React-Native Based Mobile App for Biosignal Data Acquisition Design

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ABSTRACT

Human-machine Interfaces (HMIs) is a scientific asset to the interdisciplinary research area of biomedical signal acquisition system and graphical display. Image acquisition from scanning devices has raised great technological challenges to be resolved in the past decade. The proposed mobile application is compatible with both android and iOS devices and it was developed in the React Native framework using Visual Studio code and Expo Snack tools. Biomedical instruments are used to assist doctors in their diagnosis and surgical procedures. More such products in the market have become a recent trend in the form of wearable and handheld portable devices compatible with mobile phones to assist remote patient analysis and recovery process. The signal conditioning preprocessing circuitry designed to provide the graphical information of the biomedical image acquisition devices uses low power, low bandwidth Analog-to-Digital converter (ADC). The proposed mobile application is an initial prototype to assist the design of a single-bit ADC using different CMOS technology nodes in addition to displaying a graphical output of ECG.

Keywords: Human-Computer Interface, Transducer signal conditioning circuitry, Analog-to-Digital Converter, biopotential signal processing, sampling, Biomedical data acquisition, Electrocardiogram, React-Native framework for Mobile App

INTRODUCTION

Human-Computer Interaction (HCI) used in biomedical applications gives Electronic Health Records (EHRs) that have been proven to be a more straightforward diagnosis of difficult health problems in the human body. However, the potentially adverse impacts of poor usability of EHRs continue to be a concern, particularly with respect to patient safety. A laboratory study of two commonly-used EHRs in four healthcare systems found wide variability in task completion time, required clicks, and error rates (ranging from 0% to 50% for various tasks), even though the products had been certified by accreditation authorities [1]. In order to tackle these problems encountered so frequently in health informatics, continuous re-evaluation and updation of the computational techniques within the Biomedical signal recording devices have been considered to be a prominent area of research. Health informatics is a spectrum of multidisciplinary fields that includes the study of the design, development, and application of computational innovations to improve health care [2]. The human-machine interaction can be improvised by using a more robust visual-based human-computer interface. The proposed mobile application is an initial prototype for attaining a better signal conditioning unit design that significantly eliminates errors during the visual analysis for an efficient patient diagnosis.

The recent advancements in the field of microelectronics and VLSI have driven forward the advent of biomedical devices that can be used for recording numerous biological tissue activities collectively using multichannel devices. Such channels have sensors to collect the extracellular signals from a micromachined array including several electrodes and process them through embedded microelectronic circuits for conditioning, multiplexing, and digitization [3]. These recorded physiological signals could be in any form that includes biochemical activity as hormones, neurotransmitter and electrical activity as voltage or current signal, and physical activity as pressure and temperature signals. Biomedical signals are the bioelectric potentials, generated when the human system performs nerve conduction, brain activity, heartbeat, muscle activity, and so on [4]. The majority of biomedical signals are divided into two categories such as event-related potential and action potential [5]. Electroencephalogram (EEG), Electromyogram (EMG), Electroneurogram (ENG), and Electrocardiogram (ECG) are at present action potential signals. The potentials related to an event or evoked potentials are Phonocardiogram (PCG), Electrogastrogram (EGG), Vibroarthrogram (VAG), carotid pulse (CP), Speech signal, Vibromyogram (VMG), signals from the catheter-tip sensors and otoacoustic emission signal [6]. The biomedical signals acquired from the human body are frequently very small, often in the millivolts range, and each has its own processing needs [7]. In biomedical instrumentation systems, specialized analog integrated circuits are used in the biosignal acquisition process. Most biomedical signals are characterized by their low voltage amplitude (in the range of milli-volts) and their low-frequency ranges (a few tens of kHz) [8]. A typical biomedical sensor interface consists of a band-pass filter, a low-noise programmable amplifier, and an Analog-to-Digital Converter (ADC) [9]. The proposed mobile app introduces a system design interface using a novel single-bit ADC using a comparator [10]. Most of the works on biomedical sensor designs have been focused on low-power and low-voltage techniques and architectures [11].

