ELECTRONICS WORKSHOP 2

SPRING 2023
UG 2

Heart monitoring circuit (ECG, Heart rate)

Team 16

Link to one drive folder:
https://iiitaphyd-my.sharepoint.com/:f:/g/personal/sannidhya_gupta_research_iiit_ac_in/EgJ9QPLAHIZBlJ_w_0Rzy9MBTH6wiUdICGOZ3w0bH5IflA?e=EknYz6

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Motivation

- Understanding heart health: By displaying the heart rate, individuals can gain insights into their heart health and take necessary measures to improve it.

- Educational purposes: This project can be a great learning tool for electronics enthusiasts who want to understand how to work with ECG signals.

- Innovation: With the increasing demand for wearable technology, this project can be seen as a way to track heart rate and can be potentially added to the current range of wearable devices if refined with such motive.

Literature Survey

We used the given paper to get a basic idea of how extraction of ECG works.
This paper discusses extraction and procsessing of ECG signal from the body by using 3 gel electrodes, and giving a LED output if the user's heartbeat lies outside the normal range

Link:
https://isn.ucsd.edu/courses/beng186b/project/2021/Amin_Khairil_Satish_Shah_Zaferi_Heart_rate_monitor_via_ecg.pdf

Heart Rate Monitor via Electrocardiogram

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***Abstract*—The cardiovascular system is a major part of the human body that delivers nutrients and oxygen to all cells in the body. Each time the heart beats, blood is pumped out of the heart and delivered throughout the body. It is important to keep track of heart rate because it can provide information and spot developing health problems. One of the main ways to monitor heart rate is by an electrocardiogram. An electrocardiogram (ECG) records the electrical signal from your heart to check for different heart conditions. This instrumentation is important in the medical field in order for medical professionals to detect life threatening conditions in patients. Our model for an ECG includes multiple parts in order to amplify signals, filter noises, and detect irregularities. Studies have shown average resting heart rate for adults ranges from 60-100 beats per minute. Therefore, our model identifies heart rate that is not in resting range (less than 60bpm and greater than 100bpm) by a flashing red light signal in a circuit simulation created in falstad computer software. Our model stimulates results through a one lead ECG, whereas a twelve lead ECG model can produce a more accurate interpretation of ECG model.**

I. Introduction

In the medical field, the heart rate is used to observe and diagnose the health conditions of patients. Our cardiovascular system plays an important role in making sure the body functions properly without any failure by regulating variables such as body temperature to be in equilibrium with the surrounding environment. By monitoring the heart rate, we are able to carry out any physical activities properly and take any precautions needed to avoid any fatal diseases. One of the ways to monitor the heart rate is through the electrocardiogram. We designed a circuit that models an ECG and processes and monitors heart rate. An LED light was incorporated and will light up when there are any abnormalities in the heart rate. This mechanism can help medical professionals detect and monitor irregularities of the heart.

When the heart beats, the electrical signals will travel through the heart and these signals can be measured on the surface of our skin. The ECG machine will measure the heart activities using electrodes placed on different surfaces of the skin. Our circuit model is designed to measure the heart rate in frequency Hz. The input frequency will then be converted into the voltage and processed through the comparators. The heart rate should be within the range to be considered as normal heart rate. Irregular heart beat will give abnormally high or low output. When the circuit system detects that the output is not within the range, the LED will light up to indicate the abnormal pulse rate.

The ECG can help monitor heart rate during physical exertion and can be useful in alerting a user of any abnormalities in their heart rate. Additionally, this bioinstrumentation can aid in improvement of medical treatment plans and studies for those affected by cardiovascular diseases. After careful analysis, we identified the sources of errors and the areas of improvements for our circuit model to behave accordingly to these real scenarios.

II. Physiology

A. Cardiovascular system

The human heart is made up of 4 chambers: the left and right atria, and the left and right ventricles. The right side of the heart handles deoxygenated blood while the left side does the opposite. Regardless of which side of the heart we are referring to, blood will always travel first from the atria, into the ventricles, then to the rest of the body. This implies that there has to be two muscular contractions involved on each side of the heart, first to transfer the blood from the first chamber (atrium) into the second one (ventricle), then from the second one to the rest of the body. These muscular contractions are achieved through electrical signals, each sent from the two nodes called the sinoatrial (SA) and atrioventricular (AV) nodes. The SA node depolarizes the atrial muscles causing it to contract along with the AV node that accomplishes the same role for the ventricle muscles.

Introduction

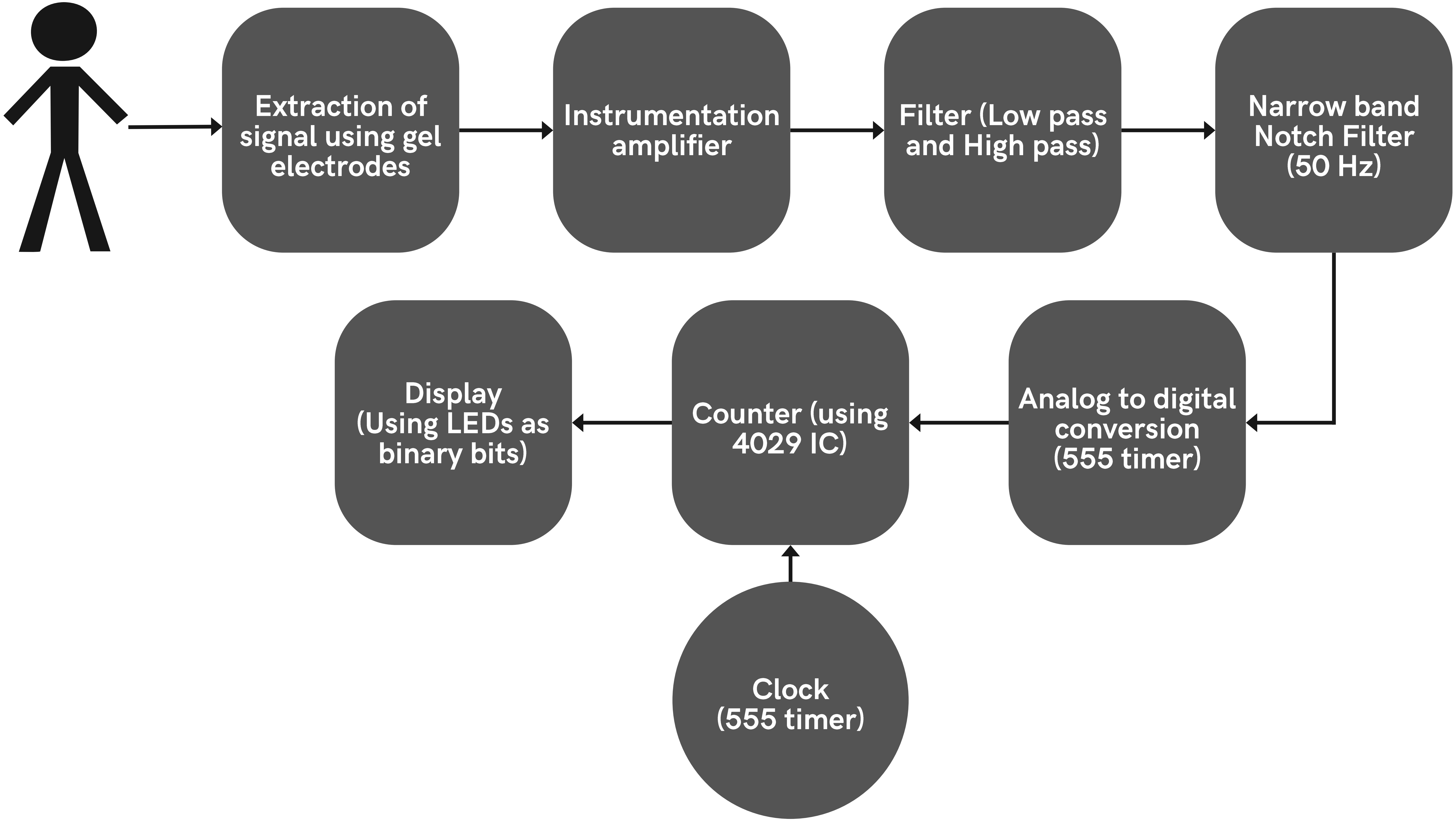
- Measuring ECG signal from the body
- Processing the signal in order to make it informative
- Analysing the signal frequency (heart rate)
- Displaying the heart rate to the user

