Faculty of Engineering

**Using Ultrasonic thermometry to assess Thermal comfort in hospitals**

A Project Report

Presented in Partial Fulfillment of the Requirements for SBE1210 Presented by

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**SBE1210 | Medical Physics**

**Under supervision of:**

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# Abstract:

Thermal comfort is one of the parameters of indoor air quality in hospitals that affects the working conditions, well-being, safety and health of the medical personnel who work in these environments. So Assessment of temperature in the different hospital environments has its own importance for maintaining both the hospital staff and patients comfort. We tried to design a device that tracks the environment temperature at hospitals mainly based on ultrasonic sensors using the relation between temperature and sound wave speed.

[**1. Abstract:**](#_heading=h.30j0zll) **1**

[**2. Literature review:**](#_heading=h.4d34og8) **4**

[3.1. Methodological review:](#_heading=h.4i7ojhp) 4

[3.2. Theoretical Review:](#_heading=h.1ci93xb) 4

[**3. Background:**](#_heading=h.2bn6wsx) **5**

[**4. System Description:**](#_heading=h.49x2ik5) **7**

[5.1. Explanation of the Algorithm:](#_heading=h.147n2zr) 7

[5.1.1. Search about project idea:](#_heading=h.23ckvvd) 7

[5.1.2. Choosing the project "Ultrasonic thermometry":](#_heading=h.32hioqz) 7

[5.1.3. Research proposal about "Ultrasonic thermometry":](#_heading=h.41mghml) 7

[5.1.4. Search for robot components:](#_heading=h.1v1yuxt) 7

[5.1.5. Simulation:](#_heading=h.2u6wntf) 7

[5.1.6. Building and testing the body of the project:](#_heading=h.3tbugp1) 8

[5.1.7. Building and test the circuit:](#_heading=h.nmf14n) 8

[5.1.8. Assembling and test the project:](#_heading=h.1mrcu09) 8

[**5. Project Design:**](#_heading=h.111kx3o) **9**

[6.1. Schematic:](#_heading=h.206ipza) 9

[**6. Project specifications:**](#_heading=h.1rvwp1q) **10**

[7.1. Arduino Uno:](#_heading=h.2r0uhxc) 10

[7.1.1. Definition:](#_heading=h.3q5sasy) 10

[Arduino hardware and software:](#_heading=) 10

[7.1.2. Types of Arduino boards:](#_heading=h.kgcv8k) 10

[7.1.3. Arduino Uno board components:](#_heading=h.1jlao46) 11

[7.1.4. Technical Specification:](#_heading=h.xvir7l) 13

[7.2. Ultrasonic sensor:](#_heading=h.uo2ft0gq3rzm) 15

[7.3. Jumper Wires:](#_heading=h.odc9jc) 16

[7.3.2. Connectors:](#_heading=h.2mn7vak) 16

[7.3.3. Types of jumper wires:](#_heading=h.3ls5o66) 16

[**7. Analysis:**](#_heading=h.302dr9l) **17**

[The basic principle of ultrasonic thermometry:](#_heading=h.1smtxgf) 17

[Tissue interaction:](#_heading=h.xk3o43wm0a92) 18

[Tissue properties:](#_heading=h.aep2o6edtzvg) 18

[8. Future work:](#_heading=h.9f4qrzhe5pkx) 19

[**9. References:**](#_heading=h.4jpj0b3) **20**

[**APPENDIX PROGRAM CODE:**](#_heading=h.1e03kqp) **21**

# Literature review:

## Methodological review:

* After the detailed literature survey through the books, periodical, journal, magazine, websites. The idea of the project is well defined.
* The logic is derived for the intelligence of the device. It is programmed and burns it to the Arduino by using the software Arduino program.
* The accuracy and viability of the program and electronic components is tested in the simulation software Proteus or TinckerCAD.
* After the successful simulation result it is implemented in the hardware.
* After finishing the programming, electrical and electronics part, the stable, reliable and flexible mechanical design and fabrication is completed.
* Finally the system is tested and an encountered error is omitted.

