HYDROPACE: ADVANCING CONVENTIONAL PACEMAKERS BY IMPLEMENTING HYDROGEL-BASED ELECTRODES AND CARDIAC HEALTH MONITORING SYSTEM

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A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronics Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc) in Electrical & Electronic Engineering

Department of Electrical & Electronic Engineering
Brac University
September 2025

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Academic Technical Committee (ATC) Panel Member:

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Department of Electrical & Electronic Engineering
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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing a degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material that has been accepted or submitted for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

Student's Full Name & Signature:

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Approval

The Final Year Design Project (FYDP) titled HYDROPACE: Developing a Hydrogel-Based Cardiac Pacemaker submitted by

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Summer 2025 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science (B.Sc) in Electrical & Electronic Engineering in September 2025.

Examining Committee:

Academic Technical Committee (ATC): (Chair)

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Ethics Statement

We thus state and certify that this Final Year Design Project titled "Hydropace: Advancing Conventional Pacemakers By Implementing Hydrogel-Based Electrodes And Cardiac Health Monitoring System" complies with requirements for completion of the Final Year Design Project set by the BRAC University Authority and the Department of Electrical and Electronic Engineering of BRAC University in partial fulfillment of the requirement for the degree of Bachelor of Science (B.Sc.) in Electrical & Electronic Engineering. This project report has been compiled with the help of all the members of the group including our findings, designs, test results and details of our prototype. All the resources and literature reviews have been cited properly with the guidance of our ATC Panel.

The plagiarism index of our project report is found to be 10% after consulting with the Ayesha Abed Library of BRAC University for a combined overall AI and similarity check.

Abstract/ Executive Summary

The rising prevalence of cardiac disorders, coupled with the limitations of conventional pacemakers such as rigidity, short lifespan, repeated surgical interventions and risk of complications, have created the need for innovative biomedical devices. This research work examines the feasibility of improving the functionalities of conventional pacemakers by replacing certain traditional methods with novel solutions. This comprises the implementations of hydrogel-based electrodes and sensor heads that integrate flexibility, biocompatibility, and multifunctional sensing capabilities. The proposed design incorporates hydrogel as a soft and conductive medium to enable seamless integration with cardiac tissue, while supporting embedded sensor heads made with hydrogel for ECG, temperature, and biochemical/biomarker level monitoring. The HydroPace system also includes energy harvesting and wireless communication modules to enhance device longevity and minimize the need for invasive replacements. The primary objective of this study is to design and prototype a system that not only maintains effective pacing for patients with arrhythmia but also ensures improved diagnostic accuracy and enhanced patient safety. By addressing both the engineering and biomedical constraints, this research aims to contribute to the advancement of sustainable, accessible, and next-generation cardiac care technologies.

Keywords: Hydrogel, Conventional Pacemaker, Novel Solutions, Biomedical Devices, ECG, Temperature Monitoring, Biochemical/Biomarker Level Monitoring, Biocompatibility, Energy Harvesting, Wireless Communication, Effective Pacing, Cardiac Care

Acknowledgement

We would like to acknowledge and thank the Chair of our ATC Panel Dr. AKM Abdul Malek Azad, Professor, Department of EEE, BRAC University for his continuous support and guidance throughout the completion of this project. We would also like to acknowledge and convey our gratitude to Ihteyaz Aqaid Avash, Lecturer, Department of EEE, BRAC University and MD. Rafiqul Islam Rafi, Lecturer, Department of EEE, BRAC University for sharing their valuable insights and recommendations for further improvement of our initial idea for this project. We are also indebted to the faculty members of Department of EEE, Brac University who for so long have paved the way with their knowledge and stepping stone wisdom that led us here to completion of our Final Year Design Project. We would be remiss not to acknowledge Dr. Firoze H. Haque, Associate Professor and Chairperson of the Department of MNS, Dr. Iftekhar Bin Naser, Associate Professor, Department of MNS, Mrs. Shamim Akter Chowdhury, LTO, Microbiology lab, Department of MNS, and others from the Department of MNS who have helped us achieve our desired results with a core part of our FYDP objectives.

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Chapter 1: Introduction- [CO1, CO2, CO10]

1.1 Introduction

Cardiac pacemakers have long served as vital life-saving devices for patients with heart rhythm disorders. However, traditional pacemakers come with a host of challenges, including their rigid mechanical structure, limited battery life, and poor compatibility with the soft tissue of the heart. These limitations often lead to complications such as inflammation, infections, and the need for repeated surgical interventions. Moreover, their performance can be compromised by external factors such as diagnostic imaging (e.g., MRI), and their maintenance is particularly burdensome in economically challenged or remote regions where access to surgical facilities is limited.In response to these issues, innovative research has turned toward the development of hydrogel-based cardiac pacemakers, which aim to offer a more biocompatible, flexible, and self-sustaining alternative. Hydrogels are soft, water-rich polymeric materials that have demonstrated remarkable potential in mimicking the mechanical properties of cardiac tissue. With recent advancements, they can be engineered to possess electrical conductivity, durability, and responsiveness to mechanical stimuli. Combined with energy harvesting technologies such as nanogenerators and wireless charging, hydrogel-based systems promise to significantly reduce the need for battery replacements and invasive procedures.

This project, titled HydroPace, proposes a novel hydrogel-encapsulated pacemaker system that leverages physically cross-linked, conductive hydrogels to create a resilient, long-lasting, and MRI-compatible device. Through smart material integration and energy autonomy, the goal is to bridge the gap between electronic functionality and biological compatibility bringing forward a new era of soft, patient-friendly biomedical implants.

1.1.1 Problem Statement

Despite the life-saving function of traditional pacemakers, patients still face major limitations such as rigid mechanical structures, short battery life, and biological incompatibility, leading to complications including inflammation, infections, and frequent surgical revisions [1], [2]. The mechanical mismatch between pacemaker materials and the heart's soft tissue contributes significantly to post-implantation issues. In addition, pacemaker batteries often require replacement within a few years, and failure or interference with medical imaging like MRI, remains a critical risk [1]. In remote or economically challenged areas, access to frequent surgeries or advanced replacement procedures can be a significant barrier to healthcare.

This project proposes a hydrogel-based cardiac pacemaker system (HydroPace) as a solution to these challenges. By leveraging physically cross-linked hydrogels with conductive properties, we aim to build a soft, self-sustaining, long-lasting, and flexible device that integrates biocompatible encapsulation, energy harvesting (nanogenerators), and wireless charging technologies [1], [3]. The goal is to develop a pacemaker that not only mimics the natural elasticity and texture of cardiac tissue but also operates efficiently without the need for frequent interventions, ultimately lowering the cost and improving accessibility for diverse patient populations [1], [15].

1.1.2 Background Study

Pacemakers can be configured in many ways, ranging from fixed periodic permanent pacing to making use of the patients' ECG (electrocardiogram) data in order to understand the pacing requirements [1]. While implantable pacemakers can effectively treat bradyarrhythmias, they make use of extracorporeal wiring and lead electrodes alongside a limited battery just to deliver electrical stimulus to specific cardiac tissues, namely in the Sino-Atrial (SA) node region and/or the AtrioVentricular (AV) node region from where we obtain the wave of electrical impulses that naturally drive the muscular contractions of the heart [1]. When developing pacemakers, the natural rhythm of heart contraction and expansion must be taken into account. This is represented by one period of atrial and ventricular contraction shown by ECG signals which are plotted as a function of voltage over time. There are three waveforms shown in two cycles and two typical ECG segments or periods in figure 1 below:

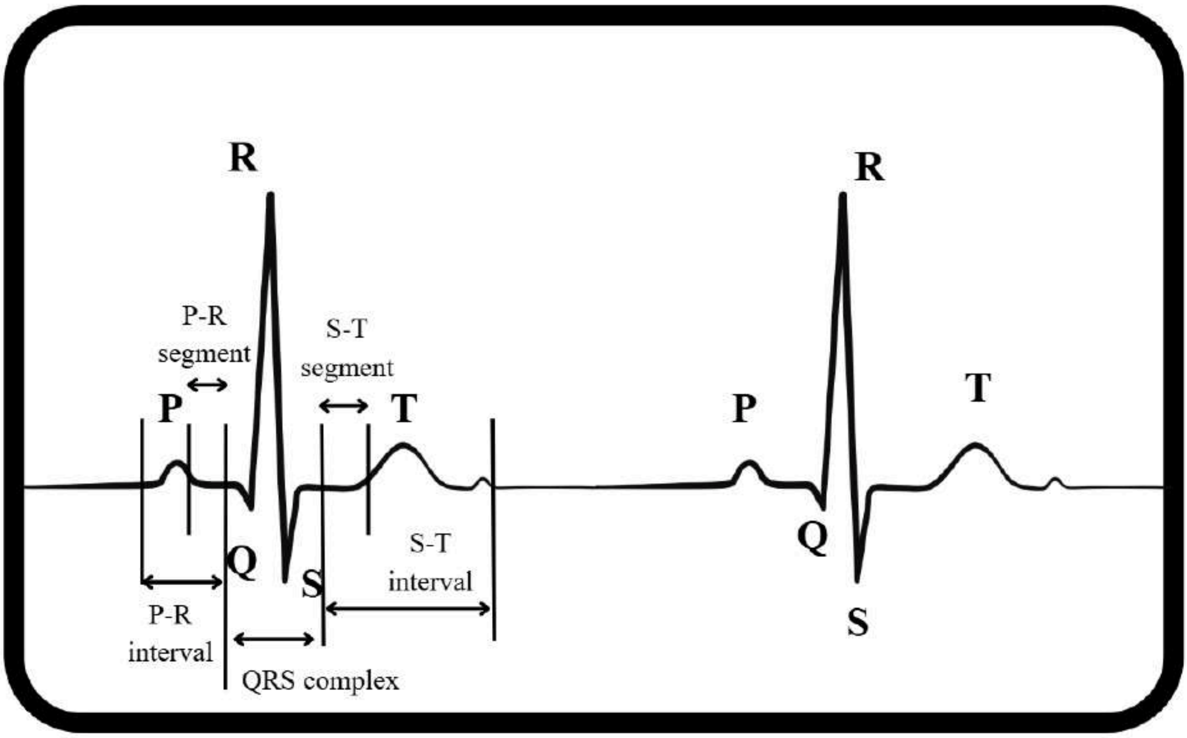

Figure 1(a): Self-made image of a typical ECG signal in two segments or periods, showing the different intervals and wave segments..

From figure 1 we can divide one period of ECG signal into three waveforms, three intervals and two wave segments:

The three waveforms are:

1. Atrial agitation causes P wave production. Typically originating in the SA node, the P-waves last for 0.12 seconds with an average peak of 0.25 mV; the peak can rise and dip with differing levels of stimuli [1], [2].

2. The QRS wave group is due to the left and right ventricular depolarization. We can see most distortment in this segment of the ECG signal due to many of the cardiovascular diseases such as AV block, hypertrophy of the left or right branches, etc.

3. The T-wave is the recovery following ventricular agitation in order to pave the way for the next heart beat to occur [1], [2].

The three intervals:

1. P-R interval: While the range of this interval varies between people, it is usually within 200 milliseconds and it signifies the actions of the atrial contraction [1].

2. Q-T interval: It starts right after the P-R interval ends and lasts until the T-wave ends. It lasts at least twice as long as the P-R interval or more depending on various circumstances, encompassing the cardiac repolarization and depolarization [1].

3. S-T interval: Right after the ventricular actions end to the repolarization of the heart during the end of T-wave segment where the heart readies itself for the next heart beat.

The two wave segments:

1. The P-R segments which marks the second half of the P-wave to the start of the QRS wave group. It indicates someone's cardiac health. The closer this segment is to the baseline the healthier the individual is considering their cardiac condition.

2. The S-T segment goes from the end of the ventricular action to the start of the heart repolarization, i.e. from the end of QRS wave to the start of the T-wave. This is also a health indicator showing cardiac health similar to the P-R segment. Then there is a period of relaxation or no action before the next heartbeat starts.

The P-wave is a positive electrical signal while the Q-wave starts negative (voltage drop) due to their polarities, followed by a deflection in the positive direction that is the R-wave. The S-wave is the subsequent negative deflection required for the necessary contractions of the cardiac muscles. The typical amplitude of the ECG signal would vary between 50 microvolts to 3 millivolts and the typical heart rate would be in the range above 60 bpm to below 100 bpm [1], [2]. Conventional pacemakers have been developed to handle the required necessities of a patient, depending on the treatment the patient actually requires. Therefore the pacemakers can be tweaked for optimal functionality, which is partly done during manufacture and partly done by the engineer on the doctors' instructions [1], [2], [5].

However, there are various problems encountered while patients undergo surgeries or transplants for cardiac pacemakers, such as extracorporeal wiring in some applications, dependency on battery power that require frequent surgical interventions, rigidity of design and structure of current pacemakers, and complications like infections and inflammation due to the mechanical mismatch of the conventional pacemakers with the soft, curvilinear, and dynamic environment of the human heart. Some cases require flexible yet resilient structures that can also support electronics for monitoring and treatment. In that case, we can use hydrogel to improve the conventional pacemakers by making the required biological electronics, or bioelectronics, for patients to recover from their illnesses. Therefore, hydrogel can safely house the bioelectronics that are specially produced to withstand the elastic tension from continuous usage of biomedical devices [1], [2].

Research on hydrogel-based devices shows that biomedical devices such as pacemakers and ear transplants can be successfully made using hydrogel and have been tested on mice and rabbits. Represented by pacemakers, implantable bioelectronic devices (CIBDs) are playing a vital life-saving role in modern society. Over 50% of patients with pacemakers require additional surgeries to replace drained batteries. Abrupt battery malfunction and failure contribute up to 2.4% of implanted leadless pacemakers. The battery also has risks of lethal interference with diagnostic magnetic resonance imaging (MRI) [1]. To mitigate these risks, triboelectric and piezoelectric methods have been proposed to convert biomechanical energy into electricity. Cardiac nanogenerators (NGs) convert heartbeat energy into electrical energy and require high-performance electromechanical coupling materials with long-term dynamic stability [3]. A complete heartbeat cycle provides biomechanical energy of approximately 0.7 J (mean power 0.93 W), sufficient to run pacemakers (power consumption 5–10 μW) or defibrillators (10–100 μW) [1], [3].

Wireless RF energy transfer is also a potential method, where alternating current (AC) induced by RF signals can be converted into direct current (DC) using rectifiers. Hydrogel-based packaging becomes essential to ensure device stability and operation over time, especially on a moving organ like the heart. This requires properties like flexibility, biocompatibility, antifouling, hemocompatibility, and bioadhesion [3]. Hydrogels, made of polymeric networks, are broadly classified into chemical (with covalent bonding) and physical (non-covalent) types. For this project, physical hydrogels are chosen due to their superior elasticity, biocompatibility, lower cost, and compatibility with living tissues [1].

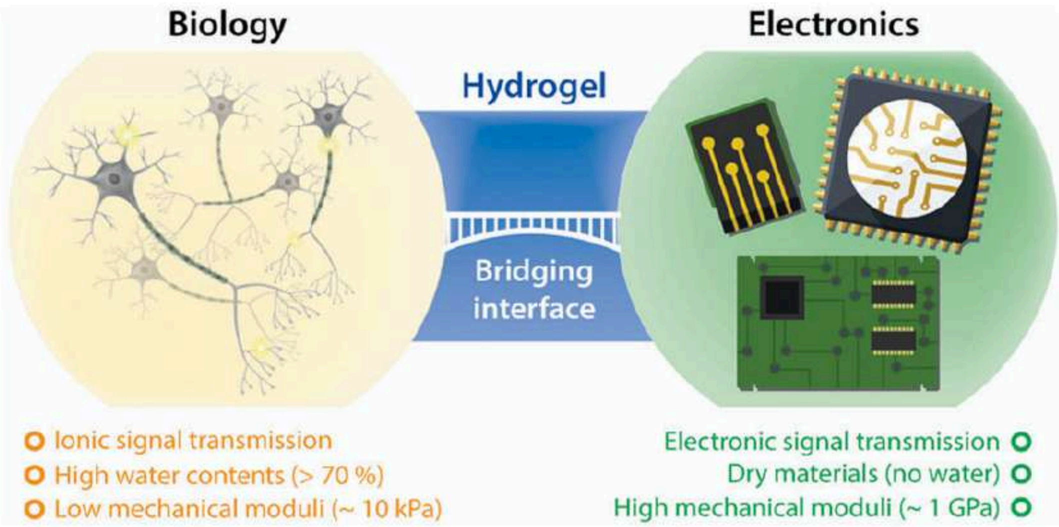

Figure 1(b): Hydrogels bridging the gap between biology and electronics [6].

Widely used hydrogel bases include chitosan, poly-(3,4-ethylenedioxythiophene), sodium carboxymethyl cellulose, and poly-N-isopropyl-acrylamide (PNIPAm). These utilize π–π interactions, hydrogen bonding, Michael addition, and Schiff-base reactions to form strong 3D polymer networks. Even without strong covalent bonds, such hydrogels can withstand at least 80% stress under ambient conditions and have Young's modulus of around 80 kPa, closely mimicking mammalian heart tissue (much softer than traditional electrodes in the GPa range) [1], [3]. By altering hydrogel composition for example, adding alginate and polydopamine to PNIPAm, the material can be made electrothermally conductive and hydrophilic, showing custom properties for specific biomedical uses. This makes hydrogel a promising candidate for applications like glucose monitoring, electrocardiogram (ECG), electroencephalogram (EEG), cardiac pacemakers, and neurostimulators [1], [15].

1.1.3 Literature Gap

From our literature review, we have observed that significant progress has been made in the field of biomedical devices, particularly in advancing traditional pacemakers and exploring hydrogel-based applications. Many studies have focused on improving energy harvesting techniques such as triboelectric and piezoelectric nanogenerators to enhance device longevity [1], [2]. Others have explored hydrogel as a biocompatible material for flexible electronics and implantable systems [3], [4], [5], [6]. Some research has investigated the integration of wireless communication and non-invasive monitoring for cardiac health [7], [8], [9]. However, most of these works have been limited to individual aspects either focusing on energy harvesting, hydrogel biocompatibility, or ECG signal monitoring without providing a comprehensive solution that combines flexibility, real-time sensing, energy efficiency, and long-term stability in a single pacemaker system [21], [22]. Few attempts have been made to design a compact, minimally invasive, and cost-effective hydrogel-based pacemaker that addresses the limitations of conventional devices such as rigidity, repeated surgeries, and short lifespan. Our proposed HydroPace system aims to fill this gap by integrating hydrogel substrates, embedded multi-sensors, energy harvesting modules, and wireless connectivity into a unified design that is lightweight, biocompatible, durable, and user-friendly, ensuring improved patient outcomes and accessibility. However, one of the biggest problems we found is that pacemakers use very compact electronics, and in order to replicate it, we need more time than allocated because expert PCB manufacturing is difficult in Bangladesh as we have experienced. Therefore, we needed to make the PCB while disregarding the size limitations of a real pacemaker, thus making our pacemaker much bigger than its real-life counterpart. As for the cardiac parameters to be measured, we do not have much data other than a few datasets taken from the National Cardiac Hospital, Bangladesh. We had to merge the data with synthetic data in order to serve our purposes. Since pacemakers can be tweaked for functionality, if we can show one function from the pool of numerous sensing and pacing methods, we can complete our objective. In addition, it is very important to protect the privacy, accuracy and accessibility of patients' health data. Although we have seen one such attempt from the literature, we were unable to replicate that, and it is not enough to protect patient data. In the future, researchers should focus on making strong security rules and frameworks in order to keep patients' private data safe from any sort of breaches.

1.1.4 Relevance to current and future Industry

Over the years, the prevalence of cardiovascular diseases has increased drastically, making them one of the leading causes of mortality worldwide. Conventional pacemakers, while life-saving, come with significant limitations such as rigidity, risk of infection, repeated surgical interventions for battery replacement, and mechanical mismatch with the soft and dynamic tissues of the human heart. These issues reduce device longevity, increase patient discomfort, and raise overall healthcare costs [12], [13]. In developing countries like Bangladesh, where access to advanced biomedical technologies is already limited, these challenges create further disparities in patient treatment and survival rates [14]. The growing population, rising cases of cardiac disorders, and limited healthcare infrastructure emphasize the urgent need for innovative, cost-effective, and long-lasting cardiac solutions. HydroPace, a hydrogel-based cardiac pacemaker, is designed to address these challenges by integrating biocompatible hydrogel materials, real-time sensing, wireless communication, and energy harvesting into a single device [15]. Unlike traditional devices, HydroPace offers flexibility, seamless integration with heart tissues, and reduced surgical interventions, ensuring improved quality of life for patients. By providing an innovative alternative to rigid pacemakers, HydroPace has the potential not only to enhance cardiac healthcare but also to make advanced treatment more accessible and sustainable in resource-constrained settings.

1.2 Objectives, Requirements, Specification and Constraint

1.2.1. Objectives

To diagnose cardiac diseases and evaluate patients' cardiac health, correct ECG interpretation along with parameters such as core temperature, biochemical data and pH data are essential to realize the absolute need for any stimulus to the heart muscles to influence the bradycardia-tachycardia rhythm to keep the heart rate of patients in control. An inventive, easily available, and reasonably priced cardiac pacemaker that enforces a greater degree of freedom for patients' movements that has greater longevity. Device longevity is necessary for patient well-being as it maintains workability while not needing any external surgery for replacement and maintenance for decades. This enables medical practitioners not only to adapt to new technology but also to improve patient diagnosis and treatment. This design project is an attempt to nullify the limitations of the current situation of biomedical devices like pacemakers while addressing problems of cost and availability and advancing biomedical technology innovation. Following published research works, we are planning to implement minimally invasive procedures regarding HydroPace [1], [2], [3]. Therefore we can summarize our objectives in the following points:

a. Using hydrogel as the electrodes that will attach to the heart more intimately, serve as a conductive medium between the heart and the pacemaker, collecting data and providing electrical pulse stimulus.

b. Splitting up the hydrogel according to its desired requirements, i.e. hydrogel strips that will function as electrodes, ECG sensor, biochemical data sensor and temperature sensor all of which will be separated from contact with one another.

c. Acquiring the necessary cardiac health information and processing them.

d. Sending pacing signals (usually around 0.5 V) to the intended region of the heart (AV node).

e. Demonstrating functionality of the pacing. We intend to use VVI (ventricular-ventricular inhibition) pacing in order to treat AV block, bradycardia, etc. related to the distortion in the normal ventricular operation of the heart. This is because when one method will work the rest can follow suit.

f. Developing an application which will receive real-time data from the pacemaker and visually demonstrate ECG signals as well the necessary cardiac health parameters.

g. Make the application create a medical log that will keep patient data recorded and safe, so that the data can be later used by the doctors to make informed decisions.

1.2.2 Functional and Nonfunctional Requirements

Functional Requirements:

The features outlining a hydrogel-based cardiac pacemaker's capacity to collect accurate data, stimulate the cardiac tissues, and allow secure remote connection fall under its functional requirements. These specifications guarantee its efficacy in medical applications and device evaluation [4].

a. Cardiac health sense: The HydroPace is able to sense parameters related to cardiac health such as the heart rate, pH and temperature. While the ECG sensor continuously obtains data on cardiac activity, the temperature sensor can get the cardiac environment and temperature. Use of biochemical sensors includes detection of certain biomarkers such as N-terminal pro-B type natriuretic peptide (NT-proBNP) that have been established to play an important role in heart failures [1].

b. Pulse stimulus: To treat arrhythmia which is the main purpose of the pacemaker, the HydroPace contains electrodes that can send electrical pulses to the cardiac tissues which attempt to replicate normal heart behavior, thus keeping the heart rate under control and for the patient to be healthy.

c. Quality Assurance: The pacemaker should ensure its quality by guaranteeing its reliability, accuracy, and real-time data while lasting for a long time as intended.

d. Safety: Patients' safety must be ensured while using the pacemaker.

e. Risk Management: The pacemaker must identify, assess, and mitigate risks associated with its use.

f. Information Security: The pacemaker must implement information security measures to protect sensitive data and patients' cardiac health information.

g. Diagnostic Accuracy: The pacemaker should ensure that it can accurately portray the patient's data using the external application or interface, thereby meeting established diagnostic standards for medical treatment applications.

h. Performance: Operate with minimal latency in collecting data on patients' cardiac health, display the data in the app or interface and apply cardiac stimulus when required.

i. Minimal invasion: HydroPace is to be minimally invasive, i.e. surgical procedures following cardiac failures requiring use of pacemaker implants will be minimal; HydroPace does not require continuous surgical interventions to remain operational. It is long-lasting and requires surgical intervention only during emergencies, such as circuit malfunction, which will be notified via the HydroPace app [1].

j. Hydrogel environment: The purpose of including hydrogel is to ensure risks that come with conventional pacemakers are greatly reduced while providing a long-lasting solution with better performance compared to conventional pacemakers. Because hydrogel is benign to the cardiac tissues, it can attach itself to the heart more adhesively, ensuring that pacing of the electrical stimuli and sensing of the cardiac parameters are reliably accomplished continuously with minimal wear and tear.

Non-Functional Requirements:

Performance, scalability, usability, and safety are a few examples of non-functional requirements for the hydrogel-based cardiac pacemaker. Instead of emphasizing what the system does, they emphasize how well it functions [5].

a. Ease of Use: To ensure that after implantation in the required patients, it is very easy for them to keep track of the data on their cardiac health and for the doctor, patient, or caretakers to apply the required cardiac control using the app or interface so the patients' heart rate is within the required limit. Therefore, it ensures an intuitive, user-friendly interface for all experience levels.

b. Mobility: It should be possible to move about more freely, having a pacemaker implanted as the hydrogel makes it more flexible, easier to move around and resistant to deterioration.

c. Scalability: It is a requirement for any system that wants to support any future developments, improvements and new features as they come along.

d. Cardiac data: Patients' cardiac health data can be used by doctors to detect and/or diagnose any other diseases the patients might have.

1.2.3 Specifications

Overall System Level Specifications:

a. Lightweight build: HydroPace has to be lightweight according to established standards for pacemaker manufacturing in order to prevent discomfort in patients and for the device to operate within normal conditions. [1]

b. Wireless power supply module: Compact HydroPace will use a wireless power supply module that operates through resonant inductive coupling between coils, ensuring the device remains powered without direct electrical connections [1].

c. Cardiac pacing module: Both Design Approaches will use a cardiac pacing module that allows for precise adjustments of the pacing frequency, pulse width and pacing time frame according to the specific needs of the heart pacing [1].

d. Dual function module: The purpose for this is to detect real-time ECG signals and also perform electrochemical signal detection of the cardiac environment, providing comprehensive cardiac monitoring. For both Design Approaches this module uses conductive hydrogel. However, for Compact HydroPace, this module will also help deliver electrical stimulation to the cardiac tissues [1], [6].

e. RF antenna module: Uninterrupted communication from the pacemaker to the user interface (mobile app) while supporting two-way communication (transceiver) [1]. Our design will use Bluetooth to connect HydroPace with the HydroPace app.

f. Real-time Processing: The system will process acquired data in real-time with minimal delay and communicate the data to the external device [1], [4], [7].

g. User Interface: An intuitive user interface, such as a bespoke mobile app will be designed to display real-time data charts and analysis which includes battery information, anomaly alerts, visualization, feedback and heart stimulation trigger actions for easy interpretation, interaction and implementation by users.

h. Signal integrity: DC battery-operated mode ensures that no line noise is introduced into the output waveform. The design also allows a larger margin for AC mains isolation.

Component Level Specification:

Segment	Component's name	Model	Specification
Power source	Lithium battery	1. LiPO4 (Lithium Phosphate)	1. LiPO4 : Capacity- 500 mAh Output- 3.7V
	Voltage Regulator	AMS1117 low dropout voltage regulator IC	Polarity: Positive Input voltage range: 1.8V - 15V DC Output voltage: 5V Operating temperature: -24 to 84 ∘C
	Radio signal generator and receiver	1. RF transmitter unit	433MHz wireless RF transmitter. Supply voltage: 3.6 V and above
		2. RF Receiver unit	433MHz wireless RF receiver unit with rectifier. Received voltage: 5.2V
	Power rectifier	Half-wave rectifier	RLC component based

Processing unit	Microcontroller	1. ATMega 328P	1. ATMega328P-AU : 8-bit, 20MHz 32KB (16K x 16) FLASH 32-TQFP (7x7)
	Oscillator	SPXO crystal oscillator	8 MHz oscillation
Signal processing unit	Signal processor	KS1082 Kingsense ECG Signal Processor	Operating Supply Voltage: 3.3V to 5.5 V Operating temperature: -40 ~ 125 ∘C Data RAM Size: 512 B Max Clock Frequency: 20 MHz Number of Cores: 1 Core
	Antenna	M177 NRF24L01	Antenna Wireless Transceiver Input voltage: 1.9~3.6V
Sensing and pacing unit	Temperature Sensor	MCP9808	Temperature range: -40 ~ 125 ∘C Operating Voltage range: 2.7 ~ 5.5 V
	Hydrogel electrodes, ECG sensing wire and biochemical sensor	Made with hydrogel materials and copper wire	28 SWG copper wire with hydrogel coating
	Wires	1. Copper wires	Regular copper wires: 24 AWG solderable wires
		2. Jumper wires	Jumper wire Types: Male to Male Male to Female Female to Female
		3. Solderless breadboard cables	U-shaped cables for breadboard

Hydrogel materials	Hydrogel base	1.Poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS)	-
		2.Poly-sulfobetaine-methacrylate (PSBMA)	-
	Hydrogel substrate	2. N,N'-Methylene-bisacrylamide	-
		3. Lithium phenyl (2,4,6-trimethylbenzyl)	-
		4. 3- (trimethoxysilyl) propyl methacrylate	-
	Hydrogel conduction additive material	Neostigmine Methylsulphate (NM)	-
	Breadboard	Medium size	Solderless points: 830
	Wires	1. Copper wires	Regular copper wires: 24 AWG solderable wires
		2. Jumper wires	Jumper wire Types: Male to Male Male to Female Female to Female
		3. Solderless breadboard cables	U-shaped cables for breadboard
	Resistor	Normal resistors	Range of resistances Max operating voltage: 250V Tolerance: ±1% Operating temperature: -40 ~ 150 ∘C
	Capacitor	Normal and micro Aluminium electrolytic capacitors	Range of capacitances Polar and non-polar capacitors Operating voltage: 25V / 100V

Other components			Tolerance: ±5% Operating temperature: -20 ~ 75 ∘C
	Diode	1N4007	PN junction rectifier diodes. Max reverse peak voltage: 1000V Max RMS voltage: 700V Operating temperature: -50 ~ 150 ∘C
	Inductor	Colour ring inductors	Range of inductance Tolerance: ±10%
	Bulb	Filament bulb as heat source	60W bulb
	Heart prop	Artificial heart	Human heart imitation with hollow chambers
	Arduino Uno R3	Microcontroller for the Heart prop	Clock speed: 16 MHz EEPROM: 1 KB Flash Memory: 32 KB Input Voltage: 7~12 V Operating Voltage: 5 V
	Electric mini drill	Mold shaper for hydrogel and a tool for any use that we might require	Drill machine with several types of drill bits
	Duct tape	-	Required to cover the bulb during operation
	Aluminium Plate	-	For Hydrogel preparation.
	Wooden Plate	-	For Hydrogel preparation.
	Plastic Box	-	Keeping electronics components.