Execution blocks

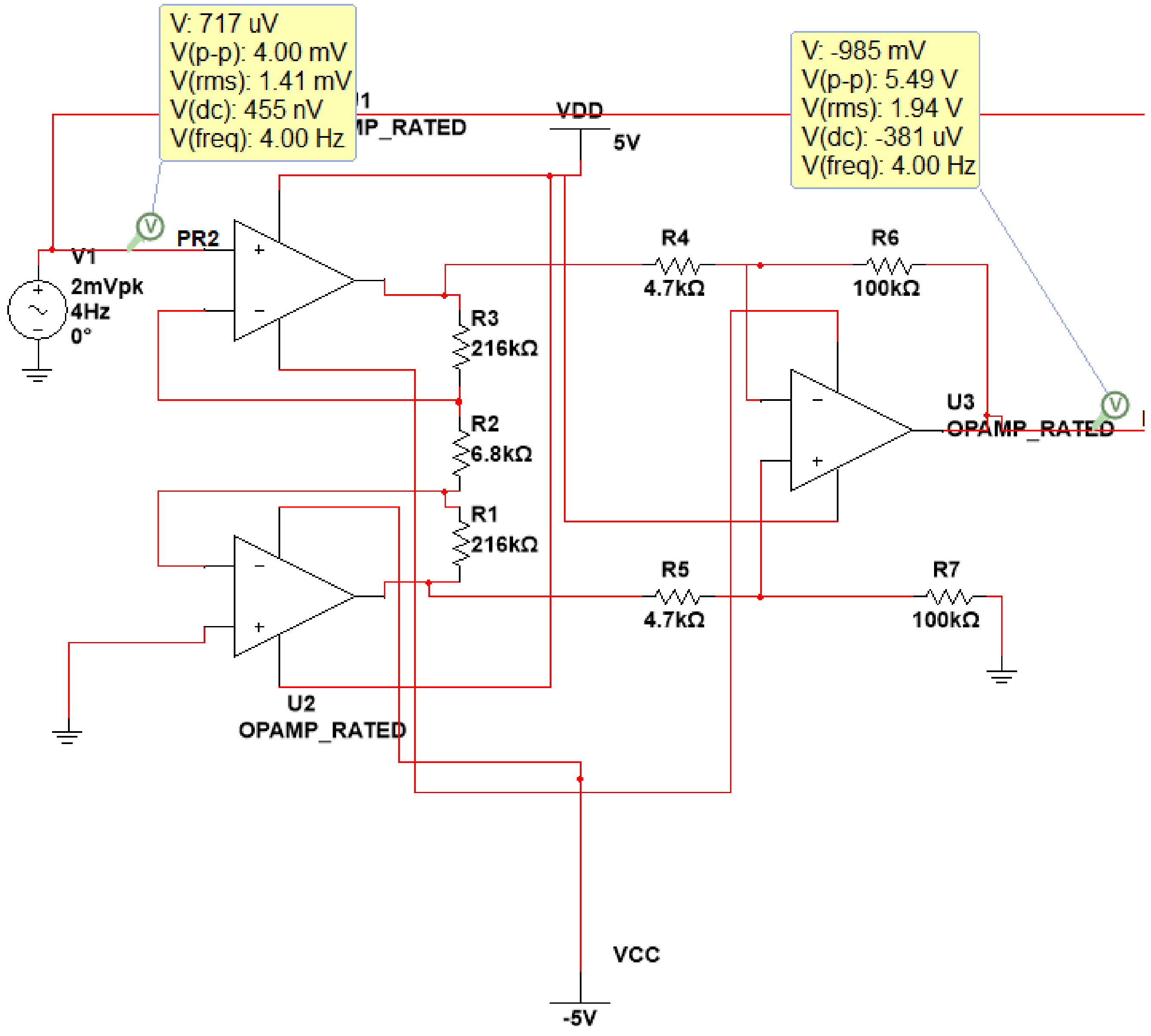
These are the subparts that we used for our circuit

- ECG signal is extracted by gel electrodes
- Amplfication
- System to remove noise
- Filters to remove unwanted bioelectronic signals
- Clock
- Display (Number of beats)

Block Diagram



Instrumentation Amplifier

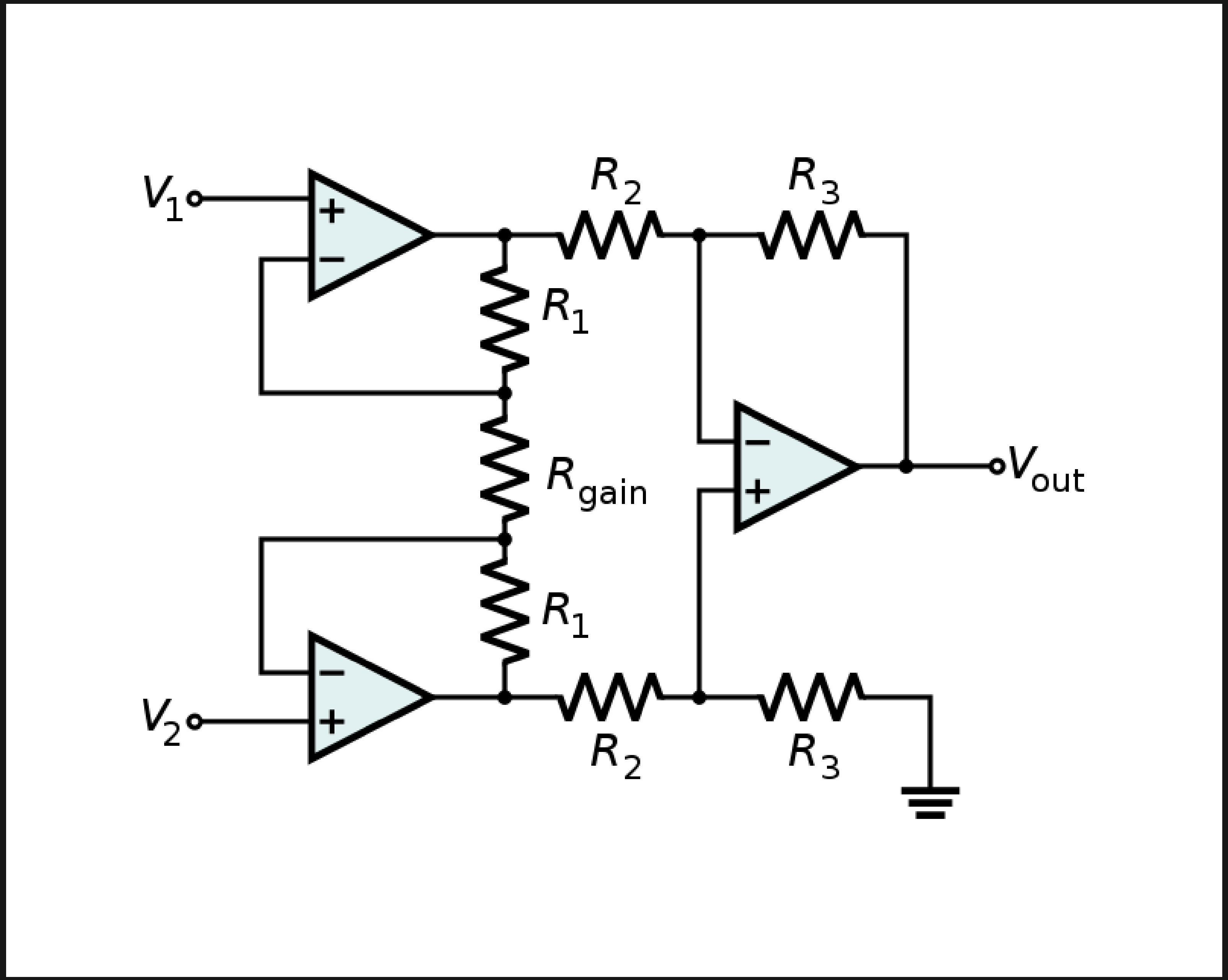


An instrumentation amplifier is an electronic device that is used to amplify small signals. It is a type of differential amplifier. The instrumentation amplifier is typically used in applications where the signal of interest is small and buried in a large amount of noise or other unwanted signals, such as in biomedical instrumentation

