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# Design of IoT-Based Digital Medical Record Devices in Medically Underserved Areas

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**ABSTRACT**

*Technology has significantly impacted daily life, particularly in healthcare, where health monitoring devices play a crucial role. One major issue is the lack of devices capable of integrating multiple health parameters into a single tool for efficient routine examinations, especially in areas with limited medical facilities. This device employs the MLX90614 sensor to measure body temperature, an EKG sensor for heart rate monitoring, and the MAX30102 sensor to measure blood oxygen levels. The data generated by these sensors is displayed on an LCD screen and managed using the Arduino Mega 2560 microcontroller. Testing results indicate an impressive accuracy level of 94.17%, demonstrating precise outcomes with relatively low error rates for each sensor: 1.05% for heart rate measurement, 2.0% for SpO2 errors with the MAX30102 sensor, and 2.78% for temperature errors with the MLX90614 sensor. With its enhanced real-time and efficient health monitoring capabilities, this device has the potential to serve as a practical solution for routine health monitoring, offering significant benefits for maintaining overall health.*

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## 1. INTRODUCTION

The Internet of Things (IoT) is a groundbreaking and swiftly advancing technology poised to transform how we engage with our environment [1-3]. Projections suggest that by

2025, more than 75 billion devices will be interconnected globally [4]. The healthcare sector is anticipated to be one of the primary beneficiaries of this expansion.

In healthcare, IoT technologies are currently being utilized to enhance patient care and outcomes, providing new possibilities for remote monitoring [5], [6], personalized treatment plans [7], and efficient healthcare delivery [8]. The limitations of integrated medical devices pose a significant challenge, especially in remote areas with limited access to healthcare services. Health monitoring often requires multiple separate devices, such as thermometers, oximeters, and blood pressure monitors, which are inefficient and time-consuming. Therefore, a solution is needed in the form of a device that can integrate all these functions into a single tool with real-time monitoring capabilities.

Health is a priceless asset in our lives, encompassing physical, mental, and social well-being, allowing us to lead fulfilling lives. Without good health, it is difficult to experience joy and happiness. Thus, maintaining good health is crucial, enabling us to reach our full potential and improve our quality of life [9]. Regular health check-ups are crucial for maintaining a healthy body [10]. They facilitate early detection of potential health issues before they escalate, including vital signs such as blood oxygen levels [11], body temperature [12], heart rate [13]. However, current clinical tools for monitoring these vital signs, such as thermometers, oximeters, and blood pressure monitors, are often used independently rather than integrated into a single device [14]. Consequently, medical professionals must conduct individual checks for each patient.

In connection with this, an integrated multisensory and multifunctional health monitoring device has been developed using Internet of Things (IoT) technology [15] to monitor human body conditions. This device allows for non-invasive examinations, enabling medical professionals to monitor and measure patients' conditions in real-time without the need for individual checks.

Based on these developments, this study employs various sensors and components to create a health monitoring device. The utilized sensors comprise the MLX90614 sensor, EKG sensor, MAX30102 sensor, alongside Arduino Mega 2560. The control of sensor parameters and the presentation of results on a Liquid Crystal Display (LCD) provide significant value to this research. The LCD offers a clear and easy-to-read display, enabling real-time monitoring of sensor results with high accuracy.

The MLX90614 sensor is an infrared temperature sensor that allows accurate temperature measurement of objects from a distance. This sensor uses infrared technology to detect the measured object [16]. The EKG sensor is used to measure electrocardiograms, monitoring patients' heartbeats [17]. The MAX30102 sensor is used to measure blood oxygen levels (SpO2) [18].

In previous research [19], developed a monitoring device for heart rate, blood pressure, and body temperature to achieve good accuracy with a rate of 98.30% for heart rate, 99.21% for blood pressure, and 98.30% for body temperature. Another study used the MAX30102 sensor to detect heart rate and oxygen saturation, and DS18B20 to detect body temperature. Test results indicated that the device achieved accuracy of 98.78% for oxygen saturation measurement, 95.12% for heart rate accuracy, and 99.07% for body temperature measurement [20].

Based on the explanation above, a health monitoring device is designed by integrating multiple sensors to measure body temperature, heart rate, and blood oxygen levels. This device utilizes Arduino Mega 2560 microcontrollers to integrate and process data from these sensors. With this device, the author aims to provide substantial benefits in health monitoring, delivering accurate information about the body's health condition, and offering a practical and efficient solution for regular health checks.

