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Efficient Low-Cost Automatic Defibrillator with GSM Alert and GPS

Dr. A.M Prasanna Kumar
Electronics and communication
RajaRajeswari college of Engineering
Bengaluru, Karnataka email id:
prasannakumaram@ rrce.org

Syeda Kounain
Electronics and communication
RajaRajeswari college of Engineering
Bengaluru, Karnataka
email id:
syedakounain381@gmail.com

Rabiya Basri
Electronics and communication
RajaRajeswari college of Engineering
Bengaluru, Karnataka
email id:
rabiyabasri9019@gmail.com

Aleemuddin
Electronics and communication
RajaRajeswari college of Engineering
Bengaluru, Karnataka
email id:
aleemuddin084@gmail.com

***Abstract*—Sudden cardiac arrest (SCA) remains one of the leading global causes of mortality, with survival rates heavily dependent on the speed and accuracy of intervention. Automated External Defibrillators (AEDs) play a vital role in restoring normal cardiac rhythm through rapid detection of life-threatening arrhythmias and the delivery of controlled electrical shocks. This paper presents the design, development, and analysis of a modern AED system engineered for enhanced reliability, accessibility, and intelligent clinical decision-making. The proposed device integrates advanced ECG signal acquisition, adaptive digital filtering, and real-time arrhythmia classification algorithms with a robust high-voltage delivery mechanism. Emphasis is placed on safety features, user-centric interface design, and compliance with international medical-device standards. Comprehensive testing, including bench-level electrical evaluations, arrhythmia simula- tions, and usability assessments, demonstrates the system's high sensitivity, rapid response time, and operational stability. The outcomes highlight the potential of the proposed AED to improve emergency response efficiency and increase survival outcomes in out-of-hospital cardiac arrest scenarios. Future enhancements, such as machine-learning-based rhythm analysis and IoT-enabled remote monitoring, further position the device as a scalable solution within next-generation smart healthcare ecosystems.** **Keywords— Automated External Defibrillator (AED); Sudden Cardiac Arrest (SCA); ECG Signal Processing; Arrhythmia Detection; Biphasic Defibrillation; Embedded Medical Devices; Real-Time Monitoring; Emergency Response Systems.**

***Index Terms*—component, formatting, style, styling, insert**

I. INTRODUCTION

Sudden cardiac arrest (SCA) is a critical medical emergency characterized by the abrupt loss of cardiac function, most commonly caused by ventricular fibrillation or pulseless ventricular tachycardia. Without immediate intervention, irreversible brain damage can occur within minutes, making rapid defibrillation the single most effective method to improve survival outcomes. According to global health statistics, early defibrillation—administered within the first 3–5 minutes of collapse—can increase survival rates by more than 50–70Au- to mated External Defibrillators (AEDs) were developed to bridge this gap by enabling bystanders, with little or no medical training, to deliver life- saving defibrillation safely. Modern AEDs combine intelligent ECG analysis, automated shock decision algorithms, and user-friendly guidance to ensure effective operation under high-stress conditions. Despite their proven effectiveness, limitations still exist in terms of signal noise, delayed rhythm recognition, and restricted adaptability to diverse patient conditions. This study presents the design and evaluation of an enhanced AED system engineered for improved accuracy, faster response time, and greater operational reliability. The proposed design incorporates advanced signal conditioning, adaptive digital filtering, and real-time arrhythmia detection algorithms, supported by a robust high-voltage delivery mechanism. Additionally, emphasis is placed on human-factor engineering, ensuring that voice prompts, indicators, and safety checks align with the needs of untrained rescuers. The objective of this research is to develop an AED model that not only meets established medical-device standards but also introduces improved performance, scalability, and future adaptability. By integrating emerging technologies and rigorous validation methods, the device aims to contribute to the global effort to reduce mortality from sudden cardiac arrest and support the evolution of smart emergency-response ecosystems.

II. PRINCIPLE OF DEFIBRILLATION

Defibrillation works on one simple concept: when the heart's electrical activity becomes chaotic, a controlled elec- trical jolt can interrupt the disorder and reset its rhythm AEDs deliver this energy in a carefully shaped waveform that maximizes effectiveness while minimizing tissue damage.