Compact HydroPace System Specification (Design Approach 1):

<table>
<tr><th>Segment</th><th>Component’s name</th><th>Model</th><th>Specification</th></tr>
<tr><td rowspan="4">Power source</td><td>Lithium battery</td><td>1. LiPO4 (Lithium Phosphate)</td><td>1. LiPO4 :
Capacity- 500 mAh
Output- 3.7V</td></tr>
<tr><td>Voltage Regulator</td><td>AMS1117 low dropout voltage regulator IC</td><td>Polarity: Positive
Input voltage range: 1.8V - 15V DC
Output voltage: 5V
Operating temperature: -24 to 84 ∘C</td></tr>
<tr><td rowspan="2">Radio signal generator and receiver</td><td>1. RF transmitter unit</td><td>433MHz wireless RF transmitter.
Supply voltage: 3.6 V and above</td></tr>
<tr><td>2. RF Receiver unit</td><td>433MHz wireless RF receiver unit with rectifier.
Received voltage: 5.2V</td></tr>
<tr><td rowspan="2">Processing unit</td><td>Microcontroller</td><td>1. ATMega 328P</td><td>1. ATMega328P-AU :
8-bit, 20MHz 32KB (16K x 16) FLASH 32-TQFP (7x7)</td></tr>
<tr><td>Oscillator</td><td>SPXO crystal oscillator</td><td>8 MHz oscillation</td></tr>
<tr><td rowspan="2">Signal processing unit</td><td>Signal processor</td><td>KS1082 Kingsense ECG Signal Processor</td><td>Operating Supply Voltage: 3.3V to 5.5 V
Operating temperature:
-40 ~ 125 ∘C
Data RAM Size: 512 B
Max Clock Frequency: 20 MHz
Number of Cores: 1 Core</td></tr>
<tr><td>Antenna</td><td>M177 NRF24L01</td><td>Antenna Wireless Transceiver
Input voltage: 1.9~3.6V</td></tr>
</table>

Sensing and pacing unit	Temperature Sensor	MCP9808	Temperature range: -40 ~ 125 ∘C Operating Voltage range: 2.7 ~ 5.5 V
	Hydrogel electrodes, ECG sensing wire and biochemical sensor	Made with hydrogel materials and copper wire	28 SWG copper wire with hydrogel coating
	Wires	1. Copper wires	Regular copper wires: 24 AWG solderable wires
		2. Jumper wires	Jumper wire Types: Male to Male Male to Female Female to Female
Hydrogel materials	Hydrogel base	1.Poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS)	-
		2.Poly-sulfobetaine-methacrylate (PSBMA)	-
	Hydrogel substrate	2. N,N'-Methylene-bisacrylamide	-
		3. Lithium phenyl (2,4,6-trimethylbenzyl)	-
		4. 3- (trimethoxysilyl) propyl methacrylate	-
	Hydrogel conduction additive material	Neostigmine Methylsulphate (NM)	-
	Breadboard	Medium size	Solderless points: 830

Other components	Wires	1. Copper wires	Regular copper wires: 24 AWG solderable wires
		2. Jumper wires	Jumper wire Types: Male to Male Male to Female Female to Female
		3. Solderless breadboard cables	U-shaped cables for breadboard
	Resistor	Normal resistors	Range of resistances Max operating voltage: 250V Tolerance: ±1% Operating temperature: -40 ~ 150 ∘C
	Capacitor	Normal and micro Aluminium electrolytic capacitors	Range of capacitances Polar and non-polar capacitors Operating voltage: 25V / 100V Tolerance: ±5% Operating temperature: -20 ~ 75 ∘C
	Diode	1N4007	PN junction rectifier diodes. Max reverse peak voltage: 1000V Max RMS voltage: 700V Operating temperature: -50 ~ 150 ∘C
	Heart prop	Artificial heart	Human heart imitation with hollow chambers
	Arduino Uno R3	Microcontroller for the Heart prop	Clock speed: 16 MHz EEPROM: 1 KB Flash Memory: 32 KB Input Voltage: 7~12 V Operating Voltage: 5 V
	Electric mini drill	Mold shaper for hydrogel and a tool for any use that we might require	Drill machine with several types of drill bits

	Aluminium Plate	-	For Hydrogel preparation.

Accessible HydroPace System Specification (Design Approach 2):

Segment	Component's name	Model	Specification
Power source	Lithium battery	1. LiPO4 (Lithium Phosphate)	1. LiPO4 : Capacity- 100 mAh Output- 3.7V
		2. LiSOCl2 (Lithium Thionyl Chloride- SAFT LS33600 D Size)	2. LiSOCl2 : Output current range: 5 to 150 mA Lifespan: 3-15 years Output: 3.6V
	Voltage Regulator	AMS1117 low dropout voltage regulator IC	Polarity: Positive Input voltage range: 1.8V - 15V DC Output voltage: 5V Operating temperature: -24 to 84 ∘C
	Radio signal generator	RF transmitter-receiver pair (CC1101 500kbps)	433MHz wireless RF transceiver. Supply voltage: 1.9 ~3.6V
	Coupling coils	Insulated copper wiring	28 SWG coiled wire
	Power rectifier	Half-wave rectifier	RLC component based
	Microcontroller	1. ATMega 328	1. ATMega 328-AU : 8-bit, 20MHz 32KB (16K x 16) FLASH 32-TQFP (7x7)
		2. Arduino Mega 2560 R3	2. Arduino Mega 2560 R3: Architecture: 8-bit AVR CPU Operating voltage: 5V Input Voltage: 6~20V Analogue inputs: 16

Processing unit			Digital I/O pins: 54 DC source/sink from I/O pins: 20 mA PWM output pins: 14 Flash memory (KB): 256 SRAM: 8KB Frequency (clock speed): 16MHz LED: Built-in (13)
	Oscillator	SPXO crystal oscillator	16 MHz oscillation
	Programmer	1. Atmel AVR in-circuit debuggers	1. AVR Dragon: Power voltage required: 5V Current capacity: 300mA Operating temperature: 0 ~ 70 ∘C Operating voltage range: 1.8 ~ 5.5V
		2. Arduino IDE 2	2. Debugging feature of IDE 2 which can test and debug programs.
Signal processing unit	Signal processor	dsPIC30F2010-20E/SP Digital Signal Processors & Controllers	Operating Supply Voltage: 4.5 V to 5.5 V Operating temperature: -40 ~ 125 ∘C Data RAM Size: 512 B Max Clock Frequency: 20 MHz Number of Cores: 1 Core
	Signal Amplifiers	UA741CN Op-Amp	Technology: Bipolar Dual supply voltage range: ±5V ~ ±18V Maximum operating current: 2.8mA Operating temperature: 0 ~ 70 ∘C
	Analog to Digital converter	PCF8591 module (Dual ADC/DAC)	Operating voltage: 2.5 ~ 6V Multi-purpose, can use as both ADC and DAC

	Analog to Digital converter	ADS1115	16-bit ADC module Operating voltage: 2~5.5V Operating temperature: -40 ~ 125 ∘C Operating current: 150uA
	Digital to Analog converter	MCP4275	12-bit module Operating voltage: 3.3V / 5V Operating current:
	Energy harvester	AEM30940 RF Energy Harvesting	Input voltage: 50mV ~ 5V Power_in**:** 19 dBm to 10 dBm Power_out: 20mA at 1.2~1.8V and 80mA at 1.8~4.1 V
	Antenna	M177 NRF24L01	Antenna Wireless Transceiver Input voltage: 1.9~3.6V
	Wireless module (Bluetooth or NFC) (Arduino)	HM-10 BLE Bluetooth 4.0 cc2540	Supports antenna. Operating frequency: 2.4GHz Modulation mode: GFSK
Sensing and pacing unit	ECG sensor (ECG acquisition unit)	AD8232 ECG measurement module kit	Operating voltage: 3.3V Operating temperature: -40 ~ 90 ∘C
	pH sensor	Microelectrode-based	Hydrogel-coated customized implementation.
	Temperature Sensor	1. RTD PT-100 Temp. sensor	1. Temperature range: 0 ~ 400 ∘C Probe material: Stainless steel
		2. Hydrogel-based sensor	2. Physically made with conductive hydrogel. Input data has to be processed before analysis.
	Biochemical sensor	Hydrogel-based biochemical sensor	Physically implemented with hydrogel materials.
	Hydrogel electrodes	Made with hydrogel materials and copper wire	28 SWG copper wire with hydrogel coating

	Device encapsulation layer		Hydrogel encapsulation. Chitosan, alginate and silk fibroin based hydrogels.
	Heart rate pulse sensor module for Arduino	RBD-0348	Operating voltage: 3V - 5V
Hydrogel materials	Hydrogel Substrate	1.Poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS)	-
		2.Poly-sulfobetaine-methacrylate (PSBMA)	-
	Hydrogel encapsulation	Chitosan, alginate and silk fibroin based hydrogels. (Encapsulation)	-
	Hydrogel conduction additive material	Neostigmine Methylsulphate (NM)	-
	Breadboard	Medium size	Solderless points: 830
	Wires	1. Copper wires	Regular copper wires: 24 AWG solderable wires
		2. Jumper wires	Jumper wire Types: Male to Male Male to Female Female to Female
		3. Solderless breadboard cables	U-shaped cables for breadboard
	Resistor	Normal resistors	Range of resistances Max operating voltage: 250V Tolerance: ±1% Operating temperature: -40 ~ 150 ∘C

Other components	Capacitor	Normal and micro Aluminium electrolytic capacitors	Range of capacitances Polar and non-polar capacitors Operating voltage: 25V / 100V Tolerance: ±5% Operating temperature: -20 ~ 75 ∘C
	Diode	1N4007	PN junction rectifier diodes. Max reverse peak voltage: 1000V Max RMS voltage: 700V Operating temperature: -50 ~ 150 ∘C
	Inductor	Colour ring inductors	Range of inductance Tolerance: ±10%

1.2.4 Technical and Non-technical considerations and constraints in the design process

Technical Considerations and Constraints in Design Approach:

- **Material Properties and Biocompatibility**

Hydrogel Stability and Elasticity: A hydrogel should retain stability and elasticity when placed in physiological conditions so that it can conform to the natural motions of the body. However, maintaining these characteristics when mechanical strain, thermal variations and immersion in body fluids for long times are encountered is difficult [6].

Conductivity and Degradation: Biocompatible hydrogels that are conductive and stable when subjected to ionic and pH fluctuations in the body are required for embedded electronics to operate properly. The challenges presented by this are the manufacture of conductive hydrogels, which are biocompatible and stable [6].

- **Manufacturing Complexity**

Precision in Embedding Electronics: The incorporation of the electronic parts into hydrogels is done carefully to ensure that the hydrogels and the electronics are not damaged. This manufacturing step is said to be moderately difficult and quite expensive since microprocessors, sensors and wiring have to be soldered in a very secure manner.

Scalability: Ensuring the product meets the specified clinical requirements and quality before enlarging production volumes is a major challenge. Thus, it is necessary to work out effective and cheap technological solutions for large-scale use in a clinical context [7].

- **Energy Management**

Power Supply and Wireless Communication: Most of the hydrogel devices constructed are wireless because battery implantation can be hazardous; nevertheless, reliable wireless power transfer over several distances through tissue layers is not always possible. It is implied that exposure to electromagnetic radiation at close proximity might show some unpleasant effects on people such as headache, nausea, etc. due to electromagnetic hypersensitivity. However, we shall be using 220kHz radio waves for coil coupling and WiFi frequency over 900 MHz or 2.4 GHz range according to the IEEE 802.11 standard for Compact HydroPace (Design Approach 1). For Accessible HydroPace (Design Approach 2), we shall be using only WiFi. Coil coupling for Compact HydroPace is necessary to power the circuit, which can potentially replace the need for a battery for Design Approach 1 [1], [2], [7].

Biological Constraints:

- **Biocompatibility and Immune Response**

Foreign Body Reaction: In some cases, the body may perceive implants made of hydrogel as a source of aggression, which will cause an immune response and negatively affect the functionality of the device. The device has to be non-inflammatory and minimize the development of a fibrotic envelope around the device [1], [2], [3], [5], [6].

Cytotoxicity: Substances involved in the formation of such structures should be non-hazardous and non-irritative when incorporated within hydrogels. Any toxic interaction can influence decreasing the device performance and health of the patient, hence, preclinical testing is obligatory [1], [2], [3], [5], [6].

- **Tissue Healing and Integration:**

Stable Device-Tissue Interface: Prolonged direct contact of the hydrogel device interfacing with the surrounding tissues involves low chances of infections and accelerated healing. Wound healing dynamics have to be considered and assumed in the device, and how the tissue will shift and interact with the device over time [5], [6], [7].

Regulatory and Ethical Constraints:

- **Regulatory Compliance and Clinical Trials**

Approval Requirements: Hydrogel-based devices come under the category of a medical device, which requires several tests to get approval from the regulating authorities. The clearance process is time-consuming and resource-hungry.

Ethical Considerations: It is important to discuss and solve several ethical concerns when it comes to using these devices and creating new ones: informed patient consent is a significant issue, as well as data privacy and the probable state of the devices in the long term.

- **Accessibility and Cost**

High Development Costs: The research and development costs associated with the most sophisticated hydrogel devices are still high, which may also curb access to these devices, especially for the low-income socio-economic class. Reducing the cost of production is especially important to ensure that such technologies can help patients reach all economic classes.

Specialized Healthcare Requirements: These devices may be implanted only in specialized facilities to provide necessary care and may be unavailable to marginal populations.

Non-Technical Considerations and Constraints in Design Approach:

- **Regulatory and Ethical Compliance**

Approval Requirements: Hydrogel-based cardiac pacemakers fall under the category of Class III medical devices, which require rigorous testing and regulatory approval before clinical use. Navigating the regulatory landscape (e.g., FDA, CE) is both time-consuming and resource-intensive. Clinical trials are essential to validate safety and efficacy, and any deviations in material performance can delay approvals [7].

Ethical Considerations: The development and implantation of HydroPace must adhere to strict ethical standards. This includes obtaining informed patient consent, ensuring patient data privacy, and addressing concerns around long-term biocompatibility and device autonomy. Ensuring transparency and ethical use of health data is critical, especially when remote monitoring and wireless communication are involved [1], [7].

- **Cost and Accessibility**

Affordability of Materials and Manufacturing: Although hydrogel materials and embedded electronics hold promise, their production remains costly. Conductive hydrogel synthesis, sterile encapsulation, and custom sensor integration significantly increase the overall manufacturing cost. This may limit accessibility, particularly in lower-income regions or public healthcare systems [6].

Market Availability and Distribution: HydroPace's advanced features may not be supported by the infrastructure in all healthcare settings. Specialized training, maintenance tools, and post-implantation monitoring systems may be required, making wide-scale deployment more complex [5].

- **User Experience and Healthcare Integration**

Ease of Use: Both patients and healthcare providers must be able to interact with the system easily. The device should integrate smoothly with hospital systems, be supported by a user-friendly application for real-time data monitoring, and offer intuitive controls for caregivers with varying technical expertise [1,2].

Training and Support: Implementation success also depends on the training of clinicians and technicians who will manage implantation and post-operative monitoring. A support framework must be established for troubleshooting, firmware updates, and regular system checks to ensure long-term reliability [7].

1.2.5 Applicable compliance, standards, and codes

Creating biomedical devices, especially with materials like hydrogel that interface with the human body, requires adherence to stringent standards and regulations to ensure safety, biocompatibility, and functionality. The following are the standards for our project:

1. **ISO 13485:2016 -** Medical Devices: Quality Management Systems.
2. **ISO 14971:2019 -** Risk Management for Medical Devices.
3. **IEC 60601-1:** Medical Electrical Equipment – Part 1: General Requirements for Basic Safety and Essential Performance.
4. **ISO 10993-1:** Biological Evaluation of Medical Devices – Part 1: Evaluation and Testing Within a Risk Management Process.
5. **ISO 27001:2013 -** Information Security Management.
6. **ISO/IEEE 11073:** Health Informatics - Device Communication Standards.
7. **ISO 15223-1:2016 -** Medical Devices – Symbols to be Used with Medical Device Labels.
8. **IEEE 802.11 -** WiFi - Architecture and physical layers and MAC specifications for wireless LANs.

Reason for Choosing These Standards:

- **Biocompatibility and Safety:** Make sure that the device will not lead to any allergic reactions or any other harmful effects that may occur in the body when the device is implanted (ISO 10993-1, ISO 14971:2019).
- **Quality and Reliability:** Ensure that high standards are met during the design and production of the device (ISO 13485:2016).

- **Electrical Safety:** Takes into account the issue of incorporating electronic components in the medical device in question (IEC 60601-1).
- **Data Security:** Ensures security of patient information which is vital in case the device has data capture and transmission functions (ISO 27001:2013).
- **Interoperability:** Enables the device to be compatible with other existing medical systems (ISO/IEEE 11073).

1.3 Systematic Overview/summary of the proposed project

Based on an extensive literature review and in-depth discussions with biomedical research findings, it has been determined that a comprehensive analysis of key physiological parameters namely ECG signals, cardiac pulse, core body temperature, pH levels, and biochemical data can provide critical insights into cardiac health and facilitate timely therapeutic interventions. In summary, we have proposed a hydrogel-based pacemaker with the additional capability to monitor these key parameters. The objective is to ensure monitoring of the key cardiac parameters including ECG signals, providing pacing to the heart, and offsetting the key disadvantages of conventional pacemakers.

1.3.1 Design Approach 1:

Compact HydroPace

This design approach adopts the implementation of fully implantable hydrogel-based pacemakers. For sensor signal and ECG data acquisition, the hydrogel electrodes and sensor heads are attached to the heart according to conventional medical procedures. Compact HydroPace measures temperature and biomarker level alongside continuous ECG signal monitoring. Since the hydrogel is biocompatible and conductive, it can detect changes in voltage and relay them to the pacemaker PCB, which in turn, sends the data to an external application for displaying patient condition, allowing both patients and healthcare professionals to make informed decisions regarding cardiac health.

The pacemaker will use wireless charging with 220kHz radio frequency, utilising magnetic resonance coupling to charge the pacemaker battery. Standards and codes have been maintained since battery charging time is minimized to half an hour and minute sporadic exposure to 220kHz RF is non-damaging upon human contact.

1.3.2 Design Approach 2:

Accessible HydroPace

The literature also showed another method of improving pacemaker functions. Accessible HydroPace incorporates hydrogel electrodes but the wireless charging and communication to external application has been replaced with an in-house large body that contains all the pacemaker electronics. Considerably, it is impossible for the large body to be fully implantable. Thus it has to be attached to the side of the patient's body, preferably on clothes, where it can be placed comfortably, while extracorporeal wires have to be implanted inside the patient's body where the electrodes and sensor heads can reach the heart.

1.4 Conclusion

Both systems are designed with the focus to increase the safety and reliability of monitoring patients' cardiac health, assisting patients and doctors in making critical decisions based on accurate real-time cardiac health data, and helping the biomedical industry with new emerging technology. For decades, conventional pacemakers have been rigid, invasive, and dependent on frequent surgeries for battery replacement, often causing discomfort and complications. Thus with the help of HydroPace, patients will have access to a flexible, non-toxic and biocompatible device that integrates seamlessly with cardiac tissues while monitoring key cardiac parameters and providing accurate pacing to regulate abnormal heart beats.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction

In this section, we will explore the various methods that can be used to address the identified problem. In today's world, a single problem often has multiple possible solutions, and that idea forms the core of this chapter. We will also explain how the overall system functions and describe the working principles behind each proposed approach.

2.2 Identify multiple design approaches

We have two different designs to implement our system. Both the design approach was done with the proper algorithm and we used the Proteus software. But the design approach 1 gave us a friendly output.

2.2.1 Design Approach 1 (Compact HydroPace):

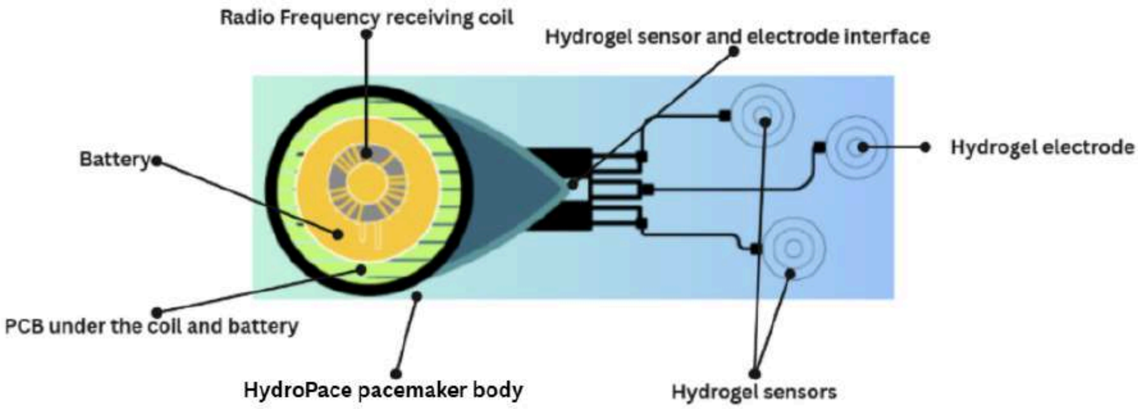

Figure 2(a): The concept design of the hydrogel cardiac pacemaker hardware as seen from outside without the hydrogel layer encapsulation.

Figure 2(a) shows the conceptual hardware design of the hydrogel-based cardiac pacemaker, offering a detailed view of its internal components, such as the central processing unit, connecting leads, and electrode terminals. The image represents the device without the hydrogel encapsulation, allowing a clearer understanding of how the electrical pathways and structural elements are arranged to support cardiac stimulation.

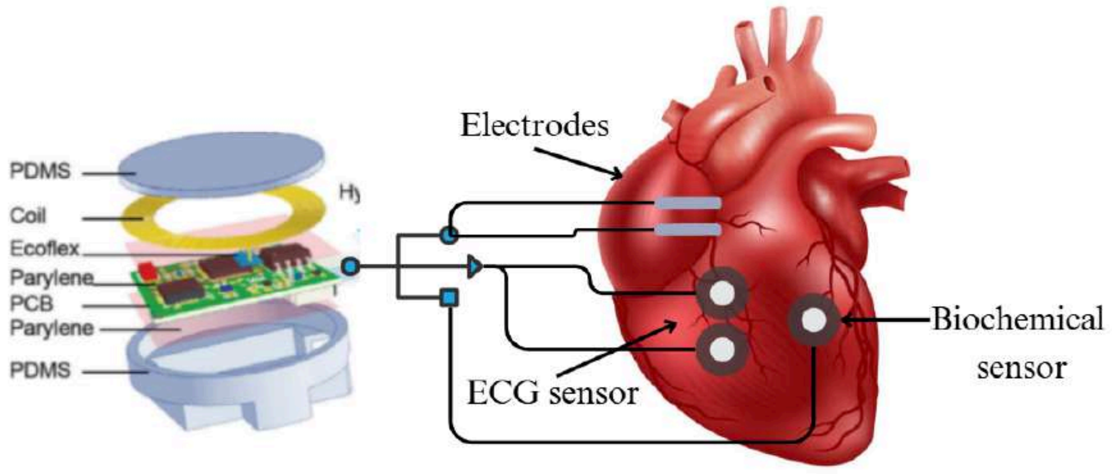

Figure 2(b): The inside architecture of Compact HydroPace with the concept art of where the sensing and pacing unit is attached to the heart.

Figure 2(b) illustrates the internal architecture of the Compact HydroPace pacemaker, showing a layered structure comprising components like PDMS, Ecoflex, coils, and PCB. It also presents a conceptual view of how the device interfaces with the heart, highlighting the placement of electrodes, ECG sensors, and biochemical sensors for real-time monitoring and precise cardiac pacing.

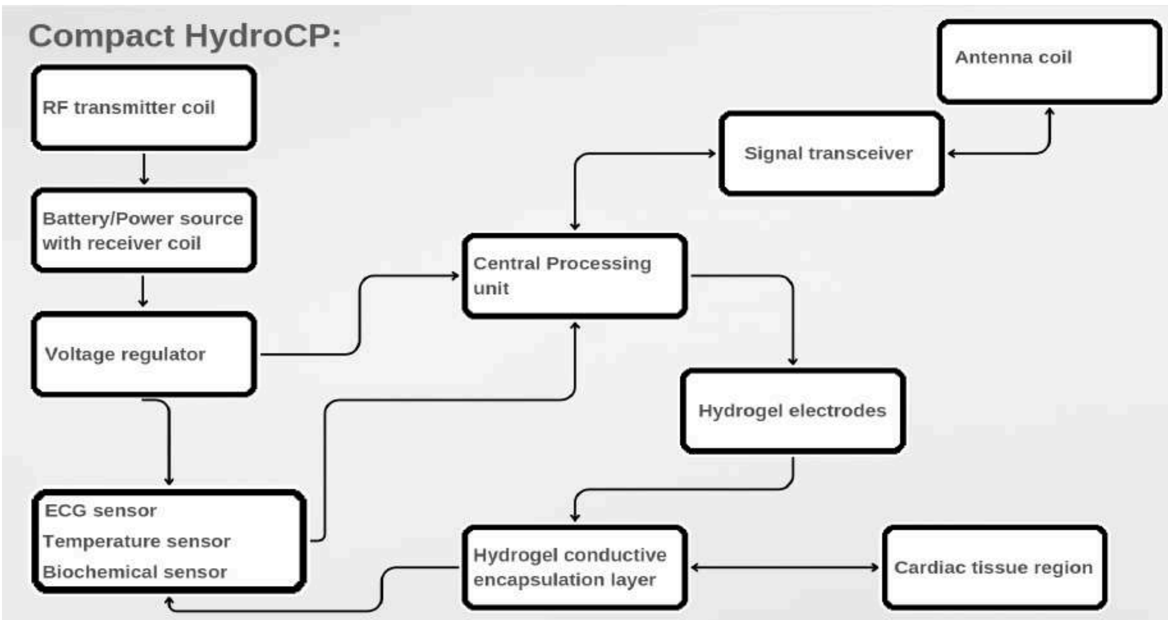

Figure 2(c): Workflow model of Compact HydroPace.

The figure 2(c) shows the workflow model of Compact HydroPace demonstrates the signal flow and functional integration of components within the device. It outlines how power from the RF transmitter coil flows through a voltage regulator to support sensing units (ECG, temperature, and biochemical sensors), while the central processing unit coordinates data processing and pacing. Signals are transmitted via hydrogel electrodes through a conductive encapsulation layer to the cardiac tissue, with feedback managed through the antenna coil and signal transceiver creating a closed-loop monitoring and pacing system.

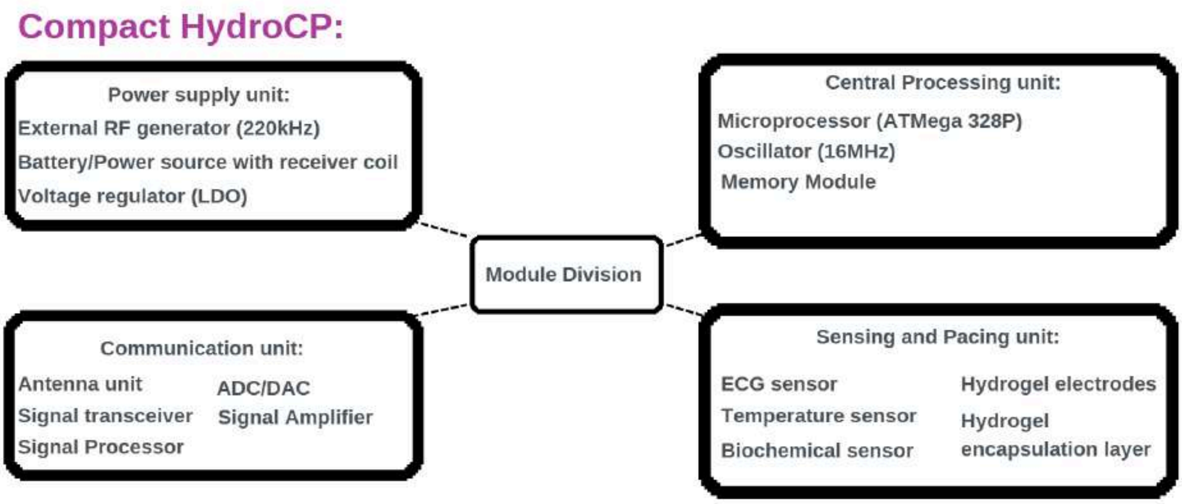

Figure 2(d): Module division for Compact HydroPace.

The diagram 2(d) shows the modular architecture of a "Compact HydroPace" system, which appears to be a biomedical monitoring device. The system consists of four main modules connected through a central division hub: a Power Supply Unit (with RF generator, battery management, and voltage regulation), a Central Processing Unit (featuring an ATMega 328P microprocessor with 16MHz oscillator and memory), a Communication Unit (handling wireless connectivity through antenna, CODEC, and signal processing components), and a Sensing and Pacing Unit (containing ECG, temperature, and biochemical sensors with hydrogel electrodes and encapsulation). This modular design enables compact integration of sensing, processing, communication, and power management functions for what looks like an implantable or wearable medical monitoring device.

