Faculty of Engineering

Medical Wristband Body Temperature Monitor

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Submitted in pursuing degree *Bachelor of Engineering* in Computer and Electronic Engineering at the North-West University.

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Date: 2021/03/08

Student Number: 30254906

Abstract

A brief overview of the importance of measuring body temperature and types of body temperature measuring devices are given to gain an understanding of the context of the problem. The problem is the need for a non-invasive body temperature measuring device that can accurately measure core body temperature, whilst being simple, low-cost, lightweight, and energy-efficient. High-level objectives are given that will be pursued in solving the problem.

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Chapter 1 Introduction

1.1 Purpose of document

This report covers the context in which a problem exists and also why it is important to address the problem by providing a short background on devices that measures body temperature, the use thereof, and the working of these devices. Some background information is then used to provide a summary of the problem at hand. A possible solution is then shortly discussed, followed by some high-level objectives that will be pursued in an attempt to solve this problem. Anticipated benefits of the solution, technical requirements, scope of the project, and project deliverables are given to provide more context of this project.

1.2 Background

Temperature is a basic prerequisite for all forms of life. The measurement of body temperature plays an important role in our everyday life (especially in the pandemic we find our-self in) since several diseases are characterized by a change in body temperature. Some body temperature measuring devices, such as the clinical thermometer, which is commonly used domestically and in hospitals, must be placed underneath one's tongue or under the armpit. This proves to be unhygienic when these measuring devices are not properly cleaned and can also cause some annoyance for certain people. The need for non-invasive body temperature measuring equipment exists, that can fast and effectively determine body temperature on the move.

Rotational motions and constant internal vibrations in molecules generate thermal energy or heat. Temperature is therefore a measure of the average thermal energy of molecular motions. Biochemical processes take place inside living cells that contain these molecules and are greatly influenced by body temperature [1]. These biochemical processes are known as metabolism. Humans are homeothermic and body temperature is regulated at about 37°C ± 1°C [2]. The body needs to maintain its temperature at a certain level to coordinate its metabolic activities. Both temperature statuses, hyperthermia (too high) or hypothermia (too low) can alter metabolic activities, cause tissue damage and disturb organic functions. Hence, it is important to examine and monitor body temperature to hunt for signs of diseases that are characterized by a change in body temperature. Body temperature measurements allow doctors and other medical practitioners to analyze the effectiveness of the prescribed treatment. Table 1.1 shows both extremes of body temperature and some associated effects at certain temperatures.

Table 1.1: *Body temperature effects*[1]

Temperature	Effect
24-28°C	Mostly death
29-33°C	Sleepiness, slow heartbeat, moderate to severe confusion, unresponsive to stimulus.
34-35°C	Bluish/Grayness of the skin, intense shivering, numbness and some confusion.
36°C	Mild to moderate shivering.
37°C	Normal temperature
38-40°C	Dehydration, headache, vomiting and severe sweating.
41-42°C	Confusion, fainting, very fast heart rate and high/low blood pressure.
43°C	Brain damage, normally death.

Various types of body temperature measuring devices already exist, some of the most popular

domestic-used devices are listed below, each followed by a short description:

- Oral Thermometer:
  Most oral thermometers are digital and made out of plastic. This is an invasive device that must be placed under the tongue for a short while allowing it to measure body temperature. In many cases, the user will be alerted when the reading is completed.

- Tympanic Thermometer:
  Tympanic Thermometers are minimally invasive since it is placed inside the ear canal to take body temperature readings. This digital device has a cone shape designed to fit into an ear.

- Mercury-in-glass/ Alcohol-in-glass Thermometer:
  This device measures oral, rectal, or armpit body temperature through the thermal expansion of ethanol/mercury. These types of devices are made of glass and the thermal expansion of the ethanol/mercury caused by heat must be noted by the user when taking a reading.

- Infrared Thermometer:
  This is a non-invasive device that measures thermal radiation (infrared) emitted from the forehead and skin to deduce body temperature. Infrared thermometers are digital and the user could be alerted when a reading is abnormal.

The devices listed have their own advantages and disadvantages. According to [3], oral thermometers are most accurate for children over 3 years of age and adults. The drawback is that, as mentioned earlier, if the device is not cleaned properly it may be unhygienic. The article also mentions that tympanic thermometers provide fast and accurate readings but objects such as earwax and improper positioning may distort results. The Mercury-/Alcohol-in glass thermometers are not digital, the user must constantly look at the expansion of the liquid to determine the reading. Infrared thermometers provide quick readings, contactless. However, it is believed that these infrared thermometers are not truly as accurate as the rest since external factors, such as direct sunlight and indoor heating, may affect the readings [3].

Throughout this section, mentions of invasive and non-invasive methods were made. These are the two main methods to measure body temperature — by measuring core (deep tissue, invasive) temperature and surface (skin, non-invasive) temperature. Invasive temperature measurements can be taken through the oral cavity, ear canal, and rectum, whilst non-invasive readings are made on the skin surface. In many cases invasive methods cannot be used, such as when someone is unconscious, confused, or sneezing repeatedly, then the oral measurement method is unsuitable. When someone has a middle ear infection or an obstruction in their ear by wax, the ear method is of no use. Non-invasive methods can easily be affected by external factors such as sunlight and indoor heating/cooling, as mentioned previously.

