



Department of Computer Science

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ECG SIGNAL CONDITIONING CIRCUIT

Amplifying and Filtering Weak Heart Signals for a Clean Monitoring System

Course: Applied Physics

Program: Bachelor's Of Science in Artificial Intelligence

Section: AM

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Abstract

Electrocardiogram (ECG)

signals generated by the human heart are extremely weak and highly susceptible to noise such as power-line interference, muscle activity, and baseline drift. Direct usage of these signals is not possible without proper conditioning.

This project presents the design and simulation of an ECG signal conditioning circuit that amplifies weak heart signals, removes unwanted noise, and produces a clean and stable output suitable for monitoring and further processing.

1. INTRODUCTION

The electrocardiogram (ECG) is a vital medical tool used to measure and analyze the electrical activity of the heart. ECG signals provide essential information about heart rate, rhythm, and overall cardiac health. However, these signals are very small in amplitude, typically in the range of microvolts to millivolts, making them highly susceptible to noise and interference.

In modern biomedical systems, raw ECG signals must be processed before they can be displayed or analyzed. This processing is known as signal conditioning. ECG signal conditioning involves amplification, filtering, and level shifting to ensure that the signal is clean, readable, and suitable for electronic devices. This project demonstrates the working principle of an ECG signal conditioning circuit using operational amplifiers and passive components.

2. OBJECTIVES OF THE PROJECT

The main objectives of this project are:

- To understand the nature of ECG signals and their limitations
- To design an ECG signal conditioning circuit
- To amplify weak ECG signals using operational amplifiers
- To remove noise and unwanted DC components
- To produce a clean and stable output suitable for monitoring systems

3. THEORY OF ECG SIGNALS

The heart generates electrical impulses that control the contraction and relaxation of cardiac muscles. These impulses can be measured using electrodes placed on the body. The recorded electrical activity is known as an ECG signal.

An ECG waveform consists of different components such as the P wave, QRS complex, and T wave, each representing specific cardiac events. Due to the extremely low amplitude of ECG signals, they are easily affected by noise sources such as muscle movement, electrode displacement, and power line interference. Therefore, signal conditioning is essential before further processing or visualization.

4. COMPONENTS USED

The following components are used in the ECG signal conditioning circuit:

- Operational Amplifiers (Op-Amps)
- Resistors
- Capacitors
- DC Power Supply
- Ground Reference
- Simulation Software (Multisim)

Each component plays a critical role in amplifying, filtering, and stabilizing the ECG signal.

5. CIRCUIT DIAGRAM

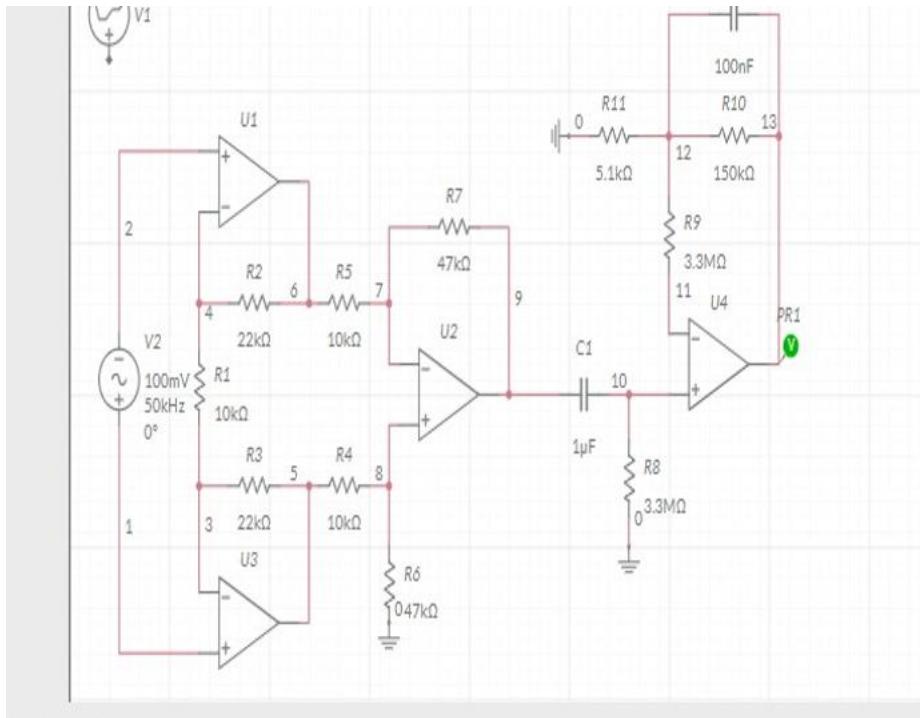


Figure 5.1: ECG Signal Conditioning Circuit

The circuit consists of multiple operational amplifier stages designed to amplify the ECG signal, remove noise, and adjust the signal level. Resistors determine the gain of the amplifiers, while capacitors are used for filtering and DC blocking.

6. WORKING OF THE CIRCUIT

The ECG signal conditioning circuit operates in multiple stages:

Initially, the weak ECG signal obtained from electrodes is applied to the first operational amplifier stage, which amplifies the signal. This amplification increases the signal strength to a usable level. In the next stage, capacitors are used to remove unwanted DC components and reduce baseline drift.

Filtering stages are included to minimize noise such as power line interference. Since ECG signals contain both positive and negative voltages, a DC offset is added to shift the signal into a

positive voltage range. This ensures compatibility with digital systems such as microcontrollers and monitoring devices. The final output is a clean, amplified ECG waveform suitable for monitoring.

7. SIMULATION AND RESULTS

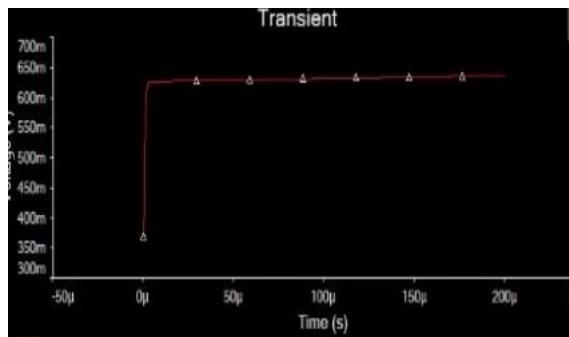


Figure 7.1: Simulated ECG Output Signal

The simulation results demonstrate that the circuit successfully amplifies weak ECG signals while reducing noise. The output waveform is stable and clearly represents the heart's electrical activity. The conditioned signal is suitable for further analysis or display.

8. APPLICATIONS

ECG signal conditioning circuits are widely used in:

- Hospitals and clinical diagnostic systems
- Portable heart monitoring devices
- Wearable health monitoring systems
- Intensive care units (ICUs)
- Biomedical research and education

These circuits play a crucial role in early detection and monitoring of heart-related diseases.

9. ADVANTAGES

- Effective amplification of weak signals
- Noise reduction and signal clarity
- Simple and cost-effective design
- Suitable for real-time monitoring
- Reliable performance

10. LIMITATIONS

- Requires precise component selection
- Sensitive to external noise if not properly shielded
- Simulation results may differ slightly from real hardware

11. CONCLUSION

This project successfully demonstrates the design and working of an ECG signal conditioning circuit. The circuit effectively amplifies weak ECG signals, removes noise, and provides a clean output suitable for heart monitoring systems. Through simulation, the importance of amplification, filtering, and DC level shifting was observed. This project highlights the practical application of applied physics concepts in biomedical engineering and healthcare technology.

12. REFERENCES

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