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PS1

ECG SIGNAL PROCESSING

Introduction

The objective of this project was to design and simulate a signal processing system for ECG(Electrocardiogram) signals, which are vital for monitoring heart health in biomedical applications.

SIGNAL GENERATION AND NOISE ADDITION

1. GENERATION OF PWL VOLTAGE SOURCE USING MATLAB
    - We set key parameters like sampling frequency and the duration of a single ECG cycle to be 0.82533 so that the RR difference is 0.826 and we get heartbeat = 60/0.826 = 72 bpm.
    - We used the ecg function from the signal processing toolbox to create a single ECG cycle waveform.
    - We replicated the single cycle to achieve the desired 10-second duration.We adjusted the time vector and signal to ensure a precise 10-second length.
    - We combined time and signal data into a matrix and saved it in a PWL file format.

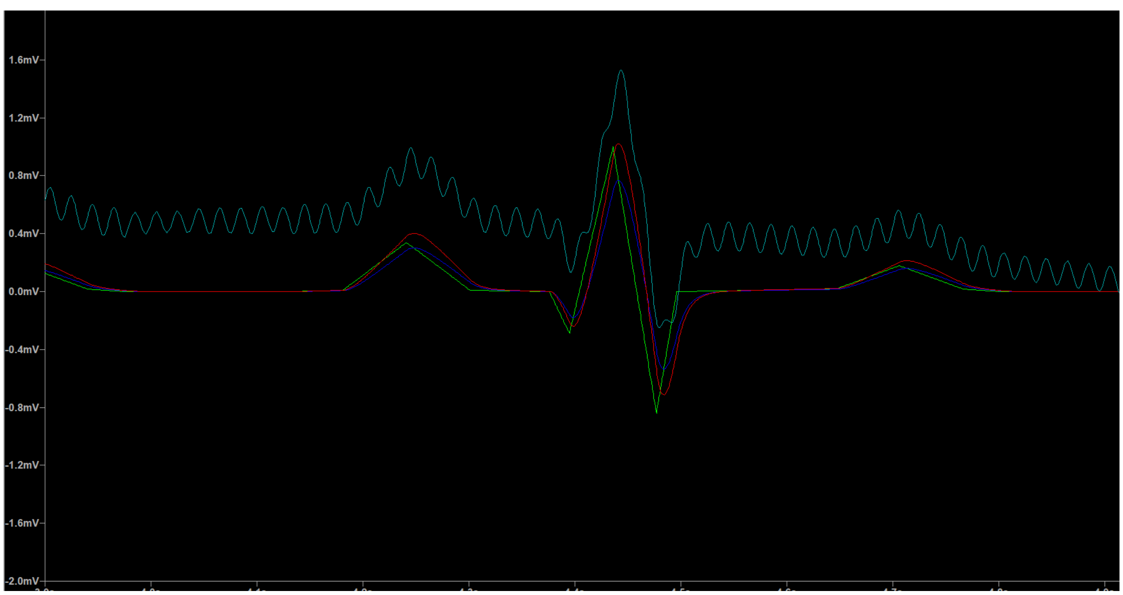
2. SMOOTHENING OF SIGNAL

The ecg signal which we generated had sharp triangular peaks, hence in order to smoothen out the peaks we used an RC low pass filter circuit. Now, the RC filter decreased the magnitude of the ECG wave so we used a differential amplifier to restore it back to 1mV.

3. NOISE ADDITION

We added two sinusoidal noises of 50 Hz interference noise of amplitude 0.1mV and 0.3 Hz noises of amplitude 0.5mV using a bivariate source.