## 2. RESEARCH METHOD

In Figure 1, it illustrates the overall framework and flow of the research conducted in this study. The study progresses through several implementation stages, namely hardware design, device assembly, tools design, and system testing.

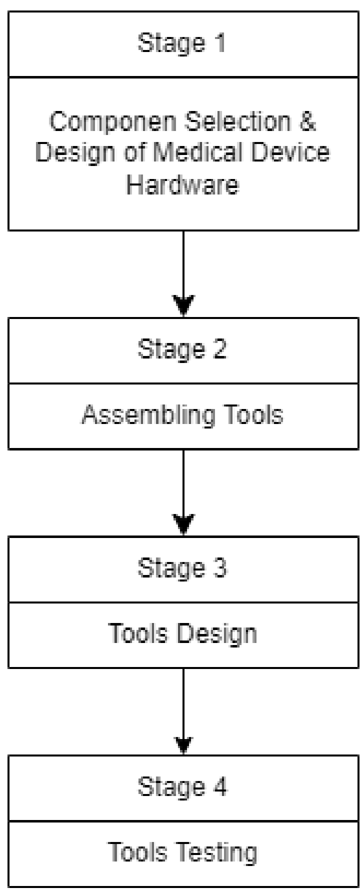



**Figure 1.** Research outline

### 2.1. Hardware Design

In hardware design, components are necessary to construct a device, and listed below are the components utilized in the health monitoring device.

1) Arduino Mega 2560
   The Arduino Mega 2560 is a development board based on the ATmega2560 microcontroller from Atmel. This board is designed to simplify the use of microcontrollers in various electronic and automation applications. With more I/O pins and larger memory, the Arduino Mega 2560 is suitable for complex projects that require numerous hardware connections [21].
2) Sensor MLX90614
   The MLX90614 sensor is a non-contact infrared temperature sensor that enables accurate measurement of an object's temperature from a distance. This sensor utilizes MEMS (Micro-Electro-Mechanical Systems) technology to detect the infrared radiation emitted by objects and then converts it into temperature values [22].
3) Sensor MAX30102
   This module integrates a red LED, infrared LED, and photodiode, utilizing I2C communication. It operates in reflectance mode, aligning the red LED, infrared LED, and photodiode in a single line. The red and infrared LEDs emit light waves, which are then absorbed by oxygen-rich blood [18].
4) Sensor EKG (AD8232)
   The EKG sensor or AD8232 sensor is a device designed to detect and measure electrocardiogram (EKG) signals, which are electrical measurements generated by the heart. This sensor is highly valuable in health monitoring, particularly for tracking heartbeats and identifying potential disturbances that may require medical attention [23].

### 2.2. Assembling Device

At this point, once all the required components for the device have been gathered, the next step involves assembling them into a health monitoring device.

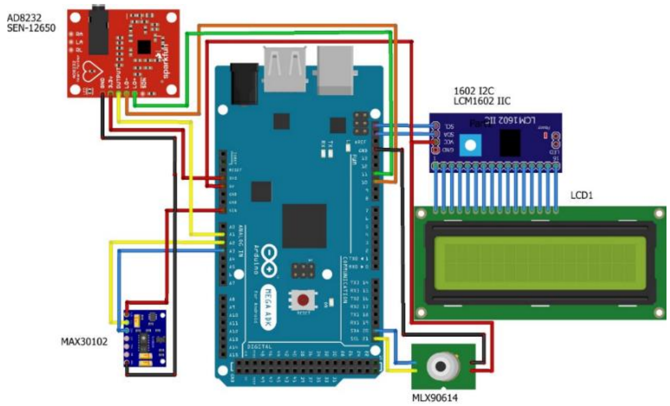



**Figure 2.** Circuit schematic device

Figure 2 depicts the circuit diagram that has been created using various hardware components. These include several sensors: the MAX30102 for monitoring blood oxygen levels, an AD8232 SEN-12650 ECG sensor for heart rate monitoring and detecting abnormalities in heart activity, the MLX90614 for body temperature sensing, an LCD 1602 I2C LCM1602 IIC for displaying data, and Arduino Mega 2560 as the main program controller.

