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DESIGN AND IMPLEMENTATION OF A HEARTBEAT MONITORING SYSTEM

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ABSTRACT

The heartbeat or heart rate (HR) and its derivatives may offer significant insights into human health and associated physiological states. Heart rate is commonly utilized in health gadgets for the aged, as it may be obtained from a fundamental electrocardiogram (ECG) input. A collection of dermal electrodes is employed to acquire the ECG signal prior to the initiation of a heart rate monitor. Monitoring heart rate is crucial for diverse purposes, encompassing exercise tracking, medical diagnostics, and overall health assessment. Traditional methods include ECG devices or manual counting over a specified duration, which may not be feasible or accessible to all individuals. A heartbeat counter device automates heart rate measurement and delivers real-time feedback. The major objective of the heartbeat counter is to utilize non-invasive methods to accurately and efficiently assess the user's heart rate in beats per minute (BPM). The device must be user-friendly, portable, and capable of providing precise measurements under many conditions, including at rest or during physical activity. This work accomplishes three tasks. The initial task involves examining the existing literature on ECG, with particular emphasis on methodologies for estimating heartbeat or heart rate. The second assignment emphasizes ECG extraction throughout significant distortion, while the third task employs an Arduino and a liquid crystal display to achieve precise heartbeat estimation utilizing the acquired ECG signal. The retrieved ECG signals are relatively clear and satisfactory for all instances. The heartbeat mechanism facilitates precise and adequate measurement of heart rate, since it focuses on the number of beats per minute (BPM).

KEYWORDS: Electrocardiogram, Heart Rate, Mechanocardiogram, Photoplethysmogram.

1. INTRODUCTION

A user-friendly, low-power, and cost-effective gadget utilizing Photoplethysmography was introduced for heart rate monitoring, with negligible discrepancies from traditional monitors.[1] A study created an automated approach for counting drosophila heartbeats using optical coherence tomography, employing chamber segmentation and PCA-based supervised learning, which resulted in mean distances and area overlap similarities, while sustaining average heart rates comparable to hand counting.[2] Athletes observe unanticipated elevations in heart rate during endurance exercise as recorded by sports heart rate monitors (HRMs). Contemporary HRMs, especially those equipped with ECG recording capabilities, are emerging as valuable diagnostic instruments for identifying cardiac arrhythmias, potentially exceeding Holter ECGs in terms of safety, user-friendliness, and cost-effectiveness.[3] A meta-analysis of 133 studies revealed no significant correlation between performance on the Heartbeat Counting Task (HCT) and trait anxiety, sadness, or alexithymia, nor with anticipated psychological mental health indices.[4] A study assessed the accuracy, clinical relevance, and user experience of a wireless fetal heartbeat monitor (HBM) for home usage, in comparison to conventional in-hospital CTG scans. A study in.[6] presented an economical cardiac pulse detection system utilizing a piezoelectric ceramic sensor for real-time heart rate monitoring, allowing physicians to oversee patients' health and respond promptly to any cardiovascular conditions. The pilot study evaluated ballistocardiography sensors for assessing heart activity in animals, juxtaposing them with electrocardiographic measures.[7] The study sought to assess the appropriateness of these sensors and discern prospective issues in animal health monitoring. A study in[8] investigated noninvasive heart rate monitoring in extramural and domestic environments with electrocardiography, photoplethysmography, and mechanocardiography, examining the underlying physical concepts, sensor attributes, advantages, disadvantages, and application protocols. A PCG system for heartbeat detection was introduced, attaining a detection sensitivity of 88.9 in 27 participants, with the objective of optimizing sensor placement for future applications.[9] The design and production of a heartbeat pulse counter for medical uses were discussed in.[10] The device detected and recorded the heart rate when a fingertip was positioned on a pulse sensor. The Arduino Uno board processed the data, which is presented on a 16x2 LCD display. The device underwent testing on numerous individuals, and additional efforts were required to integrate GSM modules. The endocardium of zebrafish sustains a constant population of hematopoietic cells, predominantly stem and progenitor cells/megakaryocyte-erythroid precursors, regulated by adhesion factors Integrin α4 and Vcam1, whereas inhibiting primitive erythropoiesis enhances these cells.[11] The heartbeat rate (HBR) is a crucial physiological parameter in the human body, assessed by non-contact imaging techniques such as PPG, ECG, and oscillometrics, facilitating remote healthcare monitoring and social distance.[12] The COVID-19 pandemic has heightened worldwide health consciousness, resulting in the proliferation of heart rate monitoring techniques such as electrodes, wearable sensors, electrocardiograms (ECG), and plethysmographs. Options comprise photoplethysmographs and non-contact heart rate monitors.[13] The methods for assessing heart rate during physical activities, specifically regarding a device for the project titled "Fireman – Rescuer of the Future," were discussed in.[14] The discussion encompassed prevalent approaches, their respective advantages and disadvantages, as well as the design of a device utilizing ECG signal detection and processing techniques. A study in[15] investigated the design of dry electrode-based sensors for a lightweight, portable, gel-free wearable ECG patch intended for point-of-care diagnostics, emphasizing a hexagonal labyrinth arrangement. A study in[16] examined the progression of ECG signal analysis, emphasizing the incorporation of machine learning algorithms and signal-processing methods, illustrating how technology enhances diagnosis accuracy and efficiency.