Gain analysis

$$A_v = \frac{V_{\text{out}}}{V_2 - V_1} = \left(1 + \frac{2R_1}{R_{\text{gain}}}\right)\frac{R_3}{R_2}.$$

Theoretical Gain
=1,372.96

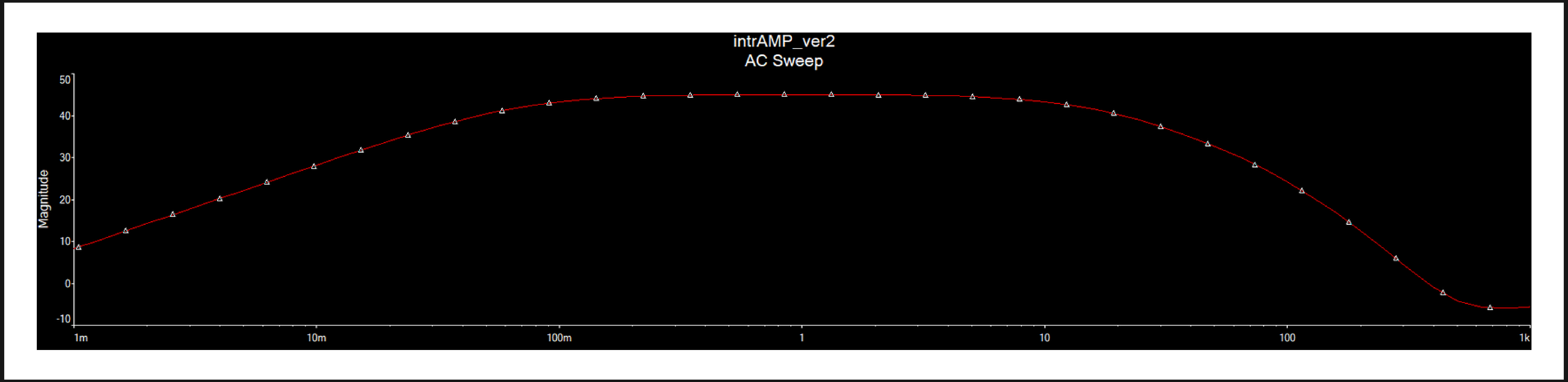


Filters - Low and High Pass

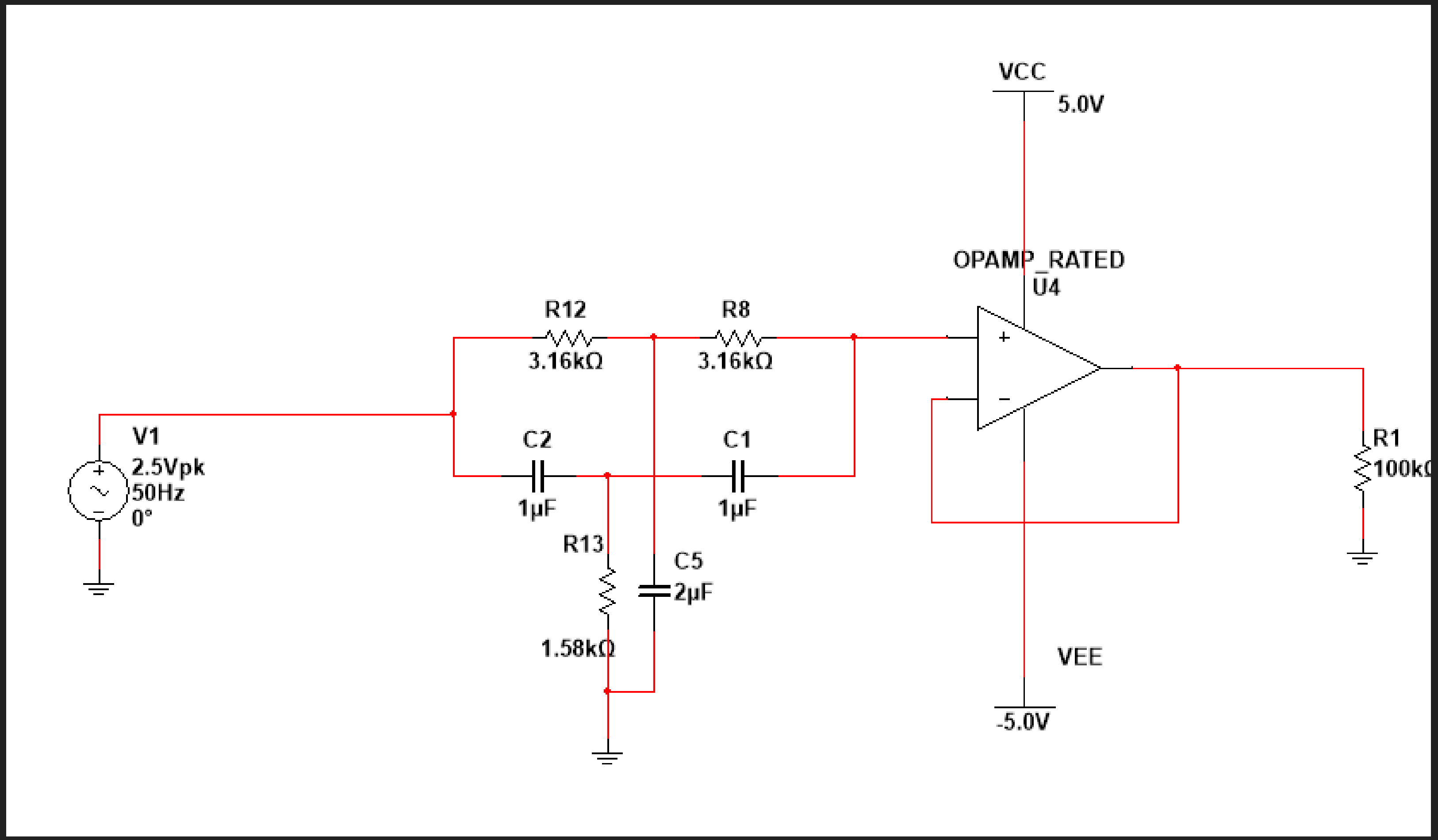
Low pass = 39.79Hz
High pass = 0.5Hz