4. **Smoothening circuit and signal waveforms (red waveform is opamp output, greenish-blue is noise added, green color is matlab generated ecg signal, blue is output of low pass filter)**

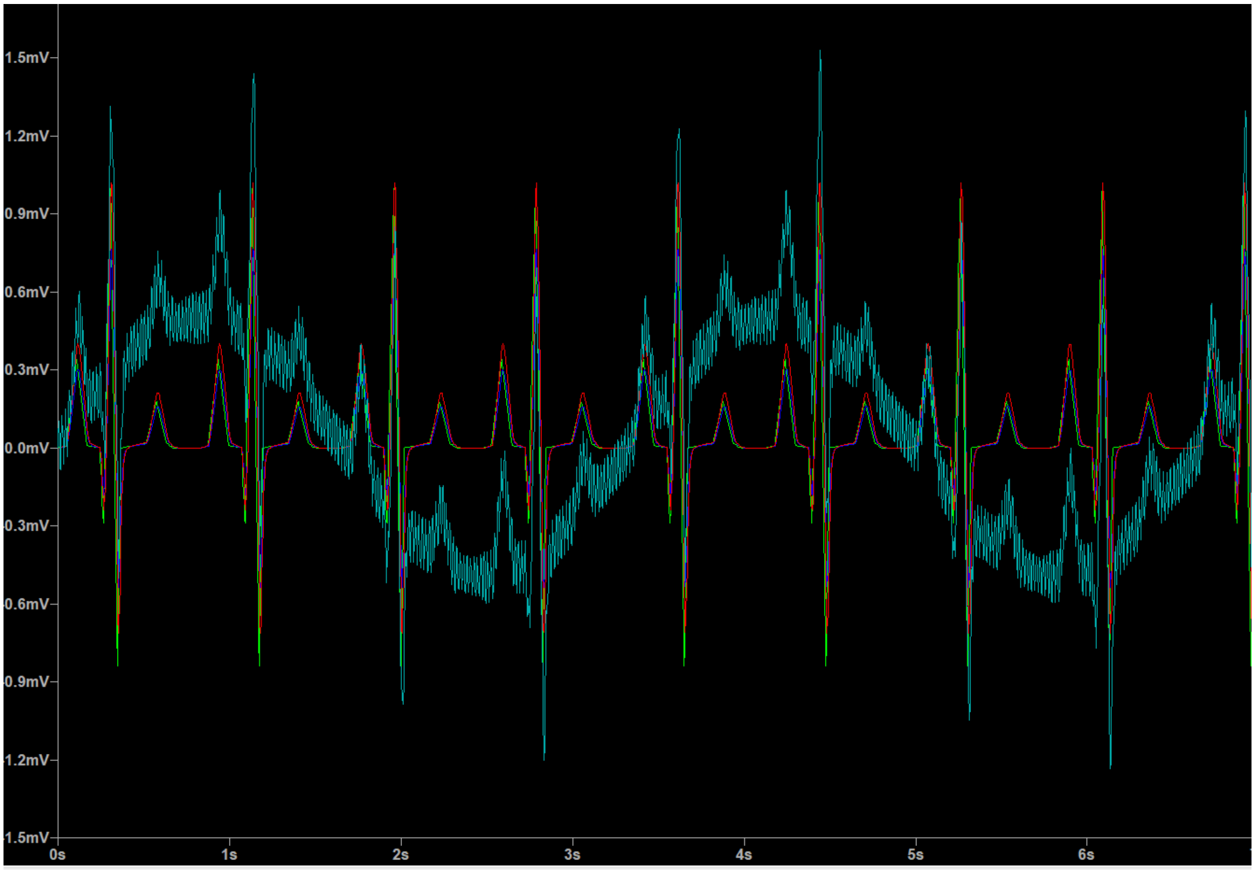


RR interval - 0.83s

PR interval - 0.19s

QRS interval - 0.12s