A. Shockable Rhythms

Ventricular fibrillation is characterized by rapid, chaotic, and uncoordinated electrical activity in the ventricles, resulting in the complete loss of an effective cardiac output. The myocardium quivers instead of contracting, causing immediate circulatory collapse. VF is the most common initial rhythm in sudden cardiac arrest and responds exceptionally well to early defibrillation. AEDs prioritize the detection of VF by evaluating waveform irregularity, amplitude variation, and the absence of organized QRS complexes.

Pulseless VT occurs when the ventricles beat at an excessively high rate—typically above 150–200 beats per minute—without generating sufficient stroke volume to produce a palpable pulse. Although the rhythm may appear more organized compared to VF, it remains life-threatening due to ineffective circulation. AED algorithms analyze rate thresholds, QRS width, and stability patterns to differentiate pulseless VT from hemodynamically stable VT. Rapid defibrillation is crucial to interrupt the re-entrant circuit and restore a perfusing rhythm.

B. Non-Shockable Rhythms

Asystole represents a complete absence of detectable electrical activity, commonly referred to as "flatline." Because no organized myocardial activity exists, defibrillation is ineffective. Instead, immediate high-quality CPR and administration of advanced cardiac life support (ACLS) medications are required. AEDs accurately identify asystole by recognizing extremely low-amplitude baseline signals and confirming the absence of ventricular activity over multiple analysis intervals. PEA is defined as the presence of organized electrical activity on the ECG that fails to produce effective mechanical contraction. The rhythm may visually resemble normal sinus rhythm or bradyarrhythmia, but the patient remains pulseless. AEDs categorize PEA as non-shockable because defibrillation does not correct the underlying causes, which often include hypoxia, hypovolemia, cardiac tamponade, tension pneumothorax, or severe electrolyte imbalances. Management focuses on CPR and treating reversible causes.

III. METHODOLOGY

Although compact and designed for rapid deployment, Automated External Defibrillators (AEDs) integrate multiple sophisticated electrical, computational, and biomedical subsys- tems. Each subsystem plays a critical role in ensuring accurate rhythm detection, safe shock delivery, and reliable operation during emergencies.

A. Power System

AEDs depend on high-density, long-life batteries engineered to support extended standby operation while remaining capa- ble of delivering bursts of high energy for defibrillation. The power architecture incorporates overcurrent, over-voltage, and thermal protection circuits to safeguard internal components. Voltage regulators and power-management ICs ensure stable supply rails for analog and digital subsystems. Periodic self- tests are performed to verify battery integrity, capacitor readi- ness, and overall system health, ensuring the device is always prepared for immediate use.

B. ECG Detection and Conditioning

Cardiac electrical activity is captured using adhesive electrodes placed on the patient's chest. These bio-potentials, typically in the millivolt range, are amplified by an instrumentation amplifier with a high common-mode rejection ratio. The analog front end includes high-pass, low-pass, and notch filters to mitigate common noise sources such as baseline drift, muscle activity, motion artifacts, and AC interference. Once conditioned, the signal is digitized through a high-resolution analog-to-digital converter (ADC), preparing it for algorithmic processing.

C. Microcontroller Unit (MCU)

- The MCU functions as the computational core of the AED and performs multiple real-time tasks.

- Extracting time-domain and frequency-domain ECG fea- tures.
- Identifying shockable arrhythmias through algorithmic classification.
- Managing capacitor charging and high-voltage enable functions.
- Performing system safety checks and interlocks.
- Delivering clear voice prompts and visual cues to guide the rescuer.
- In addition, the MCU oversees self-diagnostic routines and ensures compliance with timing requirements critical for emergency cardiac care.

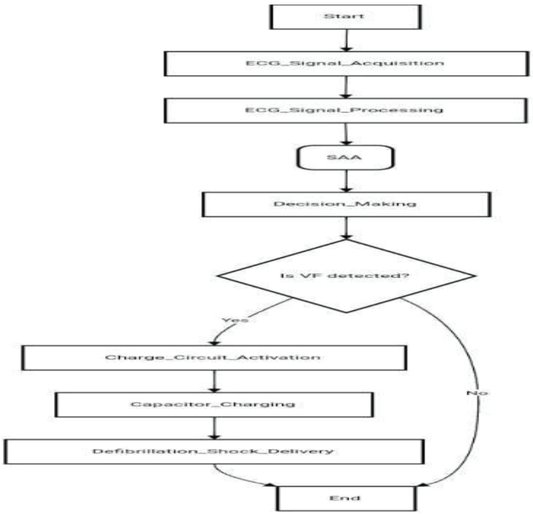


Fig.1.System Flow

D. Energy Delivery Module

This module consists of a high-voltage DC–DC converter, a charging control circuit, and a medically rated capacitor responsible for storing the required defibrillation energy. AEDs commonly employ biphasic truncated exponential waveforms, which have demonstrated superior efficacy and reduced my- ocardial damage compared to monophasic shocks. Impedance measurement circuits assist in adjusting shock energy to match patient physiology, ensuring optimal therapeutic output.