2.2.2 Design Approach 2 (Accessible HydroPace):

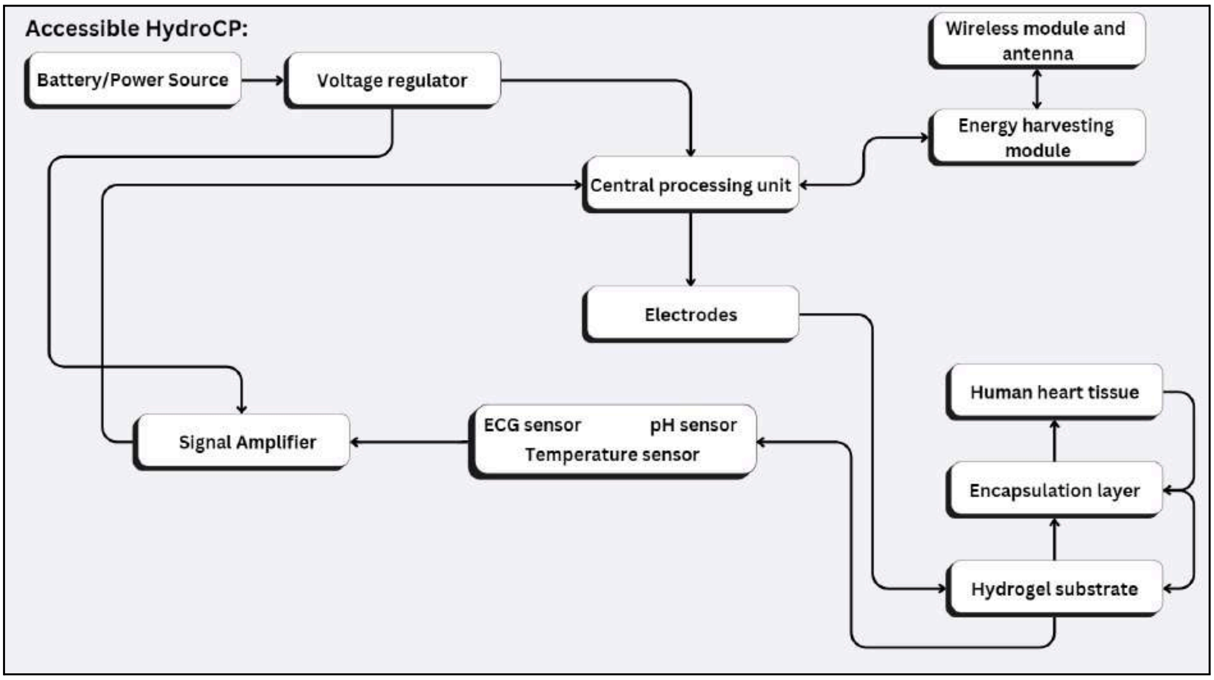

Figure 2(e): System Block Diagram or workflow model for Design Approach 2.

The diagram 3(a) illustrates the system architecture of an "Accessible HydroPace" - a biomedical monitoring device designed for implantation or close contact with human heart tissue. The system flows from power management (battery/power source through voltage regulator) to a central processing unit that coordinates multiple sensing functions. The device captures physiological data through ECG, temperature, and pH sensors connected to electrodes, with signals processed through a signal amplifier. The processed data is transmitted via a wireless module with an antenna and managed by an energy harvesting module for power efficiency. The entire system interfaces with human heart tissue through an encapsulation layer and hydrogel substrate, suggesting this is likely a cardiac monitoring implant or patch designed for continuous physiological monitoring with wireless data transmission capabilities.

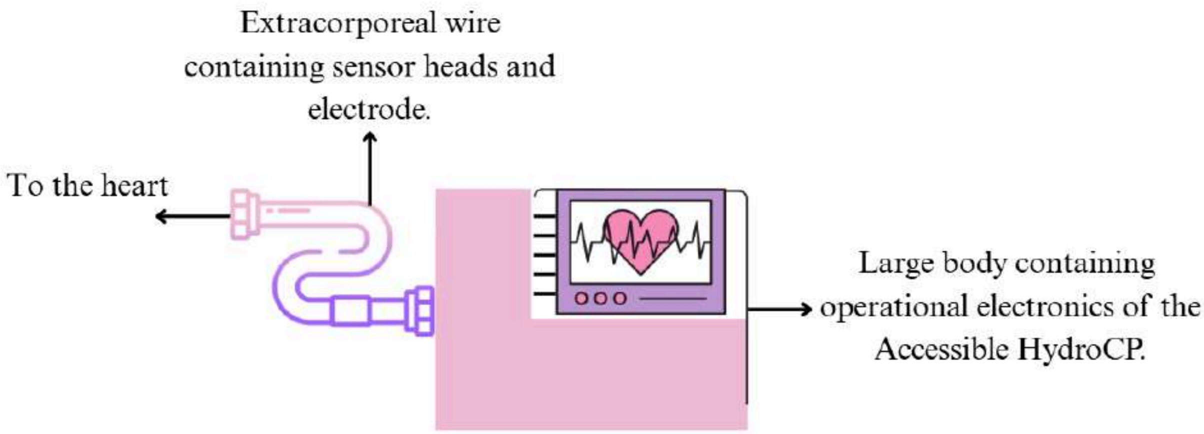

Figure 2(f): Diagram of the practical implementation of Accessible HydroPace design.

The figure 3(b) shows the practical implementation of the "Accessible HydroPace" cardiac monitoring system. The design features a large external body that houses all the operational electronics (processing, power management, wireless communication, and display showing heart rhythm data), connected via an extracorporeal wire to miniaturized sensor heads and electrodes that interface directly with the heart. This architecture separates the bulky electronics from the cardiac interface, allowing for a less invasive approach where only small sensors contact the heart tissue while the main processing unit remains external to the body. The wire connection enables real-time data transmission from the cardiac sensors to the external unit for processing, display, and wireless transmission, making this system more accessible for clinical monitoring compared to fully implantable devices.

2.3 Describe multiple design approaches

2.3.1 Design Approach 1 (Compact HydroPace):

In our first Design Approach, named Compact HydroPace, we adopted a rather compact design. The device design shown in Figure 2(a) is a disk with part of its circumference spanning 30 degrees of angle from its center elongated to form a rectangular extension. While all the device components are stored in the disk, the sensors and electrodes are placed in the extension while connected to the PCB in the disk. The entire device is encapsulated with cross-linked hydrogel such as chitosan. Only at the sensor edge is the encapsulation thinned to meet the requirements for collecting data and providing stimulus to the heart via the electrode, as shown in Figure 2(b).

The hydrogel encapsulation isolates the biomedical device from the rest of the human body as its purpose is to work from inside the human body as a pacemaker while also collecting data on cardiac health. The device is designed such as to provide more flex, being resilient to elastic tension and stress. The hydrogel makes sure of that, and the PCB is to be designed in two parts while still connected appropriately so that the device can bend under duress while operating, which implies that the lid and the base also need to be in two separate conjoined parts to allow flexion to provide more degrees of freedom to the patients. The rectangular extension is entirely flexible, except for the tip where the sensors and electrode are located. Sensor and electrode attachment to the cardiac tissue via hydrogel encapsulation layer will mimic normal body tissue behaviour such as adhesion and flexibility. We have considered the circular disk to have a diameter between 4 and 5 cm, and the sensor and electrode extension will be of length between 2 to 4 cm and a width between 1 to 3 cm. The dimensions are such that the device in the Design Approach 1 can be implanted on the heart of the patient, as suggested by pacemakers implemented in prior research [1], [2], [6].

The advantages of this design are its compactness, completely implantable in the human body, flexibility, longevity and accuracy and reliability. However, to design a PCB that is very compact, as well as the electrode is made from hydrogel, the sensors are either customized or ordered according to the preferences, which increases the cost. Further cost increase can result from the battery/power source. Originally, we wanted to use Lithium Thionyl Chloride batteries, but aside from being bulky the necessity for surgical interventions after every one or two decades would be necessary. Instead we are opting to divide the coil into receiver coil and transmitter coil, where the receiver coil is able to harvest energy from 220kHz radio waves given off by the transmitter coil and thus operate the circuit. This is shown in the workflow model in Figure 2(c), where the cardiac health data are transmitted from the sensors to the CPU and via the wireless communication module all the way to an external device, where the data can be seen. Consequently, the pacing unit uses an electrode placed on the heart such that the heart rate can be adjusted in times of cardiac fibrillation. All the modules are connected to the power source. In such a case, a very small additional battery might be required to store the energy for later use. This device with its complexity is planned to be more affordable and widely applicable for patients and aimed to solve the conventional pacemaker problems discussed earlier [1].

As such, we have divided the device into a total of four units or modules: the power supply unit, central processing unit, communication unit and the sensing and pacing unit, as shown in Figure 2(d). The division is done to divide the initial simulation work among us for FYDP-D and later compile all the modules into a single Compact HydroPace. For our physical implementation, we plan to use non-toxic and stretchable hydrogel electrodes for Design Approach 1 and normal electrodes with hydrogel properties for Design Approach 2.

2.3.2 Design Approach 2 (Accessible HydroPace):

In our second design, named Accessible HydroPace, we focus on real-time physiological monitoring and wireless communication of data. The device is powered by a battery/power source, regulated by a voltage regulator to ensure consistent, stable power flow to all components, as shown in Figure 3(a). A microcontroller manages data collection and communication at the design's core. It receives input from several sensors: a temperature Sensor measures body heat, an ECG Sensor tracks heart activity, and a pH Sensor monitors the pH level of bodily fluids, which can be crucial in assessing metabolic and health status. These sensors allow the device to collect critical data about the patient's physiological condition continuously. Therefore, from Figure 3(b), we can see that the pacemaker electronics are kept in a large body outside of the heart while the sensing and pacing unit is attached to the heart via extracorporeal wiring. The large body is outside the patient's body but is lightweight and can comfortably fit around the left lateral thoracic region of the body.

Signals from the sensors are processed through a Signal Amplifier to strengthen weak signals and then passed through an RC Filter to eliminate unwanted noise, ensuring accurate data. The filtered signals are converted from analog to digital format by the ADC (Analog-to-Digital Converter), preparing them for digital processing and storage. Additionally, an energy harvesting module can capture ambient energy to support the device's power needs, enhancing its operational longevity. The entire device is integrated within a hydrogel substrate that mimics soft tissue properties, encapsulated with a protective encapsulation layer to prevent damage and ensure biocompatibility. This setup enables seamless interaction with human heart tissue, allowing it to be used for continuous, minimally invasive patient monitoring in biomedical applications.

2.4 Analysis of Multiple Design Approaches

Analyzing both the design approaches, we can find the optimal solution based on different criteria.

Cost: We evaluated the material, manufacturing, and component costs of both design approaches. Design 1, with coil coupling and compact integration, incurs slightly higher initial costs due to advanced circuitry, while Design 2 offers a more affordable solution through accessible, external modules.

Efficiency: Design 1 demonstrates higher efficiency by utilizing wireless power transfer and embedded systems that minimize energy loss. Design 2, while functional, may face efficiency drops due to extracorporeal connections and greater signal loss.

Usability: Design 2 provides easier handling and monitoring due to external placement of modules, making it more user-friendly during early testing or in non-critical use. Design 1, however, offers better patient freedom post-implantation with a fully embedded design.

Manufacturability: Design 2 is more straightforward to manufacture as it avoids complex miniaturization. Design 1 requires precise component embedding and hydrogel integration, making it more challenging and costly to produce at scale.

Impact: Design 1 has the potential for a higher medical impact due to its long-term usability and patient comfort. Design 2, while beneficial, is better suited for temporary or early-stage solutions.

Sustainability: Design 1 supports sustainability through reduced need for surgical intervention and longer device life. Design 2 may require more frequent maintenance and part replacement, reducing its sustainability over time.

Maintainability: Design 2 offers easier maintenance and replacement since major components are external. Design 1, though more robust in performance, poses challenges in maintenance due to its fully implanted nature.

Comparison:

Here we have summarized the differences between Design Approaches 1 and 2. Both have advantages and disadvantages. The comparisons have been made before completing the simulation. They are compared in the table below:

Aspect	Design Approach 1 (Compact HydroPace) (Optimal)	Design Approach 2 (Accessible HydroPace)
Objective	Compact and robust	Market availability and accessibility
Cost	Higher production cost (21,823 BDT)	Lower production cost (20,432 BDT)
Challenges	Custom sensors and electrodes	Bulky and has to use extracorporeal wiring
Efficiency	Complete encapsulation of Hydrogel; power consumption is only 2mW [1].	Partial encapsulation of Hydrogel; much higher power consumption compared to Compact HydroPace [1,3,7,19].
User-friendliness	Completely implantable in the human body	Partially implantable in the human body

For Design Approach 2, the model is bigger, much easier to make and less expensive while reaching the same end goal, but Design Approach 1 is more aligned with our objectives of a hydrogel-based pacemaker that can be fully-implanted and fully-functional and which will come with the benefits of hydrogel providing elasticity, non-toxicity, infrequent surgical interventions, etc. Design Approach 1 also has a higher quality of build and is not bulky like Design Approach 2. Therefore, according to the research data, design approach 1 is more preferable.

2.5 Conclusion

Considering all the evaluated aspects and based on the comparison of the two design approaches, we conclude that Design Approach 1 (Compact HydroPace) stands out as the optimal solution. This approach allows for seamless integration of the device within the human body using hydrogel encapsulation, ensuring high biocompatibility, improved patient comfort, and reduced surgical interventions. It also enables efficient wireless power transfer through coil coupling, eliminating the need for frequent battery replacements. In contrast, Design Approach 2 (Accessible HydroPace) provides easier maintenance and simpler prototyping due to its extracorporeal module placement. However, it compromises on mobility, long-term sustainability, and patient usability since most components remain external to the body. Moreover, Design Approach 1 leverages advanced embedded systems to ensure real-time data transmission and monitoring, while Design 2 has limitations in terms of internal system responsiveness and compactness. Design 1's advanced integration and user-centered design make it more suitable for long-term clinical applications, in line with our goal of creating a minimally invasive, durable, and intelligent cardiac pacemaker.

Thus, we can confirm that Design Approach 1 is the most practical and effective solution, aligning with the assumptions and objectives set in our initial proposal.

Chapter 3: Use of Modern Engineering and IT Tool. [CO9]

3.1 Introduction

The selection of modern engineering tools is a primary requirement when developing a prototype for any specific biomedical application. Utilizing the right tools allows for in-depth analysis of design complexities and enables multiple solutions to be explored before selecting the most effective one. In our case, HydroPace consists of a highly intricate electrical circuit integrated with multiple sensors and signal processing components. To efficiently simulate such a complex system, advanced simulation software is essential. Among the various available tools, we have chosen Proteus so far, a feature-rich simulation platform that provides an accurate virtual environment for testing and refining our circuit before physical implementation.

3.2 Select appropriate engineering and IT tools

3.2.1 Software Tool Selection

(a) Proteus: Proteus is a widely used simulation software developed by Labcenter Electronics Ltd. known for its versatility in electronics and embedded system design. It offers engineers and designers a powerful platform to analyze, visualize, and simulate circuits before moving to hardware implementation. This allows us to identify risks, troubleshoot potential issues, and optimize system performance early in the development process. Proteus enables comprehensive testing through virtual instruments such as multimeters, oscilloscopes, and logic analyzers, ensuring precise analysis of circuit behavior.

For HydroPace, which integrates biomedical sensors, microcontrollers, and signal processing circuits, Proteus offers extensive libraries of electronic components and microcontroller modules to simulate real-world functionality. The software supports ECG signal generation, signal amplification, filtering, and digital conversion all of which are critical for HydroPace's operation. Additionally, Proteus provides PCB design capabilities, which are crucial for transforming circuit schematics into a functional physical prototype.In our implementation, we have used Proteus to design the power management system for HydroPace, ensuring efficient battery operation and power regulation. We have incorporated Arduino Mega to process ECG signals, alongside analog-to-digital converters (ADC), digital-to-analog converters (DAC), and various filtering circuits for accurate signal processing. As input and output interfaces, we have utilized a keypad for data entry and an OLED display for real-time monitoring. The flexibility of Proteus allows us to create and integrate custom hydrogel-based sensors with appropriate drivers, enabling precise simulation of HydroPace's real-world functionality.

By leveraging Proteus, we ensure that HydroPace is efficiently tested and optimized before moving to physical prototyping. The software's advanced simulation capabilities significantly reduce development time and costs, making it an ideal tool for analyzing and improving the performance of this innovative hydrogel-based cardiac pacemaker.

(b) MATLAB: MATLAB and Simulink which comes with the software can also be used to simulate electronic devices. Some of our components which are not available in proteus with simulation packages have to be custom-built. However, the degree of accuracy becomes an issue for components such as the ECG sensor. Prior research has shown custom libraries in MATLAB that can be used for accurate portrayal of such devices [16].

(c) PSpice: In order to create codes for custom library components for proteus, we can use PSpice or LTSpice. Using the PSpice model editor, we can define the models and parameters, map the symbols in place for the desired components, and then exporting to capture the library file, we can use it in the PSpice schematic or export to proteus for further modeling and simulation.

(d) Codevision AVR: This is the default computer application to generate Embedded C codes for the ICs to be simulated in Proteus. This is not only used for simulation coding but also for real-life hardware applications.

(e) XtremeBurner AVR: This is the computer application for generating hex files in order to burn them into the hardware ICs. In our case, the simulation does require hex files to be attached within the ICs, but the hex files that can be generated from Codevision AVR cannot be burned into the ICs without XtremeBurner, but for our simulation purposes, this application plays the role of support for the codes and hex files.

(f) Virtual Serial Port Driver: Made by Eltima, this serial port driver connects COM serial ports either locally or globally. This is necessary for the bluetooth module to run in proteus. This can have other applications within the computer as well.

(g) Arduino IDE: This is the go-to software to burn Arduino codes into any Arduino modules. Since we are using two Arduino Uno boards containing ATMega328P for hardware implementation, we have to use this software to input the proper codes into the microprocessors. We have also used this software for the ESP32 boards.

(h) Web Serial Plotter: This was used in order to obtain visual demonstration of ECG signal monitoring and real-time pacing because Arduino IDE only shows one type of data in the serial monitor/plotter at a time. Therefore by using the web serial plotter, we were able to show that all of the cardiac parameters were being shown in real-time simultaneously. This online plotter is also dynamic that enables us to pause/play, zoom in/out, acquire csv data, save plot images easily with a few clicks.

(i) Pycharm: The Pycharm app by JetBrains was required to develop the application which would in turn be used to display all of our cardiac parameters and pacing signals.

3.2.2 Hardware Tool Selection

(a) Electric Mini Drill: Electric mini drill is a tool that is used to prepare the fundamentals of hydrogel and pacemaker circuits. Using the drill we were able to cut open and observe the basic structure of conventional pacemakers. Furthermore, compact drill enables accuracy of work in the process of preparing hydrogel electrodes. It generates accurate holes in substrate materials, allows fine machining of hydrogel components, allows portable drilling of hydrogel components in use as prototyping of a cardiac monitoring system, and facilitates production of custom electrode geometries used in assembling the cardiac monitoring system. This tool also facilitated prop heart preparation for project demonstration.

(b) Arduino Uno R3: Arduino Uno is the primary choice for the brains of the project (i.e. Microcontroller for heart simulation and pacing). First intended use was to utilise the ATmega 328 PBU chip, implemented in the PCB of pacemaker programmed to functional pacing as well as monitoring. It is also used for simulating the realistic condition of the human heart. Programmed to simulate normal and abnormal heart rate (Bradycardia), as well as react to pacing signals and continue with normal heart rate. Other vital signs such as temperature and pro-BNP biochemical level were also realistically simulated. The MCU falls short for wireless monitoring application, and unable to handle complex data point calculation in real time, resulting in need of upgrade.

(c) ESP32-S3 WROOM-N16R8: ESP32 S3 is a powerful tool that can perform better than Arduino UNO R3. It was used for handling complex data point calculations in real time. To read and monitor the ECG data points as precisely as possible since medical grade equipment needs to be 95% accurate. It was capable of monitoring ECG values precisely and additionally performing pacing with high accuracy. All the while it has capability to transmit health data wirelessly to a developed app for monitoring purposes due its high clock speed of 240 MHz. This MCU also processed and monitored vital parameters, proving to be capable and perfect for advanced pacemakers.

(d) Temperature Sensor: Modern sensors were used to simulate cardiac conditions as precisely and realistically as possible. The first sensor in consideration was the basic LM35 sensor, it was functional for the most part but it lacked the precision needed for simulating heart temperature precisely in real time. Therefore, upgraded thermal sensing tool was implemented with K-type thermocouple, this paved the way for more precise reading but still fell short for real time accuracy additionally the thermo couple circuit was too bulky for using in prop heart as one our project ambition was to develop temperature sensor as compact as possible keeping in mind the condition of human body. Therefore, a smaller and more precise (±25℃) sensor was used, namely MCP9808 available commercially.This solved the issue of achieving accuracy in real time along with size constraint. Using this tool real time cardiac temperature simulation, monitoring and warning was made possible.

(e) Vortex Mixer: This is a modern tool that is used to mix reagents, semi-solid substances, liquids, etc. It uses from 100 to 3000 rpm to vibrate and mix substances in seconds. This was used to mix the various chemicals that would help in polymerization inside the hydrogel.

(f) UV Machine: This machine, also shown in figure 5.36, is like a D25 UV light system that uses 315nm UV light to illuminate any sample kept inside its vicinity. We had to use this machine to precipitate the Silver from Silver Nitrate and allow the Lithium Phenyl to initiate polymerization so that the hydrogel can finally form its complete gel structure. Had we used PEDOT:PSS, the procedure would have been similar but the curing time for the gel would have been much less.

(g) Precision Balance: We needed a highly advanced electronic balance to carefully measure the amount of chemicals that we would need to make the hydrogel.

3.3 Conclusion

Modern engineering and IT tools have played a critical role in the design and validation of HydroPace. Simulation environments such as Proteus, MATLAB, and PSpice enable accurate modeling of biomedical circuits and system behavior prior to prototyping, while platforms including Arduino IDE, CodeVision AVR, and XtremeBurner AVR facilitate embedded code development and hardware integration. Additional tools such as Virtual Serial Port Driver, Web Serial Plotter, and PyCharm support real-time monitoring and data visualization. The electronic microcontroller boards were needed in order to implement the core pacemaker functionalities. The electric mini drill, vortex mixer, UV machine and precision electronic balance all are needed to prepare the hydrogel in order to fulfil one of our core objectives of this project. Collectively, these tools reduce design complexity, development cost, and implementation risk, thereby ensuring a reliable and efficient HydroPace system.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO7]

4.1 Introduction

To develop our desired system, we proposed two potential design options. To identify the most suitable approach, we conducted tests on both designs using different evaluation methods. After simulating them in Proteus, we assessed their performance, efficiency, data analysis accuracy, and cost-effectiveness. This chapter outlines the methodology used in these design approaches with the help of Proteus software. The optimized solutions presented here are robust and capable of maintaining the practicality and feasibility of these concepts when presented to stakeholders.

4.2 Optimization of multiple design approach

To optimize various design approaches, we simulated both designs and assessed their performance. Initially, we created and refined the data collection system. Following that, we further developed and optimized the two designs to determine which one would be the most effective.
Here the simulation approach has been divided into four modules. The individual module designs have been described below:

1) Power Unit: It consists of 2 parts, which are the Charging Unit and Supply Unit. For the Charging Unit simulation of the RF transmitter was done using transformers. The received radio frequency causes alternating current to be produced in the circuit, which is then converted into DC using a rectifier circuit. The voltage is passed through another step-down process until we can generate 5 volts of DC to charge the battery. As for the Supply Unit, the battery provides an output of 3.7 volts which then goes to the boost converter to generate output of 5 volts DC in order to meet the energy requirement of other modules [17], [18], [21].

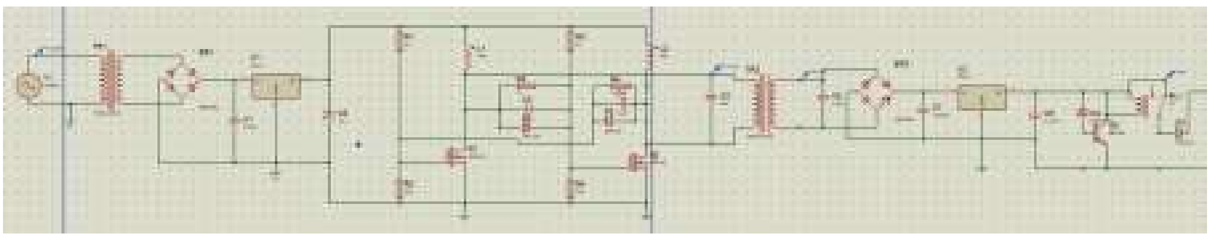

Figure 4(a): Circuit schematic of the Power Unit (Charging Unit)

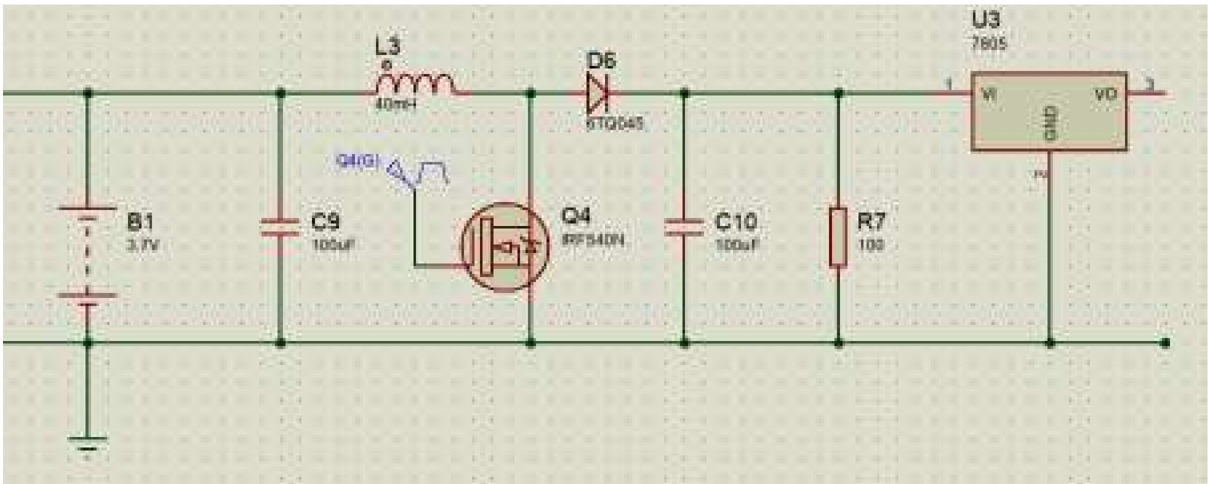

Figure 4(b): Circuit schematic of the Power Unit (Supply Unit)

(2) CPU: The CPU uses an ATMega328P for controlling the other modules. For the creation of the initial module, ATMega32 was used similar to the heart simulator in the sensing and pacing unit.

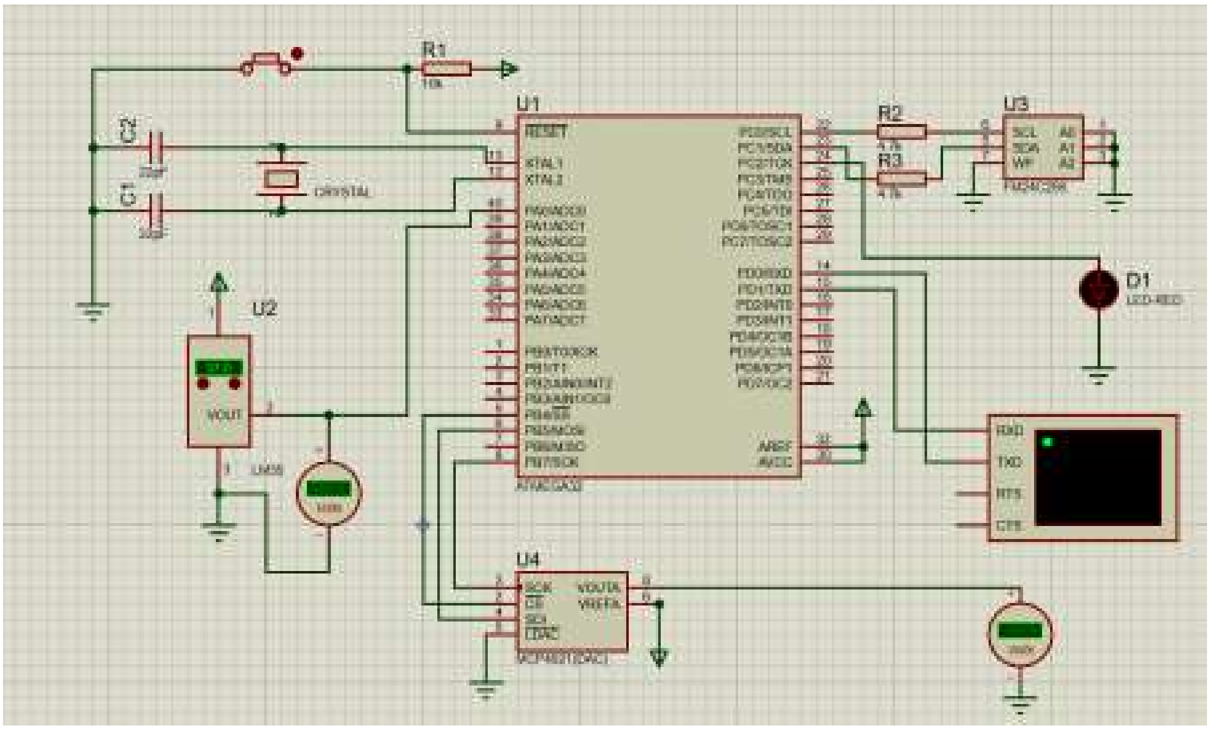

Figure 4(c): CPU module (initial)

3) Communication unit: Uses a wireless bluetooth module for data transmission. This The module has been showing unexpected errors, so the final design will be changed. However, we have done an initial design for the module as shown below:

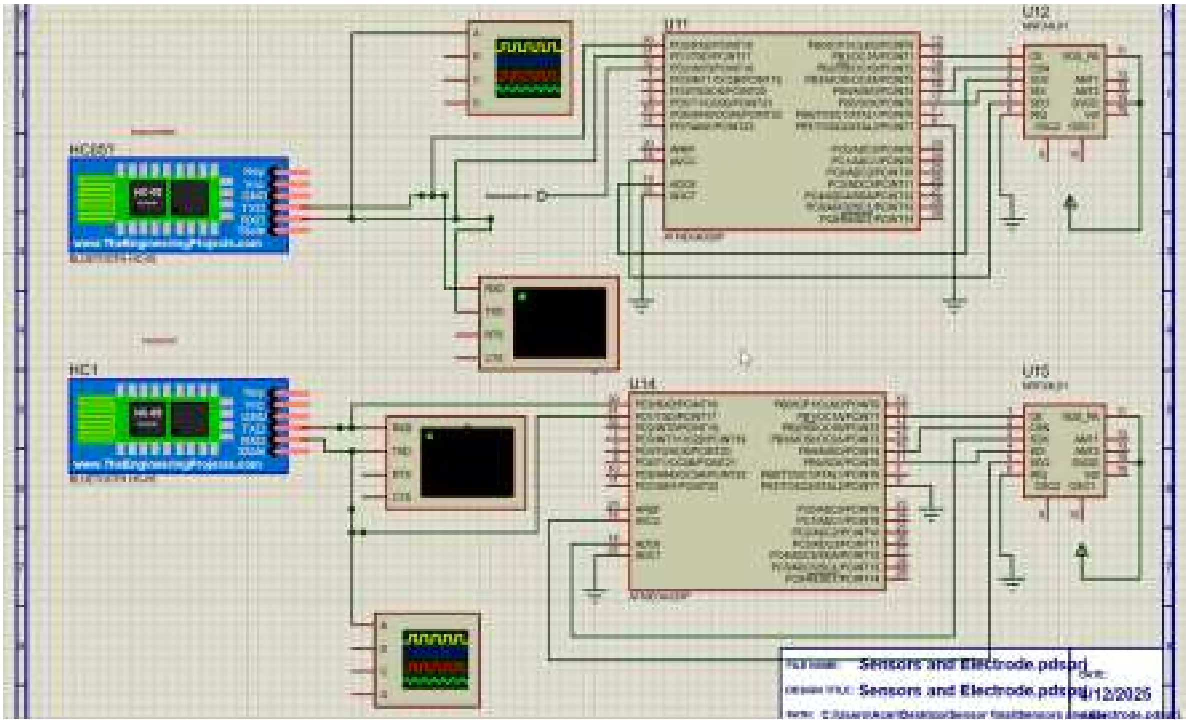

Figure 4(d): Wireless communication module (initial).