As EMG and other signals lie outside this range

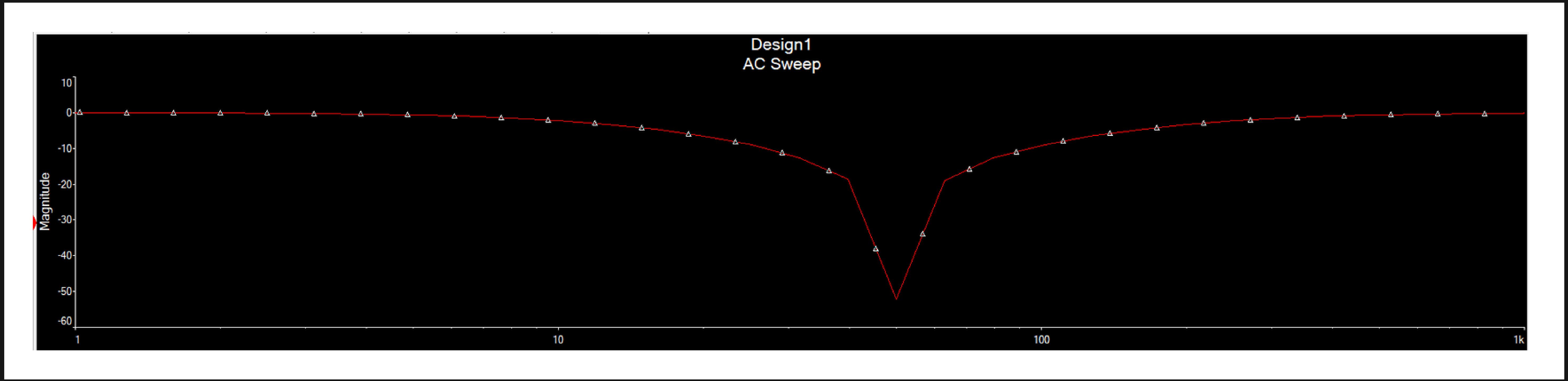
RC filters are used for this



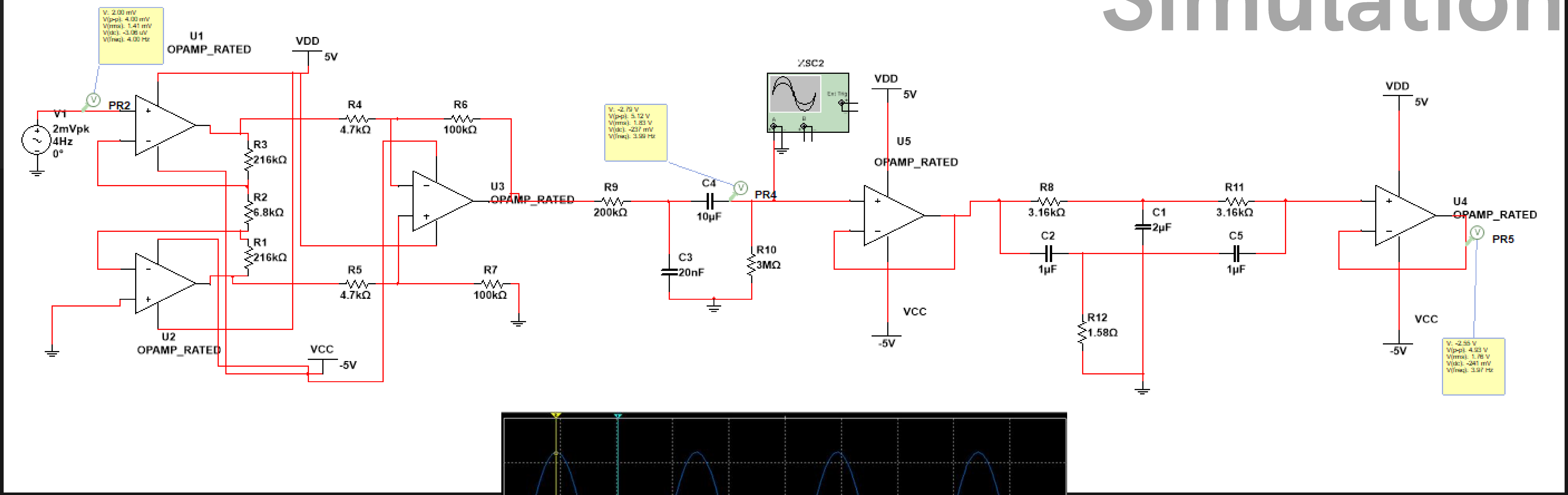
Notch Filter

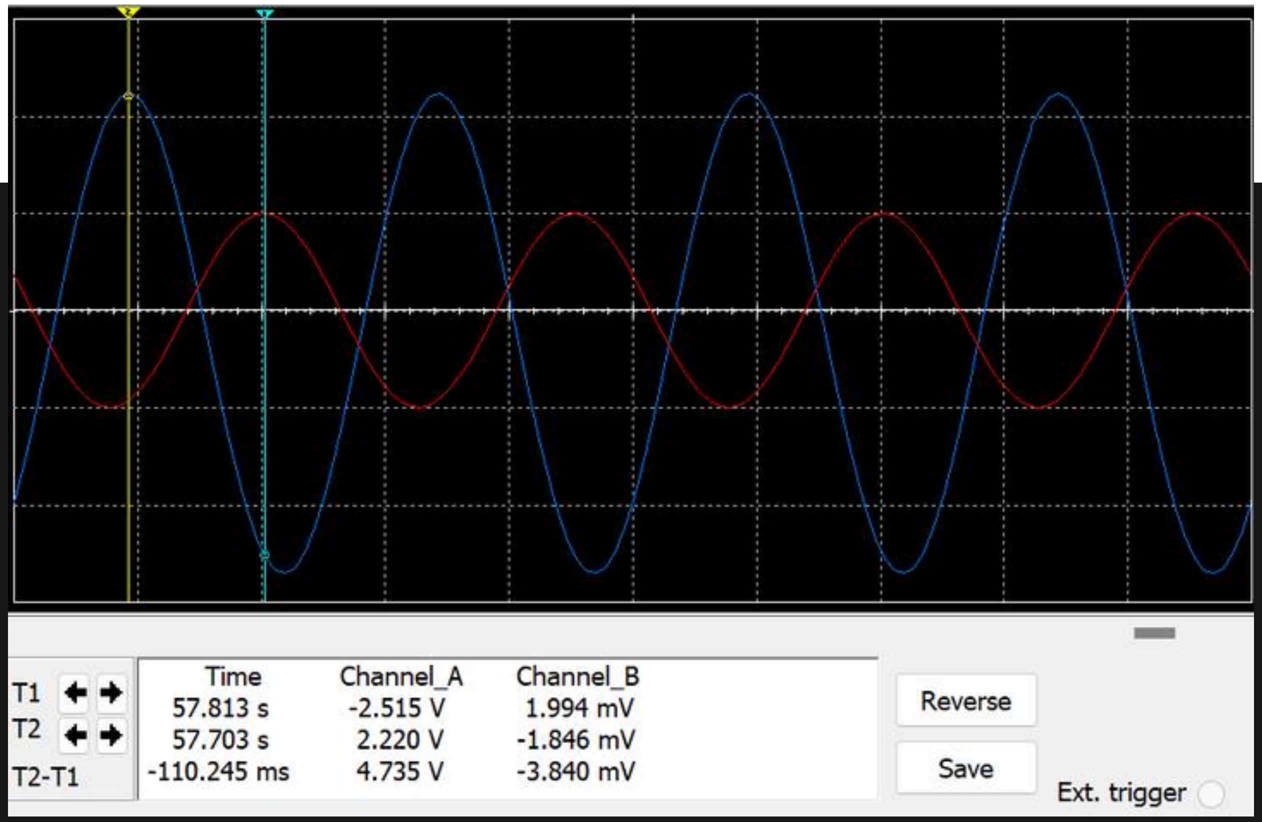


A narrow band reject filter in order to reject the 50Hz noise present in the circuit