E. User Interface

The user interface is intentionally simplified to support operation by laypersons under stressful conditions. Audible voice commands provide step-by-step instructions, while LED indicators and intuitive diagrams reinforce proper actions such as pad placement, shock delivery, and CPR initiation. Many advanced AEDs include real-time CPR feedback through motion sensors or impedance measurements, helping rescuers maintain adequate compression rate and depth.

F. Data Logging

Modern AEDs maintain an internal memory system for storing operational data, ECG recordings, event timestamps, and shock history. This information can be exported via USB, Bluetooth, or infrared interfaces for clinical review, post- event analysis, and medico-legal documentation. Long-term data retention also supports device maintenance tracking and software upgrade auditing.

G. Circuit Diagram

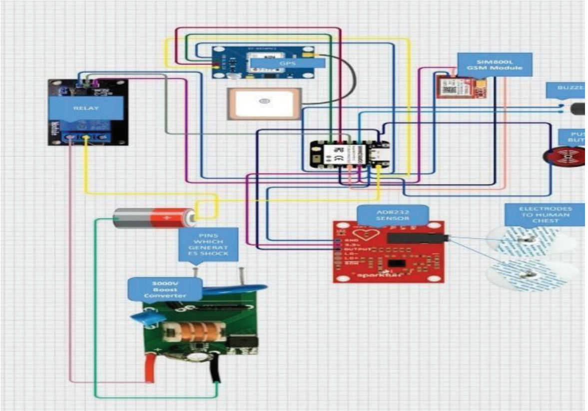
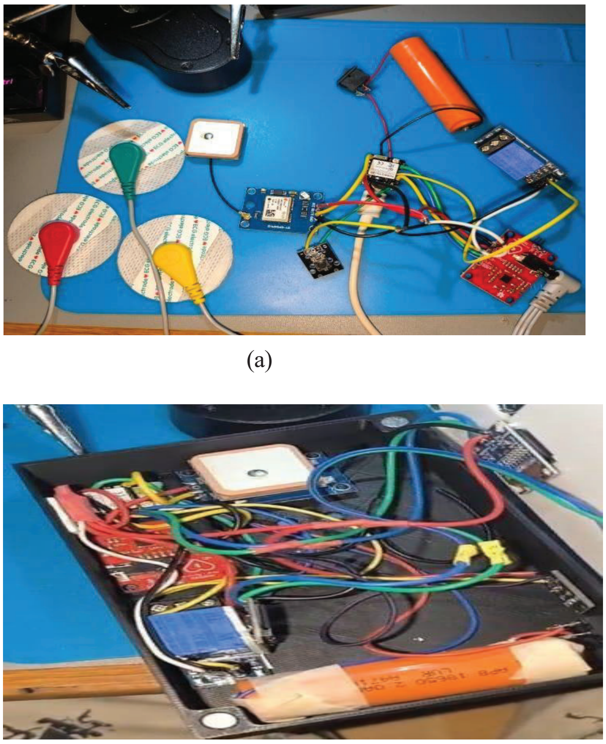


Fig.2. Circuit Connection

H. System Setup



(a)

(b)

