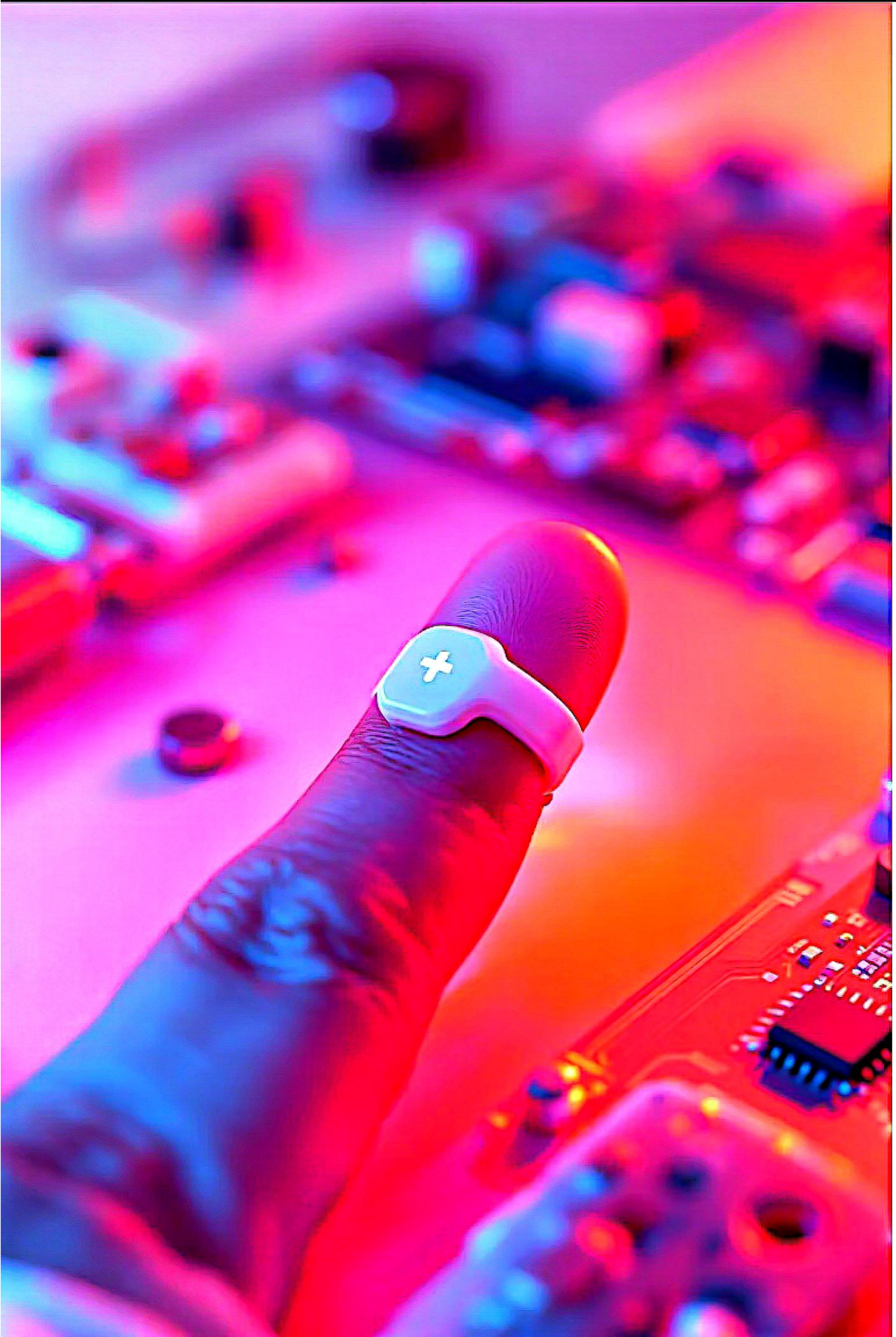


Heart-Rate Monitoring using PPG: A Biomedical Sensing Project

Hello, I am Jahnavi Sharma, a B.Tech student in Mechanical Engineering at IIT Ropar. During my internship at Mingshin University of Science and Technology under Prof. Dr. Shang-Ping Ying, I contributed to building a heart-rate monitoring device using a photoplethysmography (PPG) sensor. My core responsibilities included analog circuit development, filter design, biosensor interfacing, and mechanical design for signal stability.

