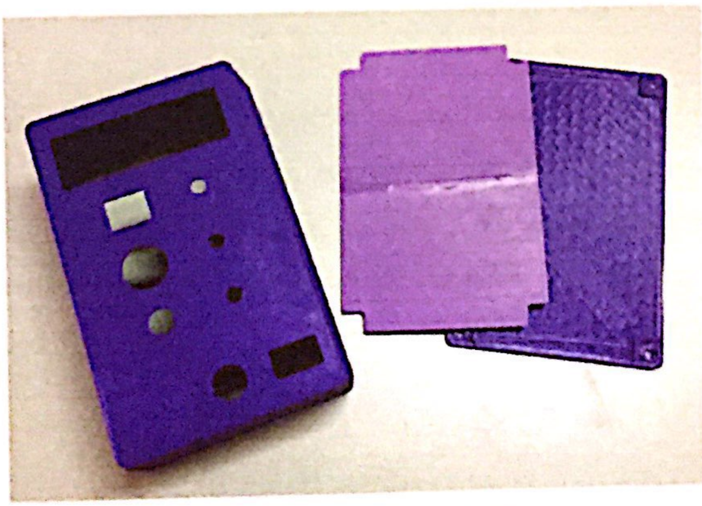

**Figure 3.19 : 3D Printed Tester**

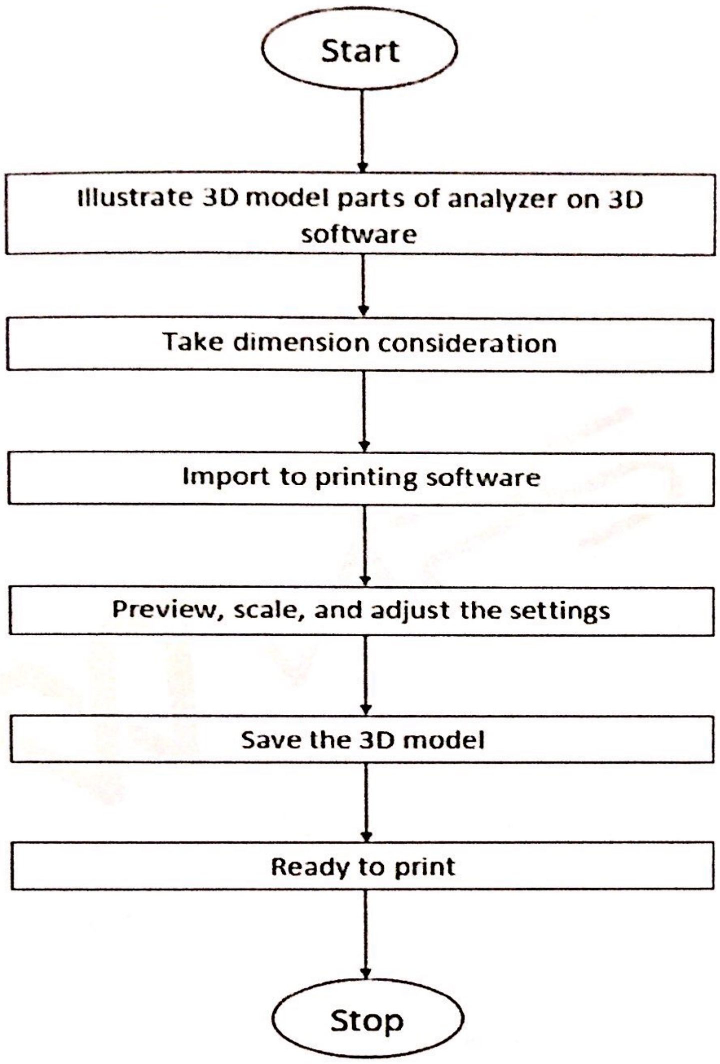


**Figure 3.20 : Flowchart Of Printing Progress**

After all the parts were 3D printed, some of the parts were not accurate enough. Small parts that were meant to fit together, simply did not fit. This was solved by using another additional layer that attached on the hole. So that the dimension had corrected n components will be fit in. This gave better results. The second layer uses light purple plastic parts.

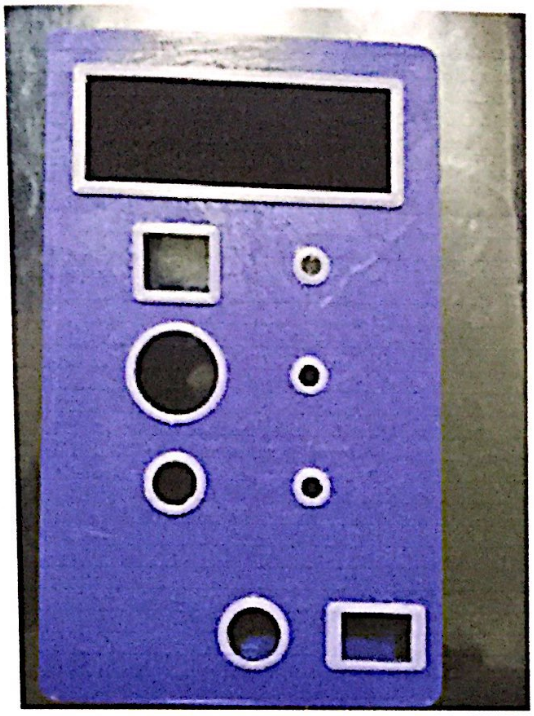

**Figure 3.21 : New Inserted Layer**

Once all the parts were printed with satisfying quality, the printing process were done.

## 3.13 QUESTIONNAIRE (SURVEY)

Questionnaire is the one of the part to verify the product. A survey form of questionnaire given to the biomedical team of Hospital Sungai Buloh after the testing procedure is done.

(Refer to the attachment)

## 3.14 COST

Total project cost is made to authorize the project's budgets and its costs. It is important that the action taken must keep the budget on track. The total cost for developing the portable tester is RM197.00. The cost is lower than the cost of actual device in the market.

TABLE 3.2 : Costing Of The Project

| COMPONENTS | COST |
|---|---|
| ARDUINO UNO BOARD | RM25 |
| LCD DISPLAY | RM15 |
| I2C MODULE | RM10 |
| BUZZER | RM3 |
| DHT11 | RM15 |
| KY- SOUND SENSOR (2 MODULE ) | RM15*2= RM30 |
| MQ135 | RM30 |
| LED (4PCS) | RM1*4 = RM4 |
| WIRE PAIR (MALE TO MALE) | RM5 |
| WIRE PAIR (FEMALE TO FEMALE) | RM5 |
| BATTERY ADAPTER | RM25 |
| DATA LOGGER | RM15 |
| SC CARD | RM15 |
| TOTAL | RM 197.00 |

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 THE RESEARCH DESIGN

A researcher emphasizes on the importance of developing a good research design and they showed how to achieve the research objectives [22]. The importance of research design in improving empirical research and theory building in organization studies [23]. An appropriate research design would facilitate a robust research process and ensure that all the research questionnaires and data are answered / addressed by the research findings.