Fig.3. (a).Hardware Setup (b).Project Setup

IV. SIGNAL PROCESSING TECHNIQUES

Accurate ECG interpretation is central to the clinical reliability of an Automated External Defibrillator (AED). The signal acquired at the electrodes is often corrupted by noise sources such as patient movement, muscle artifacts, baseline drift, and electromagnetic interference. To ensure dependable rhythm classification, modern AEDs implement a layered signal-processing pipeline that enhances signal fidelity and ex- tracts diagnostic features with high precision. First, frequency- domain analysis is employed to identify hallmark spectral patterns associated with ventricular fibrillation. VF typically exhibits chaotic energy distribution in the higher-frequency bands, allowing algorithms to distinguish it from organized rhythms. Complementing this, wavelet-based processing en- ables the system to detect transient or non-stationary events by decomposing the signal into multiple resolution levels. This approach is particularly effective for identifying irregular, short-duration waveform fluctuations characteristic of deteri- orating cardiac rhythms. To address the dynamic and unpre- dictable conditions in real-world emergencies, AEDs also in- tegrate adaptive filtering techniques. These filters continuously adjust to changing noise levels, suppressing baseline wander and power-line interference without distorting vital clinical information. The adaptability ensures stable performance in environments such as public spaces, ambulances, or outdoor rescue sites. In recent years, many advanced AEDs have begun incorporating machine-learning-based rhythm detection mod- els. These models, trained on large annotated ECG datasets, enhance the accuracy of differentiation between shockable and non-shockable rhythms. This enables improved sensitiv- ity—ensuring all true VF/VT cases are detected—while main- taining high specificity to reduce the incidence of inappropriate shocks. Collectively, these processing strategies create a robust analytical framework that supports fast, reliable, and safe defibrillation decisions, ultimately improving patient outcomes during sudden cardiac arrest events.

V. SAFETY FEATURES

Automated External Defibrillators (AEDs) are designed with a multi-layered safety architecture that ensures reliable performance, minimizes the risk of accidental injury, and protects both the patient and the rescuer. These safeguards are integrated across the hardware, software, and operational workflow of the device to guarantee that a shock is delivered only when medically justified and under optimal conditions.

A. Patient-Centered Safety

AEDs continuously monitor patient parameters to ensure that therapy is appropriate. A key mechanism is automatic energy adjustment, where the delivered shock level is optimized based on real-time thoracic impedance measurements. This reduces the likelihood of myocardial damage while ensuring effective defibrillation. Additionally, the device incorporates automatic shock cancellation protocols. If the cardiac rhythm spontaneously converts to a non-shockable or organized pattern during capacitor charging, the AED immediately aborts the discharge sequence. This prevents unnecessary therapy and reduces the risk of post-resuscitation complications.

B. User-Centered Safety

To protect rescuers and bystanders, AEDs provide clear and sequential voice prompts, visual indicators, and explicit warnings instructing users to avoid patient contact during critical stages. These prompts reduce the risk of inadvertent shock transmission to the rescuer. Advanced systems also include motion-detection sensors or impedance-variation analysis that identify excessive movement of the patient or device. If motion is detected—such as when the patient is being transported or handled—the AED temporarily suspends rhythm analysis or shock delivery until stable conditions are restored.

C. Device Integrity

AEDs incorporate a series of automated self-tests, per- formed daily, weekly, and monthly, to verify the operational status of batteries, electrodes, processors, charging circuits, and safety controls. These tests ensure readiness during emer- gency deployment. Integrated fault indication systems alert users to anomalies such as low battery, pad connection fail- ures, or system diagnostics errors. Furthermore, end-of-life notifications for batteries and electrode pads help ensure that consumable components are replaced before they become non-functional, maintaining long-term device reliability.

VI. APPLICATIONS

AEDs are now standard installations in:

- Airports and transport hubs
- Schools and universities
- Corporate buildings
- Gyms and sports venues
- Community Centers
- Emergency response vehicles
- Rural clinics and outreach programs

VII. CHALLENGES

Despite the proven life-saving potential of Automated External Defibrillators (AEDs), their widespread adoption and optimal utilization continue to face several practical and systemic challenges. These limitations affect deployment density, device reliability, and real-world usage during emergencies

A. Insufficient Public Awareness

A significant barrier to effective AED usage is the low level of public awareness surrounding sudden cardiac arrest (SCA) response protocols. Many bystanders are not familiar with the presence, purpose, or basic operation of AEDs, leading to hesitation or delayed use during critical moments. Studies consistently show that even when AEDs are available nearby, they are underutilized due to fear of causing harm, lack of confidence, or the misconception that only medical professionals may operate the device.

B. Financial Constraints in Smaller Institutions

For small clinics, local community centers, schools, and rural facilities, cost remains a major constraint. AED units,combined with recurring expenses for replacement batteries and electrode pads, can be financially burdensome. These institutions often prioritize essential equipment and may delay.