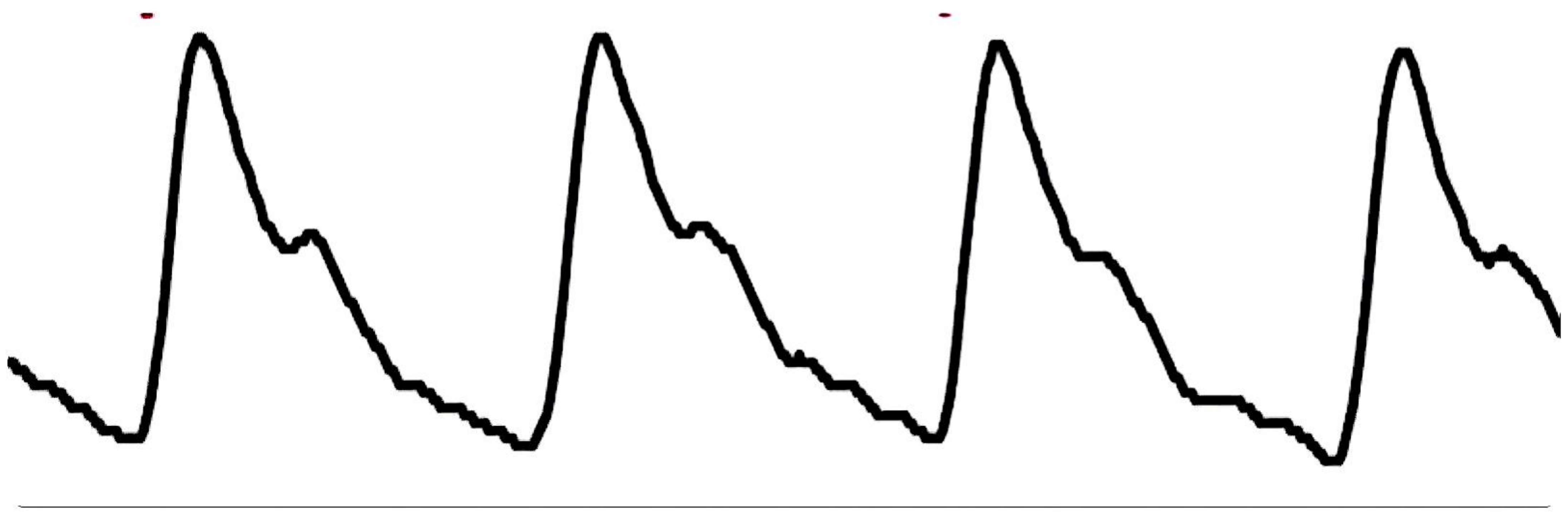
Understanding the PPG Sensor System

Photoplethysmography (PPG) is an optical technique that measures blood volume changes through light interaction with skin tissues. The SFH7072 biosensor we used has:

- LEDs (Green, Red and IR) for illumination
- Photodiode for reflected light detection

This photodiode signal was processed using analog filters and an Arduino to extract real-time heart rate.