2. Heartbeat Monitoring System

Heart rate counters record and report heartbeats during and after workouts, providing fitness information. They can be pedometer extensions, counting steps, and offering real-time information, time-in-zone tracking, and pre-programmed training schedules to help users achieve fitness goals. Heart Beat Rate (HBR) quantifies the frequency of heartbeats, generally between 60 and 100 beats per minute while at rest. Active individuals may exhibit a heart rate as low as 40 bpm due to enhanced cardiac muscle efficiency. Factors such as emotions, substances, hormones, ambient temperature, physical activity, body posture, size, age, and gender might influence the heart rate variability (HRV). Consistent surveillance is advised. The typical resting HBR values are shown in Table 1.[12]

Table 1: The normal resting HBR values.[12]

Heart Beat Rate (bpm)	Group
130-160	Birth
110-130	Infants
80-120	Children (1-7 years old)
80-90	Children (over 18 years old)
60-80	Adults

Heartbeat assessment can be conducted manually or with computerized instruments. Pulse rate (PR) and heart rate (HBR) are both physiological metrics, measured using distinct body postures and methodologies, however they refer to the same physiological characteristics. Heart rate measurements are initially recorded manually. To assess your wrist pulse, put two fingers between the bone and the tendon above the radial artery utilizing these physical techniques.[13] The electrocardiogram (ECG) is the definitive method for identifying arrhythmias and other cardiac disorders. Pulse oximetry quantifies blood oxygen saturation and heart rate. Heart rate monitors employ optical and electrical sensors. Phonocardiography captures cardiac sounds, ballistocardiography quantifies bodily motions, seismocardiography identifies cardiac vibrations, and Doppler Ultrasound monitors blood flow.[12-16] ECGs are crucial for monitoring heart rhythms, but many are still recorded on paper, making analysis time-consuming. The heart's functioning involves sequences of depolarization and repolarization, with the P wave originating from the SA node, followed by the QRS complex, S–T interval, and T wave, and finally, ventricular repolarization. Electrocardiograms are essential for monitoring cardiac rhythms; nevertheless, numerous recordings remain on paper, rendering analysis laborious. The heart operates by cycles of depolarization and repolarization, commencing with the P wave from the SA node, succeeded by the QRS complex, S–T interval, and T wave, culminating in ventricular repolarization as shown in Fig. 1.[15]