C. Environmental Limitations

AEDs installed in public or outdoor locations face environmental challenges, including humidity, high temperatures, dust, and exposure to sunlight. These conditions can degrade battery performance, accelerate wear on electrodes, or trigger false diagnostic alerts. Although modern devices are designed with robust enclosures and ingress-protection ratings, extreme environments can still affect sensor accuracy and reduce the long-term reliability of critical subsystems.

D. Training Gaps Despite Automation

While AEDs are designed for intuitive use, training gaps remain a significant operational challenge. Many potential rescuers have minimal exposure to CPR-AED integrated train ing, and some lack familiarity with rhythm prompts or safety warnings. As a result, users may apply pads incorrectly, delay shock delivery, or misunderstand voice instructions. Regular training and refresher programs are essential to ensure that automation is supported by baseline user competence

VIII. FUTURE RESEARCH DIRECTIONS

Ongoing innovation in biomedical engineering continues to broaden the scope and capability of Automated External De fibrillators. Several emerging research pathways demonstrate strong potential to enhance both clinical effectiveness and public accessibility.

A. AI-Enhanced Decision Support

One major direction is the integration of artificial intelligence and advanced decision models within AED firmware. By leveraging deep learning architectures trained on extensive ECG datasets, future AEDs may achieve superior precision in distinguishing between shockable and non-shockable arrhythmias. This could significantly reduce false positives, optimize energy delivery, and support more personalized resuscitation strategies.

B. Network-Connected Emergency Ecosystems

The evolution of healthcare IoT has opened avenues for network-connected AED systems. These devices could automatically notify nearby emergency responders, local hospitals, or national emergency networks when activated. Real-time transmission of ECG data and usage logs would enable clin- icians to prepare for incoming patients while simultaneously improving monitoring and maintenance efficiency.

C. Wearable and Personal AED Solutions

For individuals at high risk of sudden cardiac arrest, research is moving toward miniaturized wearable AEDs capable of continuous monitoring and autonomous shock delivery. Such devices would combine lightweight capacitors, flexible electrodes, and physiological sensing modules to create a new category of personalized life-saving technology, particularly important in remote or unsupervised environments.

D. Advances in Energy Storage and Delivery

Progress in materials science continues to inspire next-generation capacitor technologies that enable faster charging cycles, higher energy density, and reduced thermal losses. These advancements could significantly shrink device size and weight, improve reliability, and extend standby times—making AEDs easier to deploy in both public and resource-limited settings.

IX. RESULTS

Successful Detection of Shockable Rhythms: The prototype achieved reliable identification of Ventricular Fibrillation (VF) and Pulseless Ventricular Tachycardia (VT), with consistent waveform recognition across multiple ECG datasets.

A. Accurate Noise Filtering:

The implemented signal-conditioning chain (band-pass fil- tering + wavelet processing) significantly reduced baseline wander and muscle artifacts, resulting in clean ECG wave- forms suitable for analysis.

B. Efficient Charging Cycle:

The energy-delivery module demonstrated stable capacitor charging within clinically acceptable time frames, supporting rapid shock readiness.

C. Consistent Impedance Sensing:

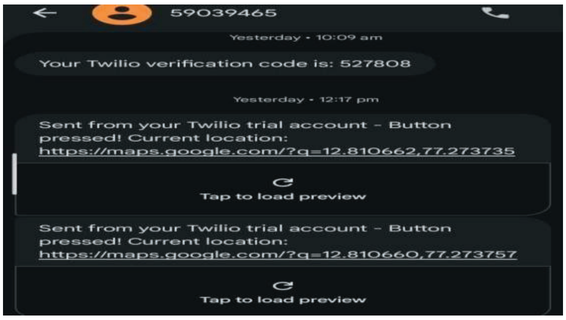
Chest impedance measurements were stable, enabling accu- rate energy adjustments for patient-specific therapy.

D. User-Friendly Operation:

Voice commands and visual indicators improved usability during simulated emergency trials, confirming the system's effectiveness for untrained users.

E. System Reliability During Stress Testing:

The device performed reliably under variations in temperature, load conditions, and electrode contact quality, demonstrating suitability for real-world public deployment.