## 4.2 COMPONENT TESTING

The components of the incubator tester is checked before it is tested under the incubator. Temperature sensor, humidity sensor, sound sensor and gas sensor is the component that were tested.

### 4.2.1 CONTINUITY TESTING

A continuity test is the checking an electric circuit to see if current flows. The test is performed by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path. A digital multimeter emits an audible response (a beep) when it detects a complete path. So, the main component which are the sensors were tested. The results of testing the components is shown in table below.

TABLE 4.1: Components Continuity Testing Result

| COMPONENTS | MEASURED VALUE(Ω) |
|---|---|
| DHT11 SENSOR | 039 |
| SOUND SENSOR | 858 |
| MQ135 SENSOR | 048 |

### 4.2.2 TECHNICAL TESTING

Technical testing is conducted to check whether the sensor is working in a good condition or not. Each sensor is tested in different condition. Temperature sensor is checked under hot and cold environment. Humidity sensor also checked under same hot and cold environment. Sound sensor is checked under high noise attenuation. Gas sensor is checked in high concentration of carbon dioxide. Figures below shows the testing result which is represented in graph form.

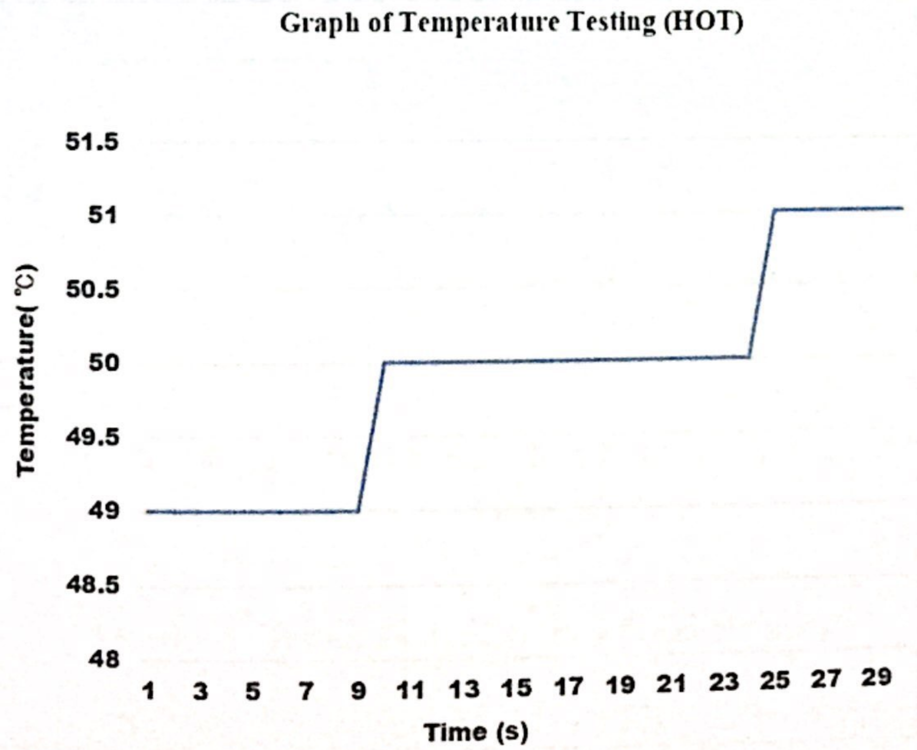


**Figure 4.1 : Testing Of Temperature Sensor(HOT)**

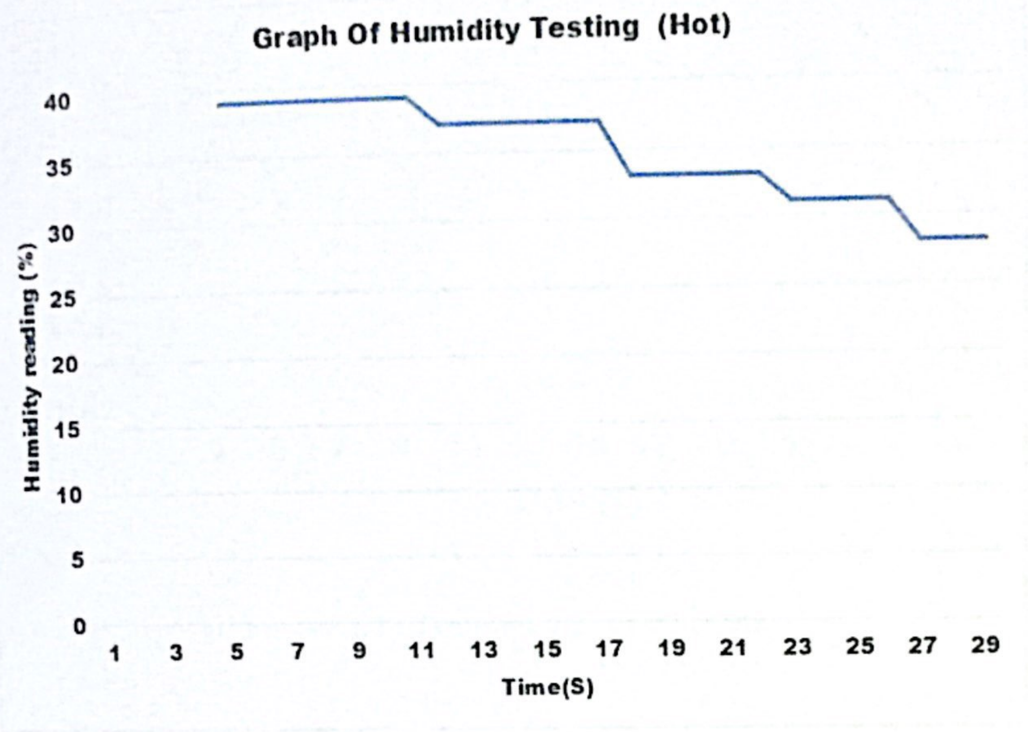


**Figure 4.2 : Testing Of Humidity Sensor(HOT)**

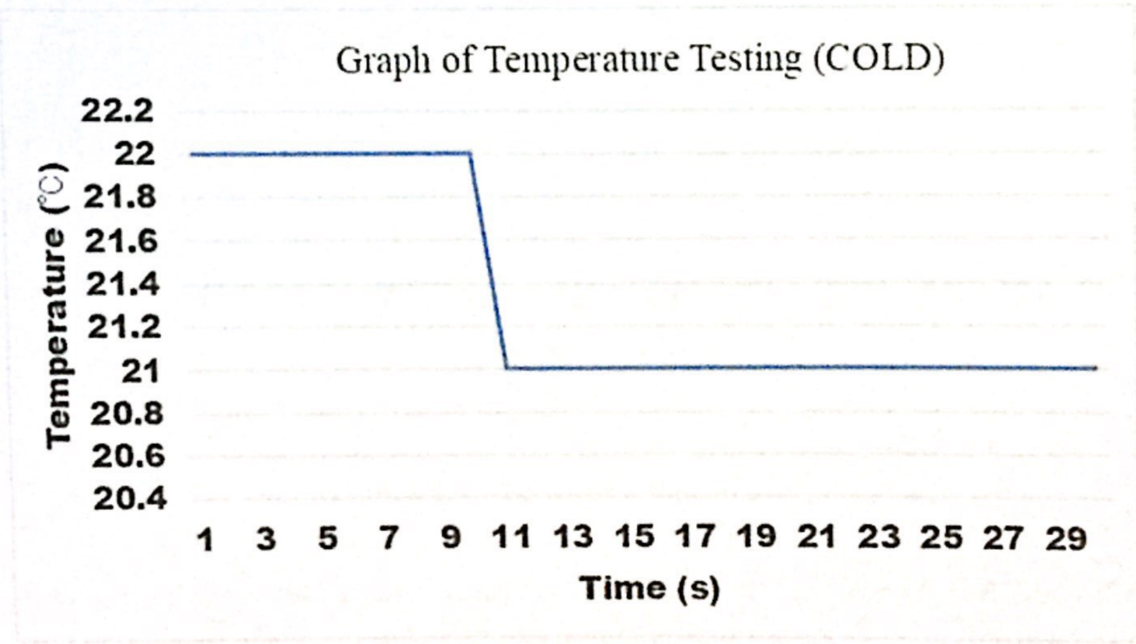


**Figure 4.3 : Testing Of Temperature Sensor(COLD)**

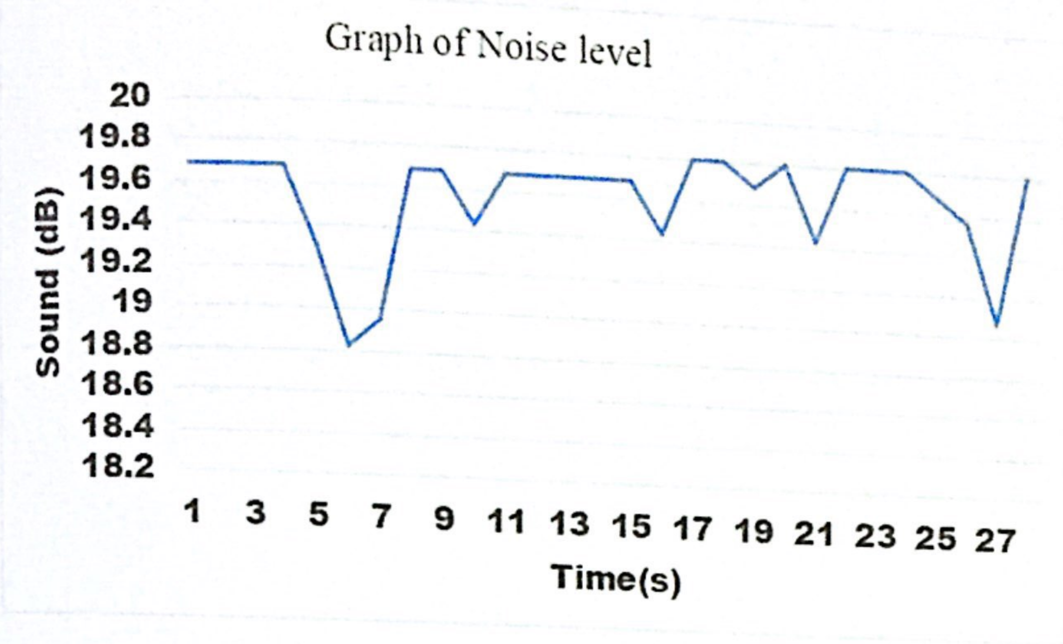


**Figure 4.4 : Testing Of Sound Sensor**

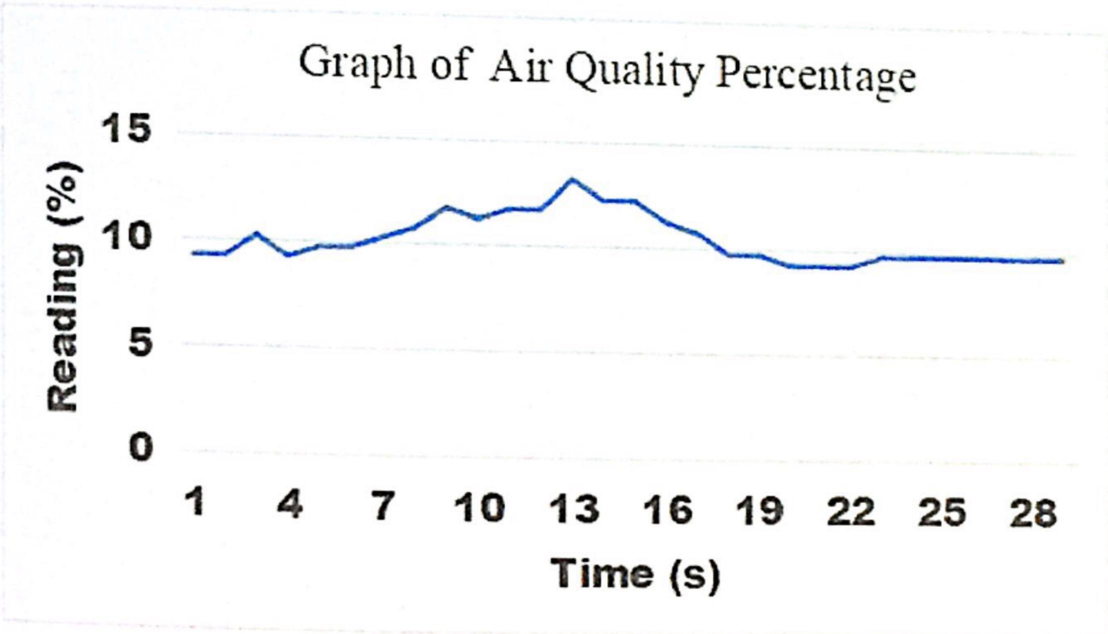


**Figure 4.5 : Testing Of Gas Sensor**

After getting the values from various sensors, the graph has been plotted.When the condition is hot, the temperature is increases but the humidity is decreases. When cold, the temperature is decreases with humidity. But humidity is not as low as in hot condition. When the environment is silent, the reading is low and only increase if there is any sound. When there is more CO2, the reading will increase n decrease when CO2 is low.