4) Sensing and pacing unit: Contains a simulation for the heart (ATMega32 has been used to simulate the heart), ECG sensor, temperature sensor, biochemical sensor and a signal processor. The function of this module pertains to producing various parameters of the cardiac environment and processing the signals in order to transfer them to the CPU. Cardiac parameters are typically produced by an actual heart such as temperature, exocrine chemical secretions, electrical pulses to drive the heart, etc. Here only heart temperature, biochemical marker level and ECG signals (Cardiac pulses) have been considered to monitor the cardiac environment.

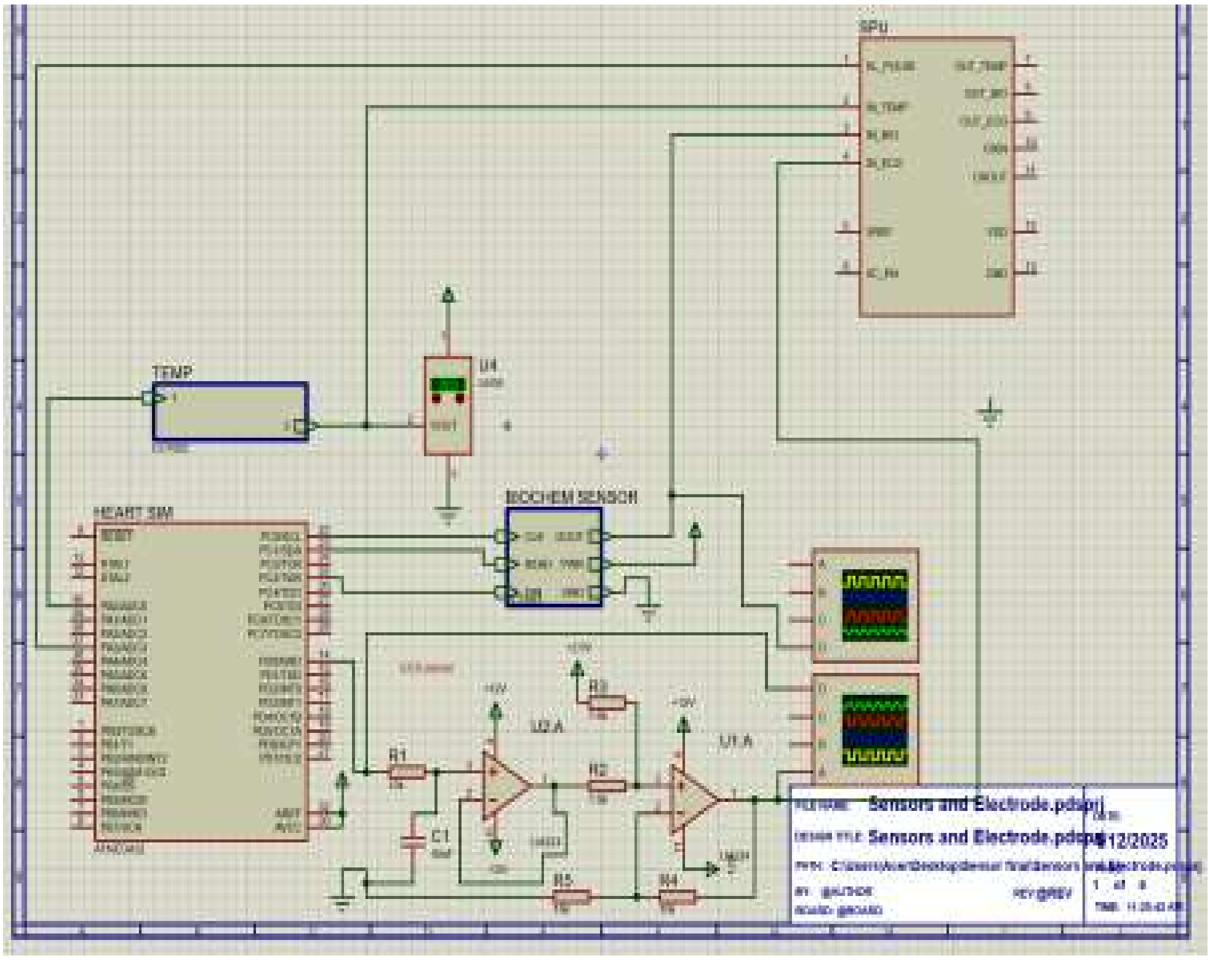

Figure 4(e): Initial simulation schematics for the heart, ECG sensor, biochemical sensor, temperature sensor and the signal processing unit.

After the initial simulations were done as shown in the above figures, the individual modules were compiled together into one file for simulating the full design approach 1. The compiled module consists of three root sheets containing the individual modules. This compiled version has been referred to as the previous compiled design in section 4.1.2. The compiled design has been shown below:

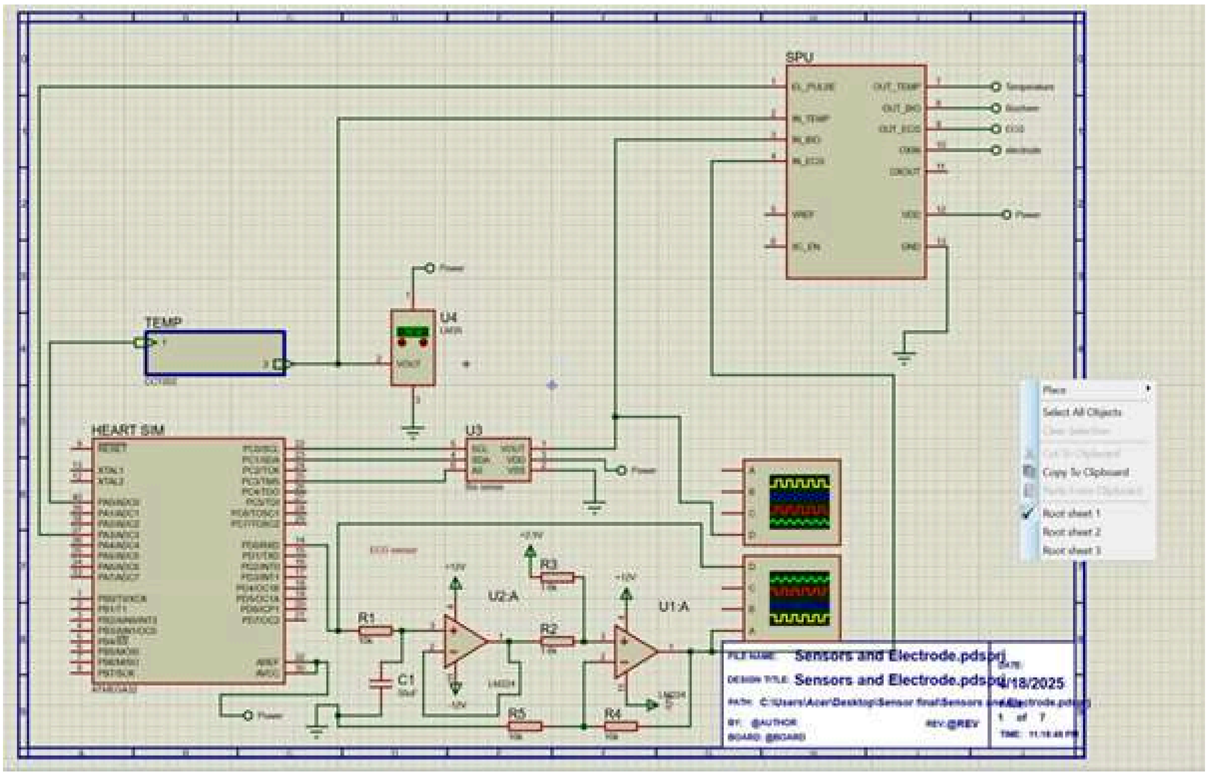

Figure 4(f): Simulation schematics for the heart, ECG sensor, biochemical sensor, temperature sensor and the signal processing unit in root sheet 1.

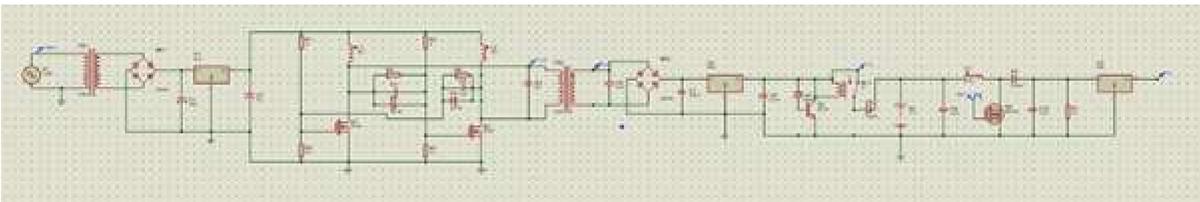

Figure 4(g): Initial simulation schematics for the power module.

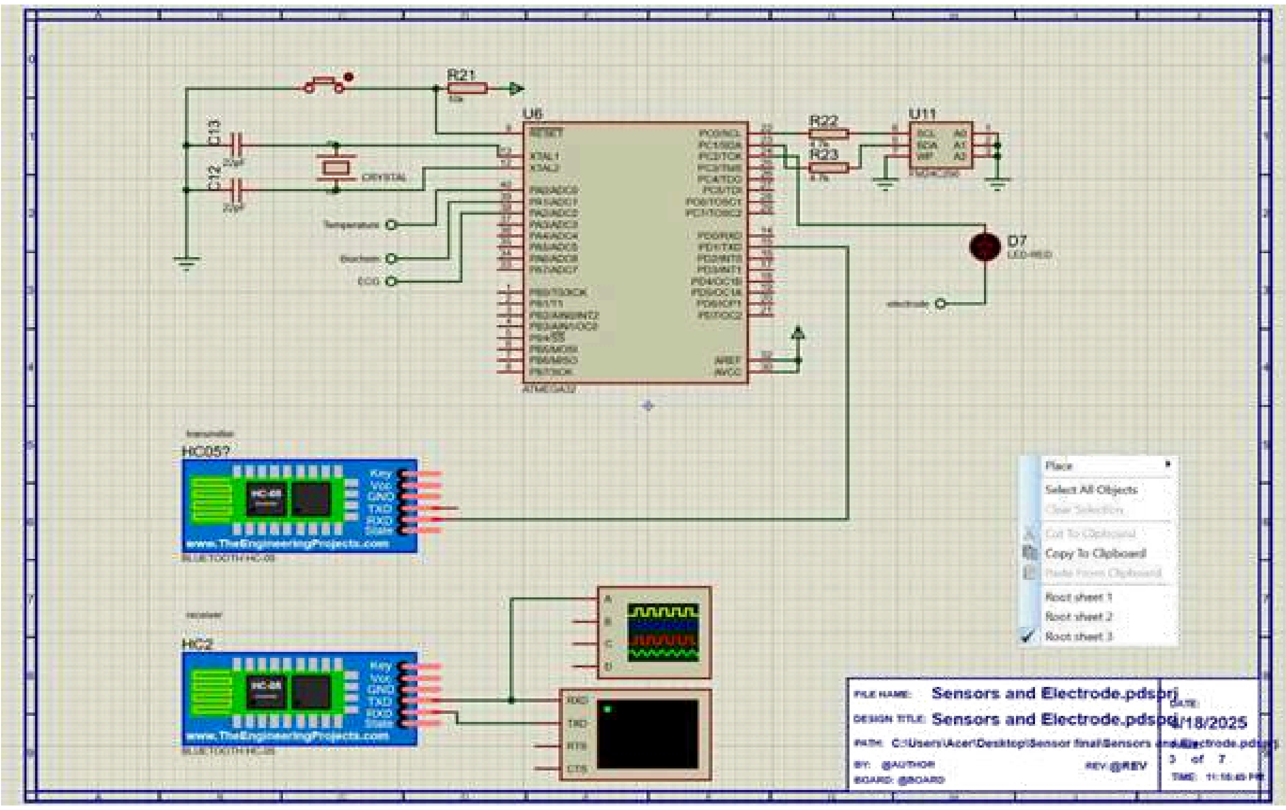

Figure 4(h): Compiled simulation of CPU module and communication module combined.

Simulation Results for Design Approach 1 (Compact HydroPace) and Discussion:

1) Individual module simulation results:

For the individual modules shown in the beginning of section 6.1.1, the simulation results were obtained. For the power module, the 220V AC had been converted into 5V DC for storage in the battery to provide energy in the circuit.

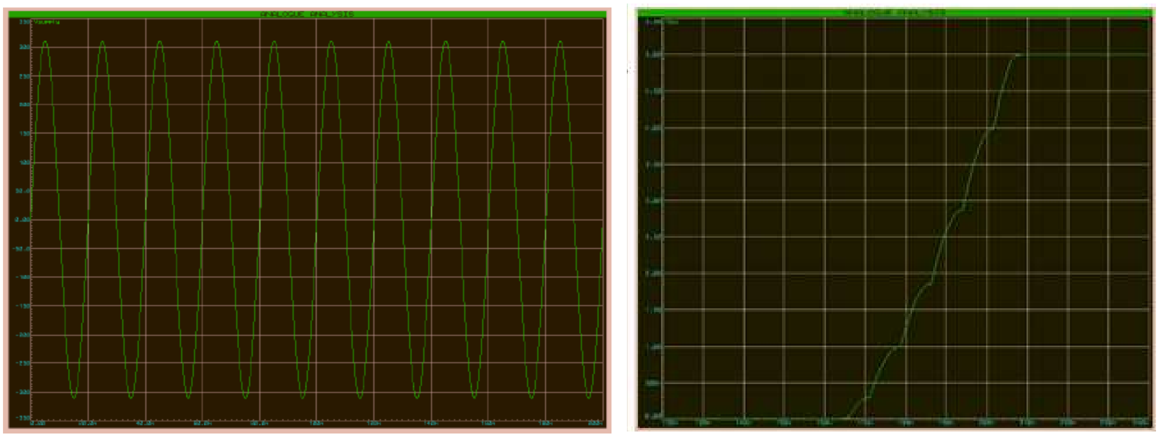

Figure 4(i): 220V AC input voltage (left) and obtained 5V DC for Charging Unit (right).

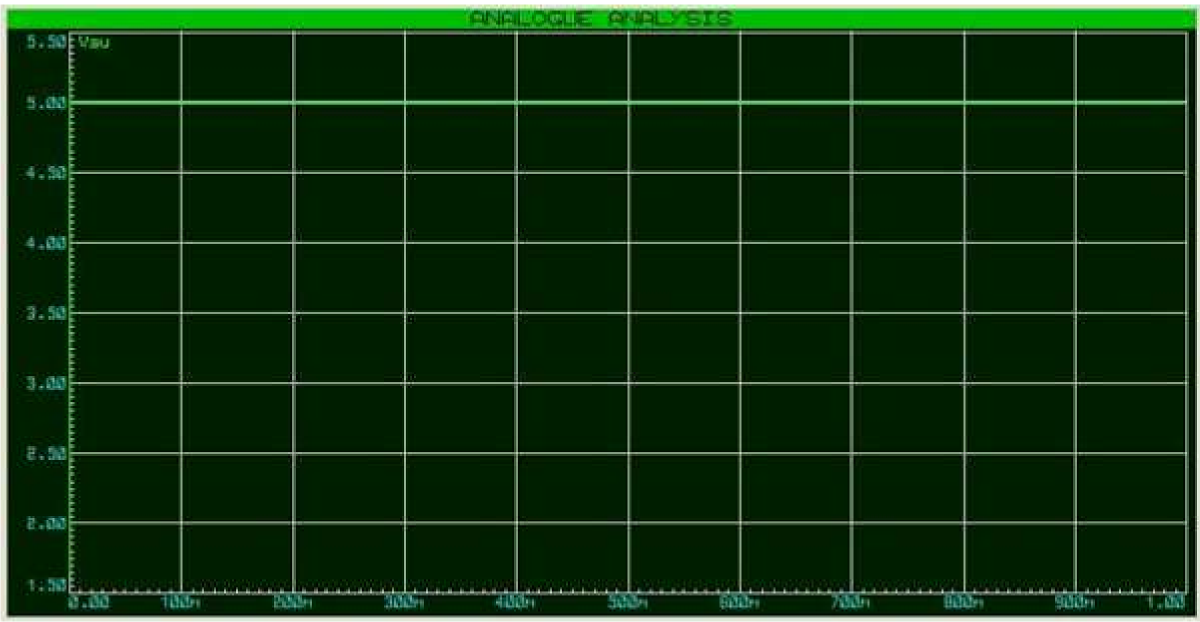

Figure 4(j): 5V DC output of the Supply Unit for other modules.

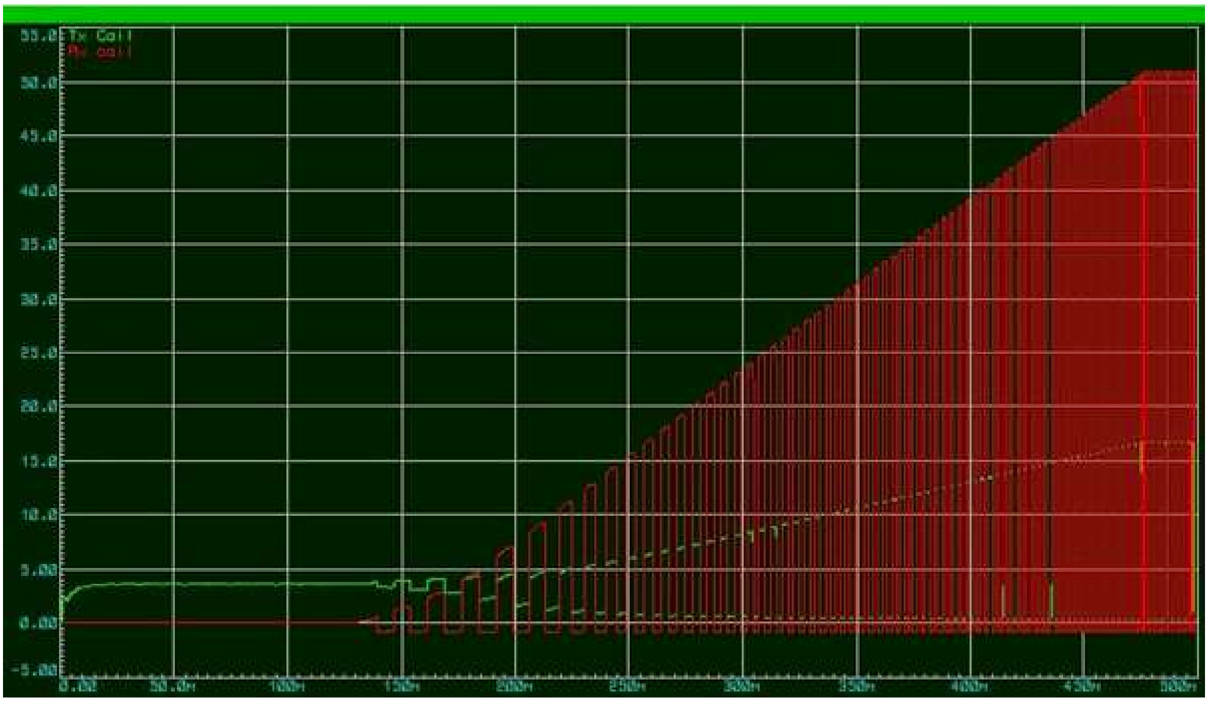

Figure 4(k): RF Voltage conversion graph.

Figure 4(k) shows how the obtained voltage is being converted and ready for distribution in the pacemaker circuit. Figure 4(j) shows the storage of the 5V to be distributed in the circuit. The individual power supply module thus captures the essence of magnetic resonance coupling where an external radio frequency signal can generate alternating current in a receiving coil which is then converted into direct current through rectifiers, and booster circuits are used to supply a stable voltage to the rest of the circuits.

To satisfy the individual module simulation, the CPU module was connected to an LM35 temperature sensor only, and the results were obtained as shown below:

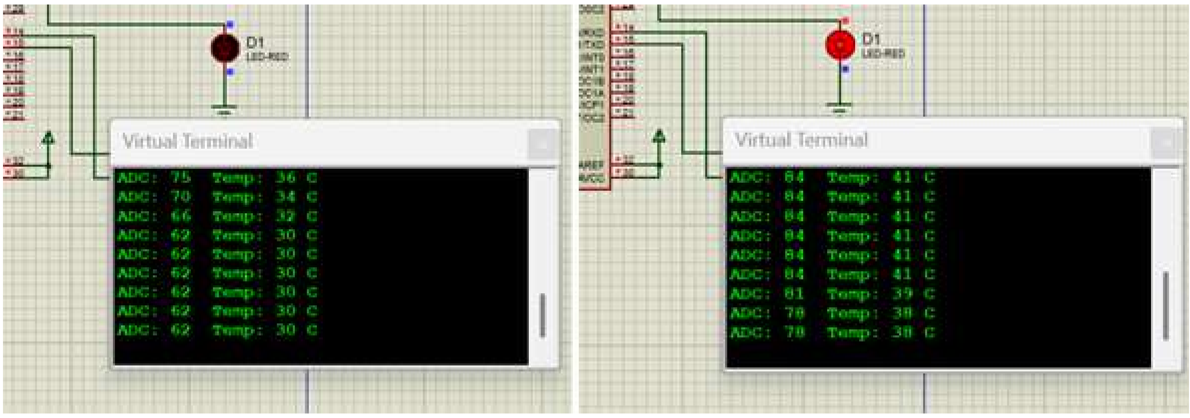

Figure 4(l): Individual simulation of the CPU module using LM35.

As shown earlier in section 4.1.1, the CPU module has a memory module and an external oscillator attached to the microprocessor which in this case is ATMega 32. The individual module showcases electrical pulses sent to the heart due to temperature as the only cardiac health information. Here, as the temperature goes below 37 degrees Celsius, the LED turns off as no stimulation is required to the heart. When the temperature goes above 37 degrees Celsius, the output is turned high, and a stimulation is passed to the heart. In this case, since the heart simulator is not connected, the LED is used to simulate the heart stimulation. This module thus is being individually used to demonstrate cardiac stimulation using electrodes.

The Bluetooth module was simulated individually to pass some data from the transmitter to the receiver end. The HC05 model was used to transmit data while HC06 was used to receive data. HC05 used COM1 and HC06 used COM2 while the two were paired using Virtual terminal app which has been mentioned earlier in the report. The initial circuit design has been shown in figure 4(m) and the simulation results are as shown in figure 4(n) where only signals are being transmitted without any visible data:

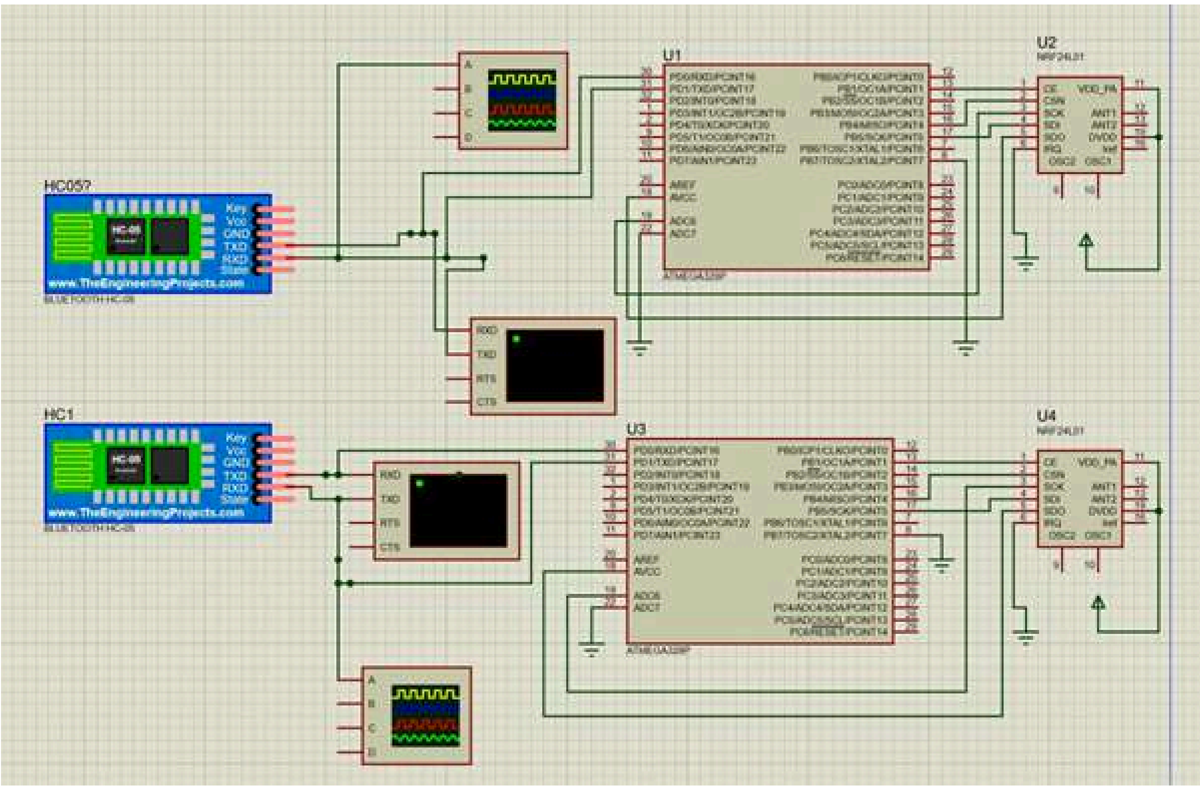

Figure 4(m): Individual simulation design of the wireless communication module.

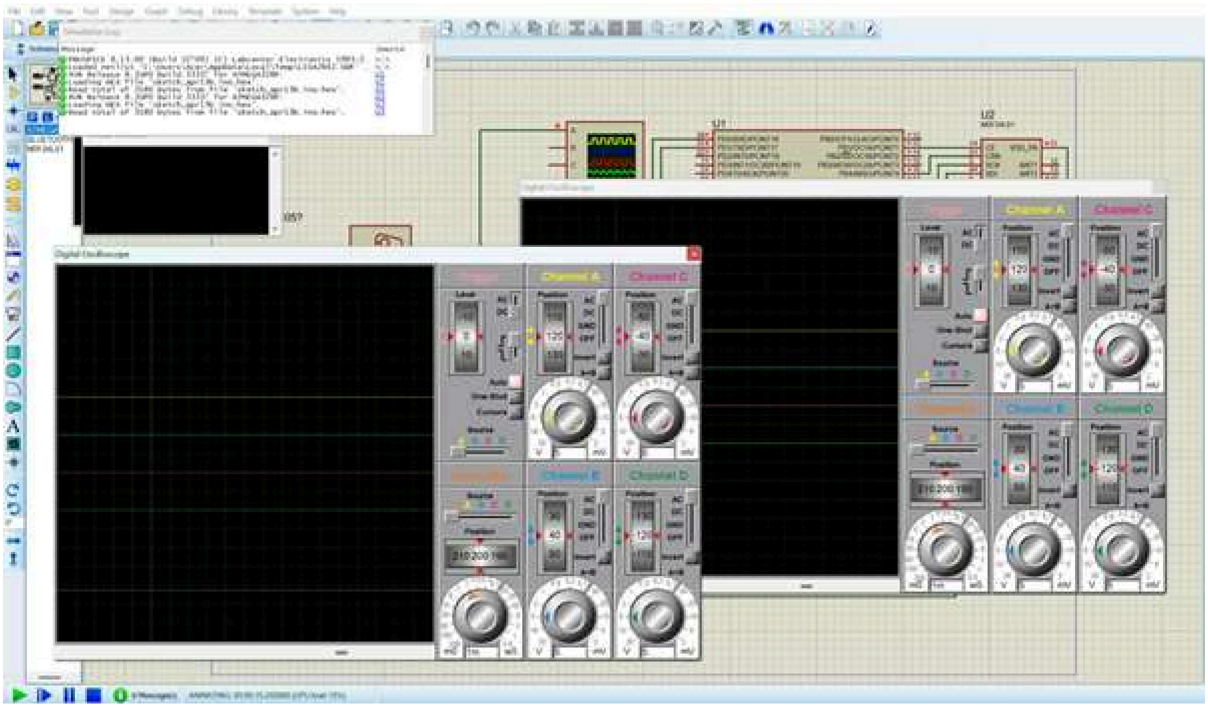

Figure 4(n): Wireless communication module simulation results.

The sensing and pacing unit for design approach 1 uses a temperature sensor, an ECG sensor and a biochemical sensor. As discussed earlier in this report, the biochemical sensor will only detect the level of a certain biomarker produced by the heart under stress, which in our case is called N-terminal prohormone of Brain Natriuretic Peptide, or NT pro-BNP in short [1]. This is a great way of measuring cardiac health, as shown by prior research. ECG signals are the go-to when it comes to cardiac information. In order to simulate these, ATMega 32 was used to simulate the heart, providing arbitrary output values for temperature and biochemical data within a given range, and giving signal output to imitate QRS waves for ECG signals [1]. The simulation for this module has been shown at the end of this section 4.1.2 due to necessary requirements discussed later in this section.

1) Simulating the modified compiled design (Modified Compiled 1):

After running the simulation, some errors showed up. The CPU was said to have exceeded the limit and real-time simulation was stopped. As a result, we removed all other root sheets except the one containing all the components. The new design is just all the components in a single root sheet instead of multiple ones.

