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Research Article

DEVELOPMENT OF AUTOMATED ALARMED WEARABLE THERMOMETER

By

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ABSTRACT

Body temperature measurements are one of the important vital signs taken in the hospital to help detect the clinical signs of systemic infections. This study developed a low cost wearable automated alarmed thermometer for continuous and efficient remote monitoring of temperature of subjects. The device was developed to monitor the body temperature and trigger off an alarm when high body temperature is detected and also send an SMS alert to connected phones of the health care personnel concerned. The implementation of the study was done using the Arduino Uno (ATMega328P), LM35 temperature sensor, Liquid crystal display (LCD), 9V battery, GSM SIM Module 800L and connecting wires as the hardware's requirements while Tinker CAD and Multisim 14.2 were used as simulation software. C++ programming language was used for sketch development. The system was soldered in the Veroboard and carefully packaged. Satisfactory results were obtained from the system after testing with eight subjects with the following temperature readings: (35.02˚C, 35.03˚C, 36.02˚C, 36.08˚C, 36.00˚C, 36.05˚C, 37.00˚C, 38.05˚C) respectively. When tested, the developed device gave an alarm at the reading of 38.05˚C which is above the body temperature range. An SMS of the reading was also received. In conclusion, an Automated Alarmed Wearable Thermometer has been developed which can be won around for continual checking of body temperature, thereby reducing constant visits of both patient and health care officers to the clinics or the hospital.

Keywords: *Automated, Alarmed, Body-Temperature, Thermometer, Wearable*

I INTRODUCTION

One of the important vital signs taken in the hospital to help detect the clinical signs of systemic infections is body temperature measurement. Temperature reading taken from patients goes a long way in assisting physicians and caregivers to arrive at accurate diagnosis and thus guides them in making proper treatment plan for the patients.

Early detection of infectious diseases through temperature measurement can prevent life-threatening situations, patient discomfort, waste of time, money and eventual deaths. Many diseases are usually characterized by changes in body temperature and the pathogenesis of most infectious diseases can be monitored using temperature readings. Temperature of

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the body is measured using the clinical thermometer which can be designed and named depending on the different sites of the body where the measurement is taken from. The oral, rectal, axillary, tympanic, infrared thermometers are used for temperature measurement in the mouth, rectum, armpit, ear, and temporal artery respectively. However, invasive temperature measurement can be carried out via a body orifice in the esophagus, urinary bladder, nasopharynx or in the blood vessels using pulmonary catheters and this usually gives the most accurate measurements of the core body temperature. However, this method of measurement causes a lot of comfort impairment to the patients. Body temperature is influenced by factors such as age, stress, gender, time of the day, drugs, smoking as well as instrument reliability and user technique.

Temperature measuring sensors are built into the thermometer and these sensors measure temperature by sensing changes in physical characteristics of the body. However, the commonly used methods and sites of measurement does not provide continuous monitoring of patients and are associated with much discomforts and are quite inconvenient. The patients pay frequent visits to and from the hospital/clinic in order to consult with the physicians, this has increased the suffering of the patients especially the chronically ill. The increasing number of geriatrics who require constant monitoring of their temperature and other health indexes to manage their health, the increase in global pandemics such as the COVID-19 pandemic have necessitated the development of a wearable medical technology that is capable of harnessing available digital health infrastructures and connect physicians remotely with their patients for accurate diagnosis and care. Moreover, considering the rise in lifestyle associated with diseases such as hypertension, diabetes and the growing demand for homecare monitoring and cases of patient isolation following recent global pandemic of COVID-19, the need for wearable medical devices that can monitor patient's vitals and transmit the health data to the physician especially that of the temperature which is usually a precursor to most systemic disease has become very important. The increased availability of information communication technology, digital health infrastructures, telemedicine paved way for wearable medical device to be of great help in medical practice.

However, an Automated Alarmed Wearable Thermometer is developed to reduce the frequent visits to and from the hospital/clinic of patients and physicians just for checking of body temperature. The unique feature of this device is that it is ambulatory and only alerts the physician at high body temperature when an attention is needed. Both the patients and the physicians can be at their different location except the need arises for them to visit the clinic. The Automated alarmed wearable thermometer is an electronic device powered by a microcontroller which is connected with a temperature sensor, a liquid crystal display (LCD) screen, alarm system and a single inline module (SIM). This system is capable of activating the alarm system when the patient's temperature is above the normal range and simultaneously send SMS alert to the physician's phone number connected to the device. The device is worn on the armpit fastened with a belt worn by a patient for constant contact with that part of the body.

Wearable medical devices are ambulatory devices designed to collect data of patients and are capable of sending this information to the physician or care givers in real time. They help to enhance patient monitoring, delivery of treatment and patient rehabilitation. When SMS is integrated into a wearable medical device using SMS application programming interface (API), there is an automated functioning of medical device and this helps the device to intelligently record the patient's vital data. This validates and transits health tips to the patients and physicians at remote locations. SMS text message reminder in health care has been shown to produce positive impacts on patient appointments, attendance and encouraged patient's medical compliance.