## 4.3 EXPERIMENTAL TESTING

The analysis of the results obtained by the tester is presented. The results are related to the testing performance of the parameter inside the incubator.First testing is done inside a incubator. The reading is taken only for 1 minute.

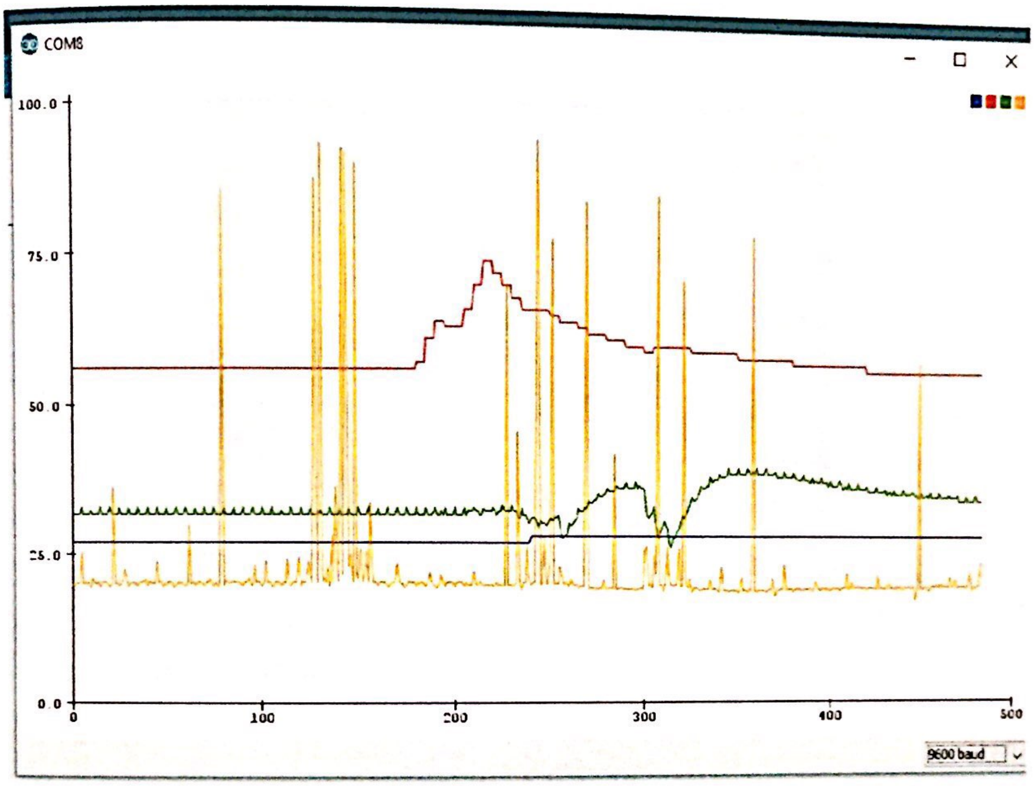


**Figure 4.6 : Result of Testing Inside the Baby Incubator**

Blue line indicates temperature, red line indicates humidity, green line indicates gas and orange line indicates noise. Inside the incubator,temperature is constant at 27°C and had a light increase to 28°C when there is changes in gas reading. The humidity(60°C) also increased when there is a change in gas reading. Air quality reading has increased when more carbon dioxide is applied in incubator. The noise reading is based on the how much noise is inside the incubator. The higher the noise level inside the incubator, the higher the reading.


**Figure 4.7 : LCD Display**

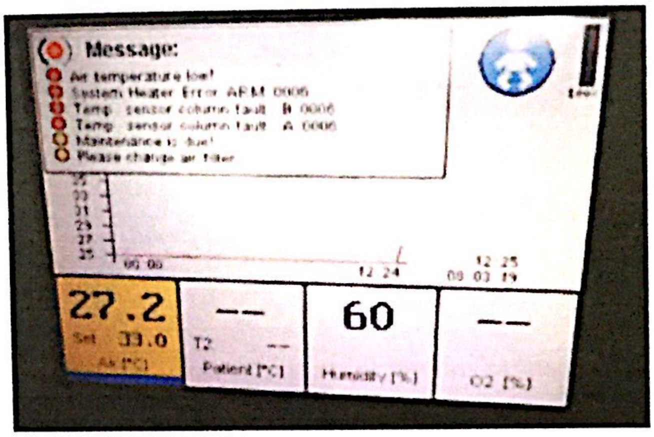


**Figure 4.8 : Display on Incubator Screen Monitor**

### 4.4 FIRST LAB TESTING

Lab testing is conducted in a real incubator. The testing has been done in Neonatal Unit of Hospital Sungai Buloh.

### 4.4.1 TEMPERATURE TESTING:

For working with this Temperature sensor we use Arduino Library (Fig9.) by using DALLAS Temperature reads 1 wire library which is used for communicating with the sensor similar to I2C Protocol. The incubator temperature is set to 35°C. The air temperature shows reading of 27.5°C. The humidity is set to 80%. The readings displayed is 59%.

TABLE 4.2 : Temperature Testing Result

| Time (mins) | Incubator reading (°C) | Tester reading °C |
|---|---|---|
| 2 | 28.5 | 28 |
| 4 | 29.5 | 29 |
| 6 | 30.5 | 30 |
| 10 | 31.5 | 31 |
| 12 | 32.5 | 32 |
| 14 | 33.5 | 33 |
| 16 | 34.5 | 34 |
| 16m and 30s | 35 | 35 |

The time interval taken for temperature in inside to increase is 2 minutes. The incubator temperature and the tester temperature shows exact reading 16 minutes and 30 seconds. The results obtained were within the ranges specified in the standards. Thee incubator temperature is set to 35°C. the air temperature shows reading of 27.5°C. the humidity is set to 80%. the readings displayed is 59%.

### 4.4.2 HUMIDITY TESTING

The humidity in incubator is set to 70%. Humidity can be increased or decreased by using water content in the air. In high signal quality, a fast response time and insensitivity to external disturbances(EMC). Each SHT11 is individually calibrated and calibration coefficients are programmed into the OTP memory. The 2-wire serial interface and internal voltage regulation allow easy and fast system integration.

TABLE 4.3 : Humidity Testing Result

| Time (mins) | Incubator humidity (%) | Tester Humidity (%) |
|---|---|---|
| 2 | 56 | 55 |
| 4 | 54 | 53 |
| 6 | 53 | 52 |
| 8 | 60 | 57 |
| 10 | 61 | 58 |
| 12 | 63 | 59 |
| 14 | 69 | 64 |
| 16 | 70 | 68 |

Within 16 minutes, the humidity is measured. The data shows that reading in incubator and tester is different by 2%.

### 4.4.3 NOISE AND GAS CONCENTRATION TESTING

The noise reading is taken along with gas concentration testing. The measured values indicate acoustical environments just a little louder in the NICU's than within the incubators. This reveals that one of the best ways to decrease the sound levels close to the infants must consider the reduction of sound levels in the NICU's.