## 2.3. Design of Devices

After the device has been assembled or the tool has been completed, the next step is to design the device. This instrument is intended to be worn directly on the chest and is compact enough to enhance its efficiency and effectiveness.

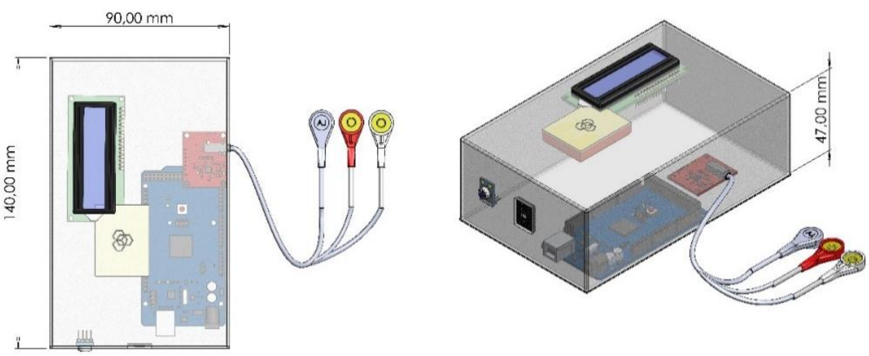
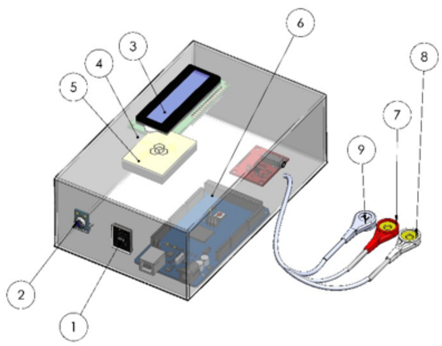



**Figure 3.** Device design

Figure 3 shows a tool design where all sensors are consolidated in one place and linked to Arduino Mega 2560, which acts as the device's main controller. Figure 4 illustrates how all components are organized and utilized.




| ITEM NO | PART NUMBER | QTY |
|---|---|---|
| 1 | MAX30102 | 1 |
| 2 | MLX90614 | 1 |
| 3 | LCD 2x16 | 1 |
| 4 | AD8232 | 1 |
| 5 | Breadboard mini | 1 |
| 6 | Arduino Mega | 1 |
| 7 | EKG connector – red | 1 |
| 8 | EKG connector – green | 1 |
| 9 | EKG connector - yellow | 1 |

**Figure 4.** Component layout

Figure 4, which shows a neat arrangement of components inside a box or casing, exemplifies optimal practices in electronic device design. This layout also simplifies long-term maintenance, repairs, and improvements.

## 2.4. Device Set

After completing the device design and component layout, the next step is assembling the actual device using the previously selected sensors and components. Figure 5 illustrates the assembled device.

**Figure 5.** Device Set

## 3. RESULTS AND DISCUSSION

### 3.1. Evaluation of Device Performance

The device undergoes testing to assess its ability to perform according to specifications and ensure proper operation of all sensors. Detailed information on the device's performance is provided in Table 1:

**Table 1.** Medical device performance testing based on stability over a 1-hour period

| No. | Date | Time | Age | Temperature (°C) | Heart Rate (Bpm) | Spo2 | Male/ Female |
|---|---|---|---|---|---|---|---|
| 1 | 12 July | 13.30 | 19 | 34 | 89 | 100 | Male |
| 2 | 12 July | 13.33 | 19 | 34 | 87 | 99 | Male |
| 3 | 12 July | 13.36 | 19 | 34 | 81 | 97 | Male |
| 4 | 12 July | 13.39 | 19 | 34 | 89 | 100 | Male |
| 5 | 12 July | 13.42 | 19 | 41 | 88 | 96 | Male |
| 6 | 12 July | 13.45 | 26 | 36 | 96 | 97 | Female |
| 7 | 12 July | 13.48 | 26 | 35 | 88 | 100 | Female |
| 8 | 12 July | 13.51 | 26 | 35 | 96 | 95 | Female |
| 9 | 12 July | 14.54 | 26 | 35 | 90 | 98 | Female |
| 10 | 12 July | 13.57 | 26 | 36 | 88 | 100 | Female |
| 11 | 12 July | 14.00 | 22 | 36 | 93 | 98 | Male |
| 12 | 12 July | 14.03 | 22 | 34 | 91 | 100 | Male |
| 13 | 12 July | 14.06 | 22 | 35 | 96 | 96 | Male |
| 14 | 12 July | 14.09 | 22 | 34 | 92 | 50 | Male |
| 15 | 12 July | 14.12 | 22 | 35 | 95 | 100 | Male |
| 16 | 12 July | 14.15 | 56 | 40 | 55 | 97 | Female |
| 17 | 12 July | 14.18 | 56 | 36 | 45 | 97 | Female |
| 18 | 12 July | 14.21 | 56 | 35 | 91 | 100 | Female |
| 19 | 12 July | 14.24 | 56 | 35 | 89 | 98 | Female |
| 20 | 12 July | 14.27 | 56 | 35 | 85 | 97 | Female |