QT interval - 0.41s

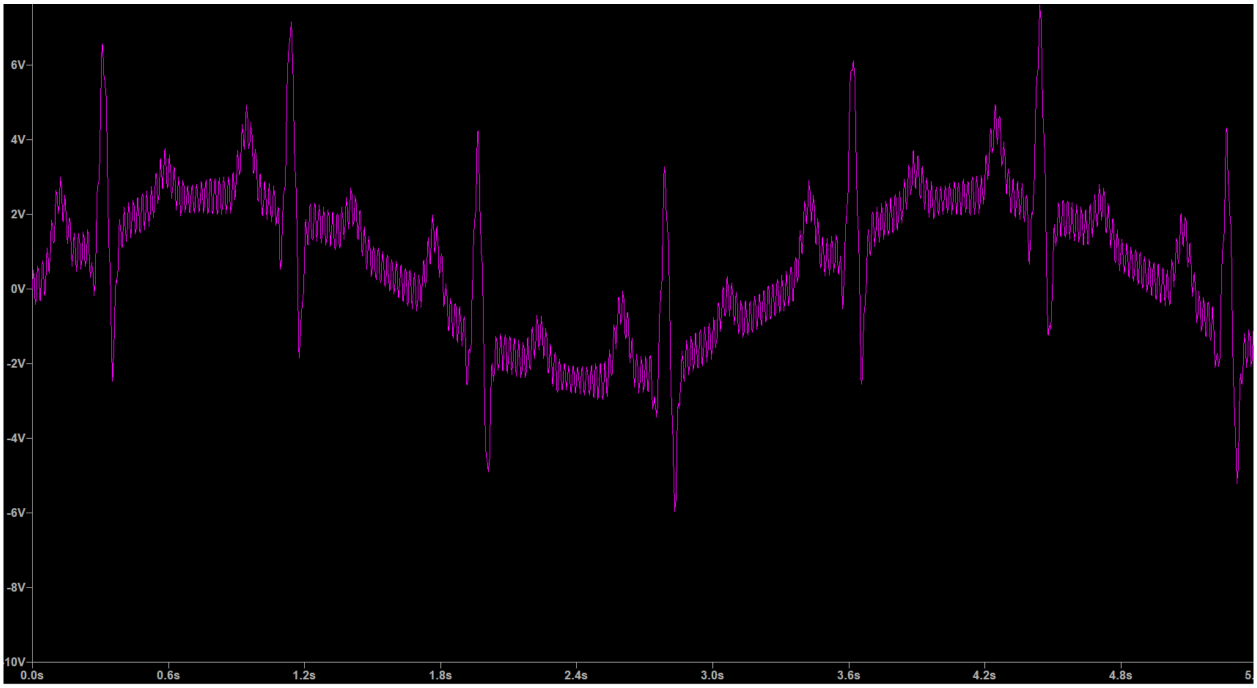


STAGE 1 :INSTRUMENTATION AMPLIFIER

This circuit we used is a **three-op-amp instrumentation amplifier (INA)**, which is commonly used for amplifying small differential signals, like ECG signals, while rejecting common-mode noise.