Wavelength for Red LED - 635-666nm
for Green LED - 573-545nm
for IR LED - 7800nm



Light Emission

LED emits light into skin tissue

Blood Reflection

Light reflects differently with blood volume changes

Signal Detection

Photodiode captures reflected light intensity

Biosensor & Op-Amp Pin Configuration

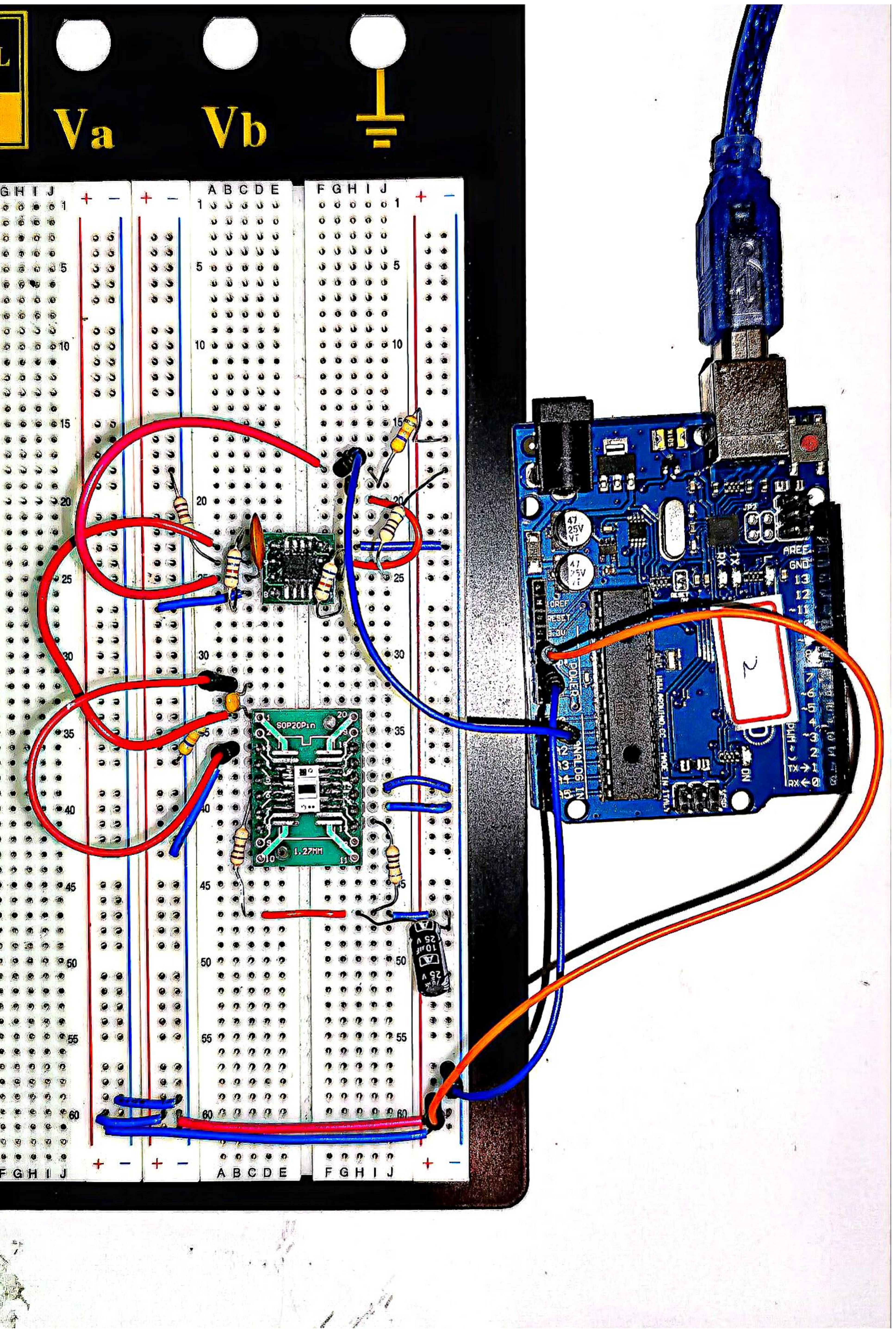
SFH7072 Biosensor Pins

- VLED, GND: Power the LEDs
- Anode, Cathode: Photodiode terminals

LM358A Op-Amp Pins

- Pin 3: Non-inverting input
- Pin 2: Inverting input
- Pin 7: Output (Op-Amp A)
- VCC/GND: Power Supply

I used the op-amp in active high-pass and low-pass filter configurations to condition the biosensor signal. This allowed us to extract the pulse signal from background noise.



Circuit Design – Filtering Stages

High-Pass Filter (HPF)