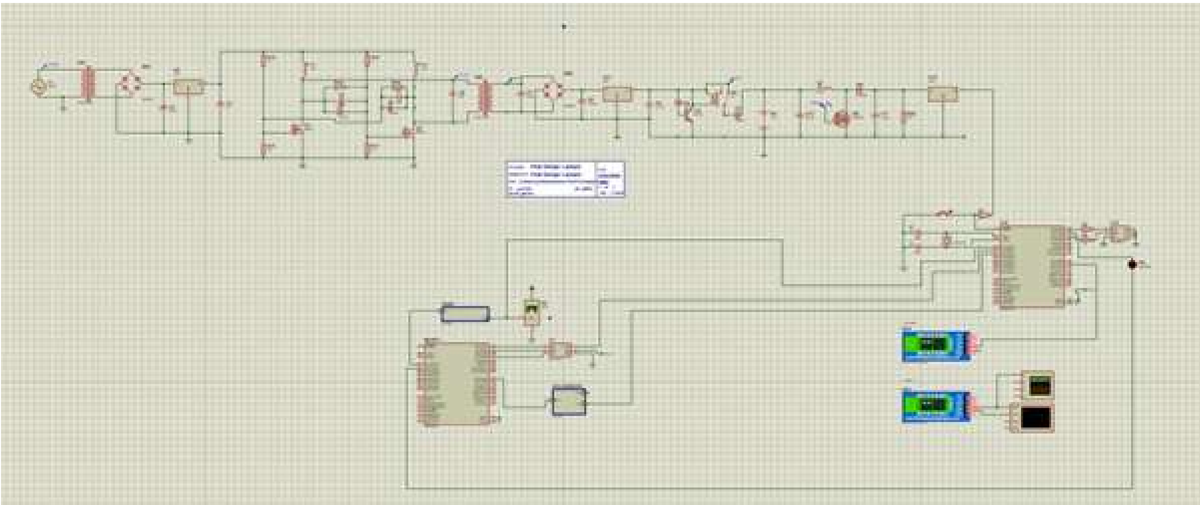

Figure 4(o): New schematic design for Design Approach 1 to facilitate real-time simulation (Modified Compiled 1).

From the figure above, we can see that there have been some changes to the power module as well. The zener diodes were replaced with LM7805 in order to bring stability in the circuit's power delivery capacity as well as reduce the load on the CPU. It is to note that the SPU-IC or the signal processor IC has been removed. This is because now the CPU has been coded with the necessary signal processing methods. Moreover, the ECG sensor and biochemical sensor do have in-built noise filtration capabilities. Therefore, the need for a custom signal processor has been deemed unnecessary. Figures 4(k) and 4(l) below show the insides of the subcircuits for temperature and ECG sensor. While the ECG sensor only had the previous amplifier-filter circuit copy-pasted inside a subcircuit to improve aesthetics, the temperature sensor subcircuit is an R-2R DAC ladder to convert the digital signal from the Heart Simulator IC for appropriate usage by the LM35 sensor, which operates with analog voltage data.

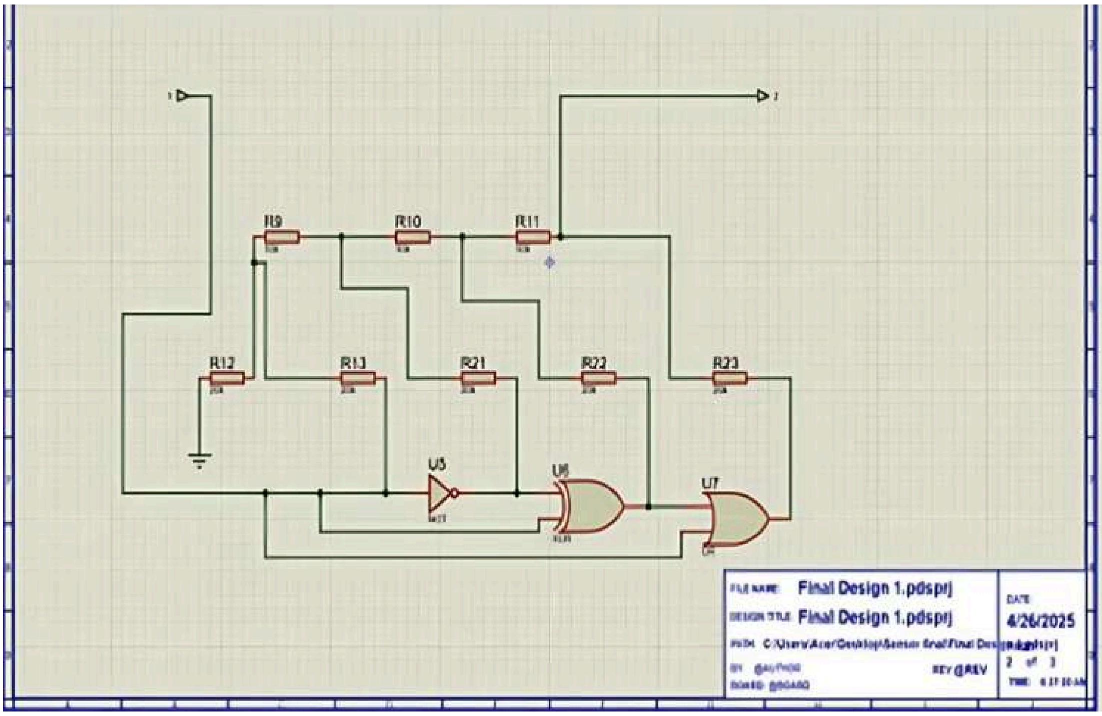

Figure 4(p): R-2R ladder for digital-to-analog conversion of temperature signal for LM35.

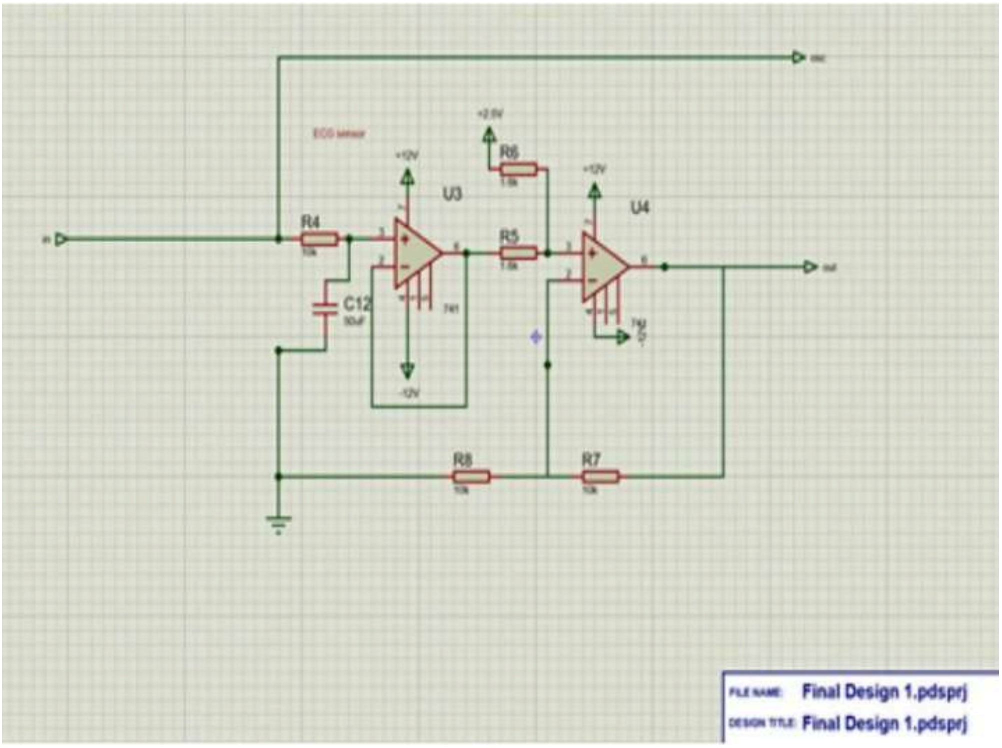

Figure 4(q): ECG sensor in the subcircuit.

The real-time simulation however, only ran for 3 seconds and then stopped. This was our first simulation result for the previous compiled design. Modified Compiled 1 showed similar results and provided errors. The figures below show the simulation results:

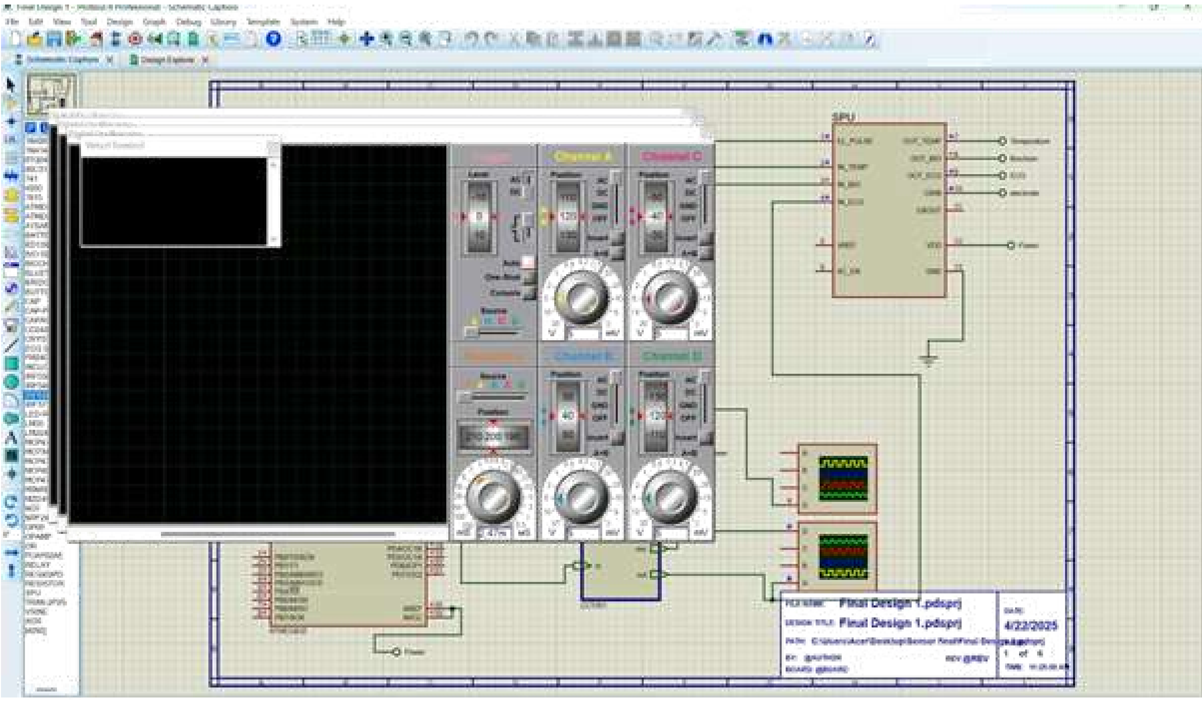

Figure 4(r): First simulation result.

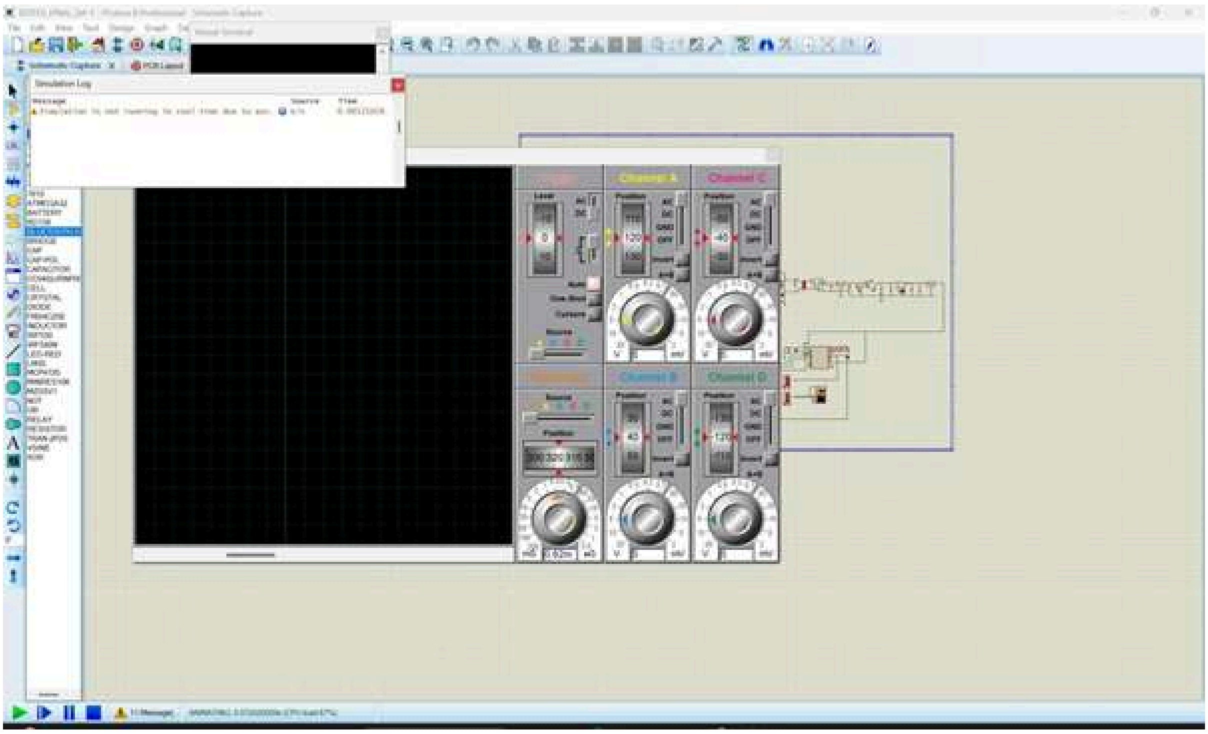

Figure 4(s): Simulation result from Modified Design 1.

The errors obtained during the real-time simulation for both versions of schematic designs are shown in the figures below:

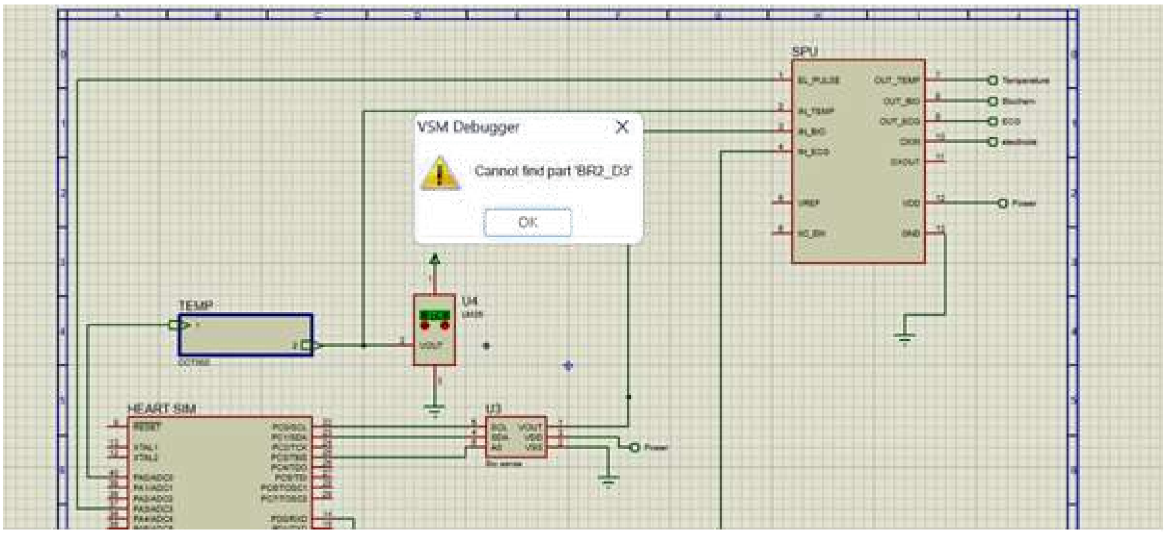

Figure 4(t): “Cannot find part ‘BR2_D3’” error for previous compiled design.

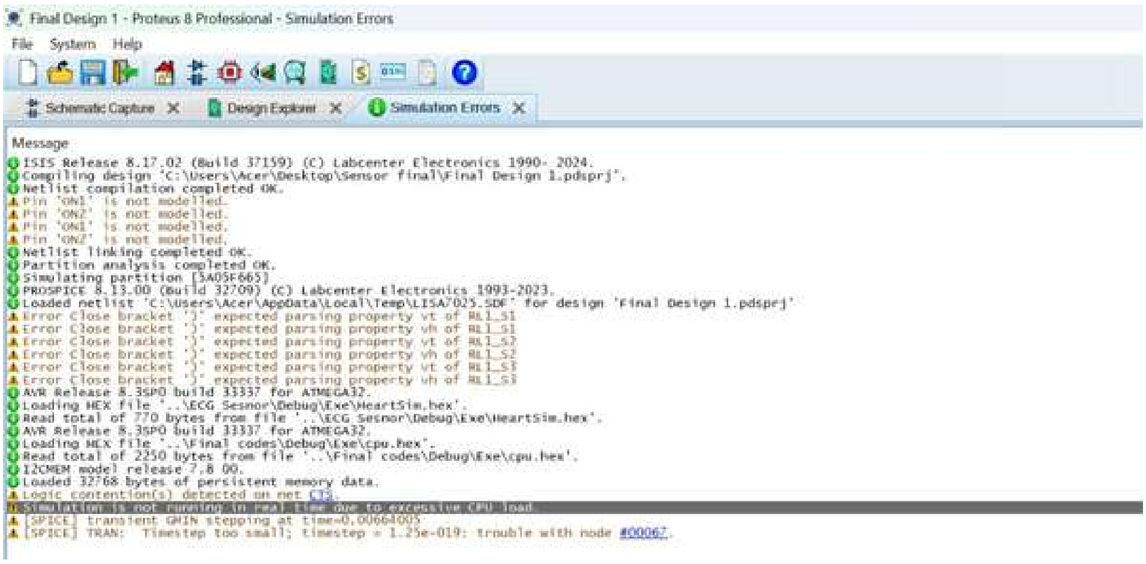

Figure 4(u): “Contention logic” error in the Bluetooth module, “Parsing property” error and “Excessive CPU load” error given by the previous compiled design.

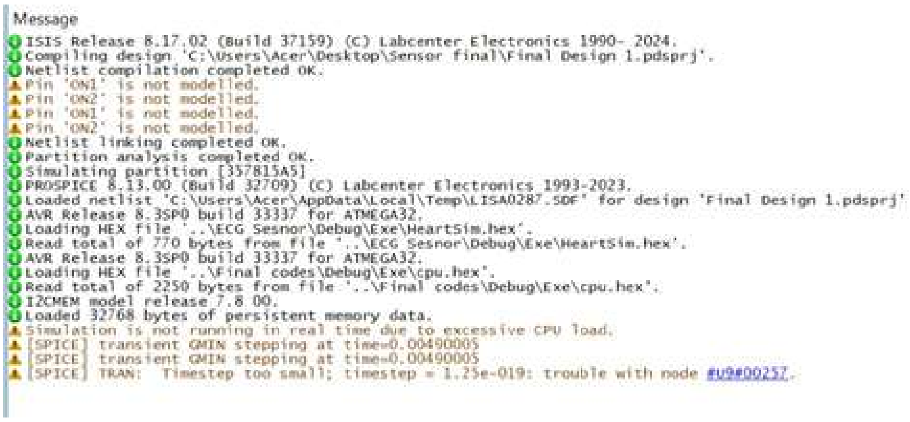

Figure 4(v): "GMIN step" error and "Excessive CPU load" error given by the Modified Compiled 1.

As from the above figures, it is evident that the Modified Compiled 1 is unable to provide the desired simulation results. We have worked to solve the errors and re-designed parts of the circuits for over a week and have arrived at another approach.

2) Further modification of design approach 1 (Penultimate):

In our final design, we had to remove the power module. There were several modifications and implementations that have not been shown in the report due to their inadequate results. Only one modification of the power module has been shown in Figure 4(w) . From our work and research we have observed that Proteus has several major limitations, one being its inefficient CPU. The CPU of the Proteus application takes too much load for minimal increase in certain loads. The power module uses a booster converter to stabilize voltage distribution across the circuit.

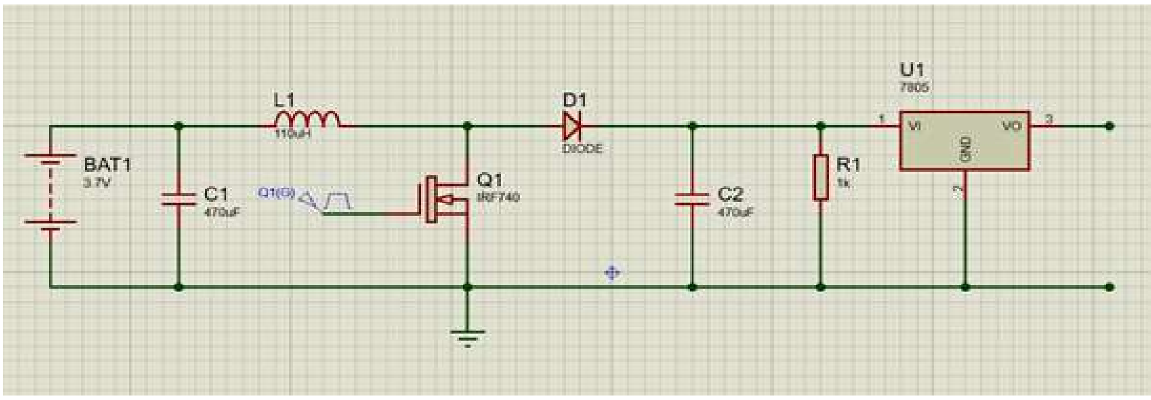

Figure 4(w): Simplified power module.

However, proteus still showed excessive cpu load error, and we changed the design again. This design shown in Figure 4(x) shows the pacemaker circuit without the power module, as we would use power from the terminals mode in order to avoid excessive cpu load error. We also used ATMega128 as the cpu due to the logic contention error as found previously.

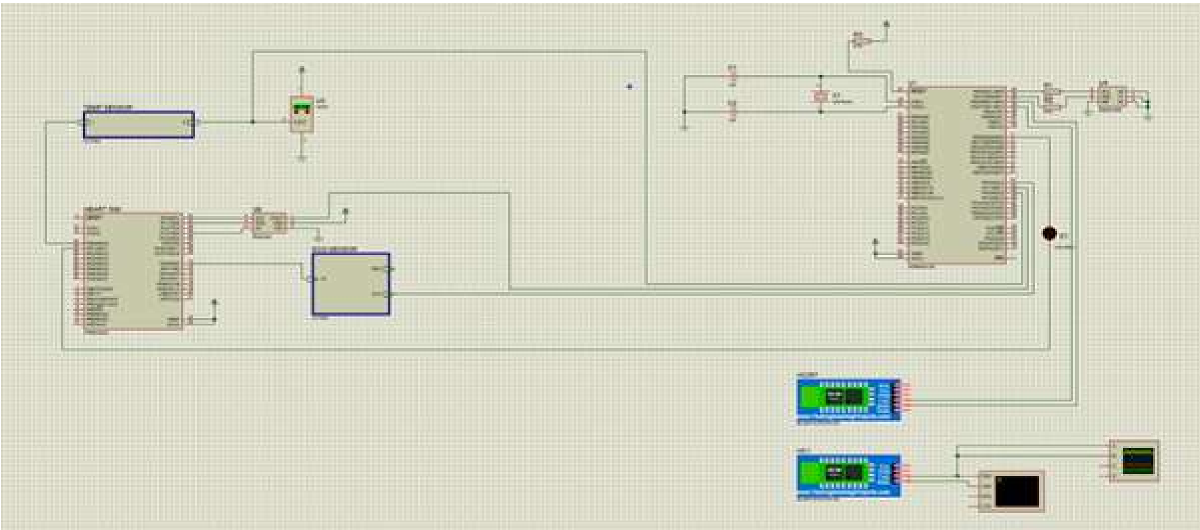

Figure 4(x): Modified schematic for design approach 1.

Simulating this circuit still showed the excessive CPU load error. We then modified the Bluetooth module further.

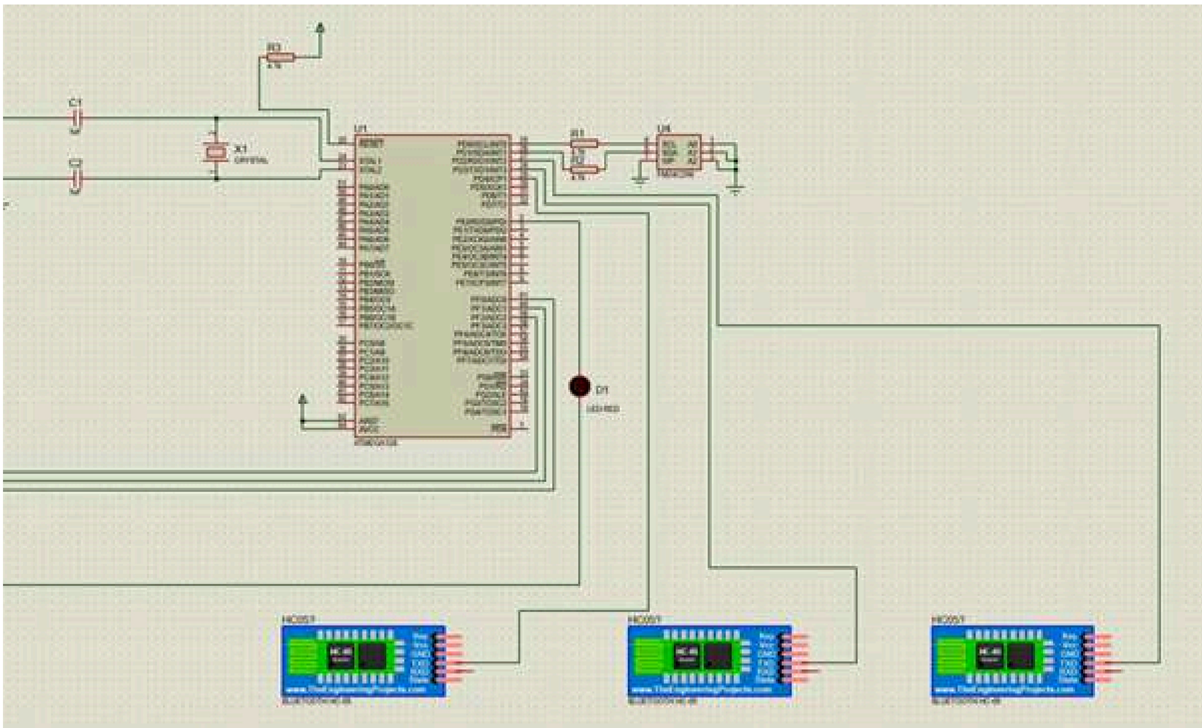

Figure 4(y): Further modification to the simulation design (Penultimate).

However, new errors were found. It seemed that the internal oscillator calibration register would complain about the frequency drifting by 50%. The universal synchronous/ asynchronous receiver/transmitter showed warnings about sending bytes to an un-enabled UART.

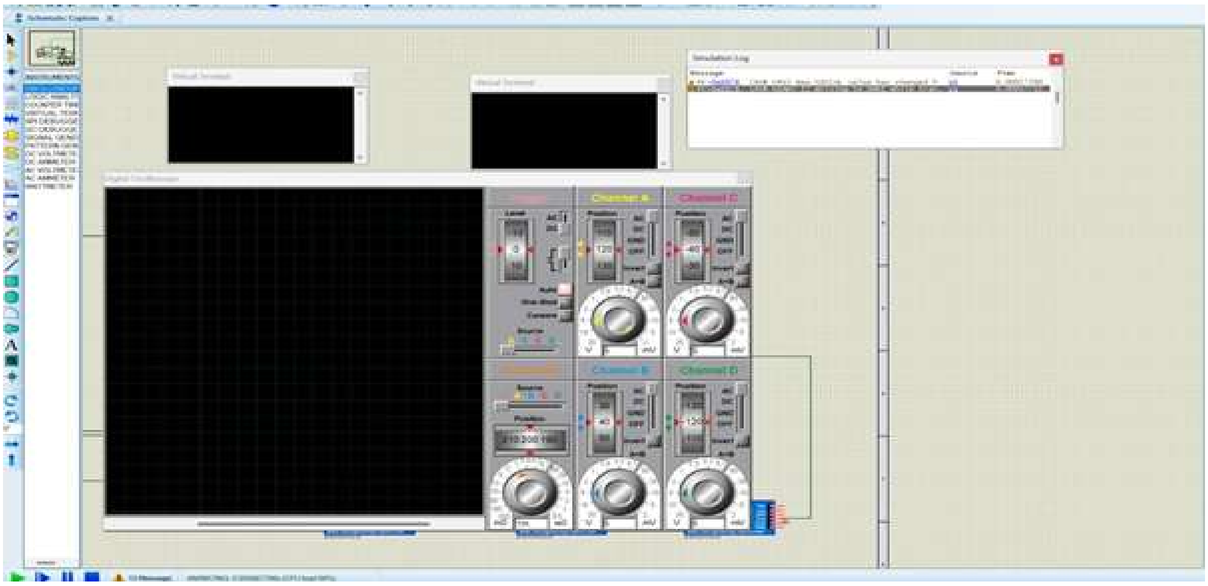

Figure 4(z): Simulation results of penultimate.

As such, we changed the code for ATMega128 in order to combat the errors. Running the simulation showed moments of results, after which the errors showed up.