Mobile application development has played a major role in the field of biomedicine which is the cornerstone of modern health diagnostic methodologies in practice. Telehealth, which has been gaining more popularity and acceptance amongst the various governing bodies, stresses the need for more robust design practices to support the accuracy of remote services provided to the people. In this paper, the proposed mobile app is the initial phase of a prototype developed in the React Native open-source UI software framework suitable for developing applications for android, iOS, etc. It has been developed with Expo Snack, an open-source platform for running react-native apps in the browser [12]. Further development has been done with the offline Visual Studio Code development environment and the mobile app developed has been shared as a public repository [13] in GitHub which is one of the most popular solutions for hosting the source code.

State-Of-The-Art

Biosensors, which are devised to integrate a biological probe and a transducer, have received increasing interest for environmental, industrial, and biomedical diagnostics [14]. Current developments in nanoelectronics, biochemistry, and information technology are providing feasible development pathways to allow the creation of medical nanorobots which will include embedded and integrated devices. The circuitry consists of the main sensing, actuation, data transmission, remote control uploading, and coupling power supply subsystems [15]. A typical person carries on average one or two mobile devices nowadays. Hence, by leveraging the increasing presence of mobile devices the cost of equipment can be reduced significantly in many industries. New services can emerge to address society's challenges such as remote health monitoring for elderly patients [16]. The driver monitoring systems for Android-based smartphone device for measuring safety-related data involves the fusion of attributes gathered from different sensors including electrocardiography. The sensory data are transmitted via Bluetooth communication to the smartphone device [17]. Healthcare applications require an ergonomic approach and high precision. Physiological biopotentials can be also measured using wearable devices for various healthcare applications [18]. The proposed smartphone app can also be used as a web-based solution in a browser, to ease the process of designing and upgrading the internal integrated circuitry for the biomedical acquisition of data. This requires a trade-off between power consumption and accuracy in the resulting ECG data that can be plotted from a single-channel data recording device. In addition to this feature, it further assists in displaying the sensor data to plot the different biosensors used in biomedical recording devices. However, the proposed system is in the initial development phase which possesses the limitation of not analyzing the ECG data sample from a real-time biosignal transducer-amplifier circuitry. Future advancements can assist in displaying the different biosensor signals and use them for automation of diagnosis procedures to assist doctors in choosing better patient-care measures in handheld devices.

PROPOSED MOBILE APPLICATION FOR BIOSIGNAL ACQUISITION SYSTEM

The rise of mobile telephony has driven significantly the development of mobile devices that incorporate different hardware and software technologies at even minor costs [18][19]. The proposed mobile app contains a MOSFET model for both nMOS and pMOS devices that can be adjusted to different technology nodes for the proposed single-bit ADC design for the biomedical instrument. The electrogram considered for the initial phase of the prototype is electrocardiography (ECG). The electrogram sample data used for the ECG plot in the mobile app has been taken from a biopotential signal recording device operating at a sampling frequency of 100Hz [20].

Design Considerations

The mobile applications for telemedical initiatives have to address certain design challenges due to constraints like limited resources in processing speed of the hardware, less memory, vulnerability of portable mobile devices to suffer damages, non-stable connectivity and variable bandwidth, low power consumption due to battery-powered circuitry, etc. The biomedical signals acquired and transferred to mobile devices need to be processed using a biomedical signal acquisition system.

Biomedical Signal Acquisition System

The biopotential electrodes in the biomedical recording instrument can be passed to the biomedical signal acquisition system using the selection control circuitry according to the electrogram as shown in Figure 1. The low-voltage, low-frequency sensor data obtained has to be amplified, filtered for noise removal, and digitized using the signal conditioning circuit. The electrogram user interface can monitor the recorded observations as images with appropriate pre-processing techniques. The diagnosis can be done by using methods like deep learning algorithms, neural networks, etc. which use training data for further comparison with the ideal scenario to assist the medical practitioners.