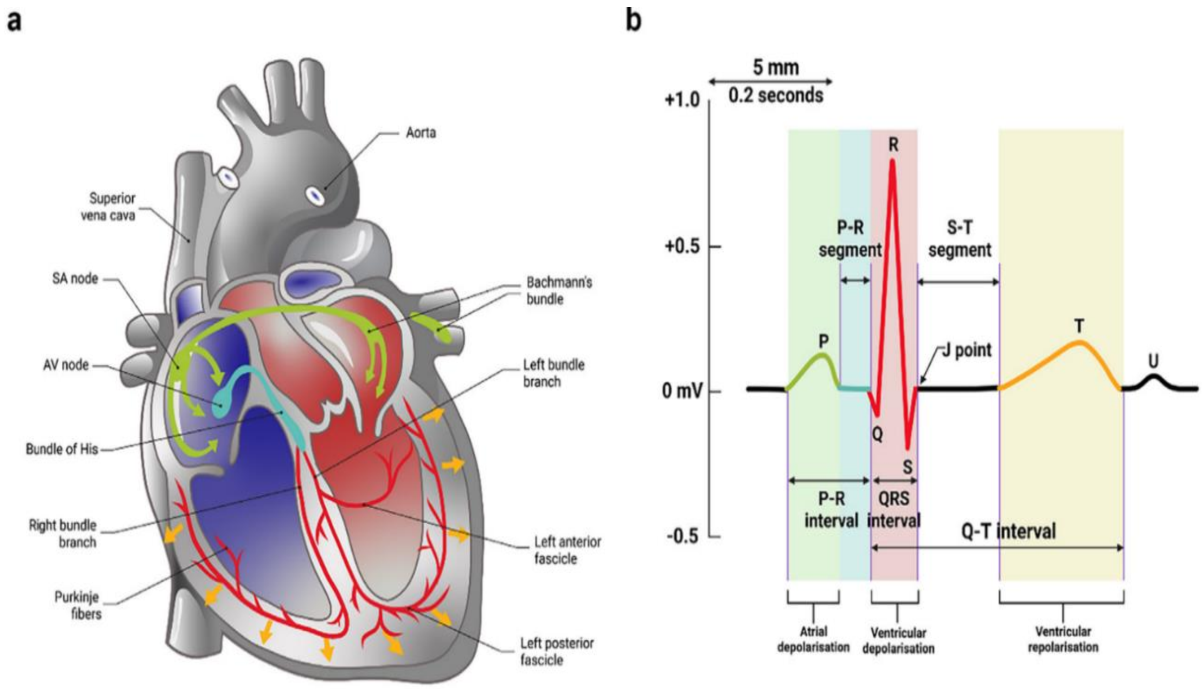

Fig. 1: ECG waves: (a) a schematic showing the sequences of cardiac depolarization and repolarization; (b) tracings of the deflection waves corresponding to these processes.[15]

2.1 The Schematic Design of the Proposed System

Heart rate is determined using an ECG, which captures electrical activity over time and displays it as waveforms. The QRS complex peak is used to determine heart rate, which is determined by 60 seconds divided by the R-R interval. Modern ECG machines use digital signal processing to improve signal quality. Consistency in electrode placement is crucial for accurate results. Real-time data handling is essential for continuous monitoring. ECG devices need calibration for accurate interval measurement. The interface should reflect computed heart rate. The proposed heartbeat monitoring system uses two dry ECG electrodes, one attached to a finger in the left hand and the other to a finger in the right, to detect the RR interval and produce a heartbeat, monitored on an LCD display. Fig. 2 illustrates the schematic design of the proposed cardiac monitoring system. Two dry ECG electrodes are employed to capture the ECG signal. Each electrode is constructed from a curved copper sheet and possesses a semi-circular hollow configuration. One electrode is firmly affixed to a finger on the left hand, while the other electrode is similarly affixed to a corresponding finger on the right hand. The extracted ECG signal is transmitted to an Arduino UNO linked to a 2×16 LCD display. The Arduino is configured to detect the RR interval and generate the matching heartbeat. The heartbeat is displayed on the LCD monitor.

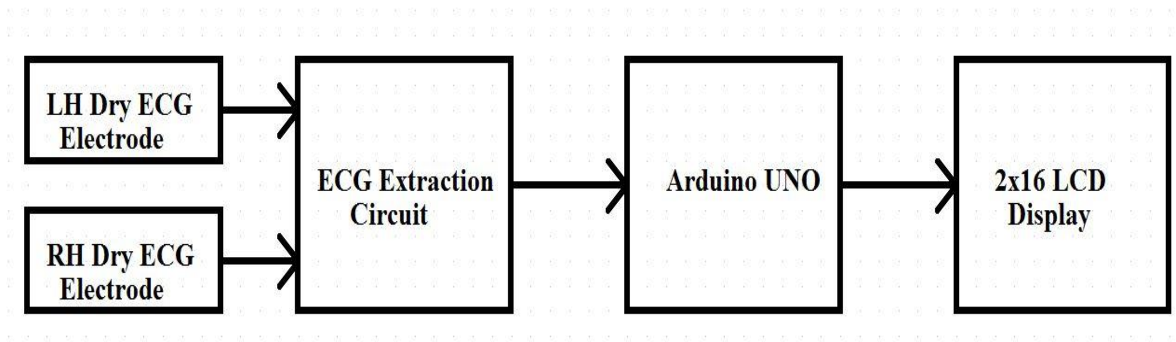

Fig. 2: Schematic design of the proposed heartbeat monitoring system.