The table above (Table 1) presents the results of a device performance test measuring stability over a 1-hour period. From the performance data, 20 entries were collected, with some showing discrepancies/errors. These issues were caused by several factors, such as:

The specifications for the temperature sensor (MLX90614) are as follows: The sensor cannot read the patient's temperature if it is not detected. In such cases, it will default to measuring the room's temperature. If the temperature reading is not within the normal range (36-37), it may be due to the patient's fingers being too far from the sensor. Conversely, if the temperature is unusually high (36-38), it indicates that the patient's fingers are covering the entire sensor, leading to abnormal readings. For accurate measurements, the patient's fingers should be positioned close to, but not completely covering, the sensor, as illustrated in figure 6.

**Figure 6.** An illustration of inaccurate temperature measurement caused by fingers being positioned both too distant and too close to the temperature sensor (MLX90614)

**Figure 7.** The finger is positioned in front of the sensor


**Figure 8.** Real-time sensor data on LCD screen

Figure 7 shows the optimal position for measuring temperature at close and far distances using the temperature sensor (MLX90614). Figure 8 shows the LCD display presenting the real-time data collected from the sensors. The display continuously updates to reflect the current readings of key health indicators, such as body temperature, heart rate, and blood oxygen levels. The real-time presentation allows users to monitor their health status immediately without delay, providing immediate feedback on their physiological conditions. The clarity and responsiveness of the LCD screen enhance the ease of interpreting the data, making it accessible for users to make quick health assessments. Accurate measurements provide relevant information about the patient's condition. Factors such as the patient's psychological state, including their level of relaxation or anxiety, and the condition of their skin (such as lotion or oily skin), significantly affect the accuracy of heart rate measurements. Therefore, it is recommended that patients prepare adequately before undergoing any measurements.

The effect that different test durations have on patients is due to:

a) On the Spo2 sensor (MAX30102): The sensor faces varying levels of difficulty in penetrating the fingertip's surface during Spo2 measurements. Tests typically proceed faster when the patient has a fingertip with thin and light-colored skin. Conversely, measurements take longer for patients with thick and dark fingertip surfaces compared to those with thin and light ones. This variation is due to the scanning method employed by the Spo2 sensor, which relies on photoreflective technology to assess blood flow in the fingertip.
b) For the AD8232 heart rate sensor, using oil or lotion on the chest can affect electrode adhesion. Electrocardiograms rely on good contact between the skin and electrodes. Oil on the skin can make the surface slippery, leading to poor electrode adhesion. This can disrupt the electrical signals transmitted from the heart to the electrocardiogram (EKG).