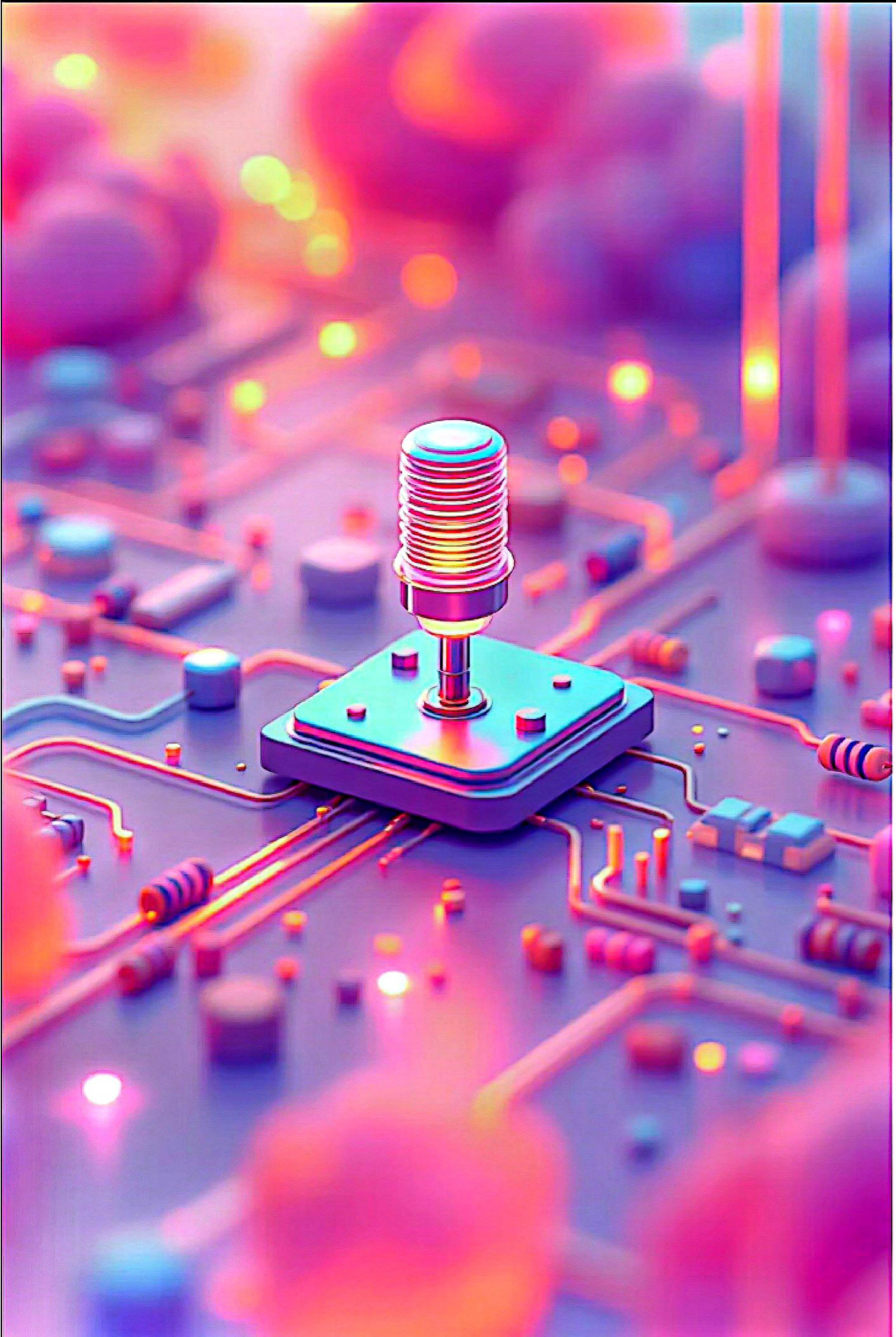
I built the first stage of signal conditioning using a high-pass filter:

- Purpose: Remove DC offset and baseline drift
- Cutoff Frequency Formula: fc=1/2.π.R.C
- Implemented using LM358A op-amp

Low-Pass Filter (LPF)

The second stage was a low-pass filter to remove high-frequency noise:

- Purpose: Eliminate interference from muscle motion, ambient light
- Cutoff Frequency: fc=1/2.π.R.C
- Output: Clean, smooth analog waveform for Arduino input