## Theoretical Review:

This Ultrasonic thermometer, A device can determine the room temperature using the relation between the speed of sound and absolute temperature from the ideal gas law.

Engineers have been developing different kinds of methods for assessing the temperature starting from the mercury thermometer to using infrared. Using acoustic waves such as ultrasound to measure the temperature is a bit new technology that is affordable and significant in some cases other tools are not.

# Background:

As technology becomes increasingly important in today's world, it is invaluable to not only learn how to use technology, but also to understand how to create it. Since being an engineer one should have sound knowledge of the other discipline. Most of the projects have limited scope to only specific disciplines. This would limit one's innovation and creativity. This project inspires to make connections across several disciplines rather than learning topics in isolation as it combines Biomedical, electronic, electrical and programming skills.

* It gives a visual grasp of math and science.
* It builds logical thinking.
* It brings out innovation and creativity.
* It enhances problem solving skills.

This idea was applied to a small model so that we can implement it with the least capabilities and the lowest cost. The initial idea was placed in this device.

The device can be developed in many ways, and even it is possible to use components, parts and a much newer and higher quality structure.

The Arduino is programmed with specific codes, and these codes are uploaded to the Arduino, and then the codes are converted into electrical signals and pulses.

The Ultrasonic sensor emits high frequency sound waves at regular time intervals as the velocity of sound in air. The waves fall on a fixed object at a known distance and get reflected back to the receiver. After that throw calculations that will be discussed below we determine the acoustic wave speed which takes part in the calculations of the temperature.

The calculated temperature is compared to the standard range of thermal comfort in hospitals. If it is out of the range the buzzer rings.

# System Description:

## Explanation of the Algorithm:

## Search about project idea:

We have done a lot of research for ideas that are useful and appropriate in terms of costs, Availability of manufacturing materials, and the environmental benefits of the idea, In despite of the Corona pandemic.

## Choosing the project "Ultrasonic thermometry":

After a lot of research about the appropriate project that fits the criteria, we settled on our project "Ultrasonic thermometry in Thermal comfort assessment”.

Nowadays, every device is done with the help of the microcontroller, and hence the circuit is too big and tough to understand and makes it costly. For these reasons, we chose the "Ultrasonic thermometry” with a simple concept with simple circuitry.

## Research proposal about "Ultrasonic thermometry":

After studying the project proposal and the components needed to manufacture it, its cost, Benefits and fields of usage, we found that the project meets the criteria we set for selecting the appropriate project.

## Search for robot components:

We searched on google about the suitable components that we are going to use for the project, the function of each component, the place where we can find the components and the total cost of the components.

## Simulation:

After knowing more about Arduino programming language and how to write a code by Arduino programming language, we wrote the program code on Arduino ide and make a simulation of it on the tinkercad site, which is a site that helps programmers to test their code before using it on their projects.

## Building and testing the body of the project:

After buying the components, we assembled the components together to form the body of the project, then we tested the parts of the body of the project and the measurements of them to see if they are accurate and correct as required or not.

## Building and test the circuit:

We Built the electric circuit and made all the connections, then we tested them to see if there are any problems in them or not.