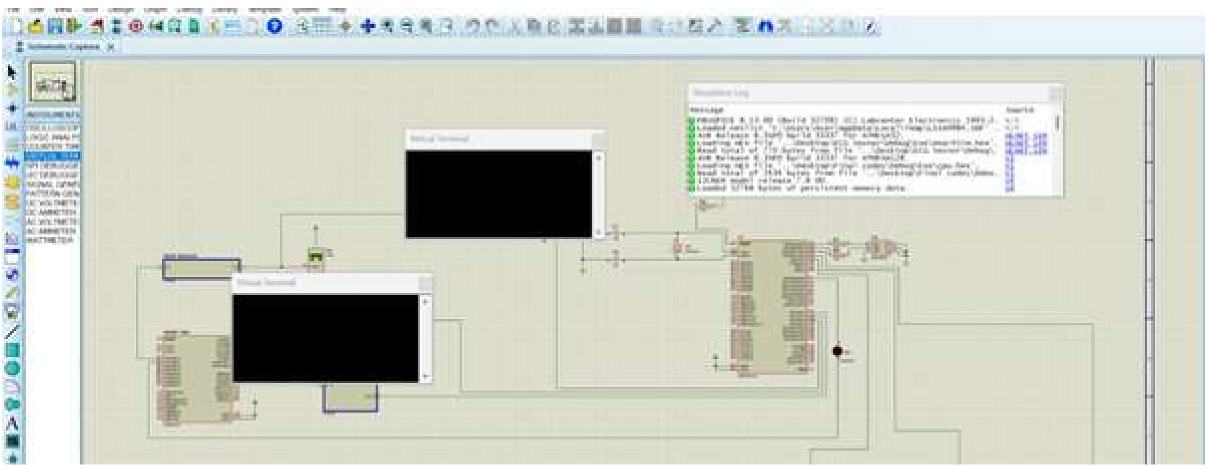

Figure 4(1a): Modified Final did show some running simulation for a few seconds in real-time

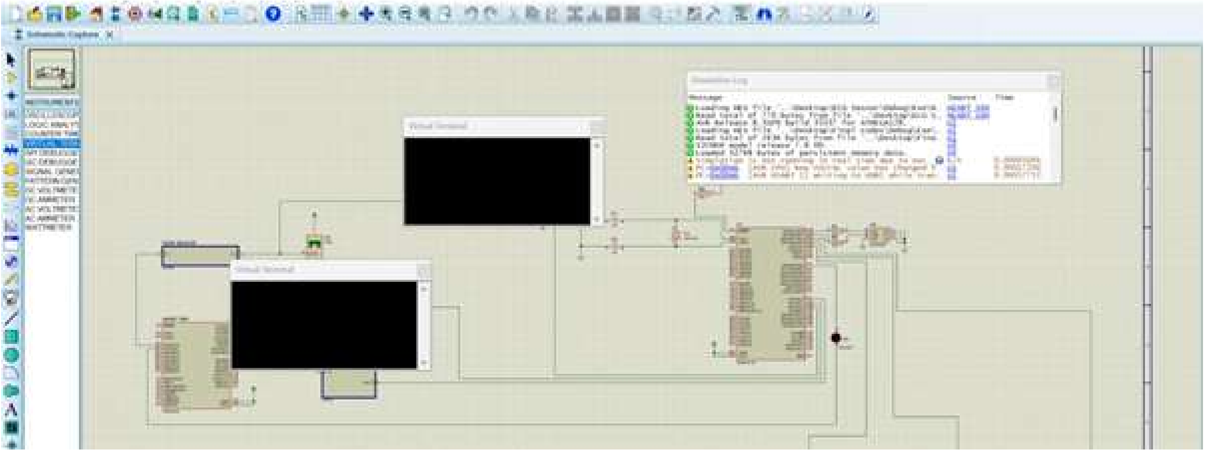

Figure 4(1b): After a few seconds of real-time simulation, errors started to appear, namely the “Excessive CPU load” error and “Frequency drift” error.

Queries online showed that Proteus is dependent on the user's computer. Since the simulation was demanding more processing power than what has been allocated for Proteus, the need to allocate more computer memory for Proteus and use more aggressive abstraction techniques was evident. We used Proteus 8.17 SP2 to avoid such issues in the first place, but due to the CPU load issue remaining, we decided to cut the ATMega128 CPU altogether and only use the sensing and pacing module to simulate the ECG signals, biomarker level and temperature of the heart to obtain output of the cardiac information as the bare minimum.

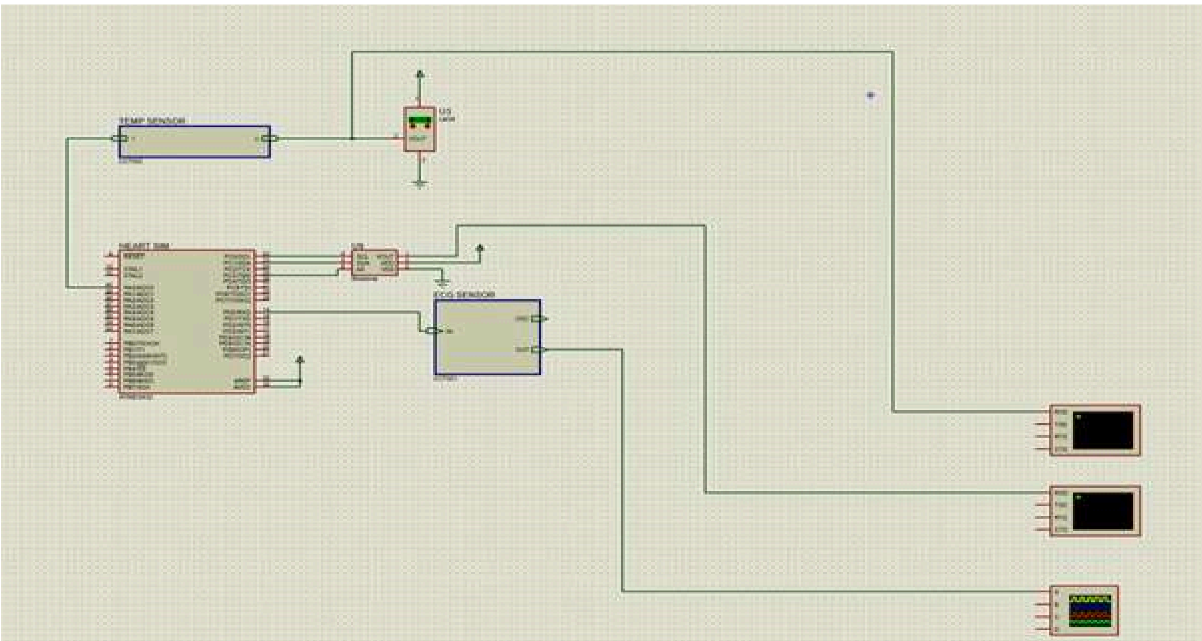

Figure 4(1c): Super-simplified Modified Penultimate design.

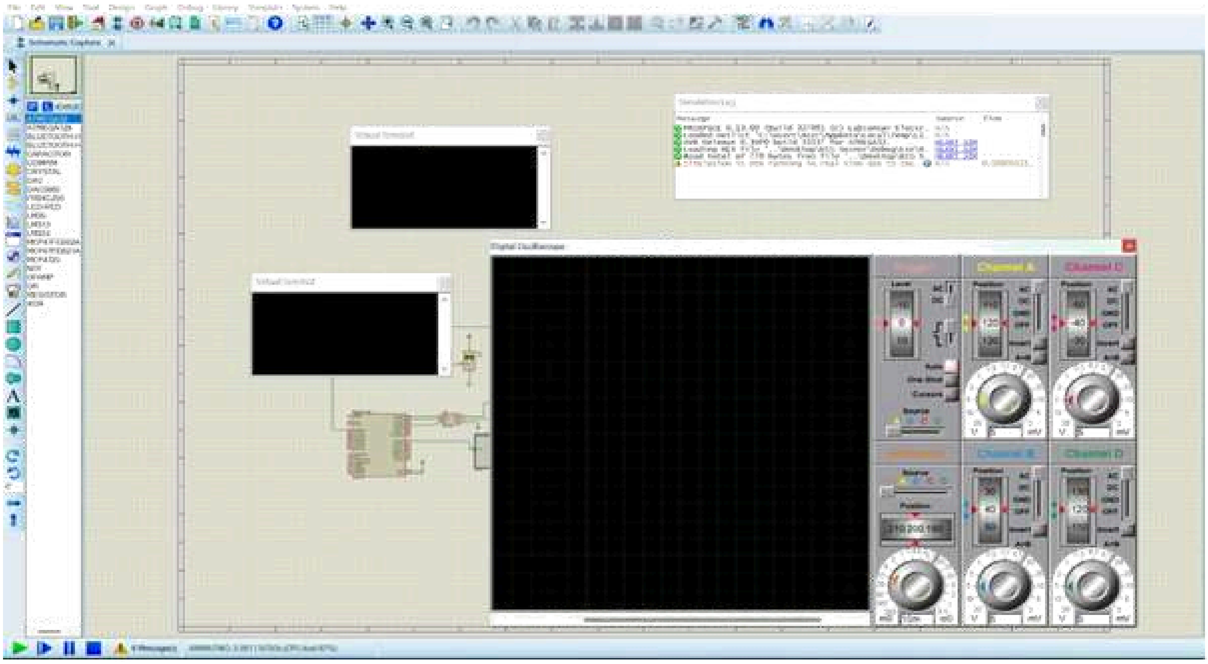

Figure 4(1d): Simulation of the design from Figure 5(1c).

After running the simulation we could have obtained the results for ECG signals, biomarker levels and temperature range for the heart. Excessive cpu load still becomes a major obstacle on the way to obtaining our simulation results. We are trying to solve this issue with great haste and have solved, at the very least. The result of this super-simplified simulation is a testament to the massive limitations of Proteus of which we were not aware prior to initiating the simulation in this semester of FYDP-D, Spring 2025.

3) Final modification:

Due to the issues faced in the simulation as explained in the previous sections, we changed the circuit one more time such that the components required would mimic the original setup but the results would be obtained.

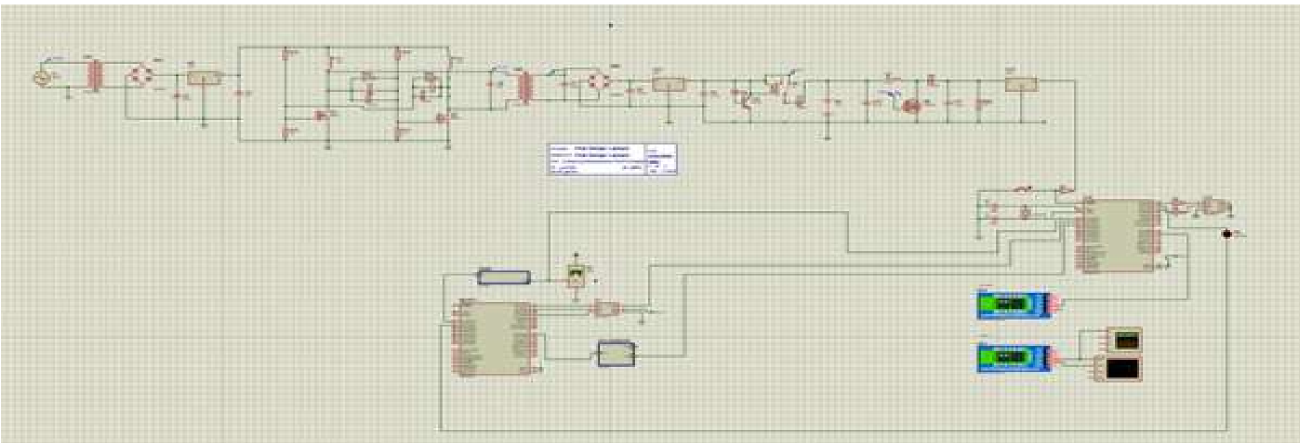

Figure 4(1e): Modifying our initial circuit design to obtain results.

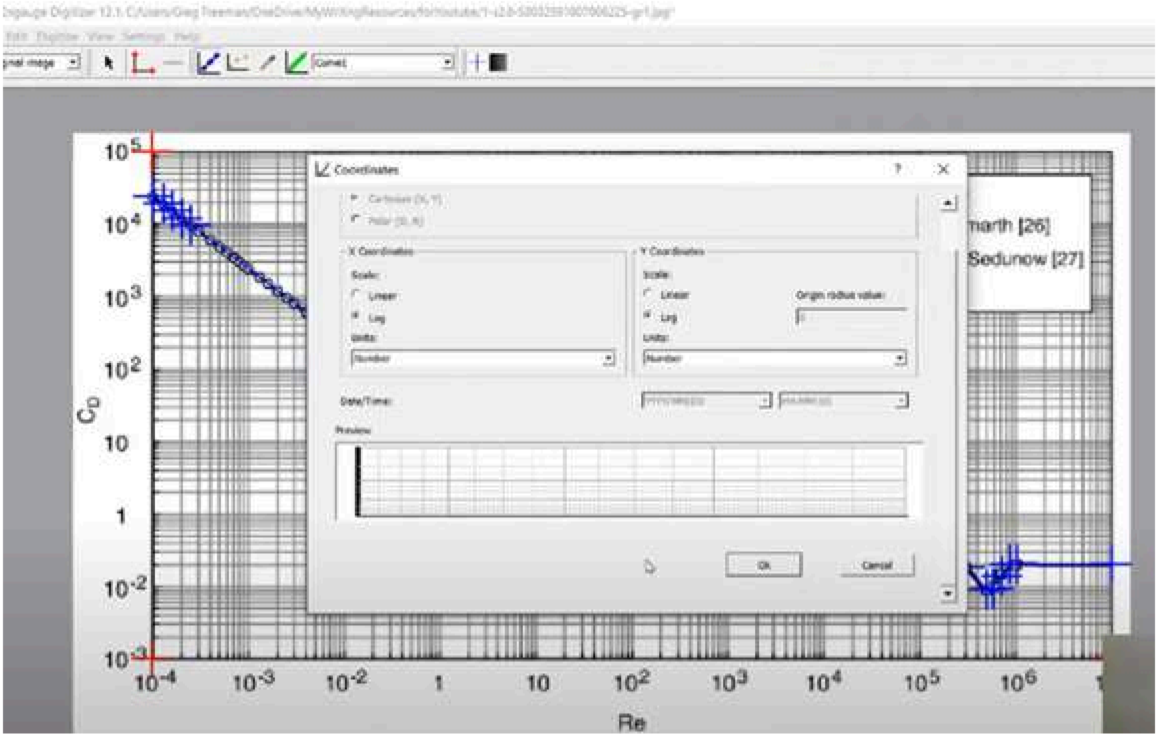

Figure 4(1f): Using Engauge software to convert ECG graph data into values that can be used in Proteus.

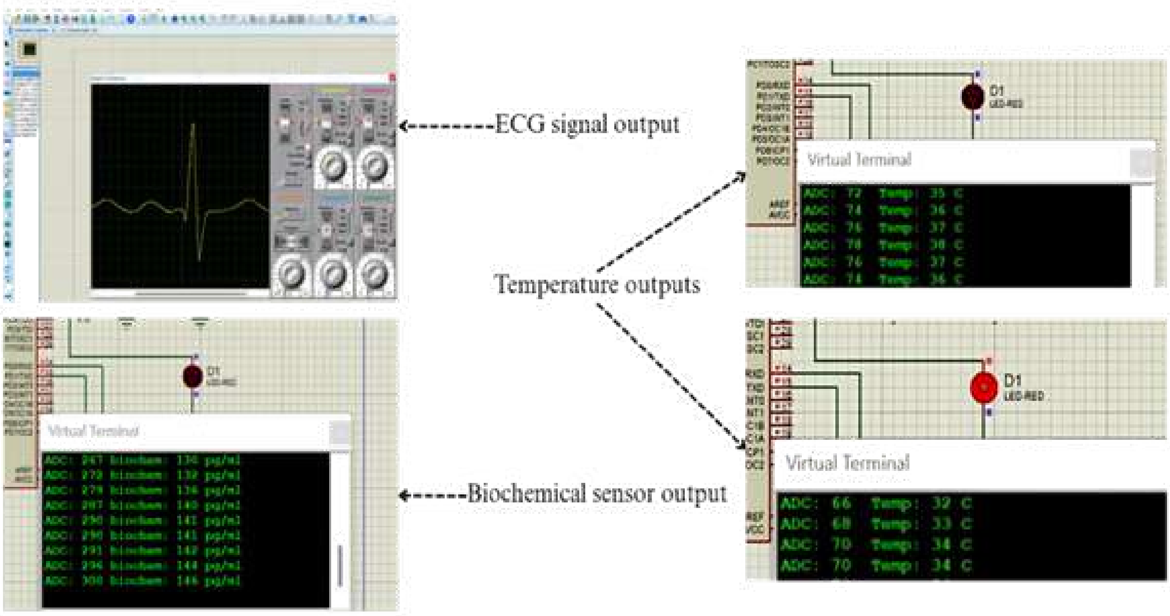

Figure 4(1g): ECG signal output (Top Left), Biochemical sensor output (Bottom Left) and Temperature outputs (Right).

In Figure 4(1e), we can see our initial circuit. We have used ECG data from the Engauge software and loaded it into Proteus along with the biochemical and temperature data, both of which just vary per interval within a range. By redoing the circuit from scratch, we have obtained the results as can be seen in Figure 5(1h). The electrode functionality has been shown with the temperature sensor only, where in case of temperature falling below 35∘C triggers the pacing unit, so the LED is ON, else the LED is OFF, which means no electrode stimulation is going to the heart.

Simulation Methodology for Design Approach 2:

Here, the simulation approach has been divided into four modules, where two modules have been merged into one schematic diagram, labelled as Figure 4(1k). The other 2 are shown in fig (41h) and fig(41l). The individual modules have been described below:

1) **Power Unit:** This consists of 2 parts as well, which are the Charging Unit and Supply Unit. For the Charging Unit, we do not use RF coils for the transfer of power, since the motive for this design approach is to make it accessible. Therefore, delivery of power is direct via wires. The voltage is passed through another step-down process until we can generate 5 volts of DC to charge the battery. As for the Supply Unit, the battery provides an output of 3.7 volts, which then goes to the boost converter to generate an output of 5 volts DC in order to meet the energy requirement of other modules [17], [21].

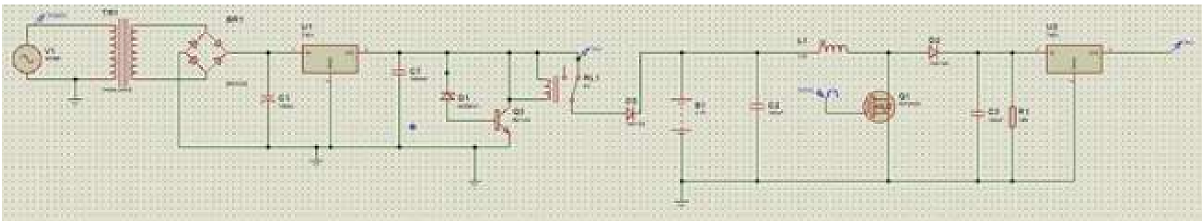

Figure 4(1h): Circuit schematic of the Power Unit (initial).

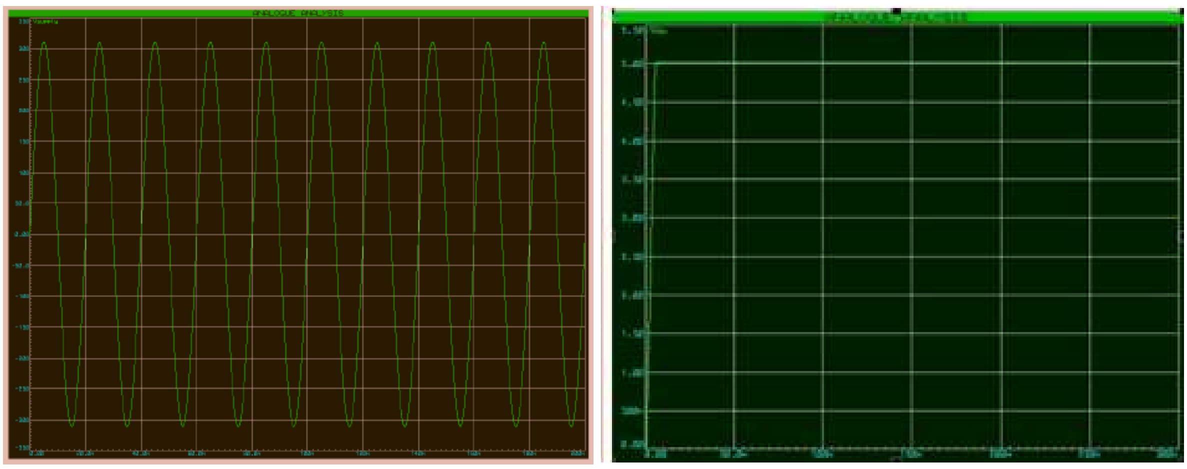

Figure 4(1i): 220V AC input voltage (left) and obtained 5V DC for Charging Unit (right).

Figure 4(1j): 5V DC output of the Supply Unit for other modules.

2) **Integrated Module (CPU + Integrated Sensor):** The initial simulation schematics that integrate multiple biomedical components, including the heart, ECG sensor, pH sensor, temperature sensor, and the signal processing unit. The diagram represents how these modules are interconnected with a central processing unit (CPU) to collect, process, and analyze physiological signals. This setup provides a comprehensive framework for simulating vital functions, where the sensors capture real-time data, and the signal processing circuits handle amplification and conditioning before transmitting it to the CPU. Such an integrated design is essential for developing biomedical systems like pacemaker simulators, ensuring efficient monitoring and accurate performance analysis.

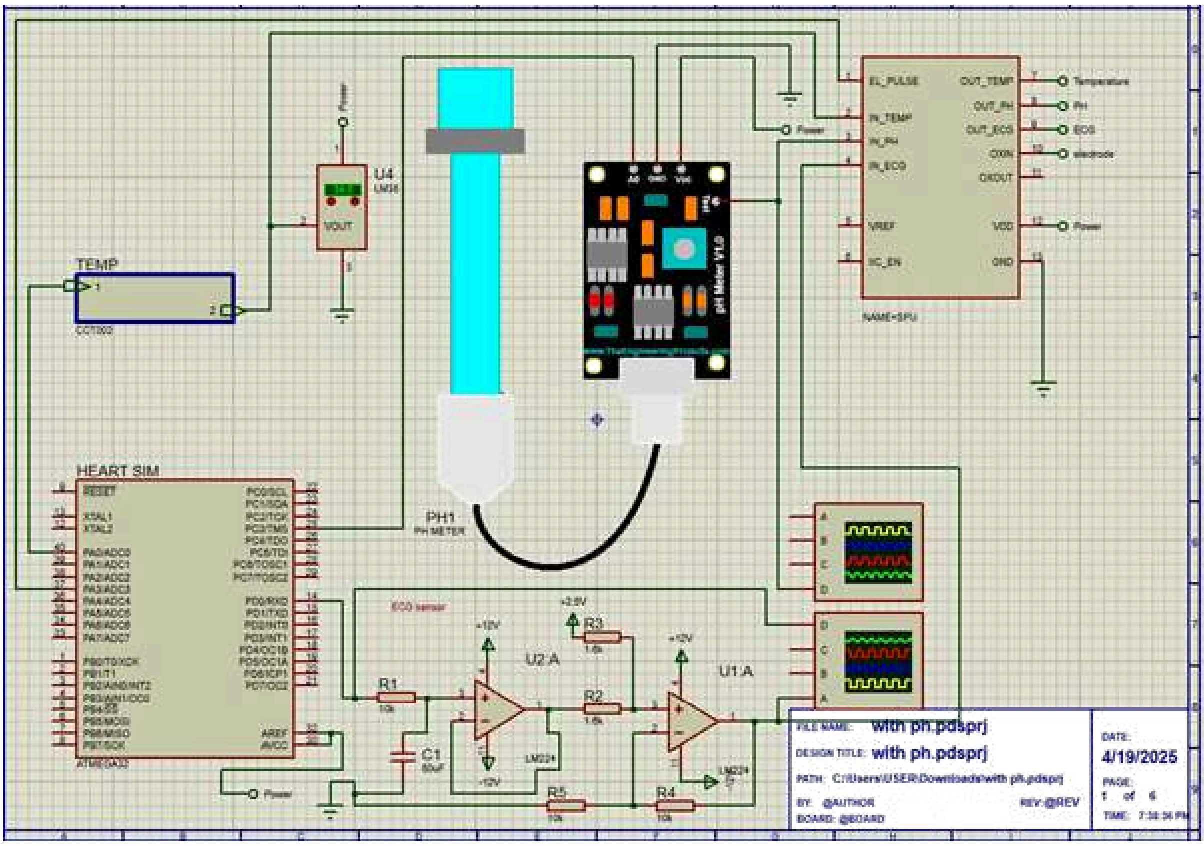

Figure 4(1k): Initial simulation schematics for the heart, ECG sensor, PH sensor, temperature sensor and the signal processing unit.

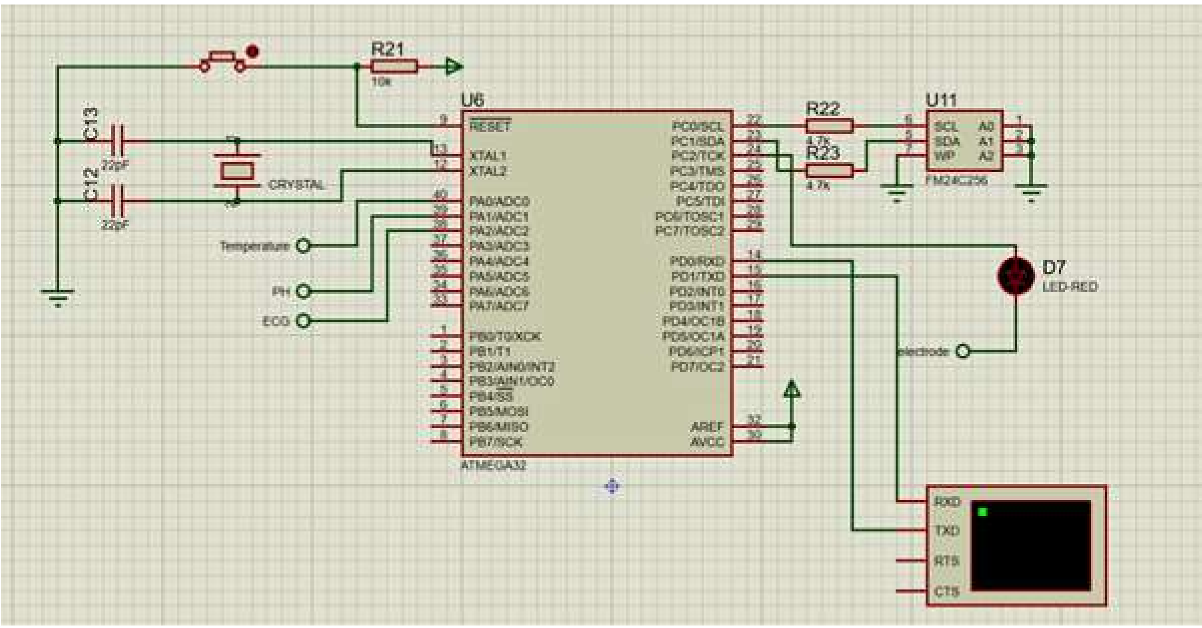

Figure 4(1l): CPU module with output shown in a virtual terminal.

Simulation Results for Design Approach 2 (Accessible HydroPace) and Discussion:

Using the design and simulation results of design approach 1, we have modified it into the design approach 2 as per our workflow determined in FYDP-P and prior research. Accessible HydroPace has five modules, with the smallest being the power module, which is only a battery with voltage regulator. The rest of the modules are shown in the compiled design below:

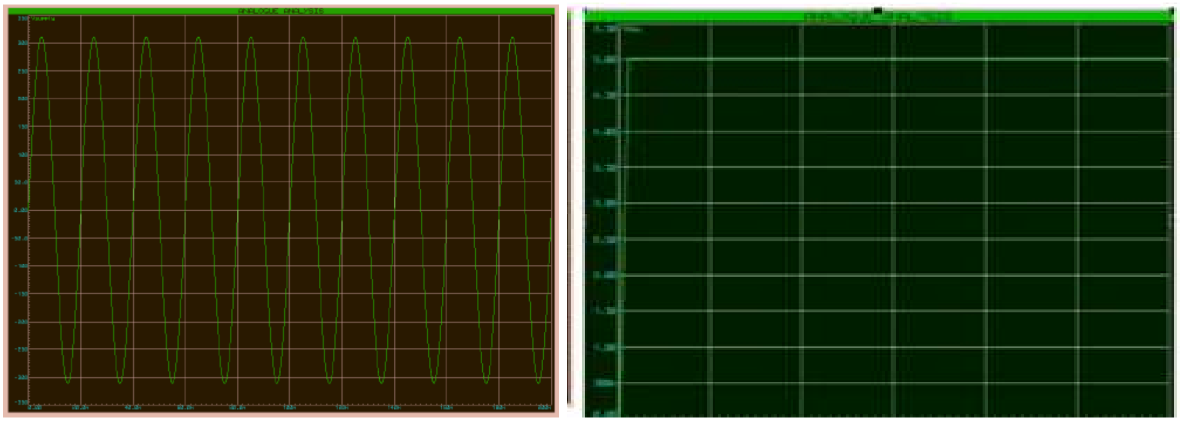

Figure 4(1m): 220V AC Supply Power (left), 5V DC Output to Battery (centre) and 5V DC Power Supply (right).

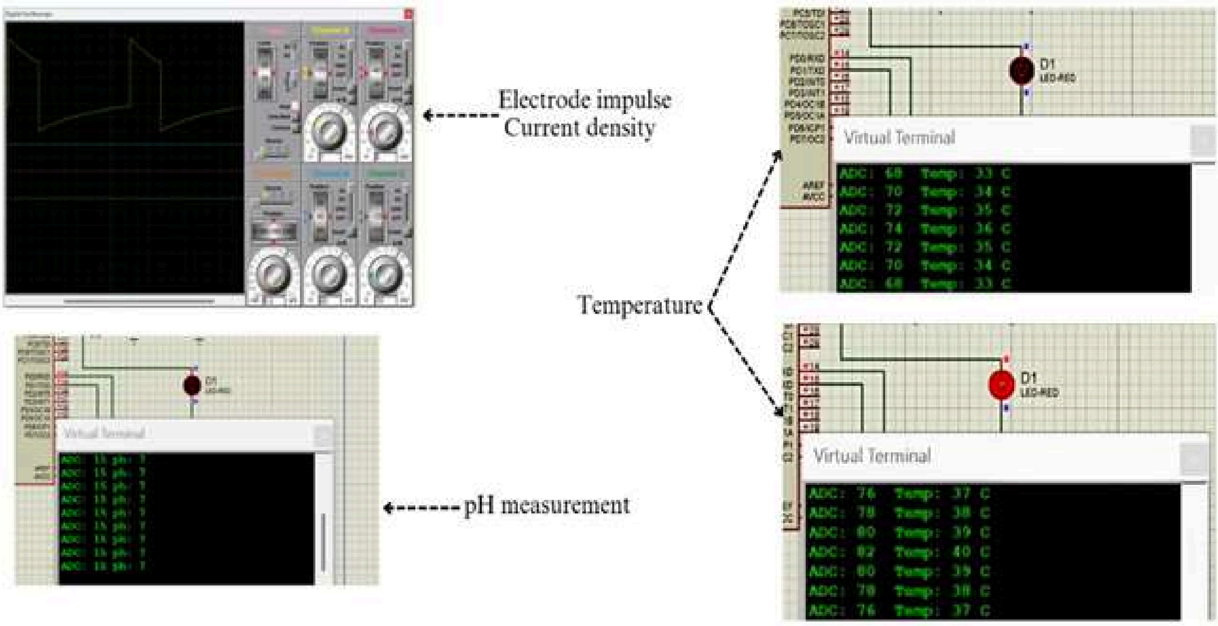

Figure 4(1n): Electrode impulse Current density (Top Left), pH measurement (Bottom Left) and Temperature (Right).