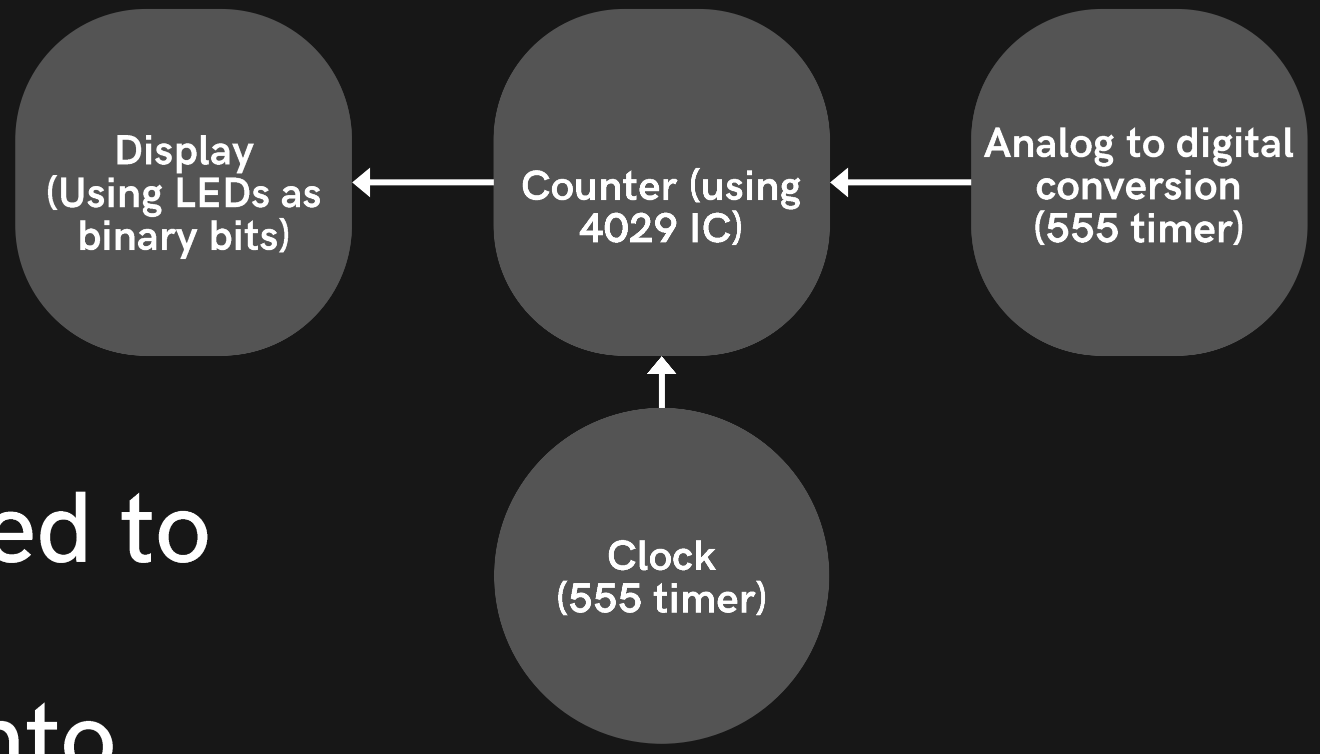


Final Simulation





Displaying the hearbeat



- ECG signal, obtained in pulses is first converted to square pulses, thus converting the hearbeat into digital domain
- A clock of time period ~ 25 seconds is constructed
- The digital signal is fed into counters after ANDing with the clock. Thus, the counter only counts when clock is on