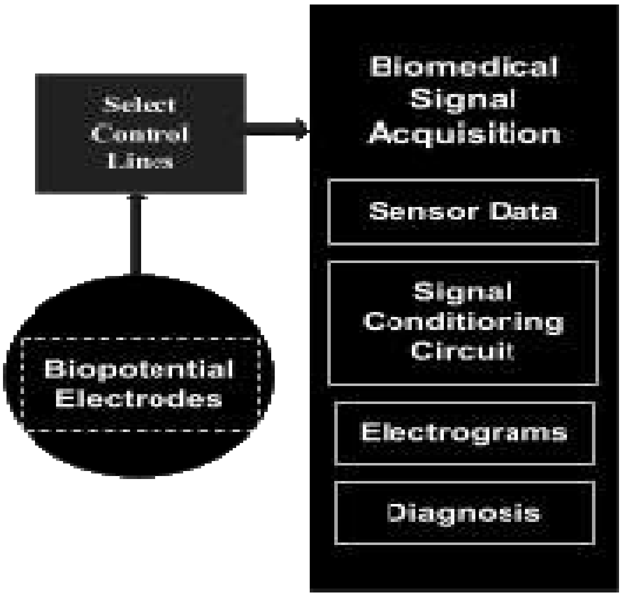

Figure 1. Biomedical Signal Acquisition System

Design considerations for Mobile App

The proposed prototype for biosignal acquisition simulation consists of implementing the home screen that navigates to the biosignal acquisition system design screen. The screen has a user interface to navigate to the other screens like the PMOS model, NMOS model, and the proposed Single-bit ADC for the acquisition system. The ECG data acquisition simulation is done using the sample data [20] as shown in Figure 2.

The design of mobile apps starts with wireframing which involves sketches using tools that can help with the prototyping and user interaction of the application [20]. The wireframe of the proposed mobile app has been designed using Justinmind UI prototyping tool used to create web and mobile app prototypes and wireframes. The biosignal acquisition system screen has been designed to include more electrogram simulation analysis using robust digitization design techniques in the later phases of this prototype.

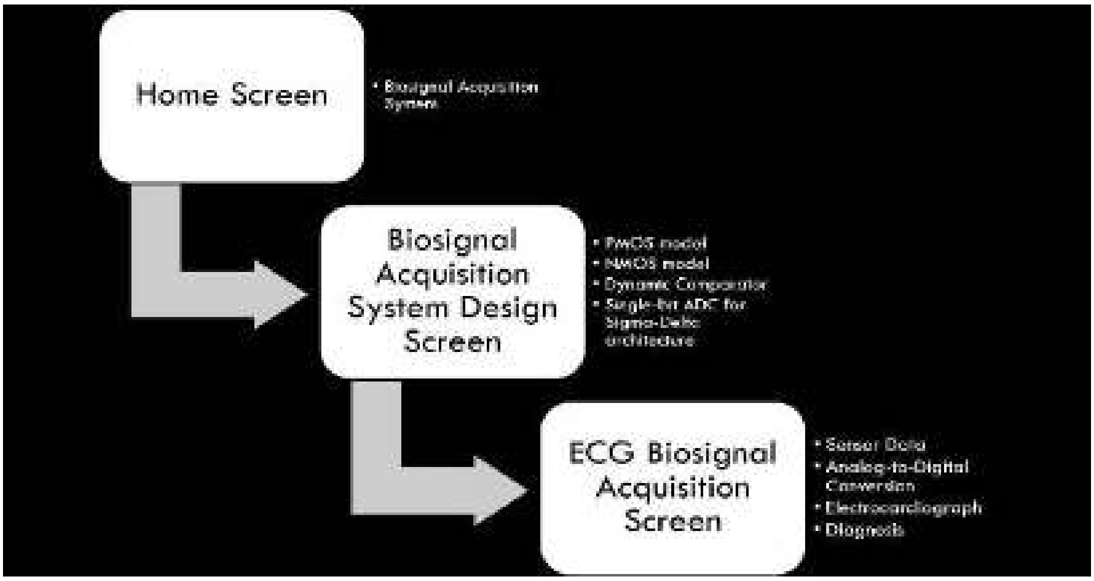

Figure 2. Flowchart of the proposed Mobile App

Figure 3. Wireframe of the proposed Mobile App with Home Screen, Screen for Biosignal Acquisition System, and Screen for ECG Acquisition System