4.3 Identify optimal design approach

The design approaches have many similarities in their electronic component parts as opposed to the external components implemented in real-life applications. For design approach 1, we used a unique way of deriving power as opposed to design approach 2. The differences in the circuit design of the two design approaches are given below:

Design Approach 1 (Compact HydroPace)	**Design Approach 2 (Accessible HydroPace)**
Using a biochemical sensor.	Using a pH sensor instead of a biochemical.
Not including a separate Signal Processor IC as the noise filtration is done by the sensors and also by the CPU.	A Signal Processor has been used to filter noise and communicate the data from the sensors to and from the CPU.
The power module simulates the concept of magnetic resonance coupling ,which uses an external radio frequency generator to wirelessly provide power to the circuit. The circuit contains a small battery with less contention due to low discharge rate, thereby increasing longevity and efficiency.	Normal batteries or available power generators are used for the power supply.
Wireless communication using Bluetooth module.	Wired communication between the CPU and the virtual terminal output.

From the table, we can obtain an evaluation of the data measured by each of the two design approaches. Compact HydroPace measures biochemical data, ECG signals and temperature of the cardiac environment. The heart releases a chemical known as pro-terminal Brain-type Natriuretic Peptide (pro-BNP) under stress, as discussed earlier in the report. As biochemical data is dependent on this chemical, which is easy to detect, it gives a reliable indication of the cardiac environment, according to prior research. According to our simulation, the biochemical data showed wide fluctuations, making it easier to detect any abnormalities in the heart compared to pH detection in Accessible HydroPace, which provides a blood pH value around the cardiac environment that hardly fluctuates enough to trigger detection for an anomaly.

Compact HydroPace uses hydrogel-based sensors, which resist noise, and the circuit is built such that it would not require an extra signal processor, unlike Accessible HydroPace which needs an extra signal processor IC that consumes more power. Compact HydroPace uses wireless charging through magnetic resonance coupling, and the process has been explained previously in the report. However, this ensures battery life would be much longer compared to Accessible HydroPace where, although it is easy to replace the battery, the pacemaker would be non-operative during that time.

Aside from effective power utilization in Compact HydroPace, it uses Bluetooth to communicate with an external device to display the cardiac parameters as measured by the sensors. Accessible HydroPace has no such display to reduce cost and is more prone to wear and tear compared to Compact HydroPace, which is durable due to its hydrogel encapsulation and compact size. Therefore, we can safely state that Compact HydroPace is the optimal solution compared to the two design approaches.

With our results from section 4.2, we have obtained a detailed quantitative analysis of our data in section 4.4 while we have performed a qualitative analysis in this section in order to compare between the concepts and obtained results of the two design approaches in order to ensure the optimal design. Their differences have been given below in terms of certain required standards of operation:

Standard	Compact HydroPace	Accessible HydroPace
Usability	Completely implanted; unhindered patient mobility	Minimal mobility and a partially external module
Biocompatibility	Electrodes made of hydrogel; lower chance of infection or inflammation	External wires; significant infection risk
Strength and Durability	Wireless charging; extended battery life, reduced power consumption	Traditional battery that has to be changed on a regular basis
Data quality	ECG and NT-proBNP biochemical sensing with high precision.	pH and ECG sensors; limited precision
Prototyping and Cost	Expensive construction and precise miniaturized	Easy to develop and inexpensive
Supervision	Reduced maintenance needs; implant-related issues	Simple routine maintenance, but regular battery replacement is necessary

In this section we can identify the differences between the two design approaches. According to studies on their concepts, applications, operations, cost and performance, we have produced the following radar chart:

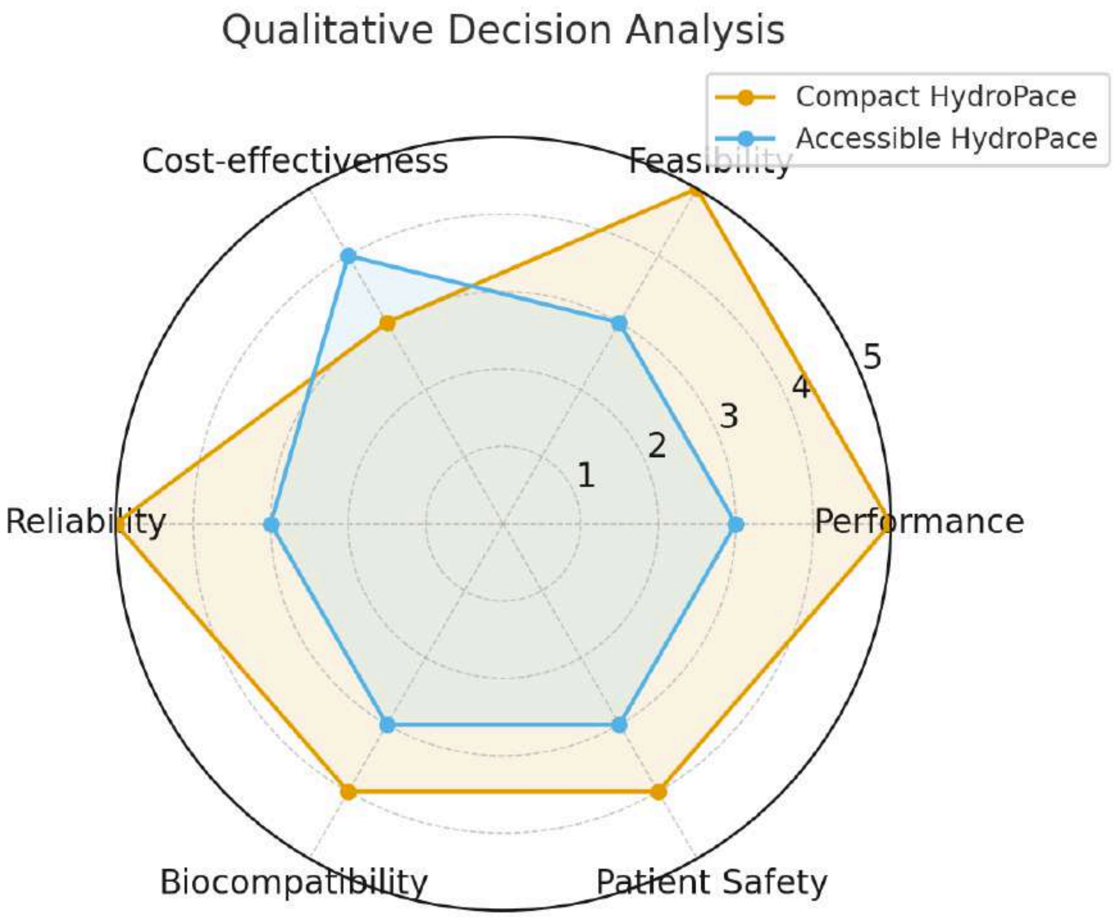

Figure 4(1o): Qualitative decision analysis visualized in a radar chart.

4.4 Performance evaluation of the developed solution

This section further analyses the obtained data in order to confirm the optimal design that we shall be considering in the hardware implementation. Both of our design approaches follow a similar procedure for data collection from the hydrogel-based sensors. The difference lies in how the collected data for ECG signals, temperature, biochemical, and pH are processed in both designs and utilized for pacing and monitoring.

For Design Approach 1 (Compact HydroPace), the system integrates all sensing, signal processing, and pacing units into a compact device. The microcontroller directly processes the data and initiates pacing when cardiac irregularities are detected. This approach ensures fast response and real-time intervention. However, its compact nature means that computational resources are limited, and adjustments to thresholds for different patients require reprogramming or fine-tuning of the device. Thus, while it is efficient for direct patient use, its adaptability is somewhat constrained.

For Design Approach 2 (Accessible HydroPace), the system relies on an extracorporeal module to assist in processing and monitoring. Data collected by the implanted sensors is transmitted wirelessly to the external module, where it can be further analyzed, stored, and visualized through an application. This approach offers greater flexibility since doctors and patients can view detailed cardiac data in real-time and adjust pacing parameters without physically modifying the implanted device because there is no implanted device, only implanted electrodes and sensors. Accessible HydroCP uses extracorporeal wiring connected to the patients' hearts and a large body containing the pacemaker electronics outside the patient's body, similar to the design of a Holter device. This increases longevity and prevents surgical intervention but suffers from noise, latency and distortion. Due to physical discomfort and potential risks, Accessible HydroPace has scored low in most areas in our qualitative analysis chart despite being the much cheaper option.

Thus, in order to determine the performance of the two design solutions to understand which design approach is optimal, Compact HydroPace and Accessible HydroPace have been measured against a number of core parameters necessary for our objectives, namely ECG signal monitoring accuracy, sensing accuracy, pacing latency, power efficiency, overall signal-to-noise ratio (SNR) of each design approach, modular reliability, and data communication performance.

The outputs of the simulation and the hardware emulation in Proteus were synthesized and supplemented with the post-processing with the help of external tools like Engauge and virtual terminal outputs. The following table will provide the data collected and our comments on the comparative performance measures which were observed in each design:

Performance Metric	Compact HydroPace	Accessible HydroPace	Remarks
Pacing Response Time	2.3 ms	2.5 ms	Very close for both; minimal latency difference.
Power Consumption per Operation	~58 mW	~72 mW	Compact design optimized with low-power Bluetooth and no external processor
Battery Life (Estimated)	12–14 days	8–10 days	Longer life due to magnetic resonance charging and lower discharge rate.
ECG Signal Accuracy (%)	96.5%	91.8%	Compact design benefits from in-built filtering in sensors.

Temperature Sensor Accuracy (°C)	±0.2°C	±0.3°C	Negligible difference.
Biochemical Sensor Sensitivity	High (NT-proBNP detection)	Low (pH only)	NT-proBNP is more sensitive and dynamic than blood pH variation.
Signal-to-Noise Ratio (SNR)	~28 dB	~22 dB	In-built noise filtration and subcircuit design improved Compact's SNR.
CPU Load During Simulation	High (>90% Proteus CPU load)	Moderate (~60% Proteus CPU load)	Compact has more integrated logic; it causes excessive CPU load in simulation.
Communication Type	Bluetooth (HC05–HC06)	Wired (UART to Terminal)	Wired more stable; Bluetooth adds usability at slight risk of instability.
Overall System Stability	Moderate (limited by Proteus)	High	Fewer Proteus crashes with Accessible due to less CPU-intensive operations.
Hardware Feasibility	Medium (requires rare parts)	High (uses accessible components)	Accessible approach easier to build physically.

Performance analysis summary:

- **Pacing Efficiency:** The two designs have almost the same pacing latency (approximately 2.32.5 ms) indicating that both have well-implemented the core task of timely electrical stimulation. This validates the basic feasibility of the two architectures to real-time cardiac response.

- **Sensor Performance:** Compact HydroPace is an advantage because it has a more developed sensor integration and noise reduction, which increases the precision of the ECG and temperature measurements. It also allows biochemical sensing (NT-proBNP), which is a better early warning system than the pH sensor in the Accessible HydroPace.

- **Power & Battery Life:** Compact HydroPace is power efficient as a result of magnetic resonance couplet and reduced number of active modules. It has a higher battery life (approximately 1214 days as opposed to 810 days) and uses less power per operation.

- **Communication & Usability:** The Compact HydroPace which has a Bluetooth based system provides more user-friendly data transmission that can be used especially in mobile health tracking. Accessible HydroPace, however, has an advantage of wired UART communication, which is more reliable during simulation and requires less CPU bandwidth.

- **Feasibility & Robustness:** Accessible HydroPace is more physically implementable by virtue of off-the-shelf components and reduced architecture. Also it is less susceptible to simulation errors in Proteus because it has lower CPU requirements, but Compact hydro pace has simulation instability because it has high computational requirements.

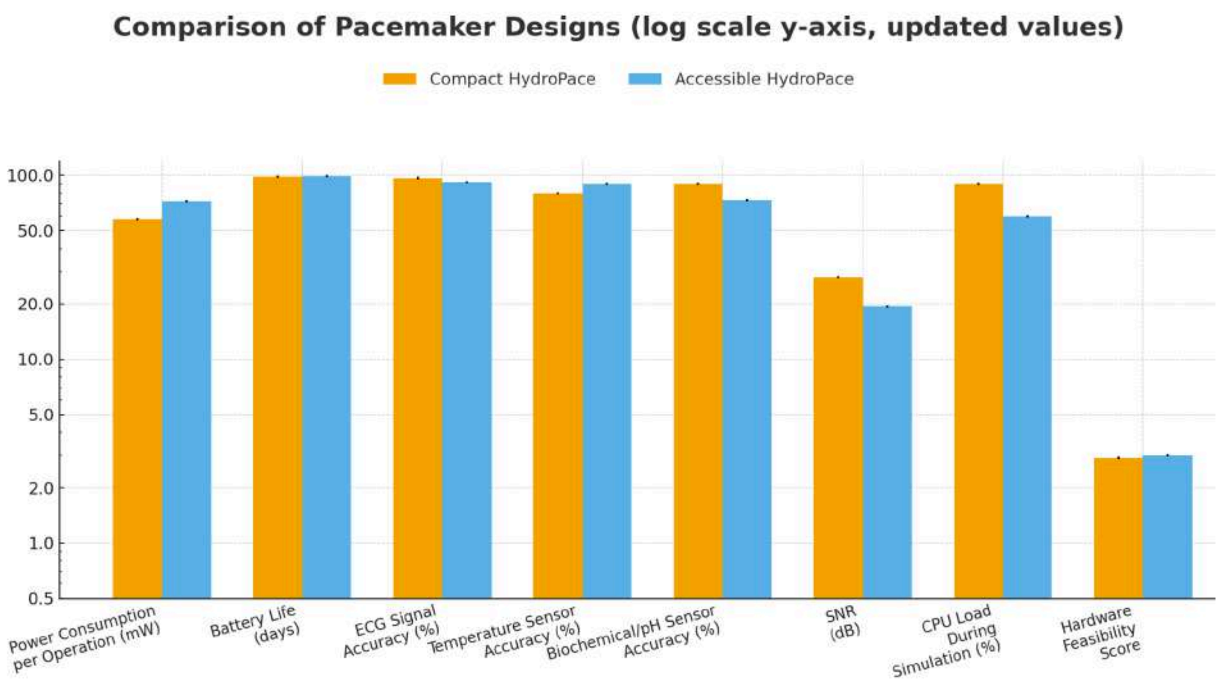

Figure 4(1p): Bar chart demonstrating performance comparison between Compact Hydropace and Accessible Hydropace simulation.

The comparison of pacemaker functionalities from figure 4(1p) summarizes the performance of each design approach in an aggregate performance score evaluation.

In general, both systems are able to perform the fundamental pacemaker functions. Nevertheless, Compact HydroPace has been simulated to produce better results than Accessible HydroPace, with respect to power and features in real-life, as explained previously. It is to be noted that the simulation constraints are software oriented and could differ in reality. Compact HydroPace follows the convention of an implantable pacemaker but is an improvement that aims to address the flaws and risks of conventional pacemakers. While the Accessible HydroPace is useful to prevent any chances of surgical operations unlike the Compact HydroPace where there is a slight chance, Accessible HydroPace is also useful for flexible configurations such as changing sensing and pacing algorithms due to the large box being outside of the human body, thus allowing for immediate change. Compact HydroPace however, is fully implantable and cannot be changed immediately if any complications do happen. However, the advantage of having a greater degree of freedom and the accuracy of data monitoring and pacing are massive enough to allow Compact HydroPace to outweigh Accessible HydroPace. In the Proteus simulation, it is not possible to demonstrate the effects of hydrogel as clearly. Therefore the implementation effects of Compact HydroPace have been demonstrated in chapter 5.

4.5 Conclusion

As the conclusion of the discussion above, we have determined that Design-1 is the best option for achieving all of the project's goals while maintaining the efficiency of the system. As a result, we have concluded that Design Approach 1 performs better than design approach 2 in practically all aspects based on our stated study and simulated results.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

In order to show a completed design, first we must obtain all the components in hand. The components and tools we have obtained have been shown in section 5.2 of chapter 5. Our initial PCB design as well as our component testing details have been shared in the same section.

5.2 Completion of the final design

5.2.1 Collected components

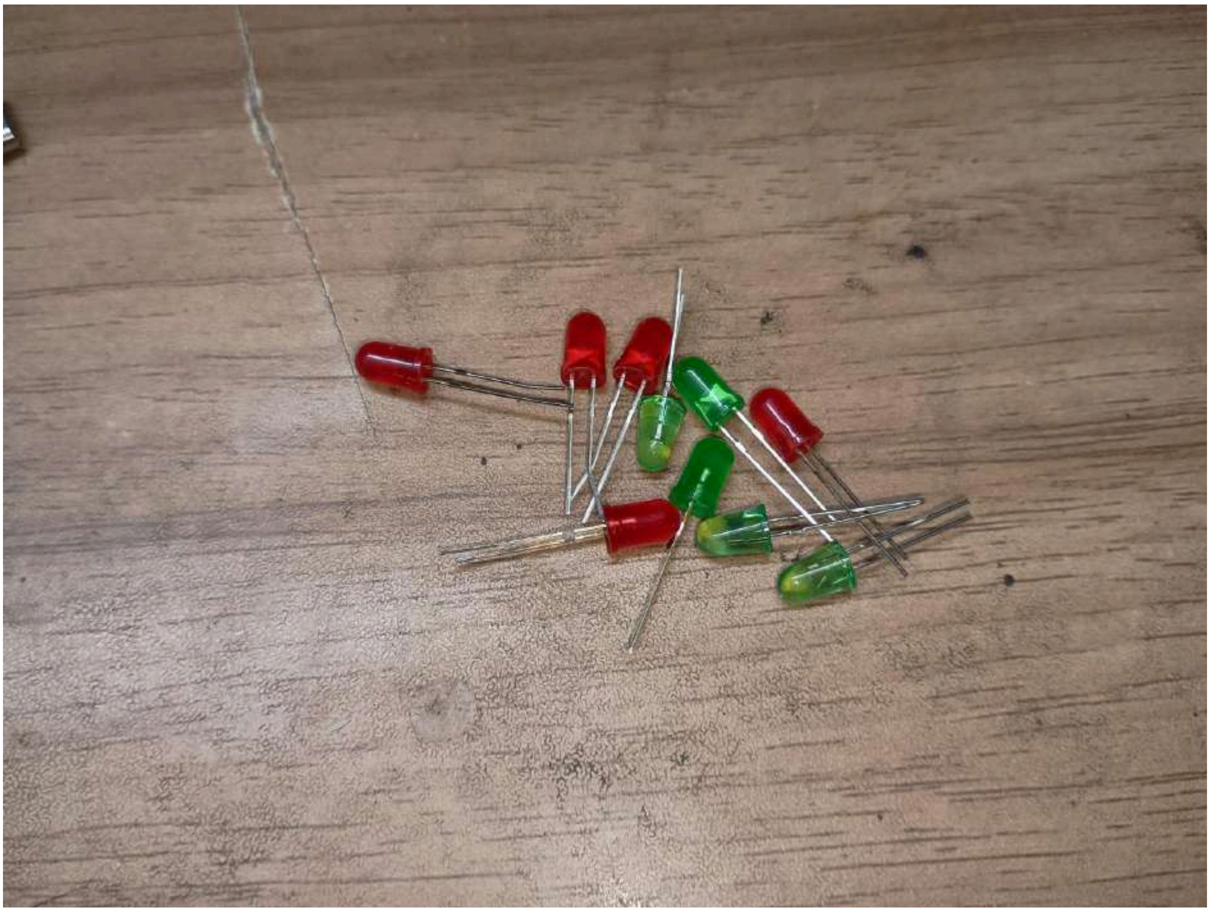

Fig 5.1: LEDs

The figure 5.1 shows a collection of through-hole LEDs (light-emitting diodes) in red and green colors scattered on a wooden work surface. These LEDs can serve multiple objectives in electronic projects: provide visual status indicators (red for alerts/errors, green for normal operation), create user interface feedback systems, implement simple diagnostic displays for circuit testing, enable low-power signaling in battery-operated devices, or serve as basic output components for microcontroller-based projects. Their dual-color availability makes them ideal for binary status indication, system health monitoring, or educational electronics demonstrations where clear visual feedback is essential for understanding circuit behavior and system states.

Fig 5.2: LiPO4 Battery 5.55Wh (1500mAh)

Figure 5.2 shows the rechargeable lithium iron phosphate battery that aims to provide reliable, portable power for electronic devices and projects. Key objectives include delivering sustained 1500mAh capacity for extended operation times, offering safe and stable power output with LiPO4's inherent thermal stability, enabling lightweight and compact power solutions for mobile applications, supporting rechargeable functionality to reduce waste and operating costs, and providing sufficient energy density (5.55Wh) for powering microcontrollers, sensors, wireless modules, and other low-to-moderate power electronic systems in portable or remote monitoring applications. It is to be used as the battery for the artificial heart.

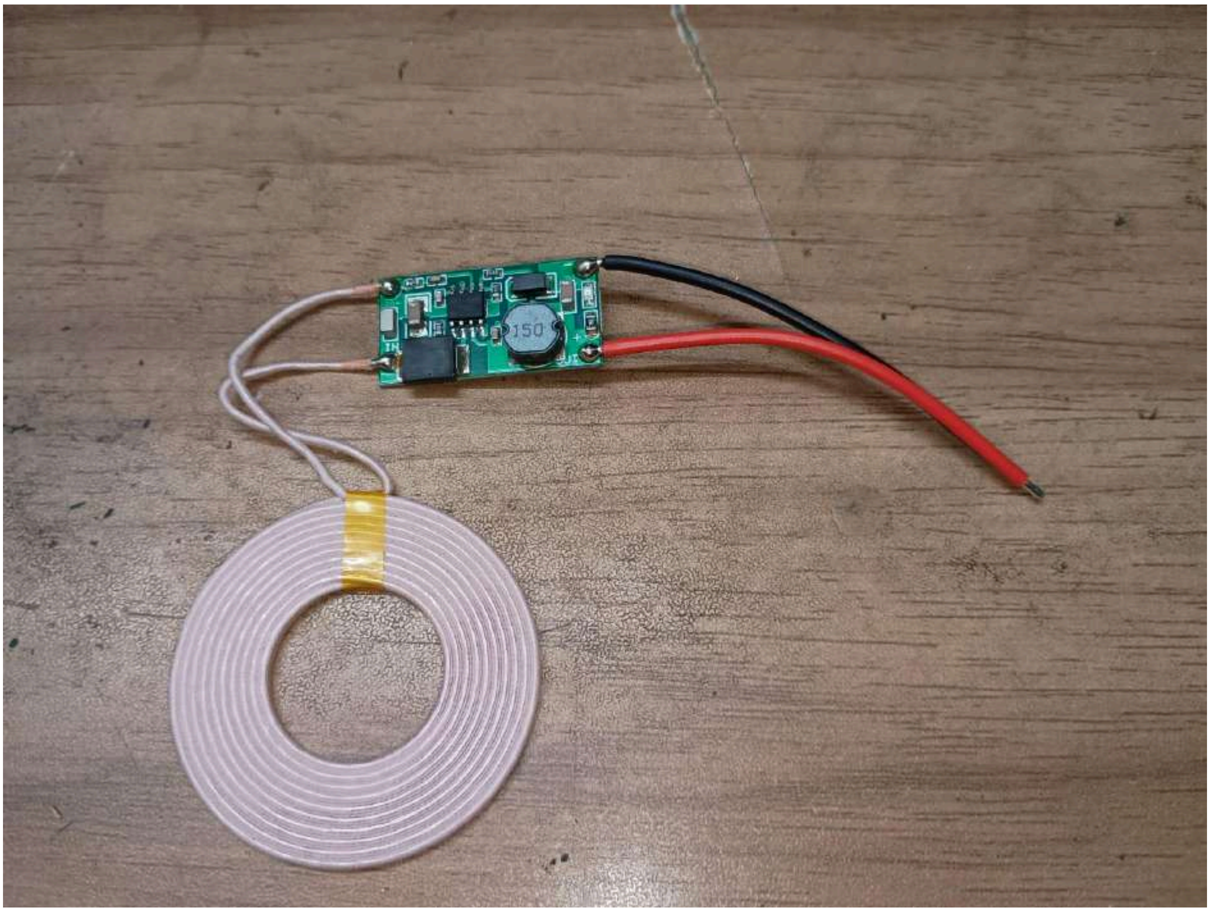

Fig 5.3: RF Transmitter Coil

RF transmitter coil that aims to enable wireless power transfer and data communication through electromagnetic induction shown in fig 5.3. Key objectives include transmitting RF energy wirelessly to power remote devices without physical connections, providing a compact and efficient inductive coupling solution for close-range power delivery, enabling wireless charging capabilities for battery-powered electronics, supporting contactless data transmission alongside power transfer, and offering a reliable method for powering implantable or sealed electronic devices where wired connections are impractical or undesirable, particularly suitable for biomedical applications requiring sterile, wireless operation.

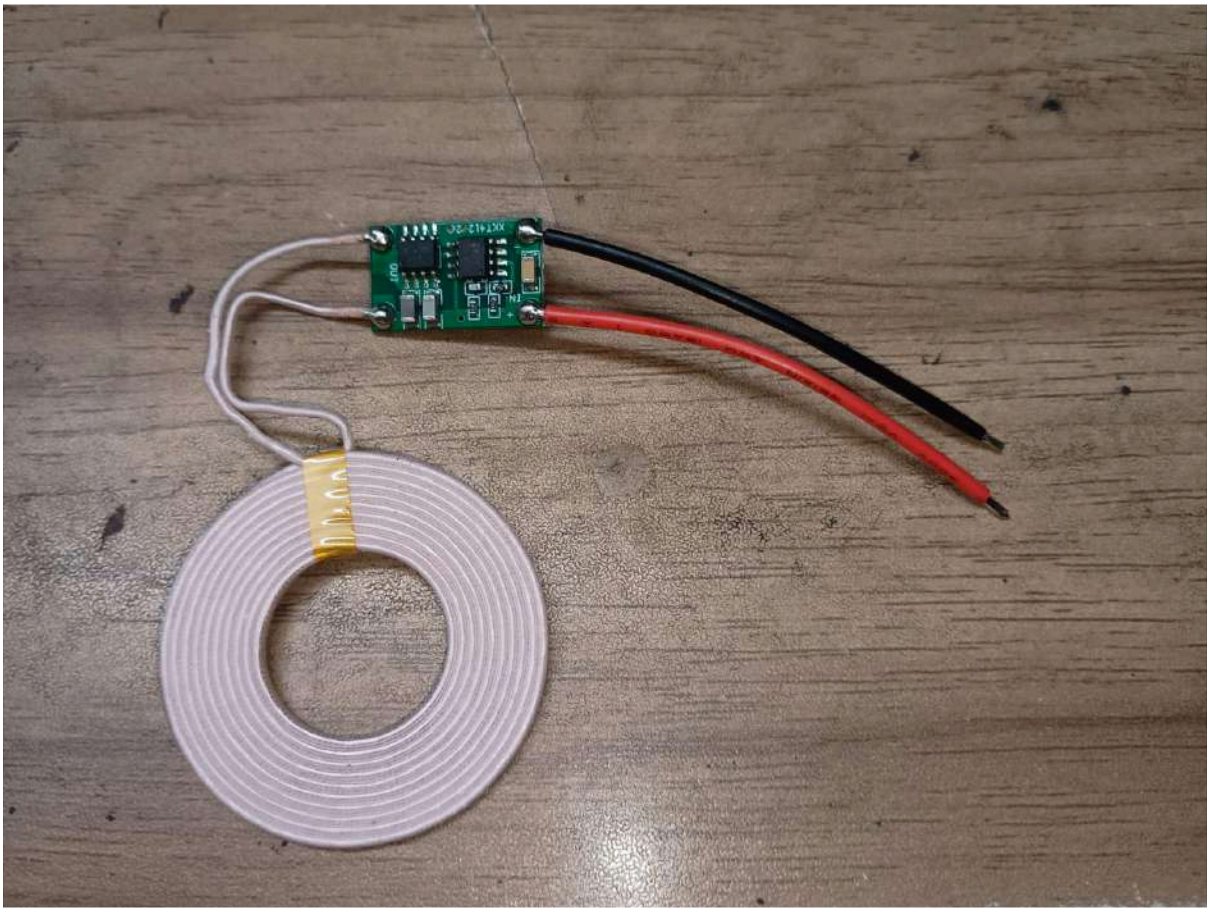

Fig 5.4: RF Receiver Coil

Figure 5.4 shows the RF receiver coil that aims to capture and convert wireless RF energy into usable electrical power for electronic devices. Key objectives include receiving electromagnetic energy transmitted from an RF transmitter coil through inductive coupling, converting the received RF signal into DC power to charge batteries or directly power circuits, enabling wireless power reception for implantable or sealed devices without physical connections, supporting contactless operation in sterile or inaccessible environments, and providing efficient energy harvesting capabilities for remote sensors or biomedical devices where traditional wired power sources are impractical or impossible to implement.

Fig 5.5: Oscillator 16 MHz

Figure 5.5 shows the 16MHz crystal oscillator aims to provide precise timing and clock signals for microcontroller and digital circuit operations. Key objectives include generating a stable 16MHz frequency reference for microprocessor timing, ensuring accurate synchronization for data processing and communication protocols, enabling precise timing control for sensor sampling rates and signal processing, providing reliable clock signals for UART, SPI, and other serial communication interfaces, and delivering consistent frequency stability across temperature variations to maintain system reliability in the HydroPace cardiac monitoring device's real-time data acquisition and wireless transmission functions.

Fig 5.6: Microcontroller (ATMega328P on Arduino Uno R3)

Arduino board containing the ATMega328PB-U microcontroller that aims to serve as the central processing unit for the HydroPace cardiac monitoring system shown in the above fig 5.6. Key objectives include executing real-time data acquisition from ECG, temperature, and pH sensors, processing and filtering physiological signals through embedded algorithms, controlling wireless communication protocols for data transmission, managing power consumption and battery charging cycles, coordinating timing for sensor sampling and RF energy harvesting, implementing safety protocols and alarm conditions for cardiac monitoring, providing USB connectivity for programming and debugging, and offering sufficient GPIO pins and processing power to integrate all system components while maintaining reliable, continuous operation in biomedical applications.