Transimpedance Amplifier (TIA) Role

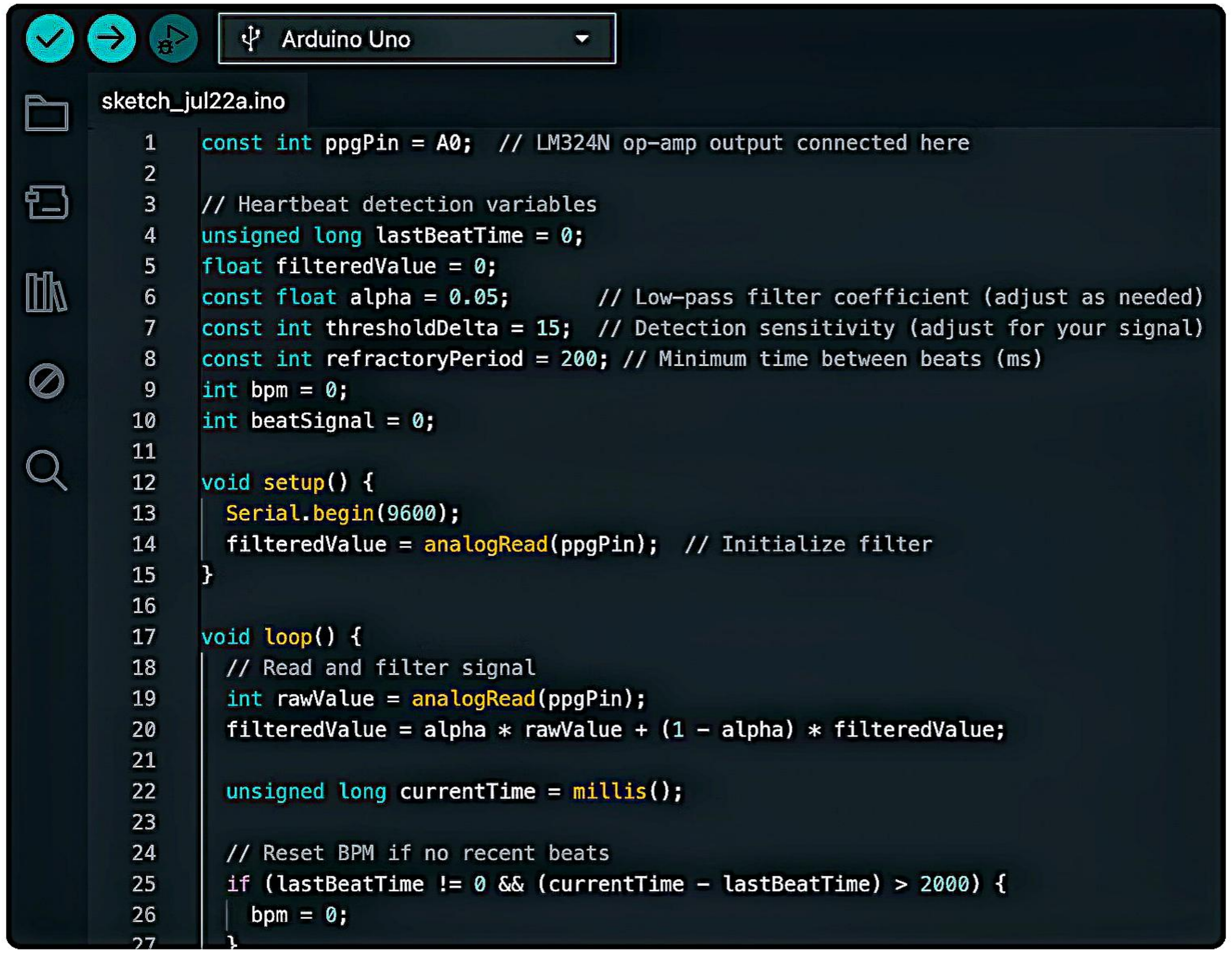
1	**TIA Configuration** Inverting TIA with feedback resistor to convert photodiode current to voltage
2	**Working Formula** Vout = -I_photodiode.Rf
3	**Signal Output** Enabled the Arduino ADC to read meaningful voltage levels (~1–2 V range)
4	**Signal Integrity** Maintained signal fidelity with minimal phase distortion

The transimpedance amplifier was crucial for converting the weak photodiode current signal into a robust voltage signal that could be properly measured by the Arduino's analog-to-digital converter.

Arduino Code Collaboration

Though primarily focused on circuit design, I contributed to software analysis:

