

BENCHTOP MODEL USED TO MEASURE THE EFFECT OF DISTANCE BETWEEN ECG ELECTRODES

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ABSTRACT

Traditional electrocardiogram (ECG) devices rely on wiring systems that create challenges in healthcare environments, including wire clutter, inefficiency, and potential for errors. To address these issues, the feasibility of reducing the distance between ECG electrodes was investigated, which is a step toward developing a wireless ECG system. By eliminating wires, healthcare professionals can benefit from improved portability, enhanced ergonomics, and streamlined workflows.

A benchtop model was developed to simulate a 3-lead ECG system and replicate Einthoven's Triangle, offering a platform to study the behavior of wired systems and signal acquisition. This model used a waveform generator to feed the signal into a 10mM NaCl solution, with electrode pairs forming a triangular configuration. The NaCl solution acts as a medium to allow for electrical current to travel. Generated signals were captured using the BIOPAC MP160 with the ECG100C module and the AD8232 integrated chip. The study examined the effect of electrode distances on signal quality.

The results consistently showed that as electrodes were positioned closer to each other and to the signal source, the signal quality improved significantly for both BIOPAC and AD8232 devices. These findings highlight that high-quality ECG signals can still be achieved with reduced electrode distances, offering a strong foundation for future innovations. Subsequent research will involve human subject testing under IRB approval to validate these results in real-world scenarios. Additionally, this work will guide the development of a wireless ECG system, enhancing usability, portability, and comfort while making ECG devices more efficient for modern healthcare applications.

Keywords: Electrocardiogram (ECG), ECG simulation, Einthoven's Triangle, BIOPAC MP160, AD8232, ECG benchtop testing.

INTRODUCTION

The electrocardiogram (ECG) is a critical diagnostic tool that monitors heart activity by recording voltage changes from cardiac depolarization and repolarization. Standard lead configurations, including limb and precordial leads, capture key waveform components such as the P wave, QRS complex, and T wave. However, traditional ECG systems rely on complex wiring setups that can create challenges in clinical environments, including wire clutter, inefficiencies in patient monitoring, and potential signal acquisition errors [1,2].

To address these limitations, researchers are exploring alternative electrode configurations, particularly reducing inter-electrode distances, to simplify setups while maintaining diagnostic accuracy. This study examines waveform integrity and noise levels across varying lead distances, as deviations in ECG morphology—such as altered P waves or prolonged QRS duration—can indicate cardiac abnormalities [3]. Enhancing the portability and usability of ECG devices is crucial in modern healthcare, where mobility and rapid diagnostics are essential.

Recent advancements in technology have enabled the development of compact and wireless ECG systems that can maintain high signal quality despite reduced electrode distances. Studies have shown that closer electrode placement can significantly improve the quality of ECG signals, thereby facilitating more accurate heart monitoring and diagnostics [4,5]. Electrode detects the voltage changes caused by depolarization and repolarization of the heart's chambers. The exploration of these configurations is

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