1.3 Problem Statement

From the previous section, it is clear that a non-invasive body temperature measuring device is needed that can measure core body temperature, without the readings getting affected by external factors, whilst being comfortable.

1.4 Hypothesis

A medical wristband that can measure body temperature will be designed and constructed. This allows end-users to wear the device on their wrist, and to see his or her body temperature that is measured and displayed by the wristband.

1.5 Project Objective

1.5.1 Primary Objective

The primary objective of this project is to design an accurate body temperature measuring device that can be worn as a wristband. The device should measure one's body temperature without the readings getting affected by external factors. The device will predict core body temperature instead of just measuring surface (skin) temperature.

Since the device will predict core body temperature, a thermal equivalent circuit model will be used to measure core body temperature with a skin-attachable sensor and experimental investigations will be used to further improve this model. Improvements will lead to more accurate readings. A low-level example of a thermal equivalent circuit model can be seen in Figure 1.1.

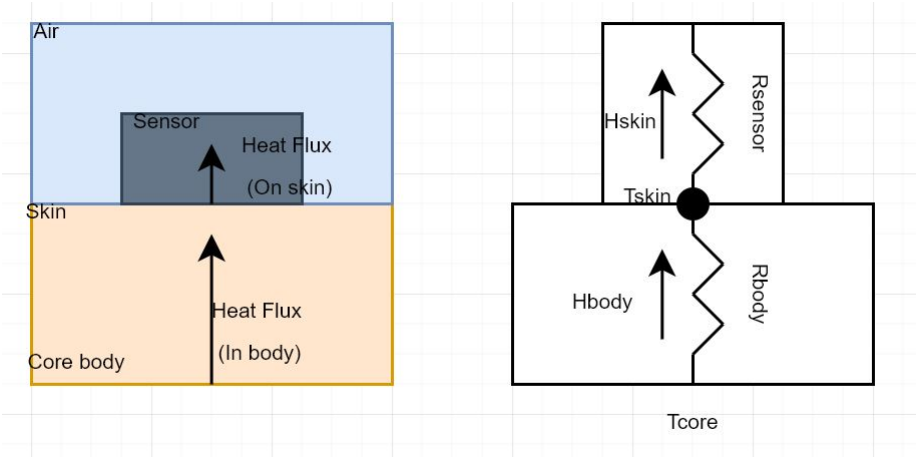

Figure 1.1: Low level model and thermal equivalent circuit.

1.5.2 Secondary Objective

The device will be able to measure body temperature, this must also be displayed to the user of the wristband. Therefore, the secondary objective is to implement a Human-Machine Interface (HMI).

1.6 Anticipated Benefits of Solution

The device in the form of a wristband will make the process of measuring body temperature easier and more efficient since the wristband can be comfortably worn throughout the day or night providing continuous readings. These readings are updated by the device on a set interval or on-demand, whilst always displaying the most recent reading. Users will be alerted when the temperature is too high or low so that treatment can be undergone right away. This will also be a low-cost, yet reliable build.

1.7 Technical Requirements

1.7.1 Requirements

The requirements are listed below:

1. Lightweight. The final wristband with the measuring device and the HMI shall be lightweight. This supports the need for a comfortable device.

2. Low energy usage. Since the end product will be in the form of a wristband, it will be portable. This means that the measuring device will be battery-powered. Low energy usage shall extend the battery life of the device.

3. Cheap. The low-cost aspect of the end product will ensure that the wristband can be widely used by anyone with the need.

4. Simple. The device will measure body temperature, show the measured temperature and alert the user when the temperature is not desirable.

5. Accurate. The device shall deliver accurate readings to the user of the device.

6. The measuring range of the device shall be from 30°C to 40°C, since these temperatures are roughly the limits any living person will achieve.

7. The device shall operate in atmospheric temperatures ranging from -5°C to 45°C, making the body temperature measuring device operational in the summer and winter.

1.7.2 Scope Definition

The scope of the project is to design and implement a body temperature measuring device that can report back a measured reading. Therefore, the sensing element, power supply, and HMI devices will not be re-designed, existing products will be used and placed on a Printed Circuit Board (PCB) to make the device small and compact. The wristband itself will not be part of the design, although this can be 3D printed.

1.8 Deliverables

A device that can measure and display body temperature on the move by placing the device on the wrist will be delivered. This device will be mounted on a wristband that can fit around one's arm at the wrist. Circuit design and PCB layout, together with an enhanced thermal equivalent circuit will also be provided.

1.9 Conclusion

This document explained the importance of measuring body temperature as it is an indication of a person's physical health status. Some requirements are given, showing what will be incorporated in the final product. The scope definition ensures that all the requirements are reached without doing unnecessary work.

Bibliography

[1] W. Chen, "Thermometry and interpretation of body temperature." *Biomedical Engineering Letters*, vol. 9, no. 1, p. 3, 2019. [Online]. Available: https://nwulib.nwu.ac.za/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edssjs&AN=edssjs.6E149113&site=eds-live

[2] T. H. Y. Ling, L. J. Wong, J. E. H. Tan, and K. Y. Kiu, "Non-intrusive human body temperature acquisition and monitoring system," in *2015 6th International Conference on Intelligent Systems, Modelling and Simulation*, 2015, pp. 16–20.

[3] C. Whelan, "Advantages and disadvantages of different types of thermometers," *Healthline*, Dec. 2020. [Online]. Available: https://www.healthline.com/health/types-of-thermometers