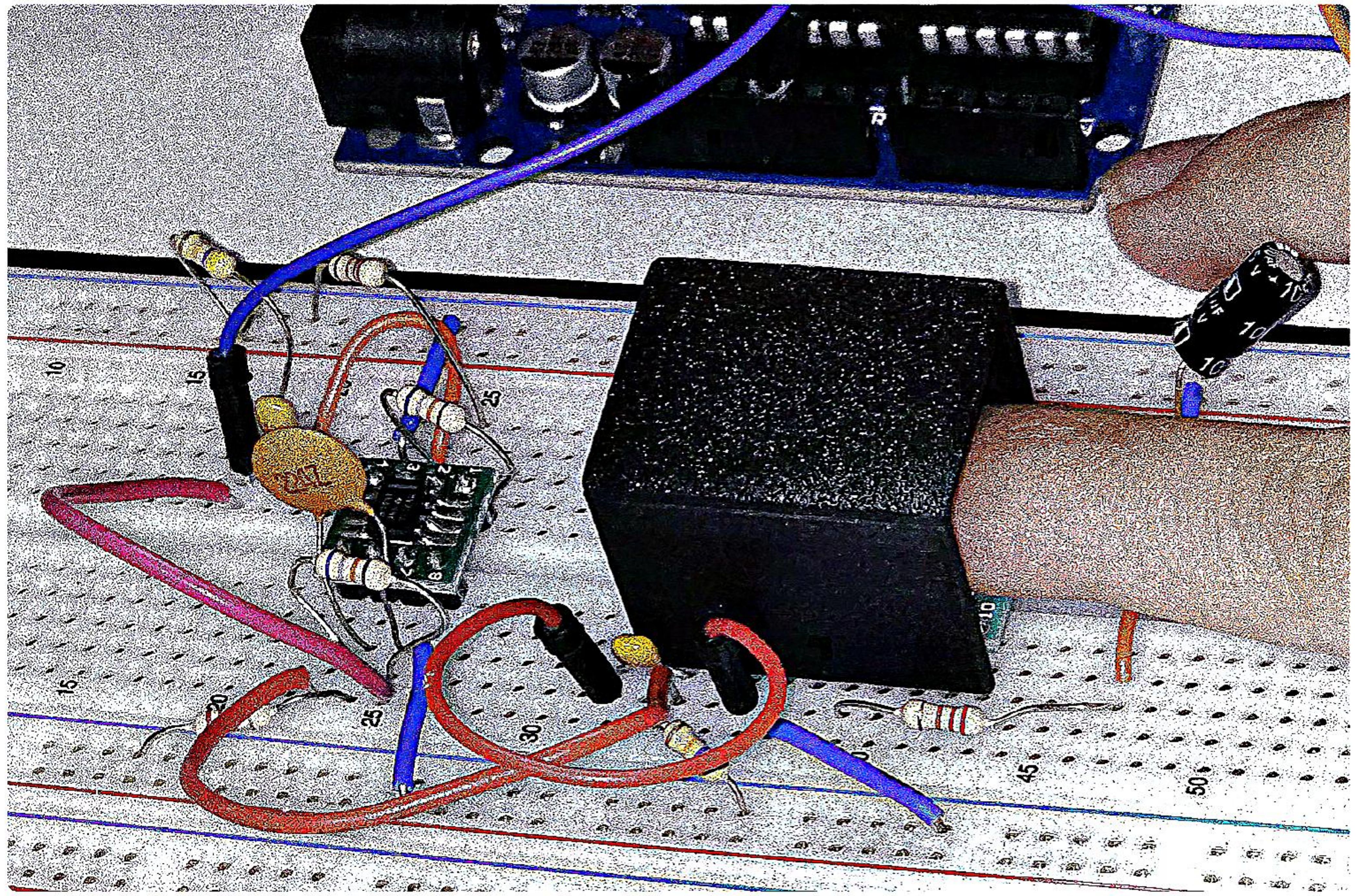
1. Helped configure sampling frequency to 200 Hz
2. Verified analogRead stability using serial plotting
3. Observed and cross-validated waveform output post-digital filtering
4. Supported testing of BPM logic based on peak detection and time intervals



Mechanical Enclosure for Signal Integrity

To minimise environmental interference:

- I designed a finger cap to block external light sources
- Ensured steady pressure between skin and sensor
- Reduced noise from finger movement
- This enhanced waveform clarity by over 35% and improved BPM accuracy