**Table 2.** Data concerning medical devices for the elderly

| **No.** | **Time** | **Age** | **Temperature ($°C$)** | **Heart Rate (Bpm)** | **Spo2** | **Male/ Female** | **Status** |
|---|---|---|---|---|---|---|---|
| 1 | 12.05 | 58 | 35 | 82 | 89 | Male | Not Healthy |
| 2 | 12.20 | 56 | 36 | 91 | 100 | Male | Healthy |
| 3 | 12.30 | 56 | 37 | 87 | 100 | Male | Healthy |
| 4 | 12.40 | 56 | 35 | 81 | 82 | Male | Not Healthy |
| 5 | 12.50 | 58 | 34 | 85 | 88 | Female | Not Healthy |
| 6 | 13.00 | 70 | 33 | 88 | 85 | Female | Not Healthy |
| 7 | 13.05 | 56 | 36 | 91 | 95 | Male | Healthy |
| 8 | 13.20 | 56 | 37 | 85 | 100 | Male | Healthy |
| 9 | 13.25 | 59 | 36 | 89 | 95 | Male | Healthy |
| 10 | 13.40 | 60 | 35 | 97 | 102 | Male | Not Healthy |
| 11 | 13.50 | 63 | 36 | 84 | 98 | Female | Healthy |
| 12 | 13.55 | 66 | 37 | 91 | 99 | Female | Healthy |
| 13 | 14.05 | 68 | 36 | 85 | 91 | Female | Healthy |
| 14 | 14.25 | 65 | 36 | 88 | 90 | Male | Healthy |
| 15 | 14.35 | 62 | 37 | 85 | 88 | Male | Not Healthy |
| 16 | 14.45 | 59 | 38 | 97 | 85 | Male | Not Healthy |
| 17 | 14.55 | 71 | 35 | 78 | 97 | Male | Healthy |
| 18 | 15.05 | 57 | 36 | 84 | 100 | Male | Healthy |
| 19 | 15.20 | 67 | 35 | 87 | 100 | Male | Healthy |
| 20 | 15.25 | 69 | 35 | 89 | 97 | Male | Healthy |

Data collection for this medical device is conducted during the daytime, performed once per individual.

**Table 3.** Data regarding medical devices for adults

| No. | Time | Age | Temperature (°C) | Heart Rate (Bpm) | Spo2 | Male/ Female | Status |
|---|---|---|---|---|---|---|---|
| 1 | 12.00 | 26 | 32 | 88 | 89 | Female | Not Healthy |
| 2 | 12.20 | 27 | 35 | 94 | 99 | Female | Healthy |
| 3 | 12.40 | 26 | 34 | 91 | 100 | Female | Healthy |
| 4 | 13.00 | 30 | 36 | 92 | 95 | Male | Healthy |
| 5 | 13.20 | 33 | 35 | 92 | 98 | Male | Healthy |
| 6 | 13.40 | 27 | 33 | 98 | 88 | Male | Not Healthy |
| 7 | 14.00 | 26 | 31 | 92 | 89 | Male | Not Healthy |
| 8 | 14.20 | 35 | 35 | 93 | 97 | Male | Healthy |
| 9 | 14.40 | 27 | 38 | 95 | 91 | Male | Not Healthy |
| 10 | 15.00 | 40 | 35 | 97 | 94 | Male | Healthy |
| 11 | 15.20 | 34 | 36 | 92 | 99 | Male | Healthy |
| 12 | 15.40 | 44 | 36 | 94 | 97 | Male | Healthy |
| 13 | 16.00 | 45 | 35 | 93 | 96 | Male | Healthy |
| 14 | 12.00 | 50 | 38 | 92 | 89 | Male | Not Healthy |
| 15 | 12,20 | 55 | 38 | 91 | 88 | Male | Not Healthy |
| 16 | 12.40 | 35 | 36 | 85 | 99 | Male | Healthy |
| 17 | 13.00 | 36 | 35 | 90 | 95 | Male | Healthy |
| 18 | 13.20 | 41 | 36 | 93 | 98 | Male | Healthy |
| 19 | 13.40 | 39 | 37 | 92 | 100 | Male | Healthy |
| 20 | 14.00 | 34 | 33 | 88 | 85 | Male | Not Healthy |

Data collection for this medical device is performed during the daytime, conducted once per individual.