GAIN = $(1 + \frac{2R_1}{R_2}) * (\frac{R_6}{R_4})$

WAVEFORM



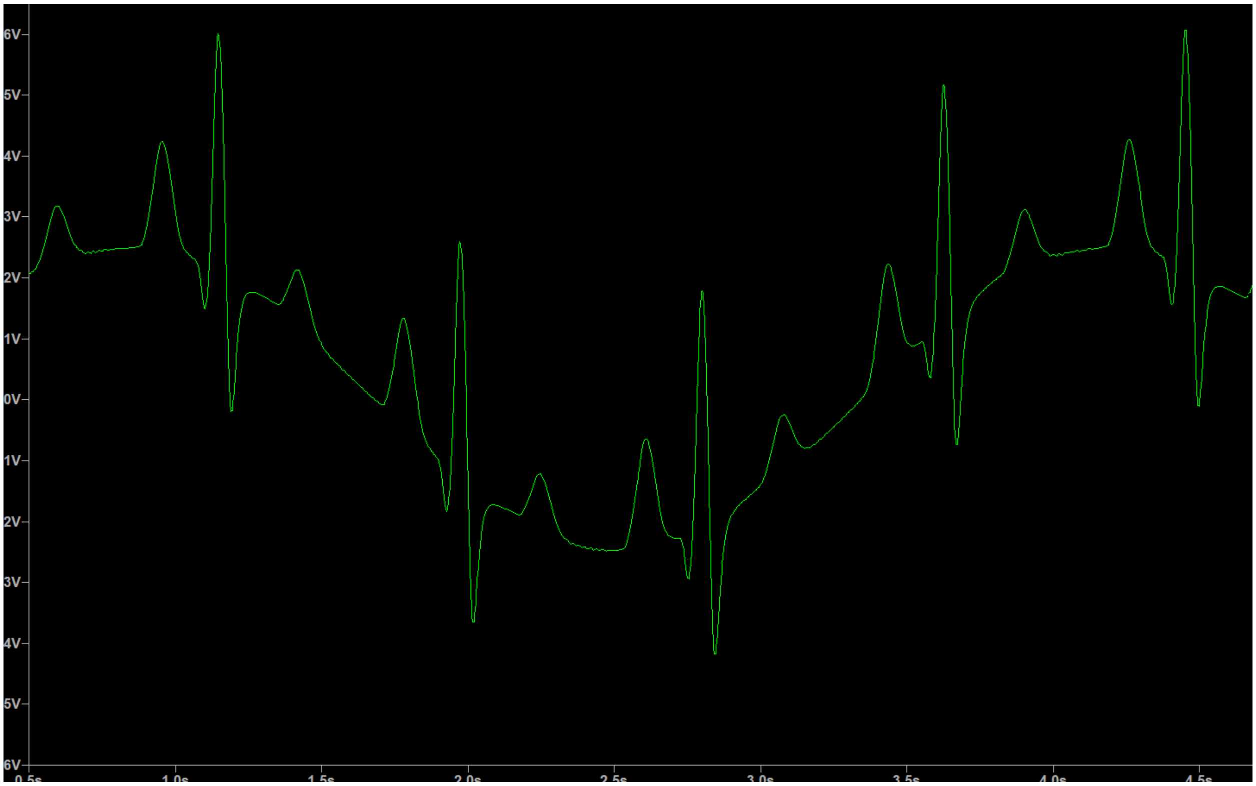
STAGE 2: NOTCH FILTER FOR 50 HZ FREQUENCY

The notch filter is designed to reject or attenuate a specific frequency . We used this circuit to filter out 50 Hz noise.