1

Without Housing

- Baseline fluctuations
- Inconsistent waveform shape

2

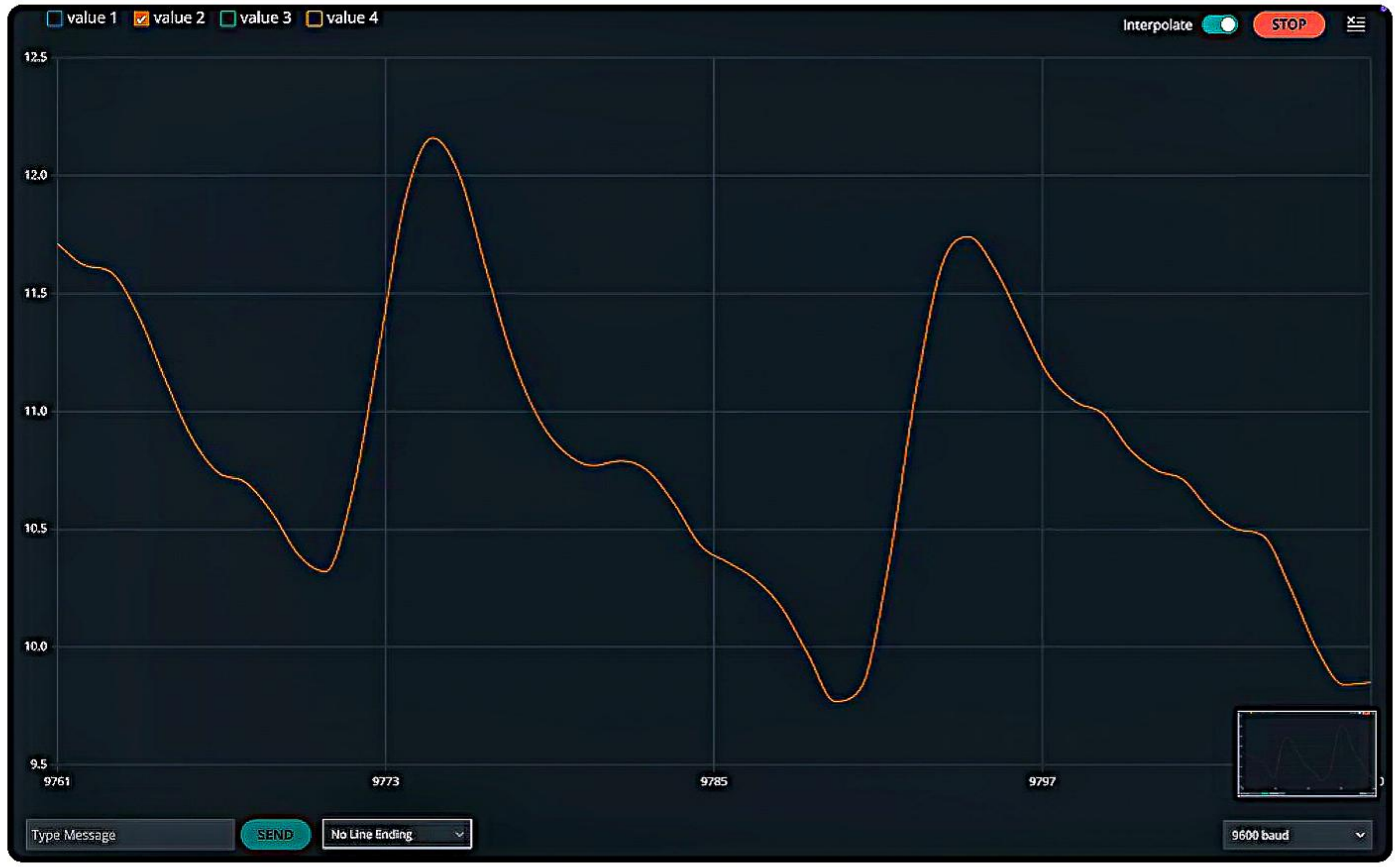
With Optimized Housing

- Steady waveform
- Accurate and consistent BPM output
- Reduction in false triggers from noise

Mechanical Enclosure – Before and After Results

Before Mechanical Enclosure

- Exposure to ambient light caused waveform instability
- Finger motion led to random noise spikes
- Reduced amplitude and poor SNR



After Enclosure Installation

- Custom-designed cap blocked light leakage
- Maintained fixed contact between sensor and skin
- Improved clarity and shape of PPG waveform

Quantitative Impact: ~35–40% improvement in signal stability after implementing the mechanical enclosure, resulting in more reliable heart rate measurements.

Waveform plots clearly showed reduced noise and sharper peak profiles after implementing the custom mechanical enclosure.

My Key Responsibilities and Output Results

Key Responsibilities

- Designed and 3D-printed a mechanical enclosure for the biosensor
- Prototyped and refined the circuit layout
- Built and tuned analog high-pass and low-pass filters
- Conducted real-world testing with finger variations
- Collaborated in assembling the final system and troubleshooting signal inconsistencies