[1] developed a microcontroller-based remote temperature monitoring system which remotely monitored patient's temperature and sent the readings to the phones of physicians through short message services (SMS) alerts and personal computers. This device helped the physicians to detect diseases early and eliminated the barrier of distance for patients and caregivers but the device is not wearable and used PIC18F4550. This developed Automated Alarmed Wearable Thermometer has the unique feature of being ambulatory and only alerts the physician at high body temperature when an

attention is needed. Both the patients and the physicians can be at their different location except the need arises for them to visit the clinic. However, it was implemented with Arduino Uno (ATMega328P).

[2] designed a wearable kids health monitoring system on smartphone. This device was able to log and communicate health related data. Their developed wearable device was made up of four parts namely: a TMP102 digital temperature sensor, a pulse sensor which measured heart rate, a mini pro Arduino microcontroller (3V) which collected and transmitted data every five minutes and a Bluetooth mate gold communication module which sent the data to the mobile application.

[3], developed an automatic heart beat and body temperature monitoring device for remote doctor. Their developed system was able to detect abnormal changes in heart beat and temperature and provided an alarm when supervision is necessary.

[4], developed a portable device for remote monitoring of heart rate and body temperature. This device provided a convenient solution for monitoring of heart rate at fingertip and body temperature using internet technology and this enabled the patients to seek immediate medical attention.

[5], developed an ear worn sensor that was used to monitor activities and levels of exertion in patients with chronic obstructive pulmonary disease using machine learning algorithms.

[6], developed a flexible wearable body temperature device for continuous home monitoring. The study was based on a microcontroller and a temperature sensor which converted the body temperature readings to a proportional analog voltage which readings were converted to a digital format by the analog digital converter and the result was displayed on the LCD screen in degree centigrade. All components of the study were connected with conductive thread on to a fabric.

[7], developed a multi sensor system which measured galvanic skin response, heat flow, skin temperature in addition to motion. The instrument accurately measured the energy expended at a slow walking speed. Their wearable device simultaneously monitored other physiological parameters of heart rate, respiration, oxygen saturation as well as skin temperature. This helped the physicians to envision a more encompassed status monitoring of patients of chronic obstructive pulmonary disease.

II METHODOLOGY

Both hardware and software requirements were used for the development of the system. Hardware requirements include: Arduino Uno (ATMega328P), Arduino uno buzzer/alarm, LM35 temperature sensor, Liquid crystal display (LCD), 9V Battery, GSM SIM module 800L, connecting wires and leather belt. Software requirements include: Tinker Cad and Multisim 14.2 which were used for simulation while C++ language was used for sketch development and programming.

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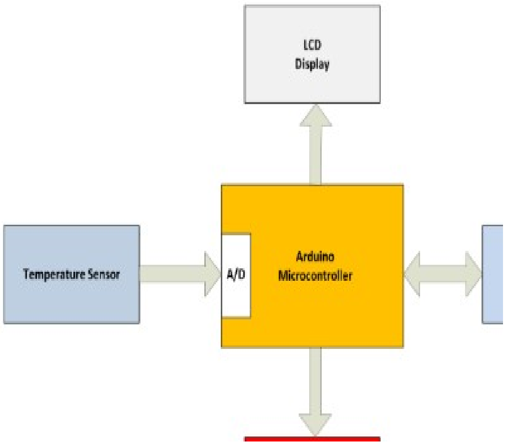