TABLE 4.4 : Noise And Gas Concentration Testing Result.

| Time (Mins) | Noise Level (dB) | Gas Concentration (%) |
|---|---|---|
| 2 | 19.68 | 9.77 |
| 4 | 18.82 | 9.28 |
| 6 | 19.43 | 10.25 |
| 8 | 19.8 | 10.74 |
| 10 | 19.68 | 11.72 |
| 12 | 21.31 | 13.18 |
| 14 | 22.96 | 11.23 |
| 16 | 19.8 | 10.74 |

## 4.5 SECOND LAB TESTING

Second lab testing is did with biomedical team of Radibems in Hospital Sungai Buloh. Two type of testing is carried out. First, the casing of the tester is opened and reading of temperature and humidity is observed and recorded in order to check whether the sensor has environmental effect or not. Second testing is done with the the casing of the tester is closed, all the sensor reading was taken.

### 4.5.1 WITHOUT CASING

After the casing of the tester is opened, the reading of temperature and humidity is measured to analyze is the reading is accurate and the sensor sensitivity level is good or not, the temperature getting down is synchronously with incubator reading. Incubator temperature is set to 27.5°C. Temperature drop started at 35.0°C in incubator and 34°C in tester. Humidity in incubator is set of 40%. The initial humidity in incubator is 71% and in tester 74%.

TABLE 4.5 : Humidity And Temperature Reading

| Time | Incubator | | Tester | |
|---|---|---|---|---|
| (min) | °C | % | °C | % |
| 7 min | 34.0 | 71 | 34 | 71 |
| 8 min | 33.0 | 61 | 33 | 58 |
| 9 min | 32.0 | 56 | 32 | 53 |
| 13 min | 31.0 | 50 | 31 | 46 |
| Total time : 36 minutes | | | | |

### 4.5.2 WITH CASING

The incubator tester is tested inside the incubator. The readings of tester are presented in table and plotted in graph.

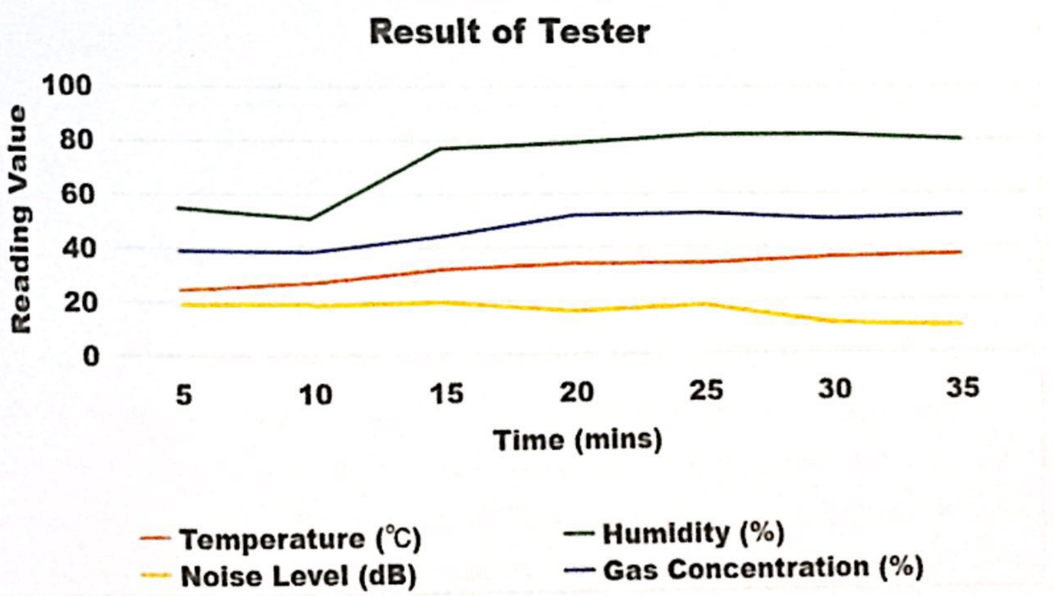


**Figure 4.9 : Result Of Incubator Tester**

TABLE 4.6 : Reading Measured By Tester

| Time (Mins) | Temperature (˚C) | Humidity (%) | Noise Level (dB) | Gas Concentration (%) |
|---|---|---|---|---|
| 5 | 24.5 | 55 | 19.1 | 39.1 |
| 10 | 27 | 51 | 18.7 | 38.6 |
| 15 | 32 | 77 | 19.7 | 44.4 |
| 20 | 34 | 79 | 16.3 | 52 |
| 25 | 34 | 82 | 18.3 | 52.7 |
| 30 | 36 | 82 | 11.2 | 50.3 |
| 35 | 37 | 80 | 10.0 | 51.8 |

## 4.6 SURVEY ANALYSIS

Survey data collection was carried out in three phases. There is open discussions with the Radibems team regarding the development of the incubator tester. The next phase to fill the questionnaire. Then, the questionnaire survey result is used to compare the usability of the tester in the final phase of the study. Biomedical team of hospital sungai buloh are the respondent who did the questionnaire. About 19 of them agreed with the innovation of the portable incubator tester. As the survey result is plotted, it shows that 78% of them thought that the incubator tester is helpful.

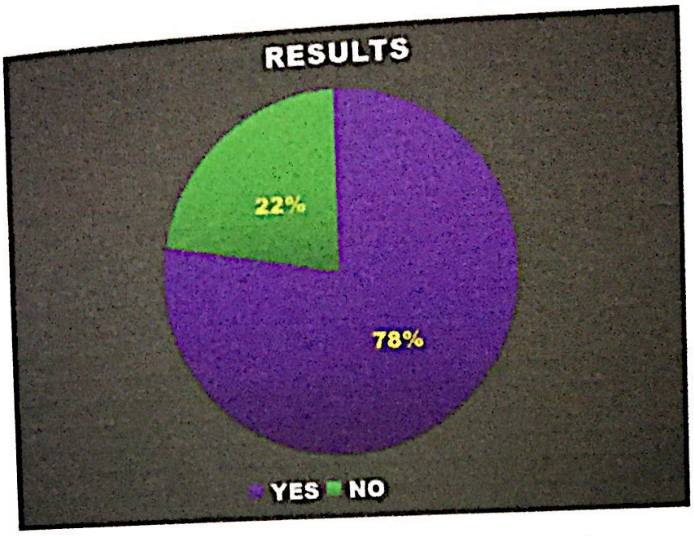


**Figure 4.10 : Result Of Questionnaire**

## 4.7 PORTABLE TESTER

The project has been developed into a device from a simple prototype. The device is named Portable Infant Incubator Tester based on its special features. It has multiparameter measurement which will sensed the temperature, humidity, noise and air quality. The tester had been viewed by biomedical team of Radibems from Hospital Sungai Buloh.