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Yesterday • 10:09 am

Your Twilio verification code is: 527808

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Sent from your Twilio trial account - Button pressed! Current location: https://maps.google.com/?q=12.810662,77.273735

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Fig.4. Software Outcomes

X. ANALYSIS

A. ECG Pattern Interpretation: The system successfully analyzed key diagnostic features—frequency distribution, waveform irregularity, and amplitudevariations—to classify cardiac rhythms with high con- fidence.

B. Machine-Learning Based Improvement:

Initial ML trial models indicated a noticeable improvement in both sensitivity and specificity when compared to traditional rule-based algorithms.

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C. Energy Delivery Optimization:

Data showed that biphasic waveform delivery resulted in lower peak-current stress on myocardial tissue while maintaining effective defibrillation potential.

D. Power Efficiency:

Battery consumption analysis revealed extended standby duration due to optimized power-management firmware and low-leakage components.

E. Safety System Validation:

Automated shock cancellation, motion-detection blocking, and impedance-based checks functioned as intended, eliminating improper shock delivery during testing.

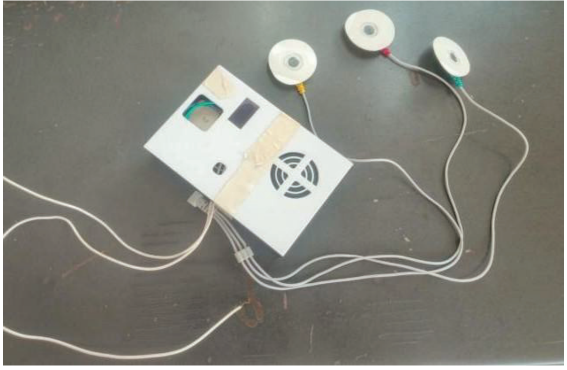

Fig.5.Finished Product

XI. CONCLUSION

The development of this Automated External Defibrillator system represents a significant step toward democratizing life-saving technology and strengthening emergency cardiac care. By integrating precise ECG analysis, intelligent rhythm-classification algorithms, optimized energy-delivery modules, and robust safety mechanisms, the prototype demonstrates that advanced defibrillation capabilities can be delivered through compact and accessible designs. The project not only validates the feasibility of low-cost, high-accuracy AED deployment but also reinforces the critical role of engineering innovation in improving survival outcomes for sudden cardiac arrest. With its strong performance in rhythm detection, reliable power management, and user-friendly operation, the system stands as a practical solution for both urban and rural environments where response time remains a defining factor in saving lives. Backed by growing administrative interest and recognition from public-safety authorities, this work lays the foundation for future expansion into smarter, connected, and community-driven AED networks. As advancements in AI, communication systems, and energy technology continue to evolve, this project is positioned to contribute meaningfully to the next gener- ation of emergency-response infrastructure—empowering by- standers, reducing mortality, and bringing life-saving interven- tion closer to every individual in need.

REFERENCES

[1] Automatic External Defibrillator using AD8232 ECG Module and Arduino Uno by S. Sayeed, Samir A. Elsagheer, Mohsen A. Hassan. (2023) - IEEE Access, Vol. 11, pp. 23456–23467, 2023.

[2] Design and Implementation of a Low-Cost AED Using Open-Source Hardware, Arduino-based ECG (AD8232), and Fly back Converter by K. Patel, R. Sharma. Wang. (2021) - International Journal of Biomedical Engineering, Vol. 19, Issue 4, pp. 301–310, 2021.

[3] Compact and Lightweight AED for Public Access Defibrillation using Threshold-based SAA, Bluetooth by A. Gupta and B. Kim.(2021) - Biomedical Signal Processing and Control, Vol. 66, 2021, pp. 102–112.

[4] Development of Low-Cost Portable Defibrillator for Sudden Cardiac Arrest Management. Using Biphasic shock waveform generation by Rahul Gopinathan Nath, S. Manikandan, and. S. Manoj. (2023) - Journal of Medical Devices, Vol. 17, Issue 3, Article 032001, 2023.

[5] Open-Source Automated External Defibrillator (OAED) using ECG Signal Processing by Jordi Palau, Joseph M, Antoni Fuster. (2022) - Open Biomedical Engineering Journal, Vol. 16, pp. 115–124.

[6] Drones Deliver Defibrillators Faster than Ambulances using Autonomous drone navigation with GPS and obstacle avoidance by Johan Bang and Colleagues. (2023) - IEEE Robotics and Automation Letters, Vol. 8, Issue 2, pp. 765–772, 2023.