Important points

MIN MAX HEARTBEART MEASURABLE

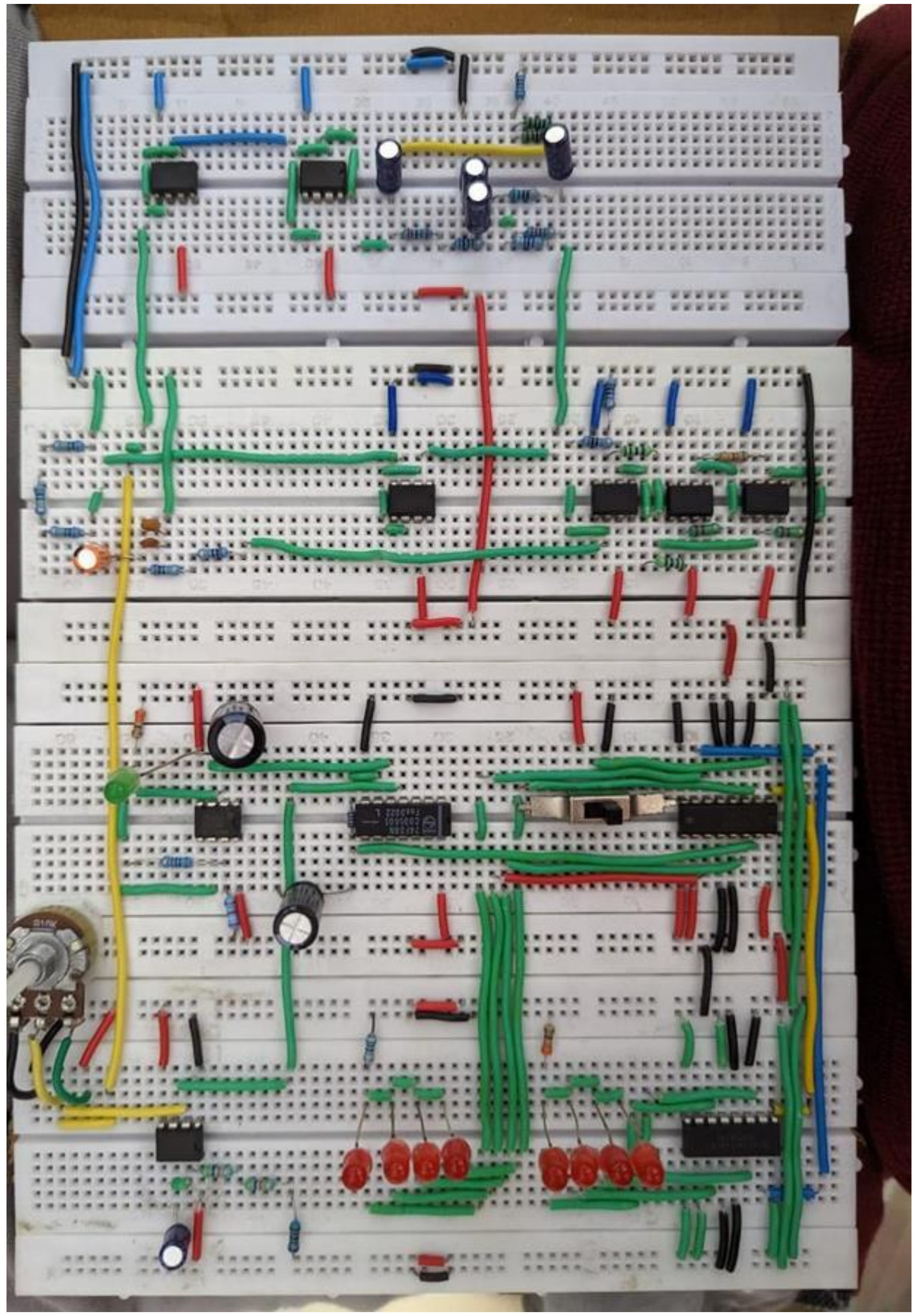
0.7Hz to 5Hz
42bpm to 300bpm

The ECG has amplitude < 5mVpp, so circuit has been designed for 2mVpp

INPUT RANGE

OUTPUT RANGE

The square wave obtained as outputs have amplitude = Vcc



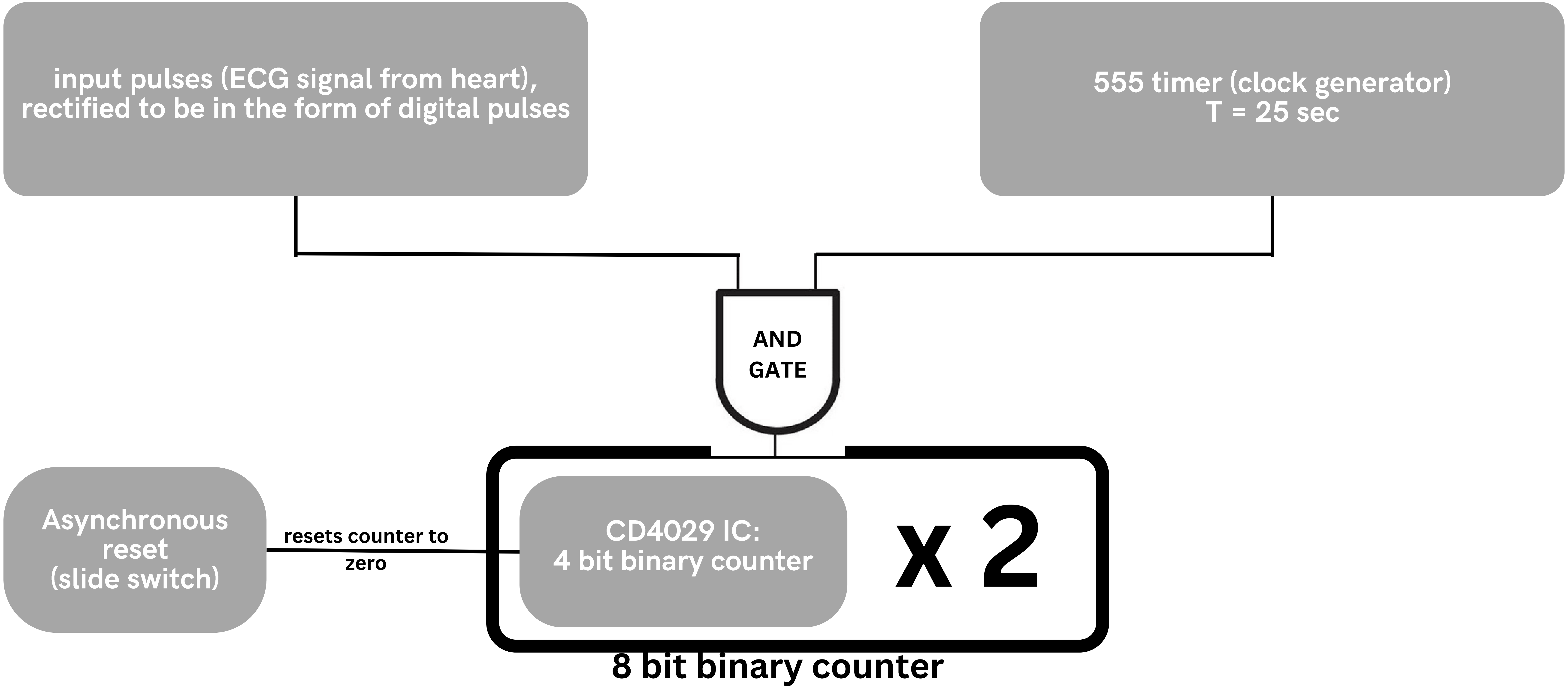
Hardware

The potentiometer adjusts our A/D converter by adjusting the required voltage for input signal

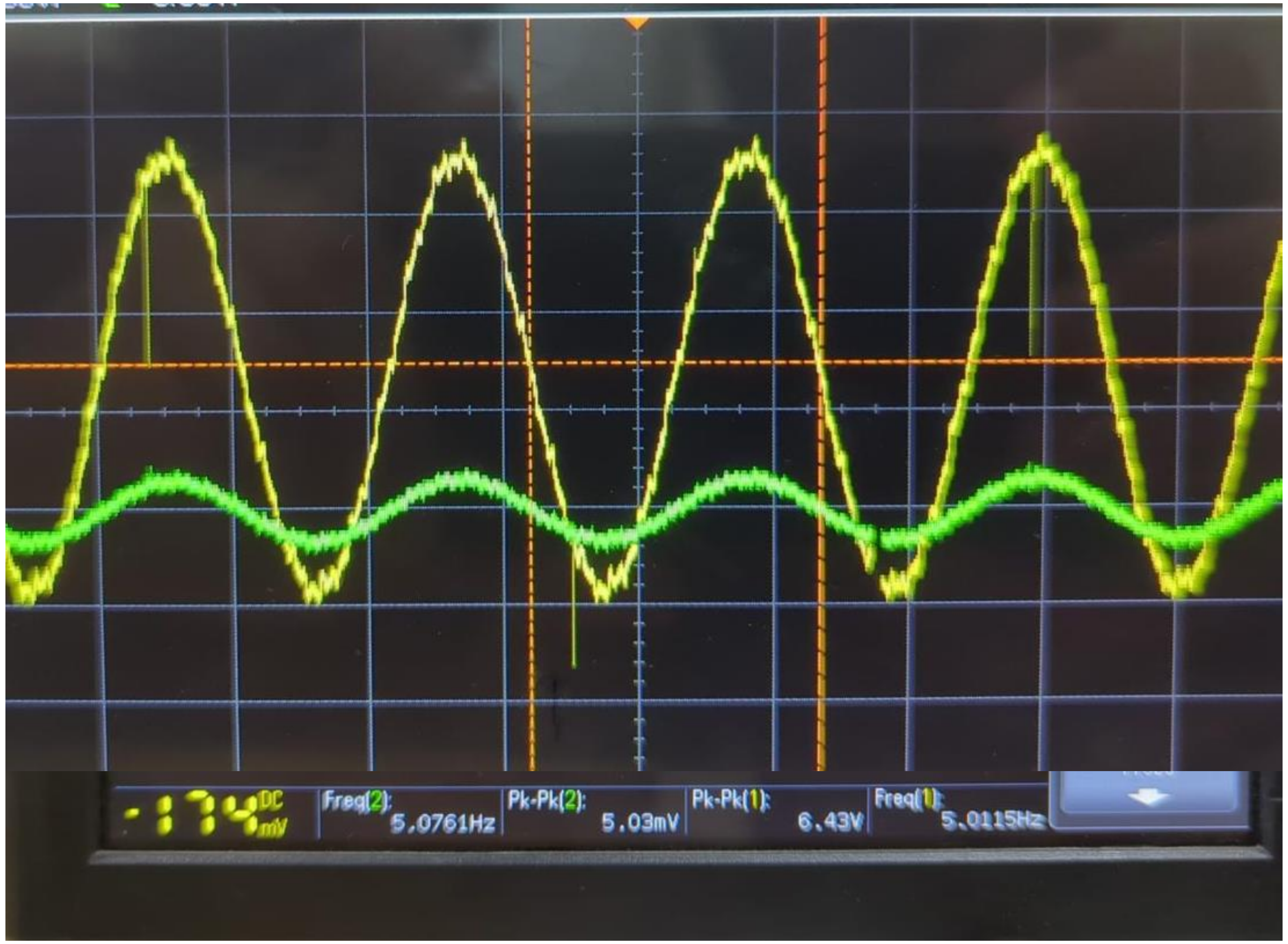
The green LED is the clock, it generates a high signal for T~25sec. The counter only counts when the clock signal is high