**Table 4.** Data regarding medical devices for adolescents

| No. | Time | Age | Temperature (°C) | Heart Rate (Bpm) | Spo2 | Male/ Female | Status |
|---|---|---|---|---|---|---|---|
| 1 | 12.05 | 19 | 35 | 79 | 100 | Male | Healthy |
| 2 | 13.00 | 22 | 40 | 90 | 88 | Male | Not Healthy |
| 3 | 13.10 | 22 | 32 | 87 | 80 | Male | Not Healthy |
| 4 | 13.20 | 22 | 36 | 85 | 93 | Male | Healthy |
| 5 | 13.30 | 22 | 42 | 80 | 89 | Male | Not Healthy |
| 6 | 21.00 | 22 | 36 | 89 | 99 | Male | Healthy |
| 7 | 21.10 | 22 | 36 | 96 | 96 | Male | Healthy |
| 8 | 12.00 | 19 | 37 | 88 | 100 | Male | Healthy |
| 9 | 12.20 | 20 | 36 | 91 | 98 | Male | Healthy |
| 10 | 12.40 | 23 | 36 | 92 | 97 | Male | Healthy |
| 11 | 13.00 | 19 | 39 | 90 | 82 | Male | Not Healthy |
| 12 | 13.20 | 20 | 36 | 91 | 92 | Male | Healthy |
| 13 | 13.40 | 22 | 36 | 97 | 97 | Male | Healthy |
| 14 | 14.00 | 21 | 36 | 93 | 95 | Male | Healthy |
| 15 | 14.20 | 23 | 37 | 95 | 97 | Male | Healthy |
| 16 | 14.40 | 22 | 35 | 91 | 97 | Female | Healthy |
| 17 | 15.00 | 22 | 35 | 90 | 99 | Female | Healthy |
| 18 | 15.20 | 23 | 36 | 89 | 98 | Female | Healthy |
| 19 | 15.40 | 20 | 39 | 85 | 89 | Female | Not Healthy |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 20 | 16.00 | 22 | 38 | 90 | 80 | Male | Not Healthy |

Data collection for medical devices occurs during daylight hours, once per individual. The testing utilizes Multifunctional Health Monitoring Technology with Body Area Network and encompasses three age categories: adolescents, adults, and the elderly. It is conducted once per participant during the day. This testing seems structured to compile comprehensive health information across diverse age groups and different times of day. The inclusion of various age groups in this study aims to discern variances in health metrics and physical responses among adolescents, adults, and the elderly.

### 3.2. Device Accuracy Calculation

The method used to calculate the heart rate error on the AD8232 sensor is as follows:

$$\%Error = \frac{True\ Value\ -\ Experimental\ Value}{True\ Value} \text{ X } 100$$

$$\%Error = \frac{95-94}{95} \text{ X } 100$$

$$\% = 1{,}05$$

The method used to calculate the Spo2 error on the MAX30102 sensor is as follows:

$$\%Error = \frac{True\ Value\ -\ Experimental\ Value}{True\ Value} \text{ X } 100$$

$$\%Error = \frac{100-98}{100} \text{ X } 100$$

$$\% = 2{,}0$$

The method used to calculate the temperature error on the MLX90614 sensor is as follows:

$$\%Error = \frac{True\ Value\ -\ Experimental\ Value}{True\ Value} \text{ X } 100$$

$$\%Error = \frac{36-35}{36} \text{ X } 100$$

$$\% = 2{,}78$$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**Accuracy** = 100 – %$Error$

= 100 – 5,83 %

= 94,17 %

According to the error calculations for the parameters measured by the heart rate sensor, MLX90614 sensor, and MAX 30102 sensor, it can be inferred that these three sensors achieve an accuracy level of around 94.17%. This indicates that the measurements obtained from these sensors exhibit an error margin of roughly 5.83%.

While there is a small margin of error in the measurements, achieving an accuracy level of around 94.17% is considered satisfactory, particularly in medical or diagnostic applications. This suggests that the sensors can produce results that closely approximate the actual values and are generally dependable for clinical purposes. However, it's crucial to recognize that sensor readings may influence medical decisions, necessitating awareness that these findings might need further verification or additional monitoring in critical clinical scenarios.

A device accuracy of 94.17% reflects strong performance and can rival standard clinical instruments like thermometers, oximeters, and electrocardiograms. A 5.83% error rate is competitive within the realm of medical measurements and health monitoring.

## 4. CONCLUSION

The health monitoring device achieves a 94.17% accuracy rate in measuring body temperature, heart rate, and blood oxygen levels. Comparative evaluations with current medical equipment confirm this. The device has demonstrated reliable performance with minimal error rates on each sensor, including a 1.05% error rate for heart rate on the AD8232 sensor, 2.0% for SpO2 on the MAX30102 sensor, and 2.78% for temperature on the MLX90614 sensor.

Variables such as distance, positioning, and patient condition can influence measurement outcomes when using these medical devices. Rigorous testing is essential to ensure that the device consistently produces precise and clinically relevant data for patient health assessments.

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