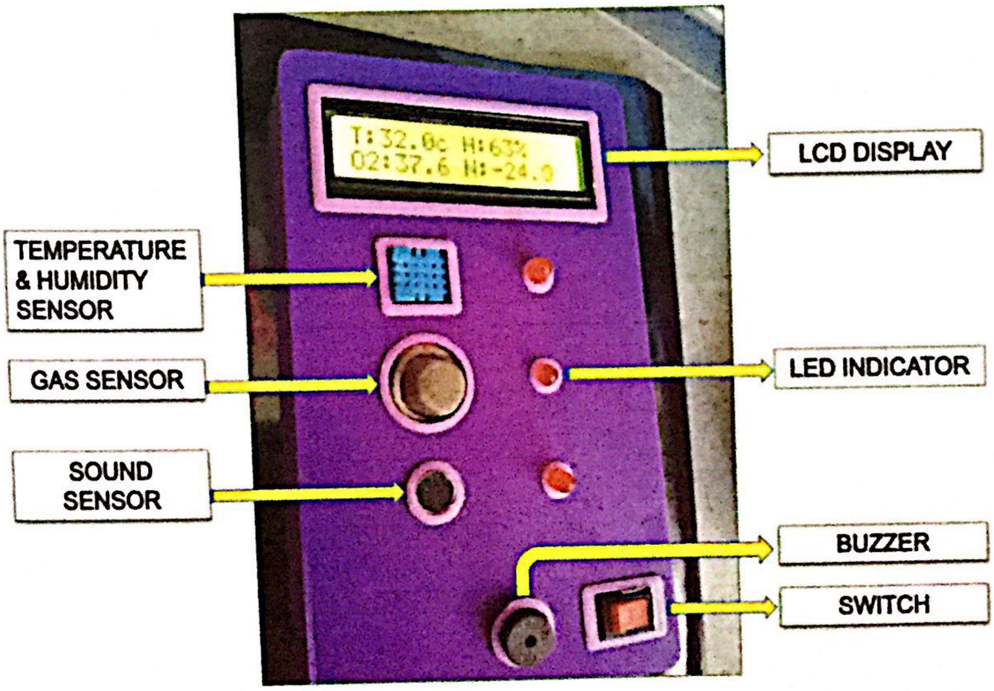


**Figure 4.11 : Portable Infant Incubator Tester**

**Figure 4.12 : Radibems Staff Setting Up Incubator**

**Figure 4.13 : Radibems Staff With Students**

## 4.8 RESULT SUMMARY

This project were designed, developed and tested. In order to ensure that the values shown on the display do not change too much, the average values of each of the ten readings of the sensor are taken and compared with the incubator readings. The sensor accuracy was also checked. From the data collection result, it can be concluded that the tester is performed well. The effectiveness of this innovation also had been identified. All the hypotheses were tested and the results clearly stated here. Next chapter gives the precise findings along with the conclusion.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 CONCLUSION

As conclusion, above figures are the evidence that project had been achieve the objective. This project determined that an incubator analyzer can be designed in form of incubator tester. By using more sensitive sensors, it can also satisfies the requirements of the standards. As a literature search, the incubator has been used in the field of medicine, the incubator calibration procedure, the investigation of the calibration standards, temperature, humidity,gas and sound sensor research were conducted.

Detailed investigation of the sensors was made and the technical characteristics of the sensors were examined. Within the scope of design, a proper firmware is programmed. In order to ensure the values shown on the display do not change too much, the average values of each of the ten readings of the sensor are taken.

The sensor accuracy was also checked by compare 3 values and the levels of acceptability were compared to standards, as a result the values were found to be appropriate. This project work has been planned by taking into account realistic constraints/conditions and the costs of the materials used are calculated. The casing of the tester is printed in 3D using PLA material. Its cost was reasonable as compared to expensive commercial incubators analyzer. In addition, the usability of the tester also has been compared with the incubator analyzer, tested in incubators and functioned properly.

The incubator tester are promising, especially in middle-income and low-income countries. The possibility of using the presented methodology, in the development of other prototypes analyzers of medical equipment, contributing to the production of national tester of good quality and low cost. The obtained test result shows that with more accurate sensors, this tester can be used as an incubator analyzer. The invention of the light-weight portable tester for neonatal incubator will help to reduce the burden of technician by bringing around the tester. It will also increase the efficiency of the staffs to perform better at workplace with user-friendly tester. These are the key driving factors for incubator tester market. The incubator tester can be used in baby incubator, transportable incubator and open infant warmers. This project can be a model for incubator analyzer.

## 5.2 RECOMMENDATION

In this part, there are some suggestion that can be made. Further researches shall be made so as the development of incubator tester can be developed to achieve the ideal product. The casing size of the tester can be made into smaller. Then, sensor should high accuracy I order to make the tester function efficiently. Beside that, interaction between sound sensor with buzzer should be reduced. The output of buzzer can be converted from sound to vibration. It is highly recommend that the future researchers to see further towards improving the whole process stage. In order to further improve the project in the future, the data from sensors will be sent via the internet to a laptop or mobile phone. This can help the technicians to save the time by using laptop or mobile phone to print the testing result directly.