## Assembling and test the project:

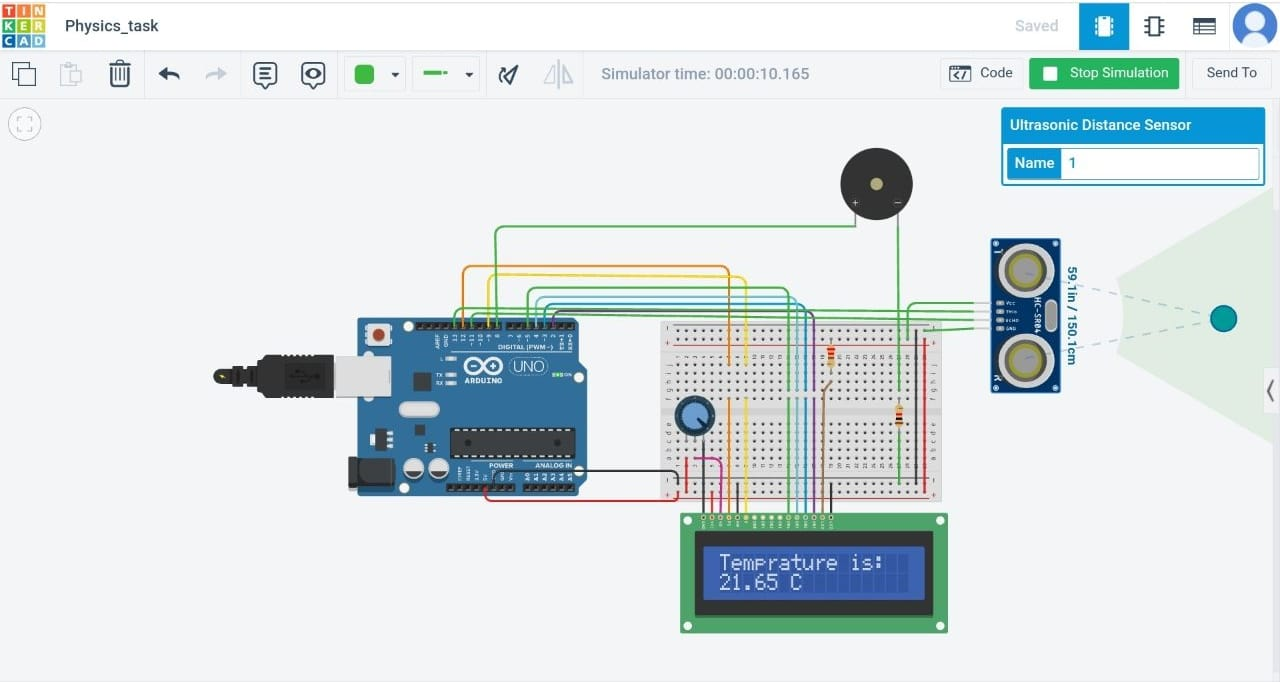
After assembling the parts of the body and testing it and building the electric circuits, making the connections and testing if they are accurate or not.

We assembled all the parts together to form the final shape of the project, then we tested it on the field to see if the measurements, the code and connections were working well or not.

# Project Design:

## Schematic:

As it was discussed earlier in the project idea, our project is an Arduino based cart. So, to start planning the way through the different parts of the device and test if the code matches with each component, we utilized a simulating application and website called “**Tinkercad**” as shown in figure 6.

**Figure 6.6.1. Circuit Simulation of the Ultrasonic Thermometer**

Each component of them has its own specifications, and they will be discussed in detail

# Project specifications:

In this section, each component will be illustrated separately.

## Arduino Uno:

## Definition:

Arduino is an open-source microcontroller board based on the microchip ATmega328P microcontroller which can be easily programmed, erased and reprogrammed at any instant of time.

The Arduino platform was designed to provide an inexpensive and easy way for hobbyists, students and professionals to create devices that interact with their environment using sensors and actuators. Based on simple microcontroller boards, it is an open-source computing platform that is used for constructing and programming electronic devices.

It is also capable of acting as a minicomputer just like other microcontrollers by taking inputs and controlling the outputs for a variety of electronics devices.

## Arduino hardware and software:

Arduino uses hardware known as the Arduino development board and software for developing the code known as the Arduino IDE (Integrated Development Environment).

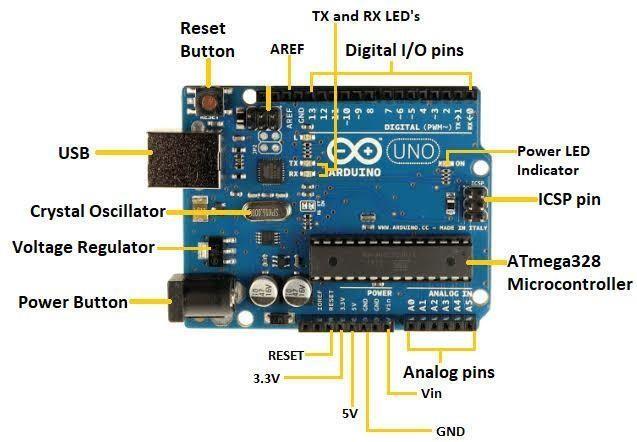
Built up with the 8-bit Atmel AVR microcontroller that are manufactured by Atmel or a 32-bit Atmel ARM, these microcontrollers can be programmed easily using the C or C++ language in the Arduino IDE.