Proposed Single-bit ADC Design

The proposed novel single-bit ADC is a dynamic comparator design that can digitize the noise-free amplified biosignals in the biomedical acquisition system. The electronic circuit shown in Figure 4 has been designed using the SPICE default model using LTspice which is a powerful, fast, and open-source SPICE simulator software with enhancements like schematic capture and waveform viewer. The proposed circuit consists of 4 nmos transistors in the main comparator circuit whose substrate has been biased to the ground potential. The negative (INN) and positive (INP) amplified, filtered biosignal inputs are given to the PMOS with substrate biased to the power supply according to the CMOS fabrication technology node in the design. The pMOS load and nMOS are clocked using CLK and CLKBAR signals which are inverted voltage pulses applied to compensate for the parasitic capacitance attenuation of the signals switching between the cutoff and saturation modes of the MOSFETs in the circuit. The inverted output is then processed using a three-stage inverter circuit designed initially with L=1 um in the MOSFET model to limit the channel length modulation effects which affect the lambda parameter that may degrade the ADC performance.

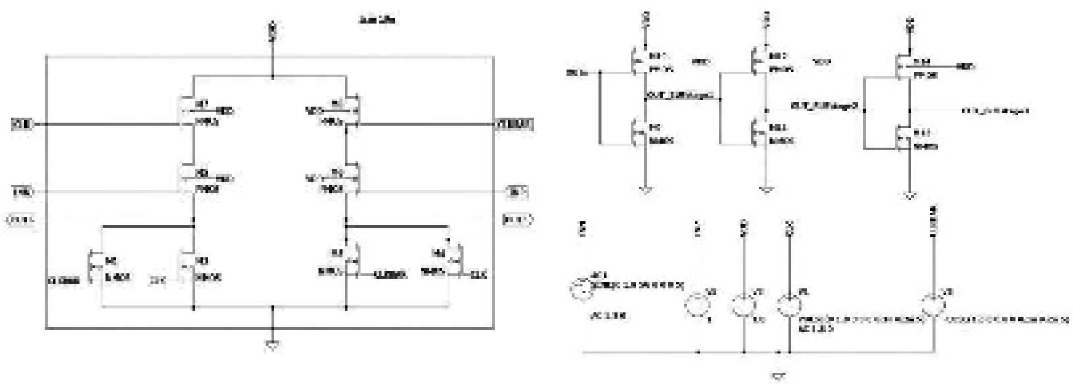

Figure 4. Single-Bit ADC using Dynamic Comparator, Transient Analysis

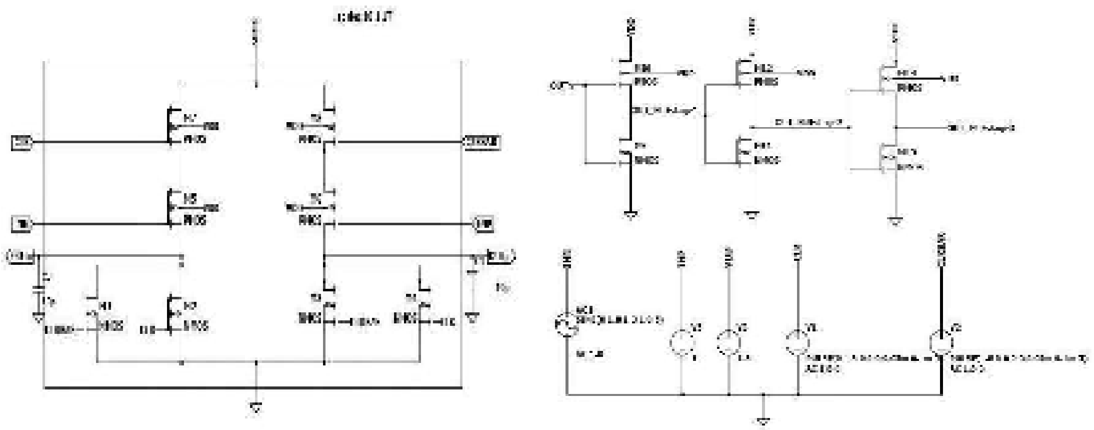

Figure 5. Single-Bit ADC using Dynamic Comparator, AC Analysis

The clock signals, input signals, and buffered rail-to-rail output with low transient distortion have been included. The AC analysis of the proposed digitizing circuit has been done with a 1.8 V peak voltage in decade steps as shown in Figure 5. The transient and AC analysis results are shown in Figure 6. The average power dissipation of the circuit is 340 µW with an f_{-3dB} bandwidth of approximately 3 MHz.

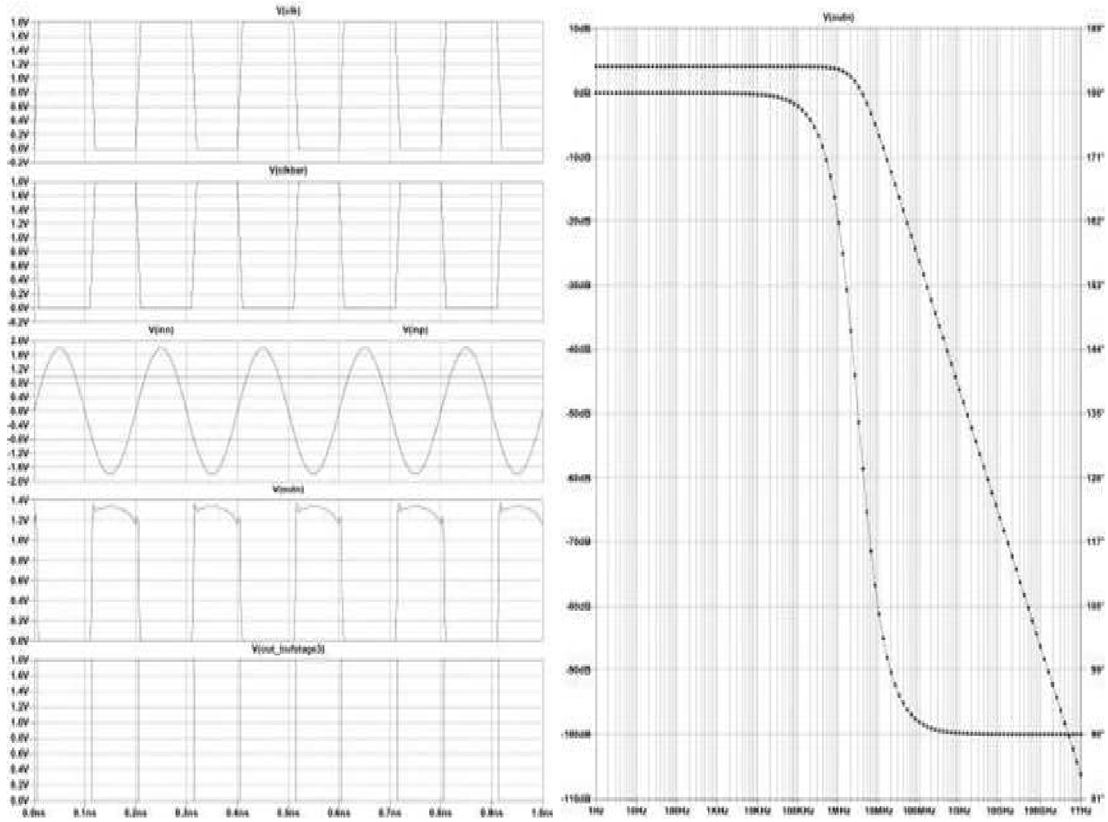

Figure 6. Transient and AC Analysis of Single-bit ADC using Dynamic Comparator logic