Figure 1a

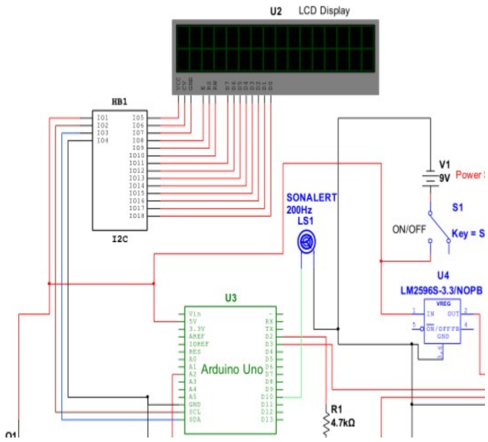

Figure 1b

Fig 1a shows the block diagram of the alarm-SMS based wearable temperature device while Fig 1b shows the circuit/schematic diagram of the developed system. In the diagram, the V_{out} or the analog out of the LM35 temperature sensor was connected to the analog input pin A_2 of the Arduino Uno microcontroller, this converts the voltage value from the sensor to digital form which the microcontroller can process and determines whether the temperature reading is within the acceptable range in degree Celsius. If the reading is within the range of acceptable temperature (35.5˚C – 37.5˚C), it will be displayed on the LCD screen but if not, then the signal will be sent through pin D10 to activate the alarm system and the microcontroller will simultaneously send a signal to the SIM 800L module through pin 2 thereby transmitting a serial communication. SIM 800L requires a voltage range of 3.4 – 4.4V to initiate a communication hence resistors R_1 (4.7k) and R_3 (9.31k) is a voltage divider that steps down the 5V coming from the D_2 so that it attains an acceptable voltage range for the SIM module. Hence, the D_2 of the Arduino Uno microcontroller is connected to the SIM 800L and instructs it to send an SMS using a GSM number and the corresponding message communicated to the SIM module by the microcontroller. As soon as this command is obeyed, the module sends a feedback to the microcontroller through pin 3 indicating that the message has been sent. The voltage source to the system is the 9volts battery, therefore, the LM2596 voltage regulator is used to regulate and provide the required voltage in order to power the SIM 800L module. The entire circuit has an off/on switch connected to it to power the system on and off.

Calculation of analog to digital by ADC of microcontroller

- Number of Arduino Uno (Microcontroller) = 10 bits
- LM35 sensor reading in multi volts divided by 1024 (corresponding value of 10 bit)
- Reading obtained after the above division multiplied by 5000
- Final value obtained after multiplication divided by 10 to convert the value to degree centigrade.

The circuit diagram of the system was first designed and simulated using tinker cad and Multisim 14.2 software. A ceramic resonator (oscillator) of 16MHz, 10ohms resistors and two (22 pf) capacitors were used to generate the internal clock signal of the ATMega328P microcontroller.

The internal clock frequently of the microcontroller is 16MHz and this was measured using an oscilloscope. On the error detection, the MOSFET activated the alarm.

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III IMPLEMENTATION AND RESULT

The test implementation of the circuit diagram was done on the breadboard as can be seen in fig 2 while fig 3 depicts the developed prototype of the Automated Alarmed Wearable Thermometer.

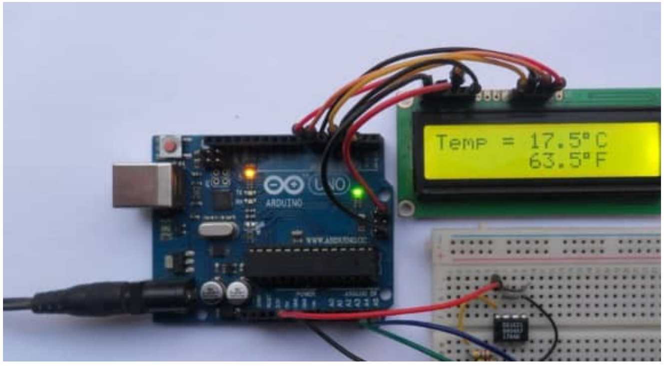

Figure 2: Test implementation of Arduino temperature measurement wiring on a breadboard.

C++ programming was used to write the codes while the Arduino IDE was used to compile and debug the codes after writing with the programming language. The Arduino IDE was also used to upload the binary file to the microcontroller. The temperature sensor was tested with human body which was compared with human body which was compared with a digital thermometer as the control and the reading was obtained.

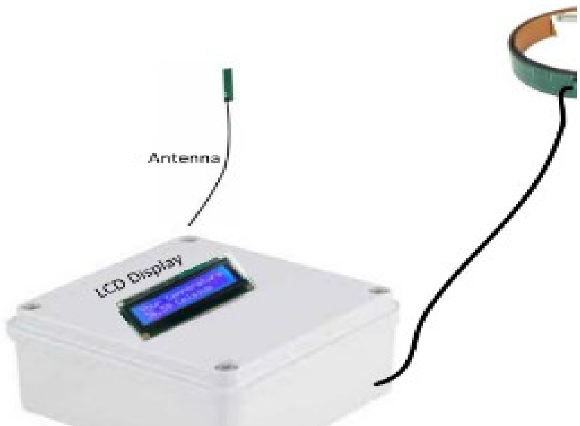

Figure 3: Developed Prototype of an Automated Alarmed Wearable Thermometer.

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IV DISCUSSIONS

The packaged prototype was tested for performance efficiency and the result was very satisfactory. The device gave an alarm at the temperature reading of 38.05˚C and an SMS alert of the reading was also received on the connected phones. This feature is not exhibited in any of the existing thermometers. This result is similar to the study carried out by [1] as found in the literature. The result obtained from the test with the digital thermometer showed consistency of reading at various temperatures and varied with a constant value of 1˚C for each temperature device. This result is better than that obtained by [6] as found in literature.

V CONCLUSION

An alarmed SMS- based wearable temperature device to help monitor temperature and enable physicians make accurate diagnosis and a good treatment plan for patient management from a remote location has been successfully developed. The developed device is easy to operate, portable and efficient in monitoring body temperature and designed with locally sourced materials. The system does not require electricity or solar system for powering rather it only needs a battery which can be replaced when there is a need for it.

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