## Types of Arduino boards:

**These types differ in the type of microcontroller and clock speed like:**

* + - * Arduino Uno.
      * Arduino Uno R3.
      * Arduino mega.
      * Arduino Nano.
      * Lily pad Arduino 328.
      * Arduino mini.
      * Arduino Ethernet.
      * Arduino Leonardo.

## Arduino Uno board components:

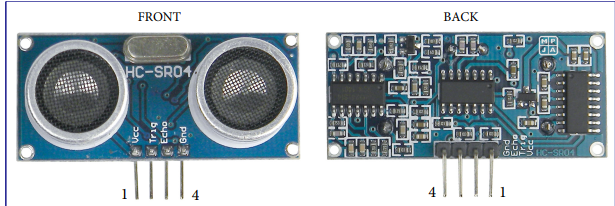
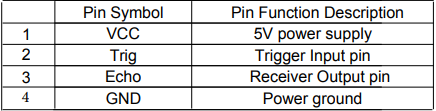
* + - * Microcontroller.
      * Crystal oscillator.
      * Voltage regulator.
      * Analog pins.
      * GND.
      * USB.
      * Reset button.
      * Digital I/O pins.
      * ICSP pin.
      * AREF.
      * TX and LED.
      * Power LED indicator.
      * Power button.

**Figure 9.7.1.3. Components of Arduino Uno**

## Technical Specification:

| * **MICROCONTROLLER** | [ATmega328P](http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf) |
| --- | --- |
| * **OPERATING VOLTAGE** | 5V |
| * **INPUT VOLTAGE (RECOMMENDED)** | 7-12V |
| * **INPUT VOLTAGE (LIMIT)** | 6-20V |
| * **DIGITAL I/O PINS** | 14 (of which 6 provide PWM output) |
| * **PWM DIGITAL I/O PINS** | 6 |
| * **ANALOG INPUT PINS** | 6 |
| * **DC CURRENT PER I/O PIN** | 20 mA |
| * **DC CURRENT FOR 3.3V PIN** | 50 mA |
| * **FLASH MEMORY** | 32 KB (ATmega328P) of which 0.5 KB used by bootloader |
| * **LENGTH** | 68.6 mm |
| * **WIDTH** | 53.4 mm |
| * **WEIGHT** | 25 g |

## Ultrasonic sensor:

* + 1. **Distance Measurement Principles:**
       - A 40KHz ultrasonic wave is emitted simultaneously a timer is started, the wave travels until it encounter an object it’s reflected, When it’s detected the timer stops and the time is recorded and the distance is calculated by the relation as D distance and C is sound speed in air and T is the time measured.
    2. **Product Features:**
       - Stable performance (Xtal.)
       - Accurate distance measurement
       - High-density SMD Board
       - Close Range (2cm)
    3. **Product views:**
       - ****
    4. **Module Pin Assignments:**
       - ****

## Jumper Wires:

* + 1. **Definition:**

A wire is a single usually cylindrical flexible strand or rod of metal wires used to bear mechanical loads or electricity and telecommunications signals. A jump wire is an electrical wire or group of them in a cable with a connector or pin at each end wires are used to connect components to each other on the breadboard or other prototypes internally or with other equipment or components without soldering.



## Connectors:

**Figure 26.7.10.1. jumper wire**

Wire connectors could be male or female.A male connector is commonly referred to as a plug and has a solid pin for a center conductor.A female connector is commonly referred to as a jack and has a center conductor with a hole in it to accept the male pin.

## Types of jumper wires:

* + - * Male – Male. Female – Female. Male – Female.