Mobile App development using React-Native

React Native platform operates using threads to run applications. Threads include UI Thread, JavaScript Thread, Native Thread, and Render Thread. The UI Thread is the main thread and handles Android and iOS UI view rendering. On Android, it is used for ‘measure//layout/draw’. The JavaScript (JS) Thread is used to handle all the logic of the application and runs your application's JavaScript code, API calls, touch events, and more. Native Modules Thread is used when an application accesses the platform API, and each module has a thread. The Render Thread is used to draw the UI only in Android 5.0 Lollipop. The Render Thread generates the OpenGL commands needed to draw the UI [13]. The proposed mobile app was initially designed using the Expo Snack web tool in version v47.0.0 is shown in Figure 7. The switch navigation component from the react-navigation has been used for navigating between the different screens mentioned in the wireframe of the prototype. Figure 8 shows the ECG plot with data recorded at a sampling frequency of 100Hz, which was then trimmed down to 95000 samples [20].

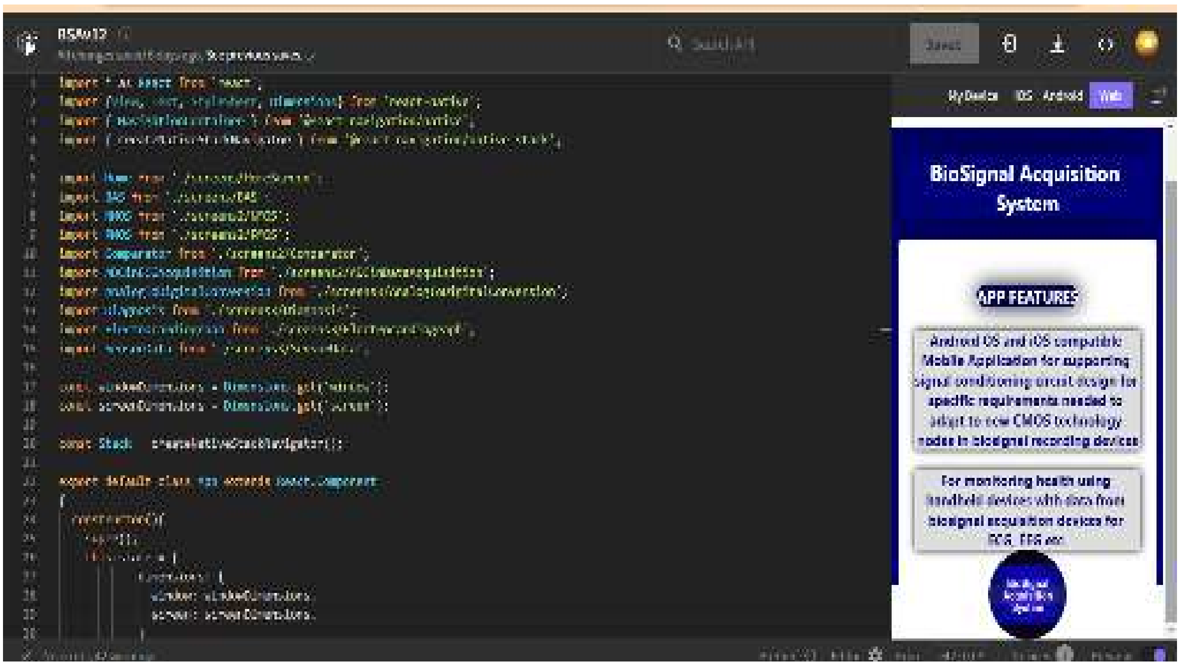

Figure 7. Mobile App Development using React Native platform

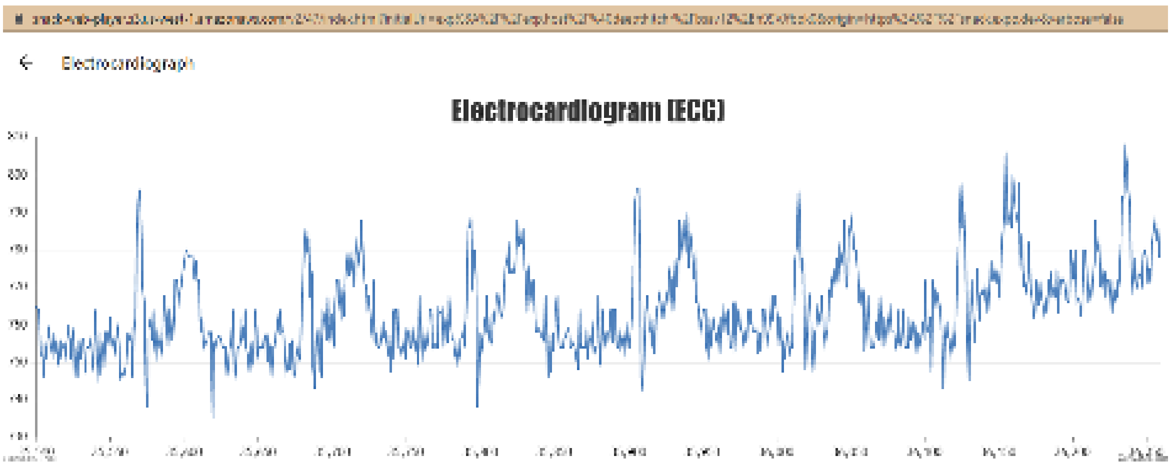

Figure 8. Electrocardiogram with Biomedical ECG database [20]

Comparison with other Mobile Apps

A comparison of the proposed mobile app with some other relevant products available in the market for ECG analysis has been listed in Table 1.

Table 1. Comparison of the proposed mobile app with other products in the market

Reference	App Features	Design support to meet the requirements specification
Proposed App	-CMOS technology node can be used to set the design constraints of the digitization circuit -Initial prototype to simulate ECG sample dataset.	-CMOS technology node can be used to set the design constraints of the digitization circuit. -ADC design specification can be used to ease the analog design of the ICs used in biomedical instruments.
AliveCor Kardia Band [22]	-FDA-cleared mobile electrocardiogram (ECG) technology for mobile devices. -World's smallest single lead medical grade ECG. -A tool to analyze heart rhythm with a quick touch of the watch strap and can reveal instantly if it is normal or possible AFib.	-Not applicable since product-based technology.