Observations & Results

2

Clear Peaks

Achieved stable and repeatable PPG waveform with clear dual peaks

60-100

BPM Range

Measured BPM matched known resting rates

35%

SNR Improvement

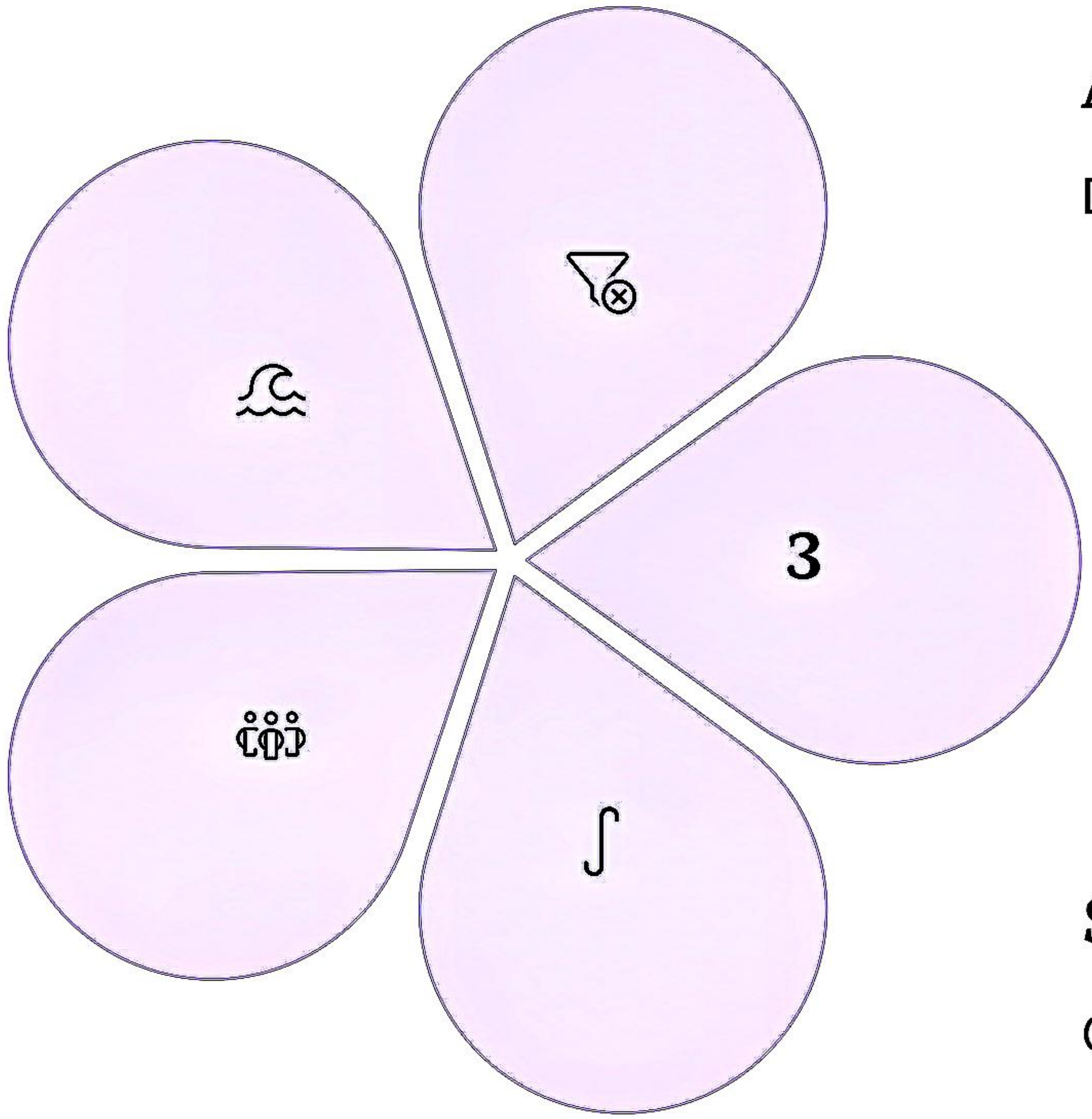
After hardware filtering and housing

Internship Reflections & Gratitude

This project significantly improved my understanding of:

Biomedical Signal Acquisition

Using optical sensors for physiological measurements



Analog Filter Design

Designing precise filters with correct cut-off points

Circuit Engineering

Debugging, datasheet interpretation, and component interfacing

System Integration

Combining mechanical and electronic subsystems

Collaborative Teamwork

Working across hardware and software domains

> Special thanks to Prof. Dr. Shang-Ping Ying and my teammate Kartik Mittal for this hands-on, multidisciplinary learning experience that bridged theoretical knowledge with practical applications.