Cut off frequency of the notch filter is given by:-

$$f= \frac{1}{4*\pi*R*C}$$

1. WAVEFORM

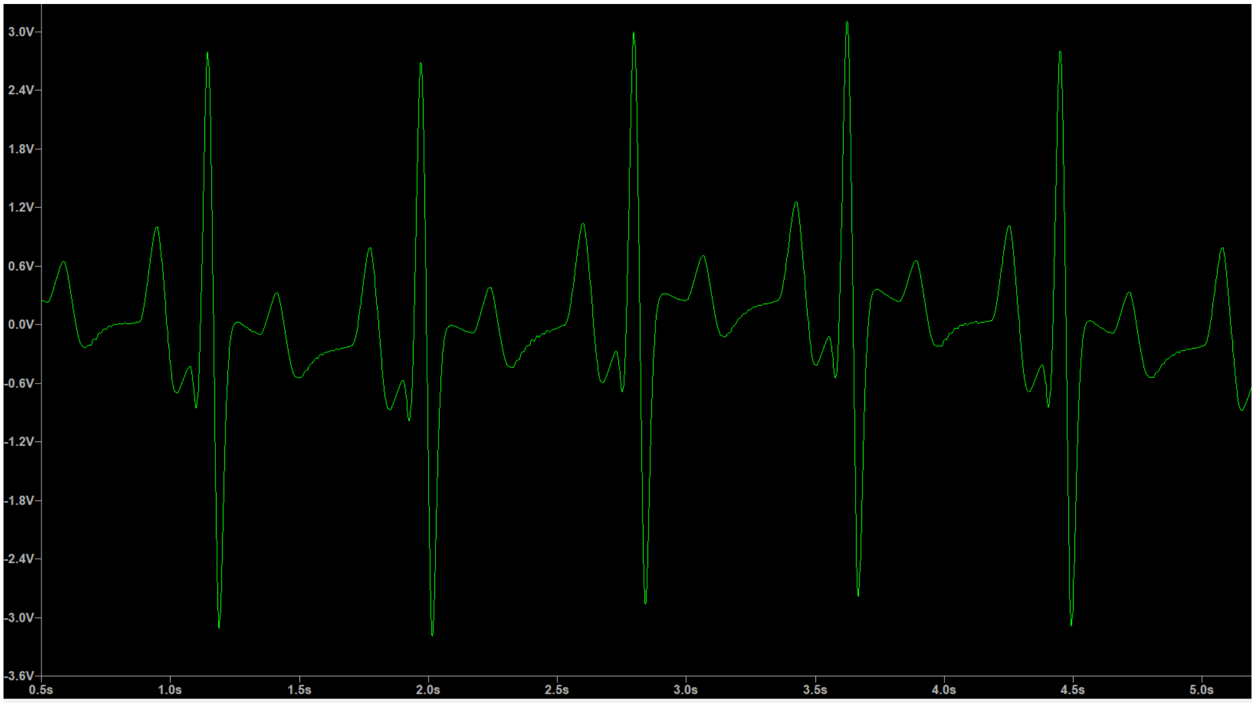


STAGE 3 : BANDPASS FILTER (3.183 Hz-150 Hz)

A significant source of noise arises from electrical signals traveling through the body. To address this, a bandpass filter with cutoff frequencies of 0.5 Hz and 150 Hz is commonly used to reduce distortions in the ECG signal. This filter consists of a high-pass and a low-pass filter connected in series, effectively removing signals outside this frequency range. The resistor and capacitor values were determined using the formula shown in equation. This formula was applied twice: once for the high-pass cutoff at 0.5 Hz and once for the low-pass cutoff at 150 Hz. In both cases, the capacitor value was fixed at 1 μF, and the corresponding resistor value was calculated.