Fig. 3 shows the experimental part of the proposed ECG signal extraction circuit. It is implemented on a breadboard and powered by a DC source of 5V.

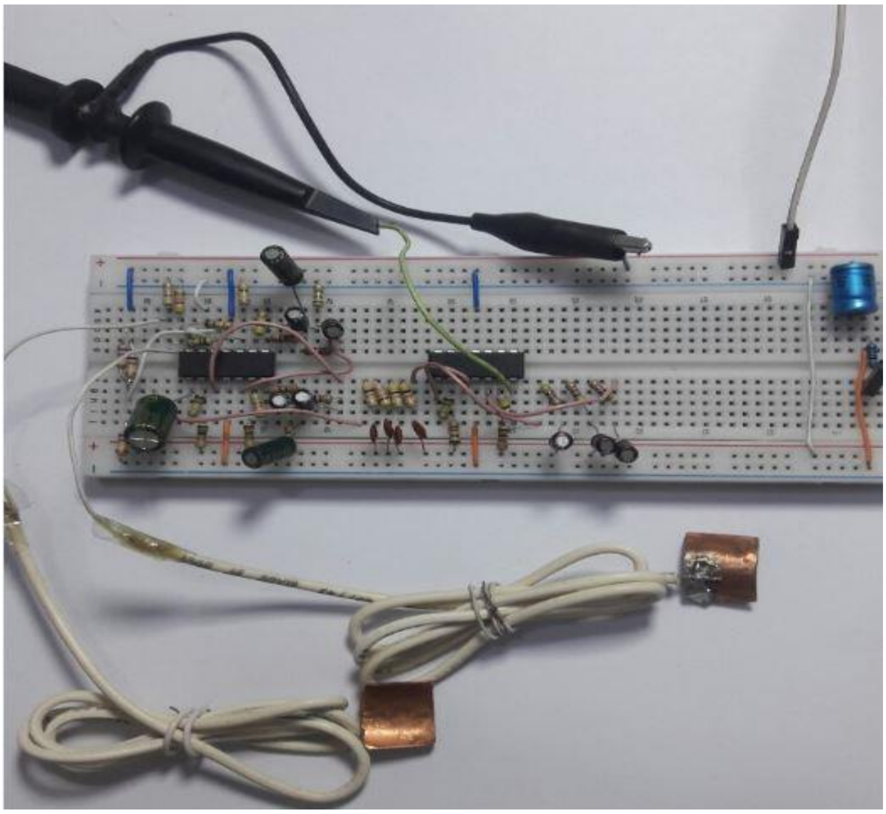

Figure 3: The experimental ECG extraction circuit with two dry copper electrodes.

The above ECG extraction circuit is an electronic device that captures and processes heart electrical signals for diagnosing cardiac conditions. It uses two dry metal electrodes on the skin to detect heart activity and converts it into electrical voltages. The circuit includes a high gain differential amplifier, low-pass filters to remove DC and low-frequency noise, high-pass filters to remove the low-frequency noise, and two notch filters to remove power line frequency interference. The circuit amplification is accomplished via successive amplifiers. The rough ECG signal is usually saturated with 50Hz line frequency interference, therefore two active 50Hz notch filters are used.

The block diagram of the proposed heartbeat counter, illustrated in Fig. 2, is implemented as hardware. The retrieved ECG signal is utilized by a comparator to identify the R-R intervals. The R-R pulse train is input to an Arduino to properly determine the interval between successive R-R signals. This predicted time will be utilized within the Arduino to ascertain the heartbeat count. The resultant heart rate will be exhibited on the liquid crystal display as illustrated in Fig. 4.