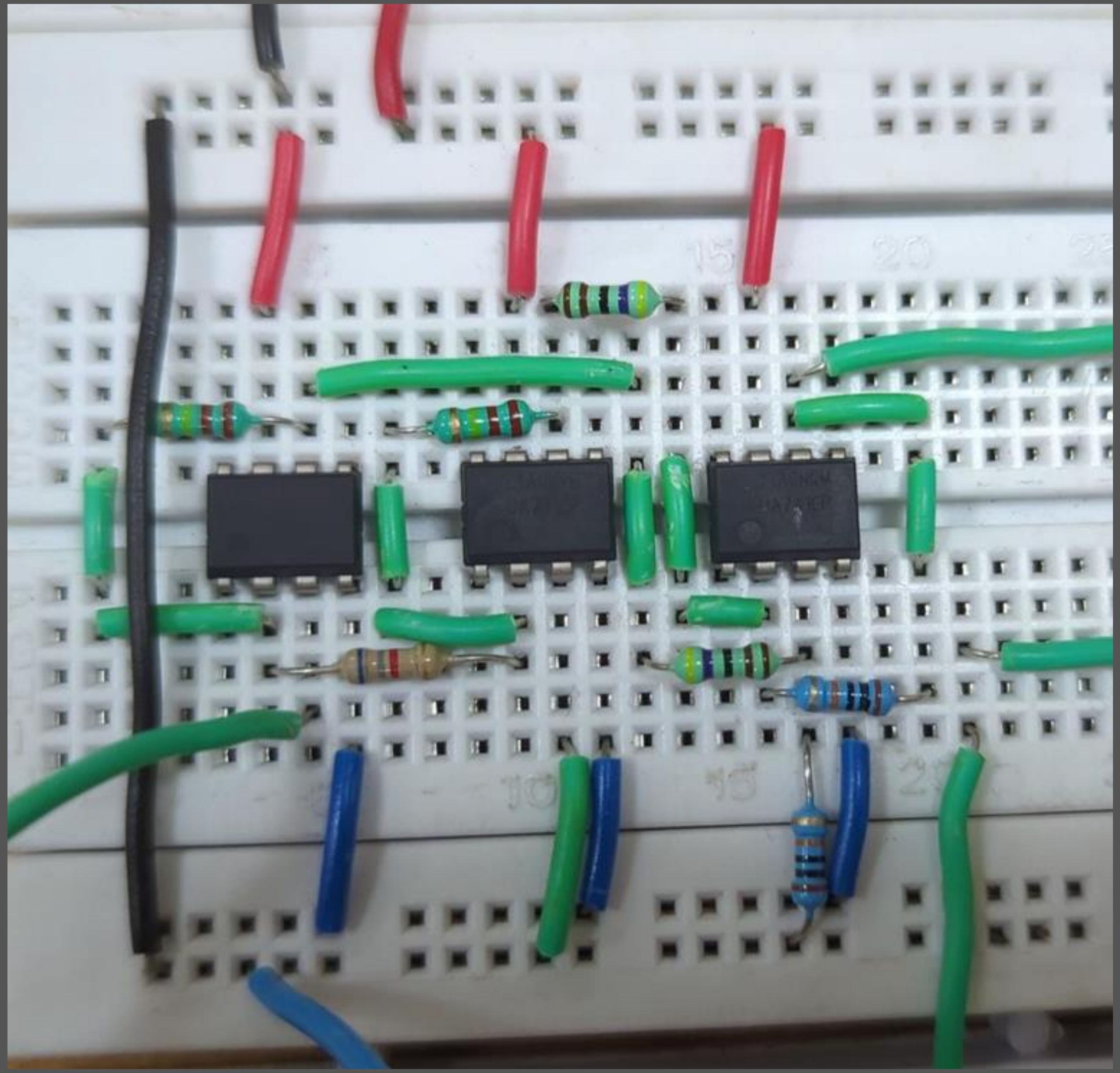
The 8 red LED's count the heart beats and display it in binary