Sanket Life 2.0 [23]	-PQRST Analysis for Heart Rate variability and Stress Levels -Compatible with most Android and iOS devices	-Not applicable since product-based technology.

Conclusions and Future Scope

The proposed mobile app is a prototype showing the simulation of real-time ECG acquisition hardware and software design user interface for empowering more robust designs that may assist in future developments for addressing the practical challenges in biomedical instrumentation and the latest diagnosis techniques. The React-Native application provides a UI for easy navigation and access to the design platform integrated with the ECG data graphical display of the biomedical dataset [19] recorded at an operating frequency of 100Hz. The biosignal acquisition screen provides UX for setting the NMOS and PMOS models for the calculation of design parameters to assist better chip design within the biosignal signal conditioning module for processing in even wearable bioelectronic technologies [18].

The single-bit ADC design has been inspired by the proposed comparator circuit operable at the desired bandwidth of 2.97 MHz and phase margin of 181.84°. The single-bit ADC design can be optimized using the application for different CMOS technology node process parameters. The current design has been simulated using the SPICE model available in LTSpice for the transient and AC analysis. The future scope involves the inclusion of more electrogram analysis, the inclusion of machine learning algorithms to support actual diagnosis, and the implementation of the design system for the complete amplification, filtering, and digitization functionalities of the biosignal acquisition unit. The proposed smartphone-compatible app can be further integrated into Internet-Of-Things (IOT) Remote Patient Monitoring using advancements in web services and cloud computing [16].

Acknowledgments

This work has been developed using open-source tools and resources. The LTspice has been used for additional analog circuit analysis. The mobile app has been developed in visual studio code in the offline mode and has been published as a repository using GitHub. I acknowledge the support of Dr. Rajeev R.R., Programme Head (e-Governance and Development) at ICFOSS for further guidance during the project idea discussion.

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