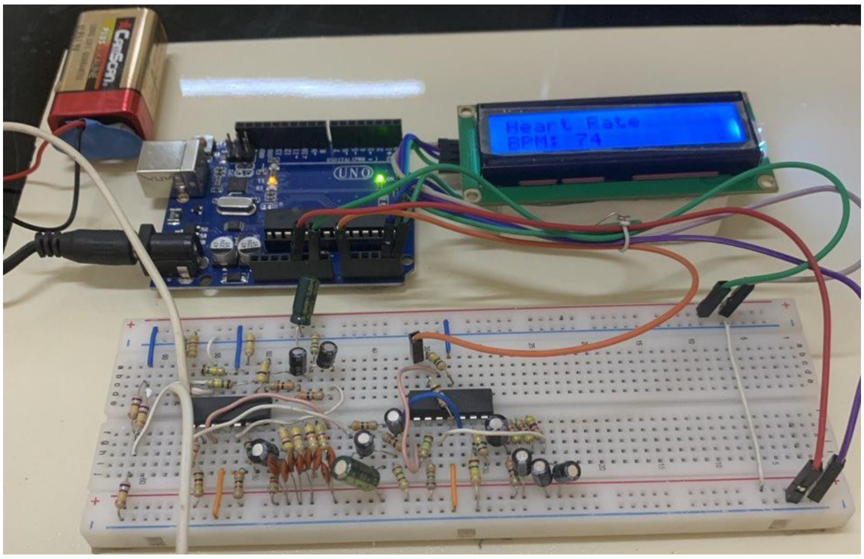

Fig. 4: The experimental circuit of heartbeat monitoring system.

3. RESULTS AND DISCUSSION

The circuit depicted in Fig. 3 was evaluated by various cases of ECG extraction from individuals of diverse ages. The circuit depicted in Fig. 4 was utilized to measure the heartbeats of individuals across various age groups. The experimental circuit shown in Fig. 3 was used to extract an ECG signal from a person of 34 years. Fig. 5 shows the extracted ECG signal for this person. The recovered ECG signal depicted in Fig. 5 is exceptionally clear and encompasses all components of the ECG, including the P-wave, QRS complex, T-wave, and U-wave. The image illustrates the effective extraction of R-R intervals, which will be utilized later in heartbeat estimation.

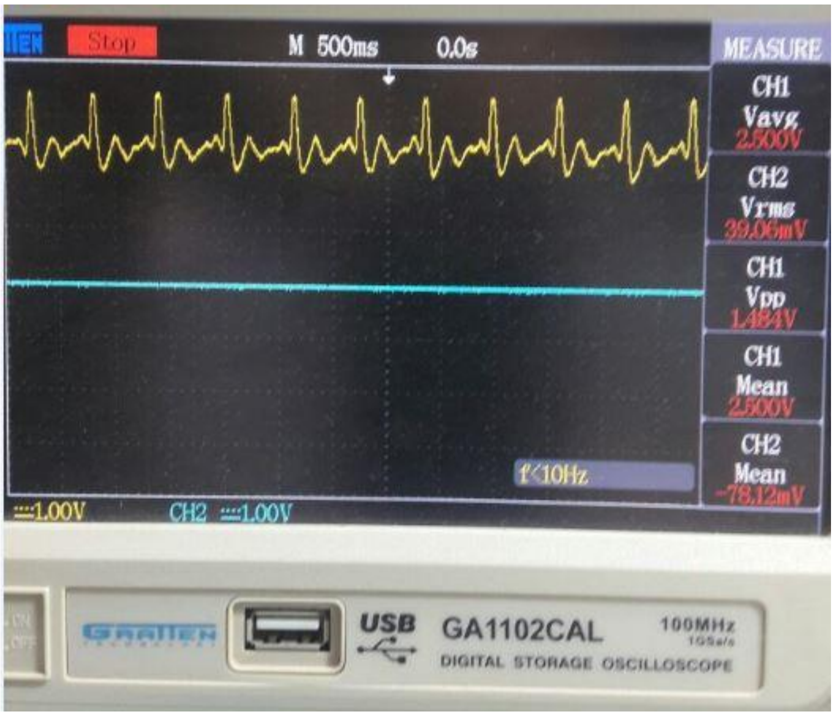

Fig. 5: An ECG signal of 34 years old person.