# REFERENCES


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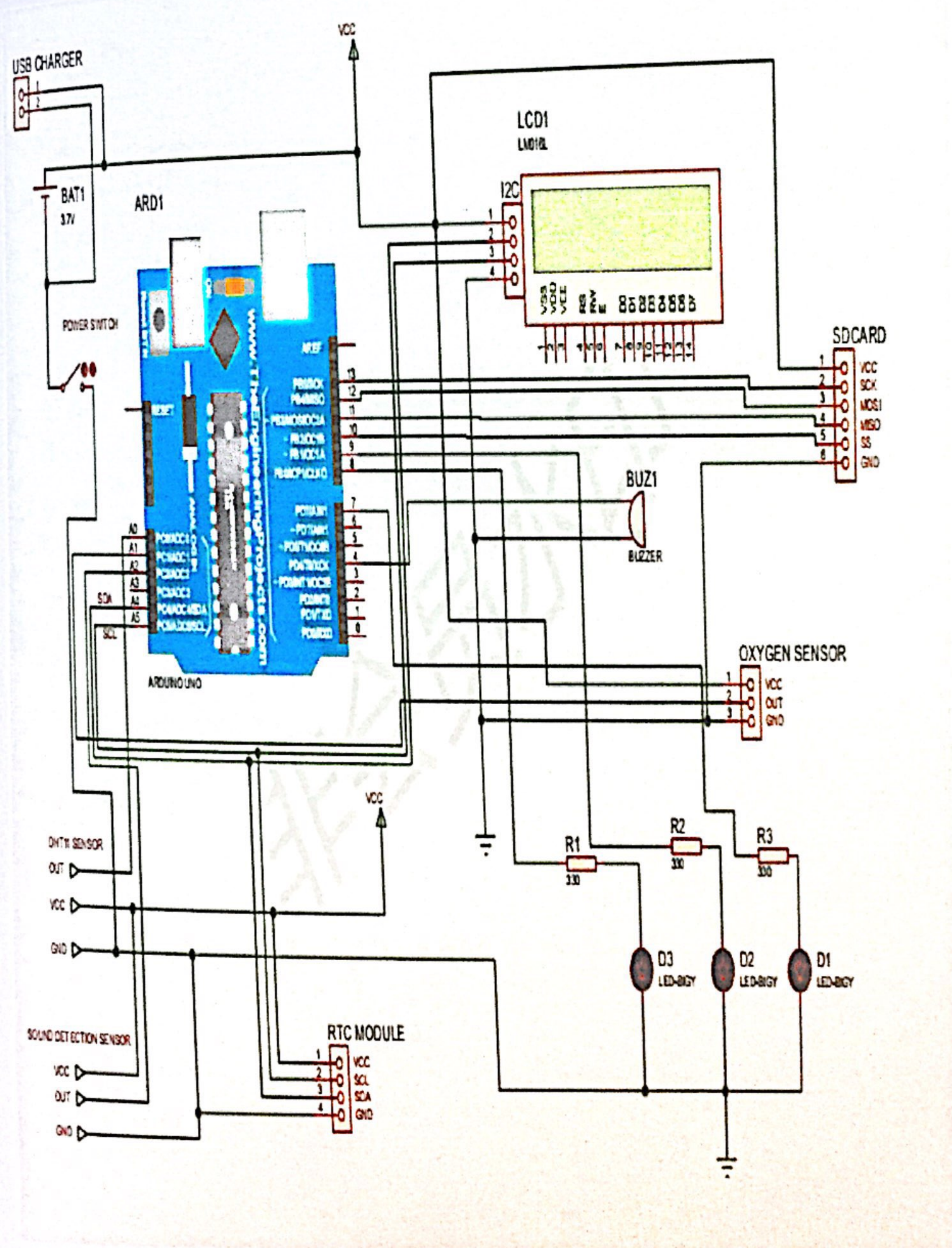
# APPENDIX A
# SCHEMATIC DIAGRAM



# APPENDIX B

# PROGRAMMING CODE

```
void setup()
{
  lcd.begin(16,2);
  lcd.print("Calibrating.....");
  Res = SensorCalibration();
  lcd.print("Calibration done.");
  lcd.setCursor(0,1);
  lcd.print("Res=");
  lcd.print(Res);
  lcd.print("kohm");
  delay(2000);
  lcd.clear();
  pinMode(buzzer, OUTPUT);
}
/*
  Temperature Sensor
  Reading temperature sensor.

// include the library code:
#include <LiquidCrystal.h>

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(7, 8, 9, 10, 11, 12);

//declare variables
float tempC;
float tempF;
int tempPin = 1;
```

```
  // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);
  lcd.print("Temp1=");
  lcd.setCursor(0, 1);
  lcd.print("Temp2=");
}

void loop(){
  tempC = analogRead(tempPin);                //read the value from the sensor
  tempC = (5.0 * tempC * 100.0)/1024.0;   //convert the analog data to temperature
  tempF = ((tempC*9)/5) + 32;                //convert celcius to farenheit

  // print result to lcd display
  lcd.setCursor(6, 0);
  lcd.print(tempC,1);
  lcd.print("'C");

  lcd.setCursor(6, 1);
  lcd.print(tempF,1);
  lcd.print("'F");

  // sleep...
  delay(1000);
}
/*
  Temperature Sensor
  Reading temperature with LM35 sensor.
*/
// include the library code:
#include <LiquidCrystal.h>

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(7, 8, 9, 10, 11, 12);
```

```
//declare variables
float tempC;
float tempF;
int tempPin = 1;

void setup(){
   // set up the LCD's number of columns and rows:
   lcd.begin(16, 2);
   lcd.print("Temp1=");
   lcd.setCursor(0, 1);
   lcd.print("Temp2=");
}

void loop(){
   tempC = analogRead(tempPin);              //read the value from the sensor
   tempC = (5.0 * tempC * 100.0)/1024.0;   //convert the analog data to temperature
   tempF = ((tempC*9)/5) + 32;               //convert celcius to farenheit


   // print result to lcd display
   lcd.setCursor(6, 0);
   lcd.print(tempC,1);
   lcd.print("'C");

   lcd.setCursor(6, 1);
   lcd.print(tempF,1);
   lcd.print("'F");

   // sleep...
   delay(1000);
}
```

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
#define buzzer 9
#define sensor A0
#define load_Res 10
#define air_factor 9.83

float SmokeCurve[3] ={2.3,0.53,-0.44};      // (x, y, slope) x,y coordinate of one point
and the slope between two points

float Res=0;
void setup()
{
  lcd.begin(16,2);
  lcd.print("Calibrating.....");
 Res=
 SensorCalibration();

   lcd.print("Calibration done.");
   lcd.setCursor(0,1);
   lcd.print("Res=");
   lcd.print(Res);
   lcd.print("kohm");
   delay(2000);
   lcd.clear();
   pinMode(buzzer, OUTPUT);
  }
  void loop()
  {
     lcd.setCursor(0,0);
     lcd.print("SMOKE:");
     float res=resistance(5,50);
     res/=Res;
     int result=pow(10,(((log(res)-SmokeCurve[1])/SmokeCurve[2]) + SmokeCurve[0]));
     lcd.print(result);
     lcd.print( " ppm          ");
     if(result>1000)
     {
         digitalWrite(buzzer, HIGH);
         delay(2000);
      }
      else
      digitalWrite(buzzer, LOW);
      delay(500);
   }
   float resistance(int samples, int interval)
   {
      int i;
```