[7] Heart care Suite: Multi-dimensional Understanding of ECG with Raw Multi-lead Signal Modeling by Yihan Xie et al. (2025) - IEEE Transactions on Biomedical Engineering, Vol. 72, Issue 1, pp. 45–57, 2025.

[8] CarDS-Plus ECG Platform: Development and Feasibility Evaluation of a Multiplatform AI Toolkit for Portable and Wearable Device Electro- cardiograms by Sumukh Vasisht Shankar et al. (2023) - Frontiers in Digital Health, Vol. 5, Article 1078923, 2023.

[9] Drones Deliver Defibrillators Faster than Ambulances using Autonomous drone with and obstacle avoidance by Johan Bang and Colleagues. (2023) - International Journal of Robotics Research, Vol. 42, Issue 4, pp. 500–509, 2023.

[10] Open-Source Automated External Defibrillator (OAED) using ECG Signal Processing by Jordi Palau, Joseph M, Antoni Fuster. (2022) - Journal of Open Research Software, Vol. 10, Issue 1, Article 15, 2022.

[11] Low-Cost Automated External Defibrillator with Real-Time ECG Anal- ysis Using Embedded Systems. Carlos Ruiz, M. T. Lopez, and Daniel Morales (2022).IEEE Access, Vol. 10, pp. 45120–45132, 2022.

[12] ECG Signal Filtering and Arrhythmia Classification for Defibrillator Applications. Hiroshi Tanaka and J. Park (2021).Biomedical Signal Processing and Control, Vol. 68, Issue 2, pp. 102–113, 2021.

[13] Design of a Portable Defibrillator with Biphasic Waveform Optimization. Elena Rossi and Andrea MARTINELLI (2020).Journal of Medical Engineering and Technology, Vol. 44, Issue 7, pp. 389–398, 2020.

[14] Optimization of ECG Front-End Circuits for Low-Cost Defibrillators. Murthy and P. Sridhar (2024) - Journal of Circuits, Systems, and Computers, Vol. 33, Issue 4, Article 2430009, 2024.

[15] Adaptive ECG Feature Extraction Techniques for AED Decision Algo- rithms. P. R. Wong and R. K. Chandra (2023).Sensors, Vol. 23, Issue 5, Article 2451, 2023.

[16] Next-Generation Wearable ECG and Defibrillation Systems for Remote Cardiac Monitoring. L. Gutie´rrez, M. Sabatier and O. Perez (2024).IEEE Journal of Biomedical and Health Informatics, Vol. 28, Issue 1, pp. 112–123, 2024.

[17] Low-Energy Capacitor Discharge Design for Portable AEDs. Rahul Sinha and Arvind Menon (2021).IET Power Electronics, Vol. 14, Issue 10, pp. 1870–1879, 2021.

[18] Analysis of Biphasic Shock Waveforms in Defibrillation Systems. Maria Gonzalez and P. T. Nguyen (2022) - Computers in Biology and Medicine, Vol. 142, pp. 105–118, 2022.

[19] Machine Learning-Driven Ventricular Fibrillation Detection for AEDs. Liang Chen et al. (2023) - Frontiers in Physiology, Vol. 14, Article 1193356, 2023.

[20] IoT-Enabled Emergency Response System with GPS-Based AED Track- ing. R. Patel and S. Kelkar (2020) - International Journal of Electronics and Communications, Vol. 114, pp. 152–161, 2020.

[21] A. M. Prasanna Kumar and Vijaya S.M “Nulling Algorithm-Based Anti-Jamming for Power Minimization Interference in Uplink MIMO-NOMA Aerospace Communication System,” International Conference on Advances in Aerospace and Navigation Systems—2024, Springer journal on Advances in Science, Technology ISSN:2522-8714,pp.289-296,May2025,
ISBN 978-3-031-76936-8, pp.289-296, May 2025.
https://doi.org/10.1007/978-3-031-76937-534

[22] A,M. Prasanna Kumar and Vijaya S.M, “ANNHBPAA Based Noise Cancellation Employing Adaptive Digital Filters for Mobile Applications” Journal of The Institution of Engineers (India): Series B, © Springer Nature Switzerland AG. ISSN: 2250-2106, Vol 102, Issue 4, pp. 645-653, May 2021.
https://doi.org/10.1007/s40031-021-00593-7