The experimental circuit depicted in Fig. 4 was evaluated on a 60-year-old individual to ascertain its heartbeat utilizing an ECG extraction circuit, a comparator, an Arduino, and a liquid crystal display. Fig. 6 illustrates the technique for estimating heartbeats.

Fig. 6: The mechanism of heartbeat estimation.

Fig. 7 displays the actual ECG signal of a 60-year-old individual, which is thresholded in the comparator to generate a train of signals supplied to the Arduino for heartbeat measurement.

Fig. 7: The actual ECG signal of the 60 years person.

Fig. 8 illustrates the pulse train obtained from the comparator's output. The localization of these pulses coincides directly with the R waves in the ECG signal.

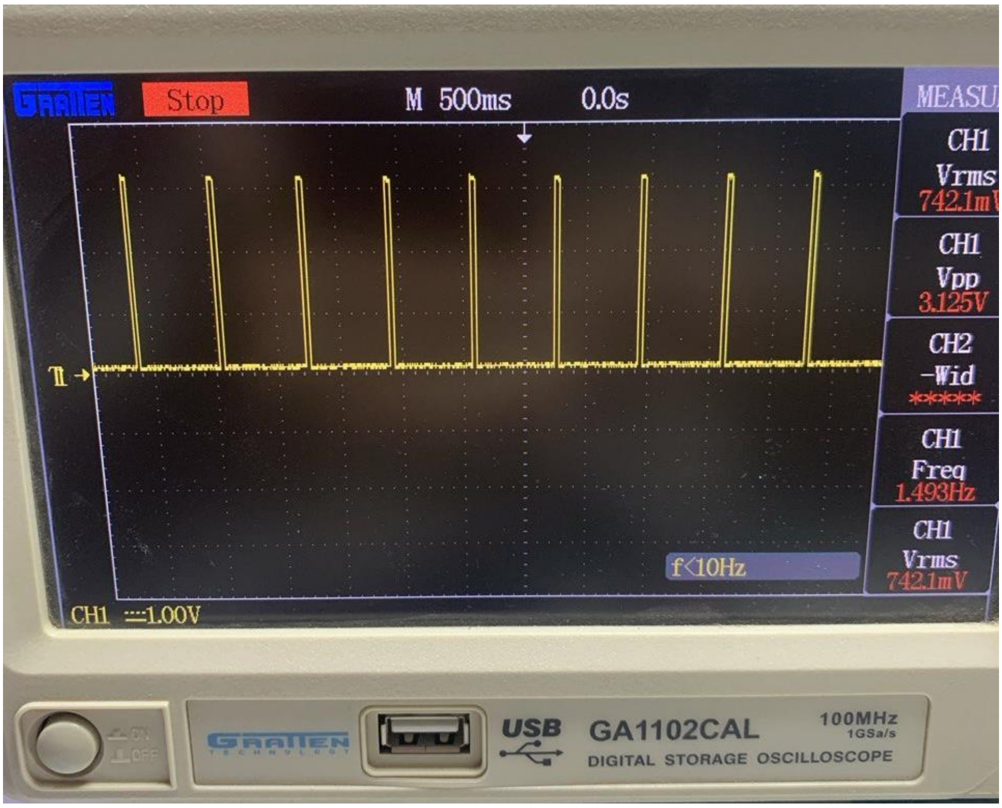

Fig. 8: The extracted pulses at the output of the comparator.

Fig. 9 illustrates the heartbeat recordings displayed on the liquid crystal display for 60 years person.

Fig. 9: A heartbeat of 74 BPM for a 60 years person.

4. CONCLUSION

In this work, three tasks are accomplished. The first task is reviewing the previous literatures about ECG in general and special focus is directed toward the techniques dealing with heartbeat or heart rate estimation. The second task focuses on ECG extraction amongst severe distortion, whereas in the third task, an Arduino and a liquid crystal display are used to accomplish an accurate estimation of heartbeat using the extracted ECG signal. The extracted ECG signals are to some extent clean and acceptable for all cases. The heartbeat mechanism leads to accurate and satisfactory estimation of heartbeat, since it targets the number of beats per minute (BPM). In future, a different approach of heartbeat estimation technique may be considered and implemented in a compact hardware.

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