```
float res=0;
for (i=0;i<samples;i++)
{
    int adc_value=analogRead(sensor);
    res+=((float)load_Res*(1023-adc_value)/adc_value);
    delay(interval);
}
res/=samples;
return res;
}


float SensorCalibration()
{
  int i;
  float val=0;
  val=resistance(50,500);
  val = val/air_factor;
  return val;
}


      myFile.print("      ");
     myFile.print(Temp);
  myFile.print("      ");
 myFile.print(Hum);
  myFile.print("      ");
 myFile.print(GAS);
  myFile.print("      ");
 myFile.println(NOISE);
```

## APPENDIX C

## QUESTIONNAIRE

KEMENTERIAN PENDIDIKAN MALAYSIA

POLITEKNIK MALAYSIA SULTAN SALAHUDDIN ABDUL AZIZ SHAH

**GENERAL QUESTIONAIRE**

Title of project : **Development Of Portable Tester For Neonatal Incubator With Multiparameter Measurement**

Gender : ☐ Man ☐ Woman          Age : ...... years old

Occupation:...........................................................................

(PLEASE TICK BELOW)

| QUESTIONS | YES | NO |
|---|---|---|
| 1.Have you heard about incubator analyzer? | | |
| 2. Is it the tester can be replaced with analyzer? | | |
| 3. Is the tester is suitable used in neonatal unit for testing the incubator? | | |
| 4. The main four parameter is suitable to test the infant incubator? | | |
| 5. Is the tester is light weight? | | |
| 6. Do you think the tester is easy to use? | | |
| 7. Will you recommend the tester to biomedical team at hospital?<br>If no, state the reason :<br>...........................................................................<br>........................................................................... | | |
| 8. Do you like this tester? | | |

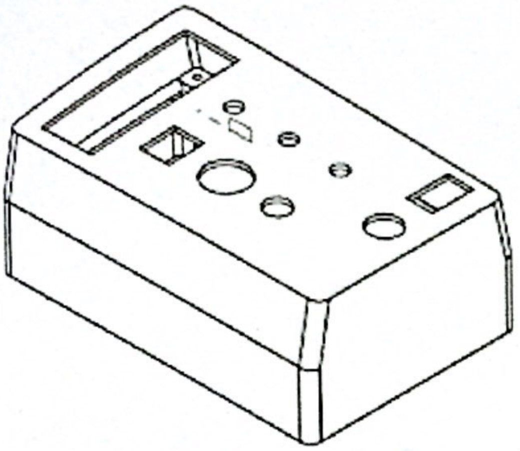
**9. Please leave your comment and suggestions.**

...........................................................................

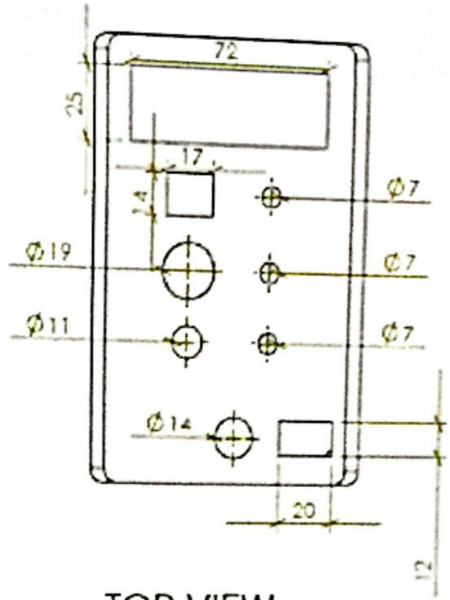
...........................................................................

## APPENDIX D

## 3D DESIGN SKETCHING



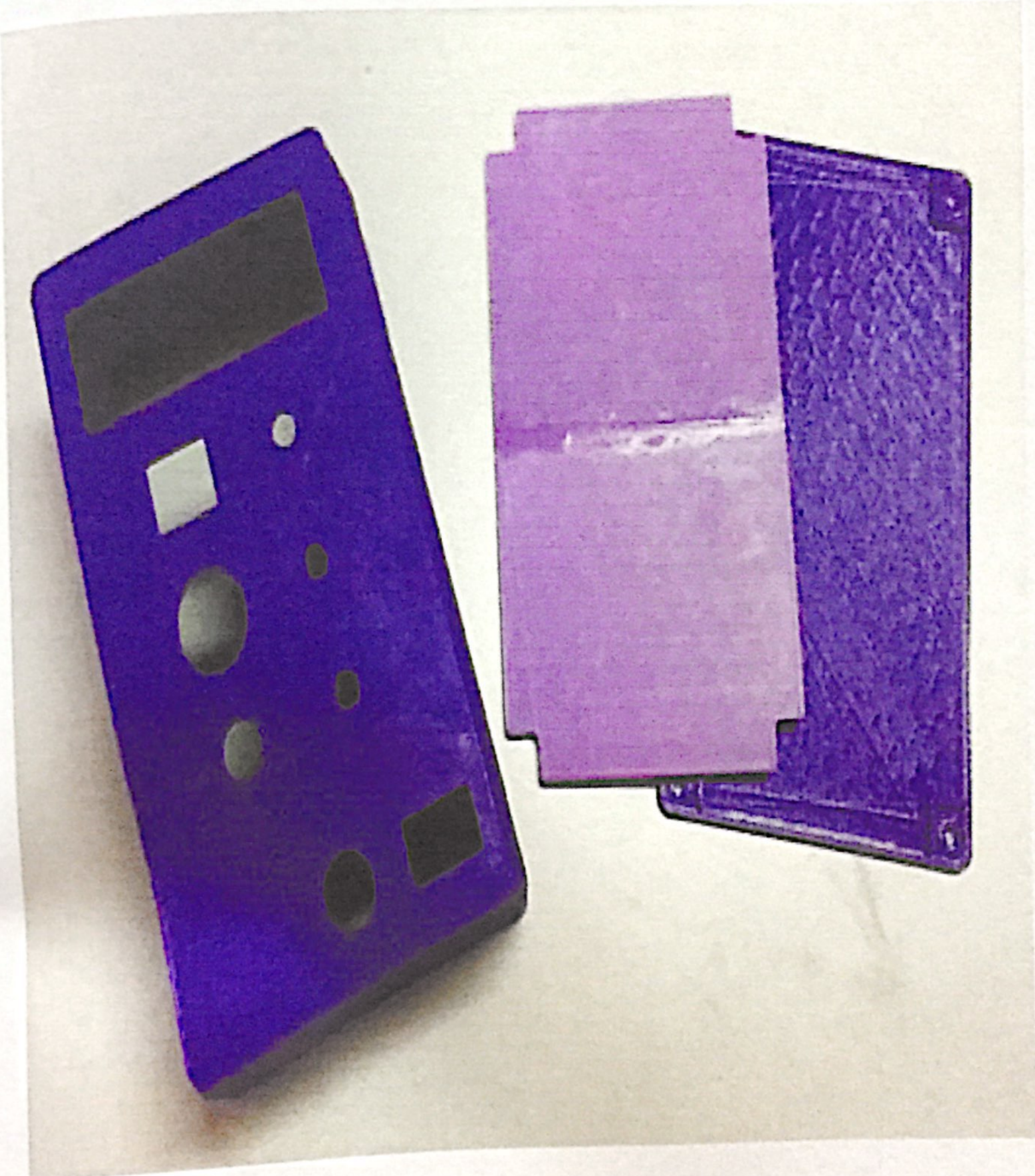
ISOMETRIC VIEW




TOP VIEW

## APPENDIX E

## 3D DESIGN OF THE TESTER



## APPENDIX F

## PORTABLE NEONATAL INFANT INCUBATOR TESTER