Counting system



Amplifier





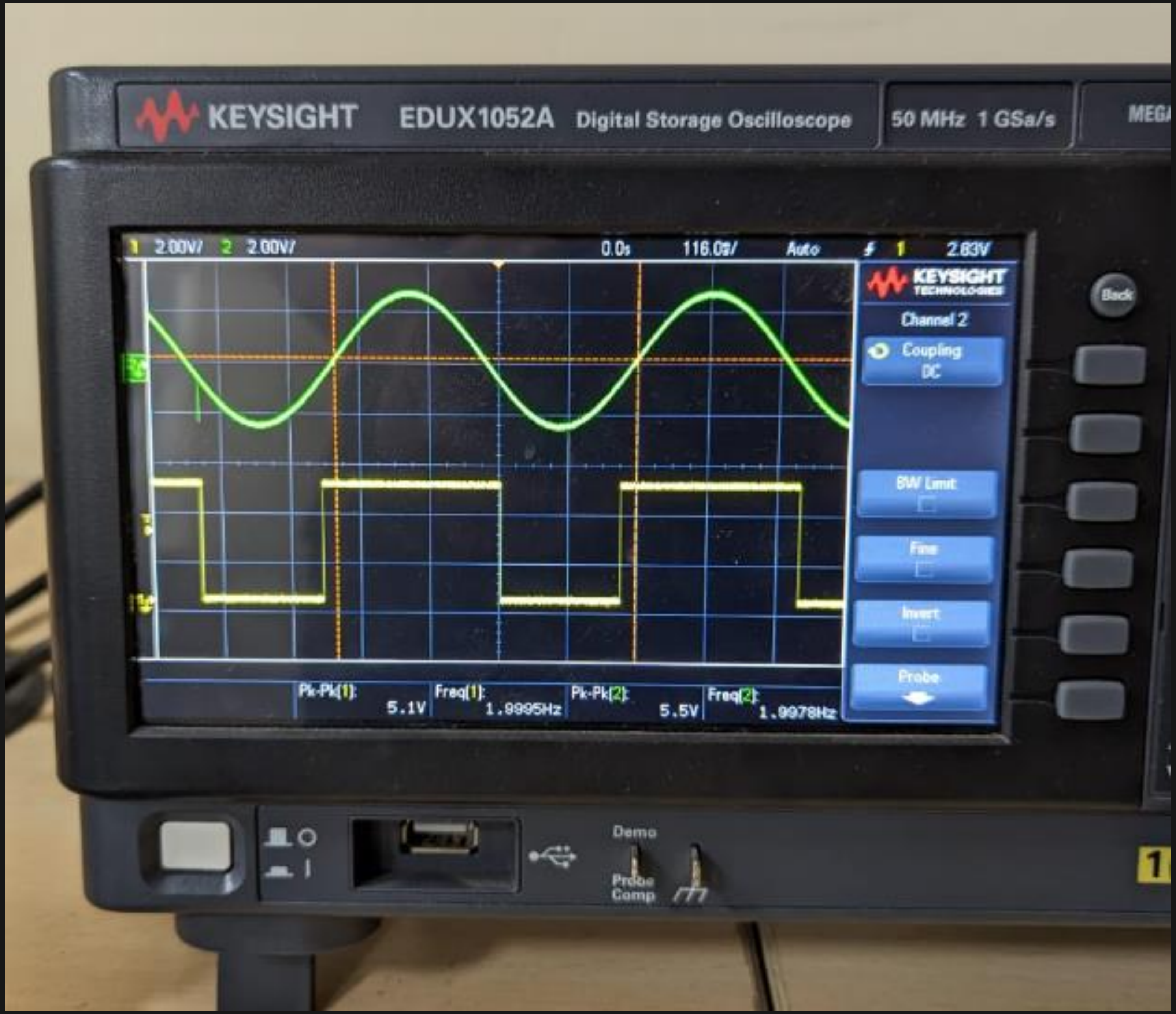
Observed Gain: 1278.36

Theoretical Gain =1,372.96

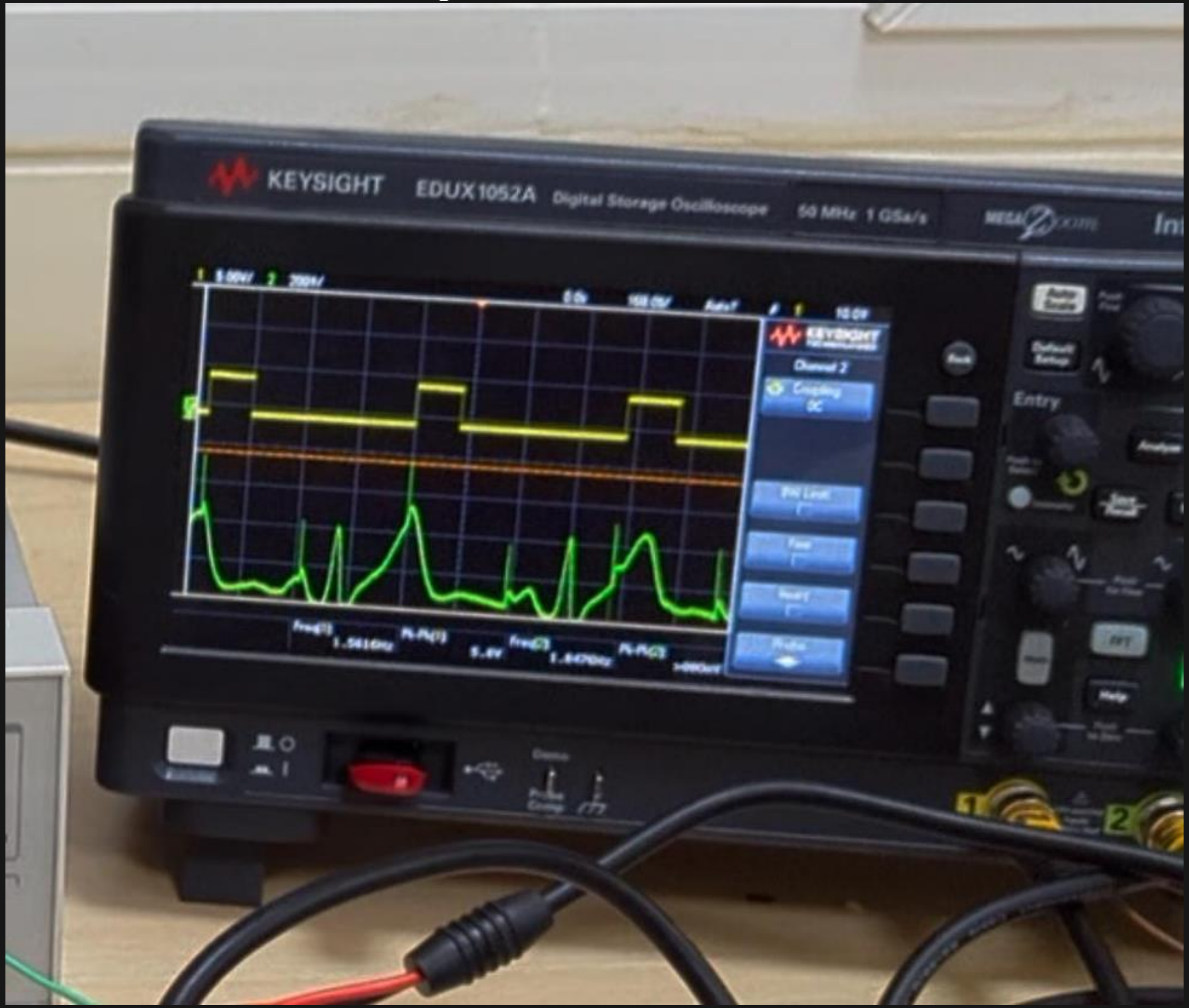
Frequency Response analysis of filters

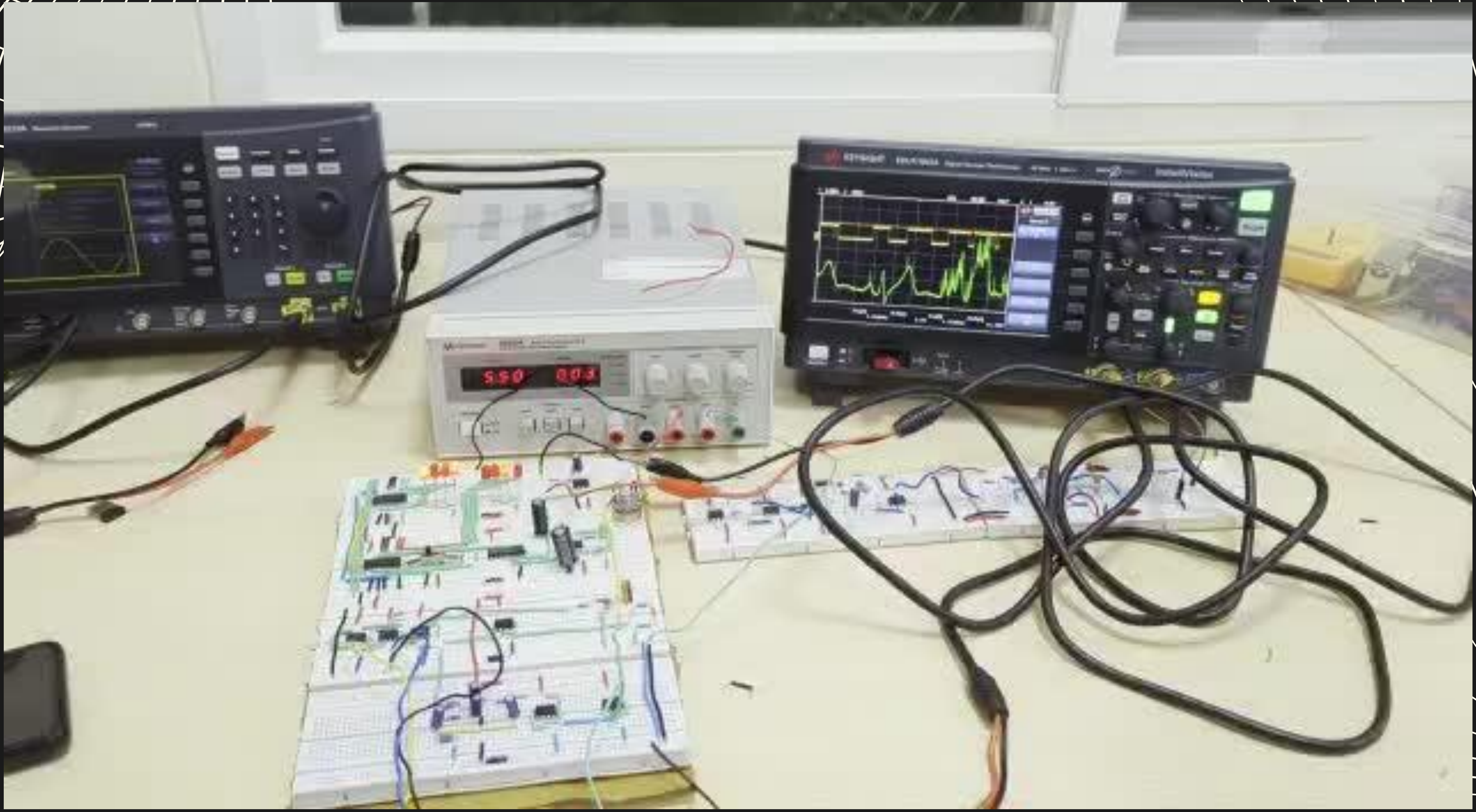
Analog to digital conversion

Sinusoid wave from waveform



ECG signal from human body





Challenges faced

ANALYSING THE ECG AND EXTRACTING HEART RATE WITHOUT USING MICROCONTROLLER

FORM OF DISPLAY USED TO OUTPUT THE HEARTBEAT

NOISE REDUCTION - REJECTING THE PREVELANT 50HZ NOISE

ANALOG TO DIGITAL CONVERSION, AND FIGURING OUT PULSE WIDTH OF PULSE

Improvements

MAKING THE CIRCUIT MORE ROBUST TO PROCESS ECG SIGNAL OF DIFFERENT AMPLITUDES

ADDING A DIGITAL DISPLAY INSTEAD OF USING LED OUTPUTS AS BINARY BITS

IMPROVING THE ECG EXTRACTION PROCESS AND USING A WAY BETTER THAN GEL ELECTRODES

Thank you

Conclusion

WORKING ON THIS PROJECT HELPED US TO:

- BETTER UNDERSTANDING AND WORKING WITH BIOPOTENTIAL SIGNALS
- HOW EVERY PART OF AN ELECTRONIC CIRCUIT CONTRIBUTES TO THE WHOLE PROBLEM STATEMENT
- IMPROVE OUR THINKING CAPABILITIES BY FINDING SOLUTIONS TO NEWLY ENCOUNTERED PROBLEMS AND ISSUES