$$R=\frac{1}{2*\pi*f*C}$$

WAVEFORM

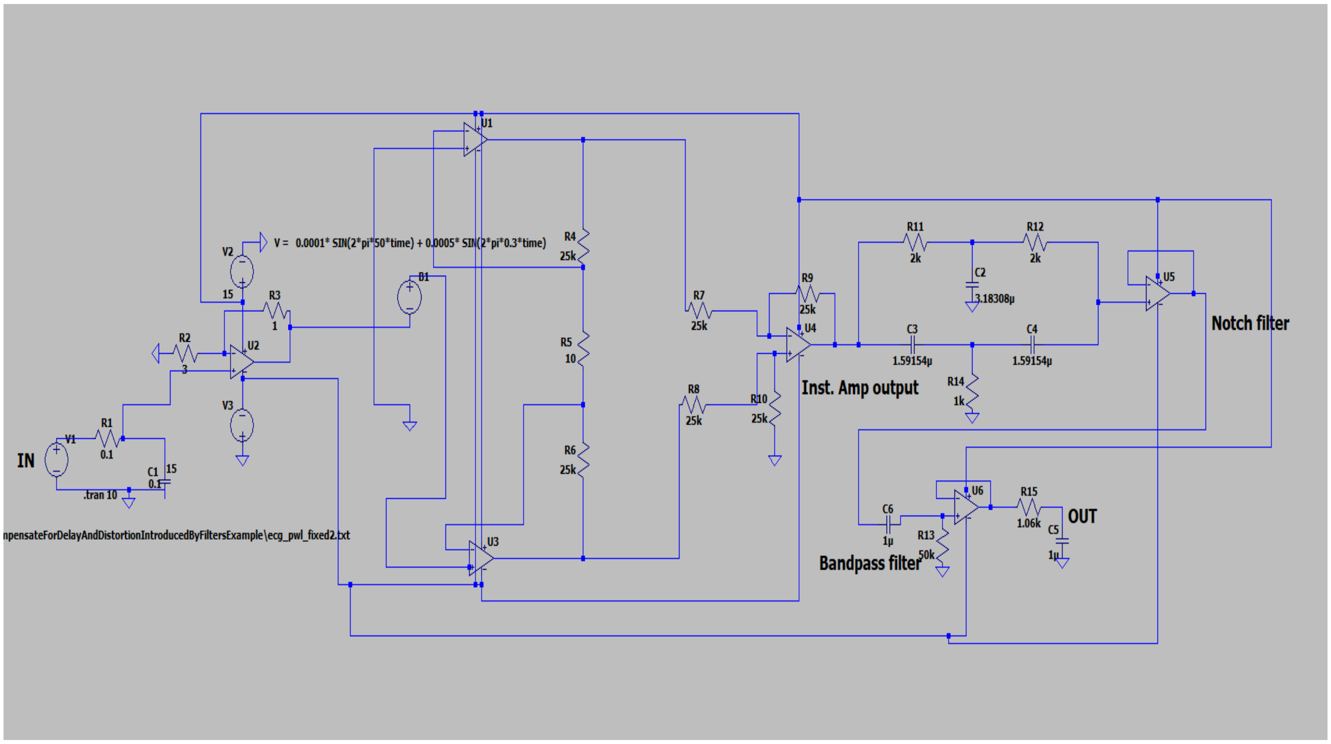


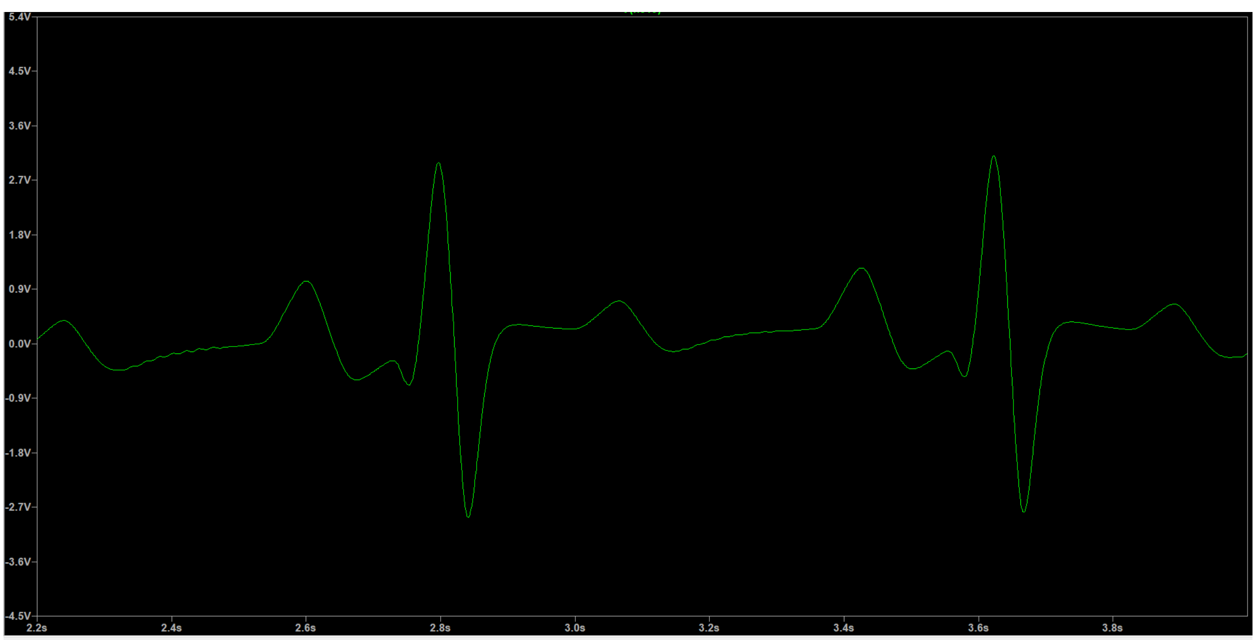
STAGE 4 : OUTPUT

Following observations were made in output:-

- A clear ECG waveform with appropriately amplified amplitude.
- Elimination of baseline drift and minimal low-frequency interference.
- Absence of 50/60 Hz noise and suppression of high-frequency disturbances.

Complete Circuit and Final Waveform





RR interval - 0.83s

PR interval - 0.19s

QRS interval - 0.14s

QT interval - 0.41s