# Analysis:

|  |  |
| --- | --- |

The practical analysis of the components and the mathematical calculation are performed at different stages of the project.

This project depends mainly on the Ultrasonic thermometry which is based on the relation between the velocity of ultrasound and the properties of the medium ,which the ultrasound travels through, we determine the average temperature by determining the ultrasonic speed.

## The basic principle of ultrasonic thermometry:

Under the conditions of ideal gas, according to Boyle’s law:

**Where: c:** ultrasonic speed, **:** C is the heat capacity at constant pressure(p) and at constant volume (v) ,**T** is the absolute temperature , **M** is the average molecular weight of the gas, **R**  is the specific gas constant.

So **Z**  is a constant for the same medium and equals 20.05 when the medium is Air

Then the relation between the temperature and ultrasonic speed can be reduced to:

Since Z is a constant for a gas then if c is known, we can obtain T directly. And also we set the distance between the object and the ultrasonic sensor. Then the only parameter needed to be determined is the time of travel.

The Time is calculated as shown in the specifications of the ultrasonic that:

as t is the time of travel and D is the known distance and c is speed of sound in air.

D is already known as we set it while coding, after that the temperature is calculated.

The calculated temperature is compared to the standard range of thermal comfort in hospitals. If it is out of the range the buzzer rings.

## Tissue interaction:

The type of tissue interaction is reflection, because we set a timer to calculate the time needed to detect the reflected wave from the object.

## **Tissue properties:**

The wave is traveling through air then it encounters an object that reflects the wave. It;s desirable that the object be solid and flat to reflect the wave properly and to cover all the range of the ultrasonic.

## Future work:

The field of Ultrasonic thermometry still has a huge space for development and innovation in sectors like body design, materials and performance and there are many other applications for it other than mentioned .

We can optimize the design to make it more suitable for the hospitals, and to decrease the errors. We can also embed it in many medical applecations the at need a temprature mentoring.

# References:

1. [Thermal comfort in hospitals – A literature review - ScienceDirect](https://www.sciencedirect.com/science/article/abs/pii/S1364032112002377?casa_token=c28GF6w05YQAAAAA:TPhNC81NsluKW1-SDMs-FiH3Dh15rNDuQ_ajpBgot6VrGMvcBMwgwppw6tS1vkbBnUU5ZsaPUTj7)
2. [Study of ultrasonic thermometry based on ultrasonic time-of-flight measurement: AIP Advances: Vol 6, No 3 (scitation.org)](https://aip.scitation.org/doi/10.1063/1.4943676)
3. HC-SR04 User Guide
4. [About Arduino | Arduino](https://www.arduino.cc/en/about)

# APPENDIX PROGRAM CODE:

#include <LiquidCrystal.h>

#define trigpin 13

#define echopin 11

#define buzzer 8

float time,spead\_of\_sound,temprature;

float distance=150; //initialize the distance in cm!!

LiquidCrystal lcd\_1(12, 9, 5, 4, 3, 2);

void setup()

{

pinMode(buzzer,OUTPUT);

pinMode(trigpin, OUTPUT);

pinMode(echopin, INPUT);

lcd\_1.begin(16, 2);

lcd\_1.print("Temprature is:");

}

void loop()

{

lcd\_1.setCursor(0, 1);

digitalWrite(trigpin, LOW);

delayMicroseconds(2000); // Wait for 1000 millisecond(s)

digitalWrite(trigpin, HIGH);

delayMicroseconds(10); // Wait for 1000 millisecond(s)

digitalWrite(trigpin, LOW);

time = pulseIn(echopin , HIGH);

spead\_of\_sound = 20000\*distance/time;

//Serial.println(spead\_of\_sound);

temprature = (spead\_of\_sound\*spead\_of\_sound)/(1.4\*287);

//temprature=(spead\_of\_sound-331.4)/0.6;

lcd\_1.print(temprature-273);

lcd\_1.print(" C ");

if((temprature-273)>30||(temprature-273)<20)digitalWrite(buzzer,HIGH);

else digitalWrite(buzzer,LOW);

delay(1000); // Wait for 1000 millisecond(s)

}