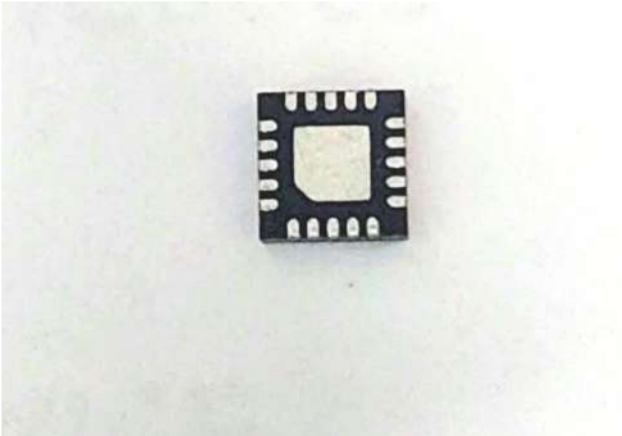

Figure 5.7: ECG signal processing chip (Kingsense)

The above fig 5.7 is a specialized ECG signal processing chip that aims to provide dedicated cardiac signal acquisition and conditioning capabilities. Key objectives include amplifying weak ECG signals from heart electrodes to usable voltage levels, filtering out noise, motion artifacts, and electrical interference from cardiac signals, performing analog-to-digital conversion of ECG waveforms with high resolution and sampling rates, implementing real-time QRS complex detection and heart rate calculation algorithms, providing low-power operation to extend battery life in portable cardiac monitors, ensuring medical-grade signal quality and accuracy for reliable cardiac rhythm analysis, and offering integrated front-end processing to reduce the computational load on the main microcontroller while maintaining precise cardiac monitoring functionality in the HydroPace system.

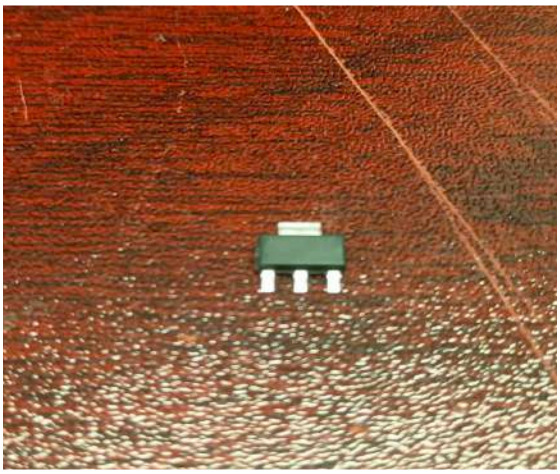

Figure 5.8: Voltage Regulator IC (AMS1117)

AMS1117 voltage regulator IC in the figure 5.8 shows to provide stable, regulated power supply management for the HydroPace cardiac monitoring system. Key objectives include converting variable input voltages from batteries or RF energy harvesting into consistent 3.3V or 5V output levels, protecting sensitive electronic components from voltage spikes and fluctuations, maintaining power efficiency to extend battery life in portable medical devices, providing thermal protection and current limiting to prevent component damage, and ensuring reliable power delivery across varying load conditions to support consistent operation of microcontrollers, sensors, and wireless communication modules in the cardiac monitoring application.

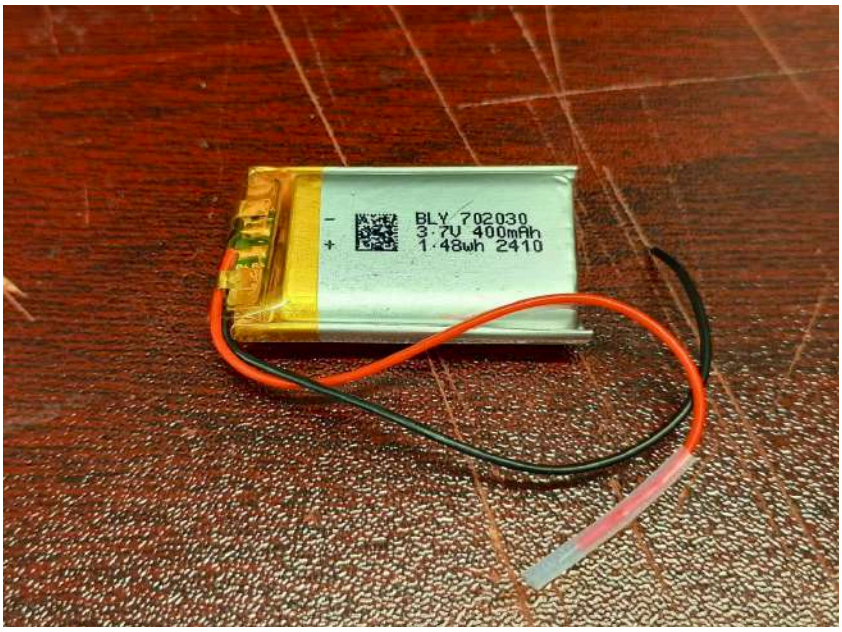

Figure 5.9: Battery for pacemaker 1.48 wh (400 mAh)

A compact lithium battery aims to provide long-term, reliable power for implantable cardiac devices and similar biomedical applications shown in fig 5.9. Key objectives include delivering sustained 400mAh capacity for extended operational life in low-power medical devices, offering high energy density (1.48Wh) in a miniaturized form factor suitable for implantation, providing stable voltage output over extended periods to ensure consistent device performance, maintaining biocompatible materials and sealed construction for safe in-vivo operation, supporting ultra-low self-discharge rates for multi-year shelf life, and enabling reliable power delivery for critical cardiac pacing or monitoring functions where battery failure could have serious medical consequences.

Figure 5.10: Neostigmine Methyl Sulphate (used to synthesize hydrogel)

Neostigmine methyl sulphate in the above figure 5.10 is used to create hydrogel materials for the cardiac monitoring device. The main goals are to make soft, body-safe gel electrodes that stick well to heart tissue, create protective gel coatings around electronic parts, reduce irritation and inflammation when implanted, and form stable gels that work safely inside the body for long periods during heart monitoring.

Figure 5.11: Arduino Uno Board (for the artificial heart) with cable

Arduino Uno microcontroller serves as the central control unit in fig 5.11 for an artificial heart system. Key objectives include precisely controlling pump timing and chamber sequences to simulate natural heartbeat patterns, monitoring vital sensors for pressure and flow rate feedback, implementing critical safety protocols and emergency shutdown mechanisms, providing USB connectivity for programming custom heart rhythms and collecting diagnostic data, managing power distribution to actuators that drive the artificial heart chambers, and offering a programmable platform for testing, calibrating, and operating artificial heart prototypes in research or clinical environments.

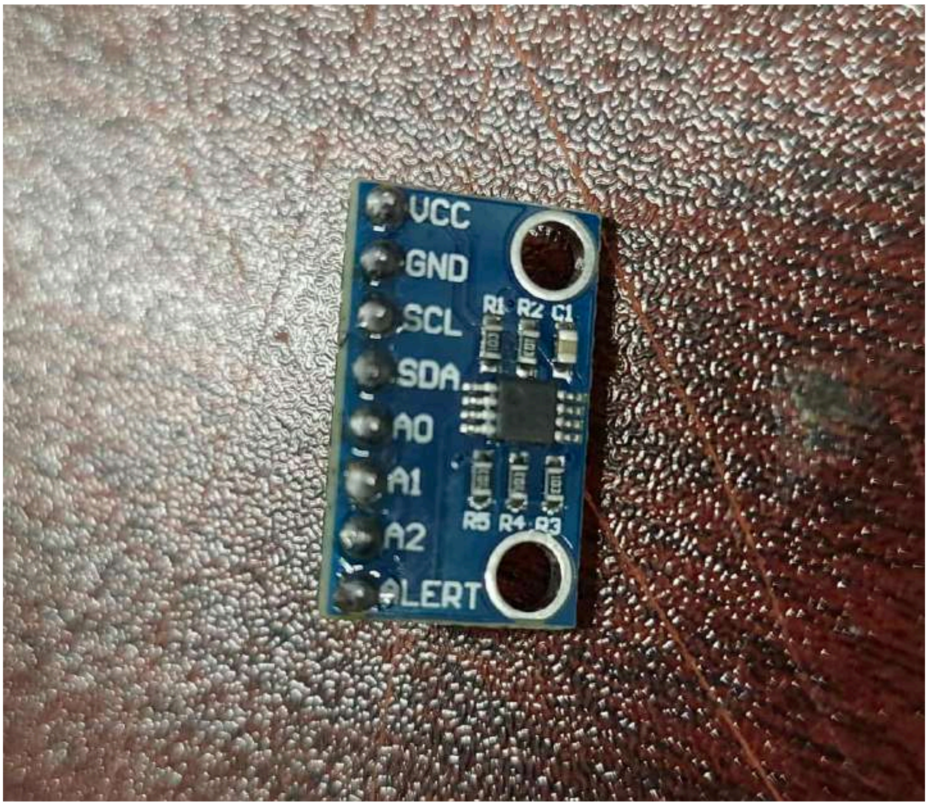

Figure 5.12: MCP 9808

This is a breakout board for the MCP3424 (or MCP3421/22 series) 18-bit Delta-Sigma ADC, which communicates via the I²C protocol. The board has pins for VCC and GND (power), SCL and SDA (I²C clock and data), along with A0, A1, and A2 pins that let you configure the device's I²C address so multiple ADCs can be used on the same bus. The ALERT pin can function as a programmable comparator output or data-ready indicator. This module is widely used for high-resolution sensor data acquisition, voltage monitoring, and precision measurement tasks with microcontrollers such as Arduino, ESP32, or Raspberry Pi that is used in fig 5.12.

Fig 5.13: Four different chemicals acquired for the preparation of hydrogel

Here in figure 5.13, we have shown four of six chemicals that are required to make the hydrogel. One of the chemicals that had been acquired early has been shown in figure 5.10. Each of the chemicals are wrapped in plastic airtight bags except the small red jar.

Fig 5.14: N,N'-Methylenebisacrylamide chemical

Figure 5.14 shows N,N'-Methylenebisacylamide or bis, which is one of the most essential chemicals to create polymer chains in order to maintain hydrogel stability.

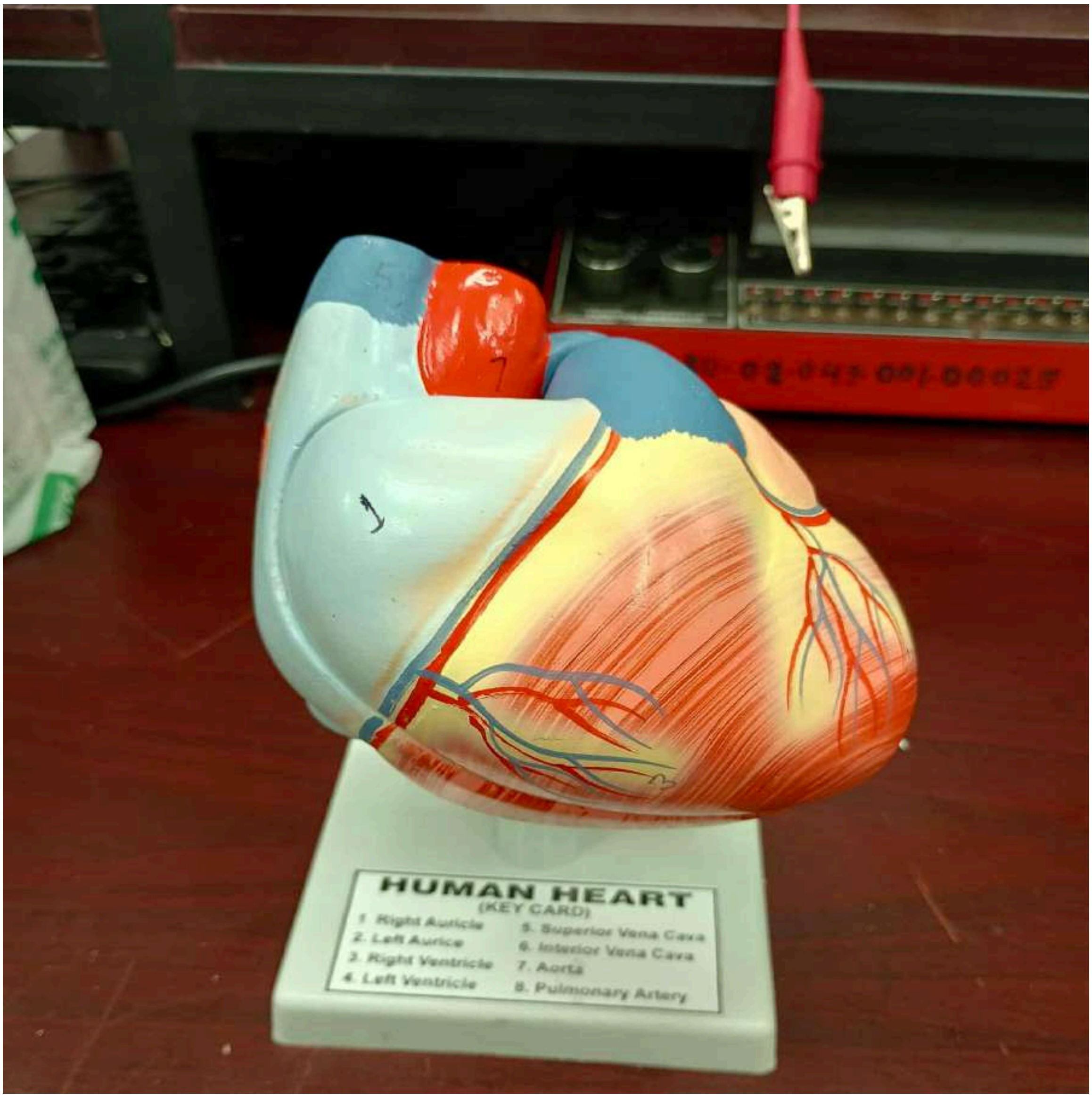

Fig 5.15: Artificial human heart model

The above fig 5.15 is an artificial human heart. We have searched for a mechanical beating heart that we could bring from overseas. However, the budget, complexity, operational capability and the overall size were beyond our time and ability to handle for the FYDP-C project.

Fig 5.16: Silane A174

Figure 5.16 shows Silane A174, also known as TetraMethylSPMA. This is particularly crucial for the elasticity of the hydrogel.

Fig 5.17: Lithiumphenyl(2,4,6-trimethylbenzoyl)

The chemical shown in figure 5.17 is among all the chemicals mentioned in the literature that are essential for the formation of the hydrogel. This chemical in particular aids in increasing cross-linkage of the hydrogel polymer chains.

Fig 5.18: ESP32-S3 bluetooth integrated board

The microprocessor board shown in figure 5.18 has been chosen to be the final dedicated central processing unit for the HydroPace pacemaker. This is because more tests done with the previously selected ATMega328PB-AU showed that the former microchip is unable to handle the modified codes for our purpose. As a result, we switched to this processor which has built-in bluetooth support and is within the size constraint of our pacemaker in order to fulfill our objectives with more ease.

Fig 5.19: Silver nitrate (AgNO3) solution

We could not obtain the PEDOT:PSS chemical due to geopolitical issues between India and Bangladesh. As an alternative, we are using Silver Nitrate in order to achieve conductivity in our hydrogel, since that was the role that would have been fulfilled by PEDOT:PSS. Silver Nitrate (AgNO3) is shown in fig 5.19.

5.2.2 Tools for Assistance:

Figure 5.20: Mini drill (for hydrogel preparing process)

The compact drill facilitates precision work during hydrogel electrode preparation. It creates precise holes in substrate materials, enables fine machining of hydrogel components, provides portable drilling for lab prototyping, and supports manufacturing custom electrode geometries for the cardiac monitoring system assembly shown in fig 5.20.

Fig 5.21: Power Brick 12V-2A

In the fig 5.21 the power adapter converts AC power to stable 12V DC output at 2A capacity. It provides reliable bench power for testing the cardiac monitoring system, enables continuous operation without batteries, and supplies sufficient current for charging batteries and powering external components during development and laboratory use.

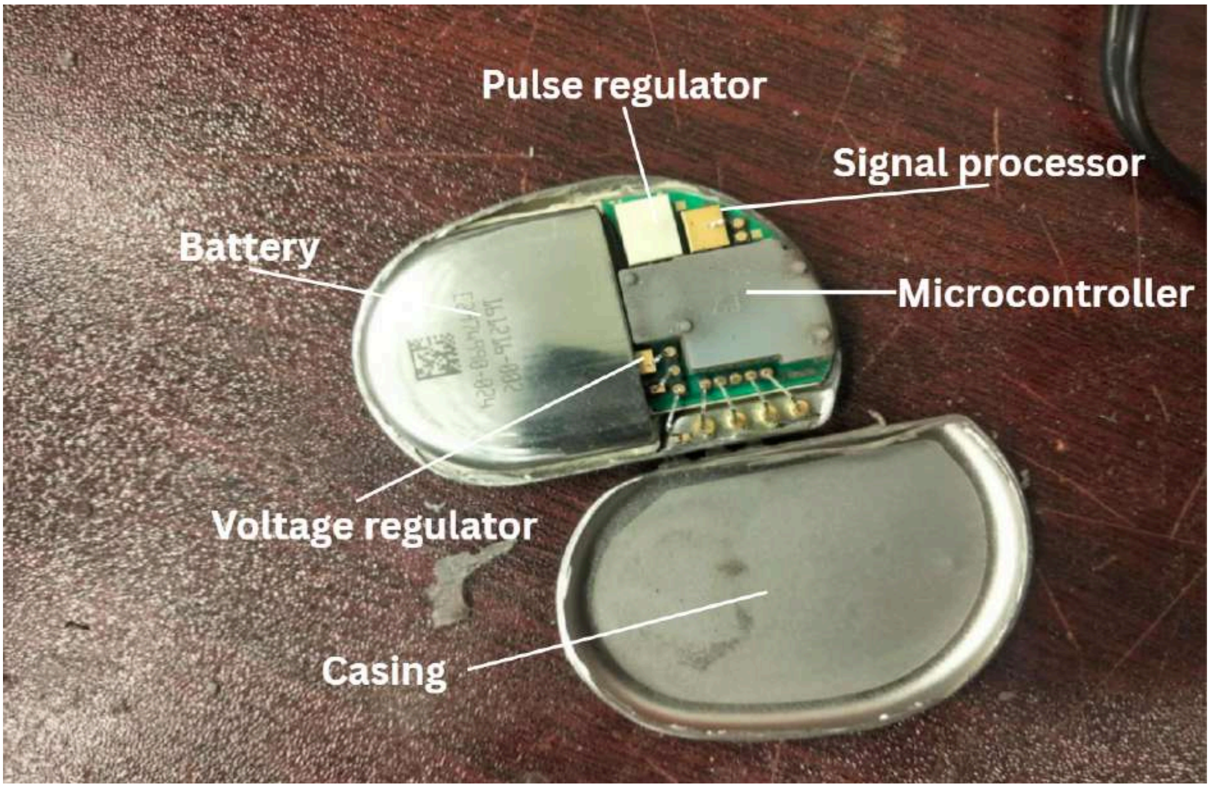

Figure 5.22: Inside of a traditional pacemaker

Disassembled pacemaker reveals the internal components for study and analysis shown in fig 5.22. Key objectives include examining the compact battery, circuit board layout, and miniaturization techniques, understanding power management and signal processing designs, studying biocompatible encapsulation methods, and extracting design principles for developing the HydroPace cardiac monitoring system.

5.2.3 Designing Schematics in Altium Designer:

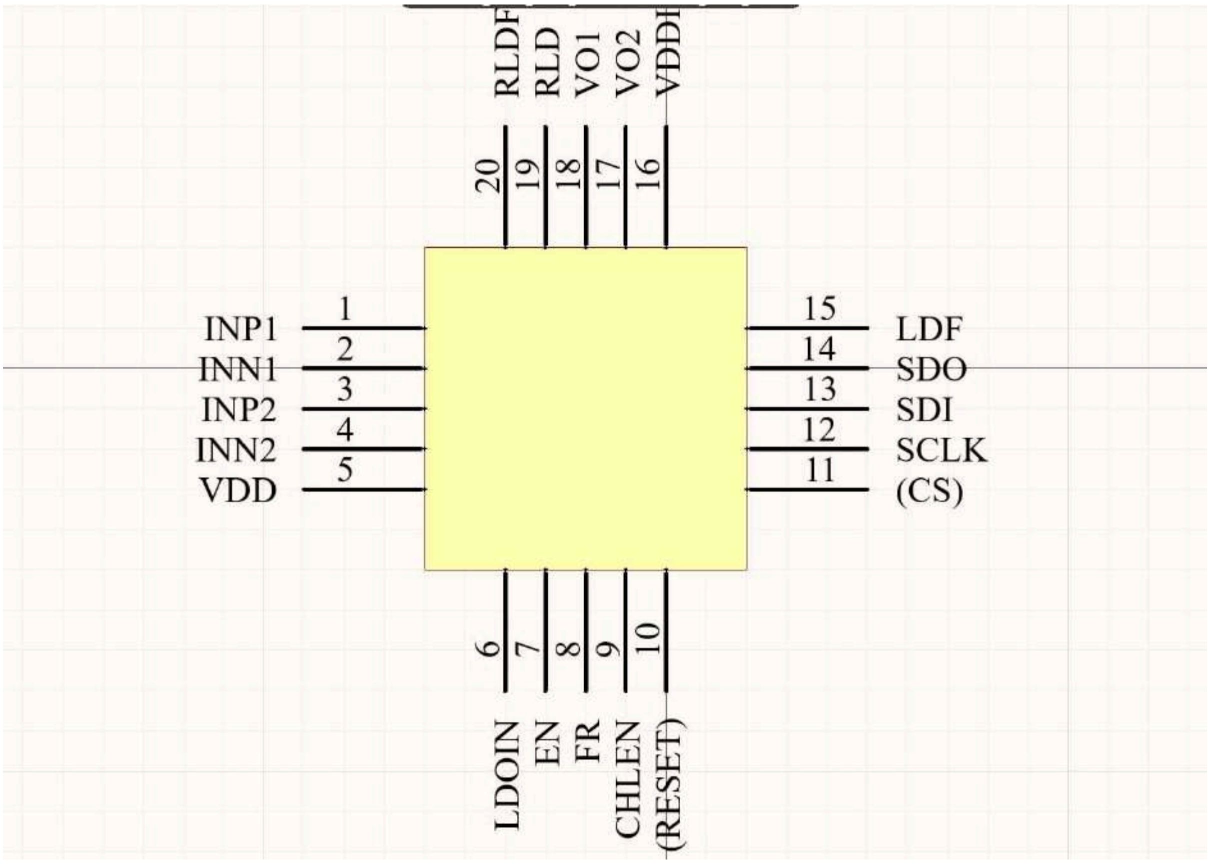

Figure 5.23: Schematic of signal processor

In the fig 5.23 shows the schematic of the Kingsense 1082 signal processing IC using Altium Designer, mapping all essential analog input channels, digital interfaces (SPI: SDO, SDI, SCLK, CS), power pins, and control signals to facilitate accurate biosignal acquisition and data communication within an embedded system. This was required to be made, as no existing model of our signal processor exists for use in Altium, therefore making the signal processor IC model will enable us to create an accurate design of the PCB.

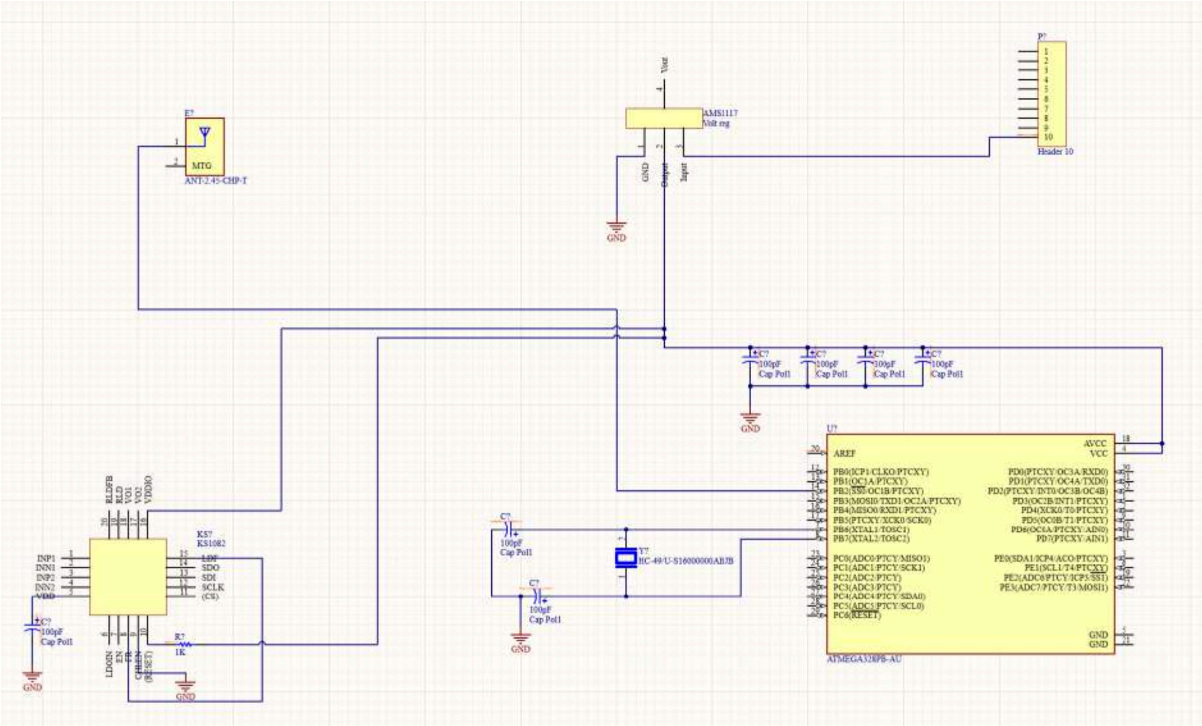

Figure 5.24: Initial 2D PCB circuit schematic model for HydroPace

Here, in figure 5.24 we can see the initial circuit schematic for our PCB. According to the literature, they used a microcontroller with a built-in low-noise amplifier. However, we were unable to obtain that microcontroller, and are using ATMega328PB-U, which does not have a built-in LNA. Therefore, we are considering an additional external LNA. However, we are unsure as to whether we will require one as we are not using an actual heart, rather, we are simulating the actual cardiac environment. Further modifications in this schematic will lead to the completion of our PCB design, which will be then ordered for manufacturing.

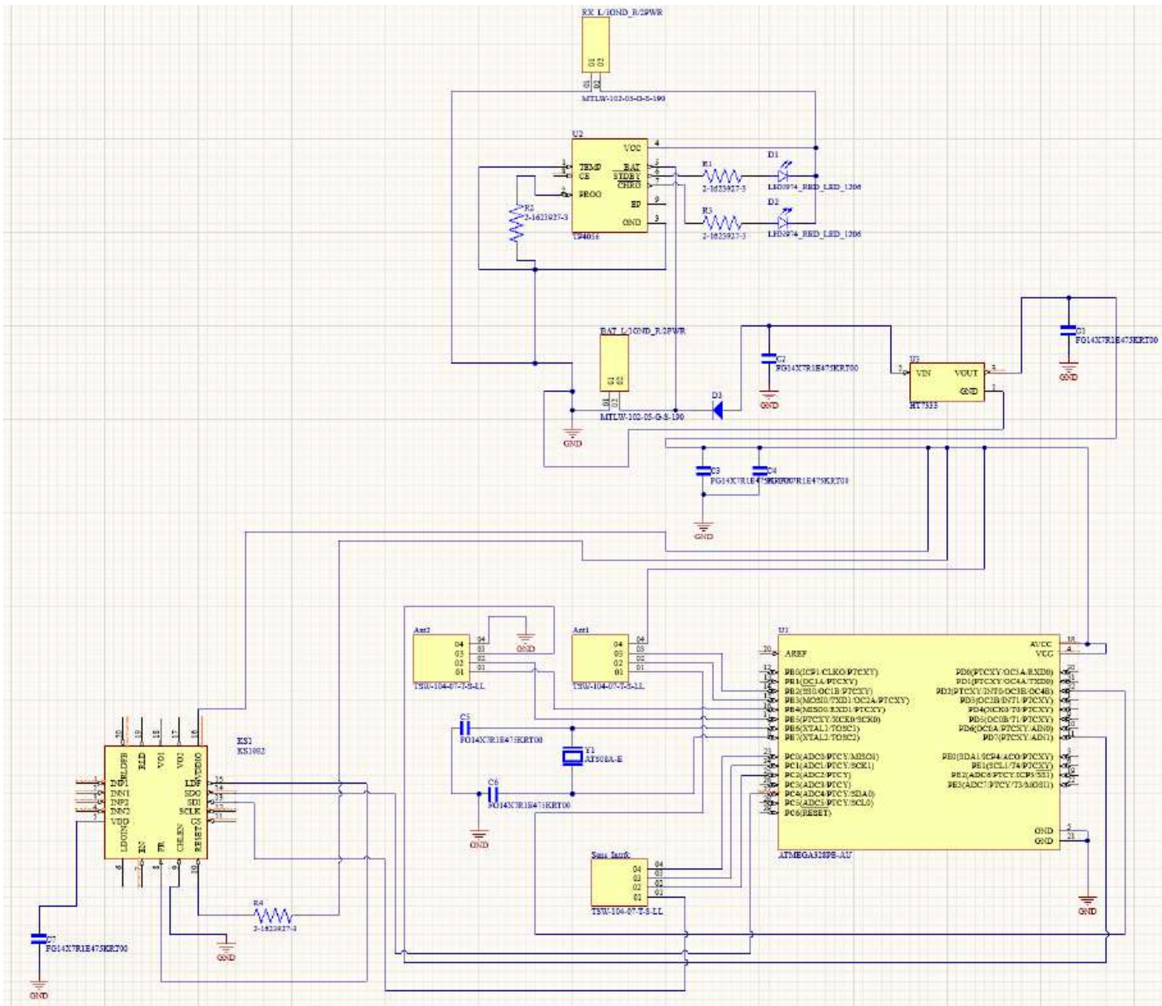

Figure 5.25: Revised 2D PCB circuit schematic model for HydroPace

Unlike in figure 5.24, here in figure 5.25 we can see the revised circuit schematic for our PCB. In accordance with the components in hand and figuring out the best possible way we could find to build the schematics for our PCB was nothing short of challenging. Nevertheless, we have been able to complete the schematics and PCB files for our design. In figure 5.25 we can see that there is one 2H header pin which is a connection where the battery terminals will be soldered. The two header 4Hs will accommodate the antenna pinouts, and the header 5H will be the interface between the incoming strap of wire from the sensors and the PCB. The signal processor is on the bottom left, and the voltage regulator is towards the top. The largest component is the ATMega328PB-U microprocessor. With this design, our schematic for the PCB is complete.

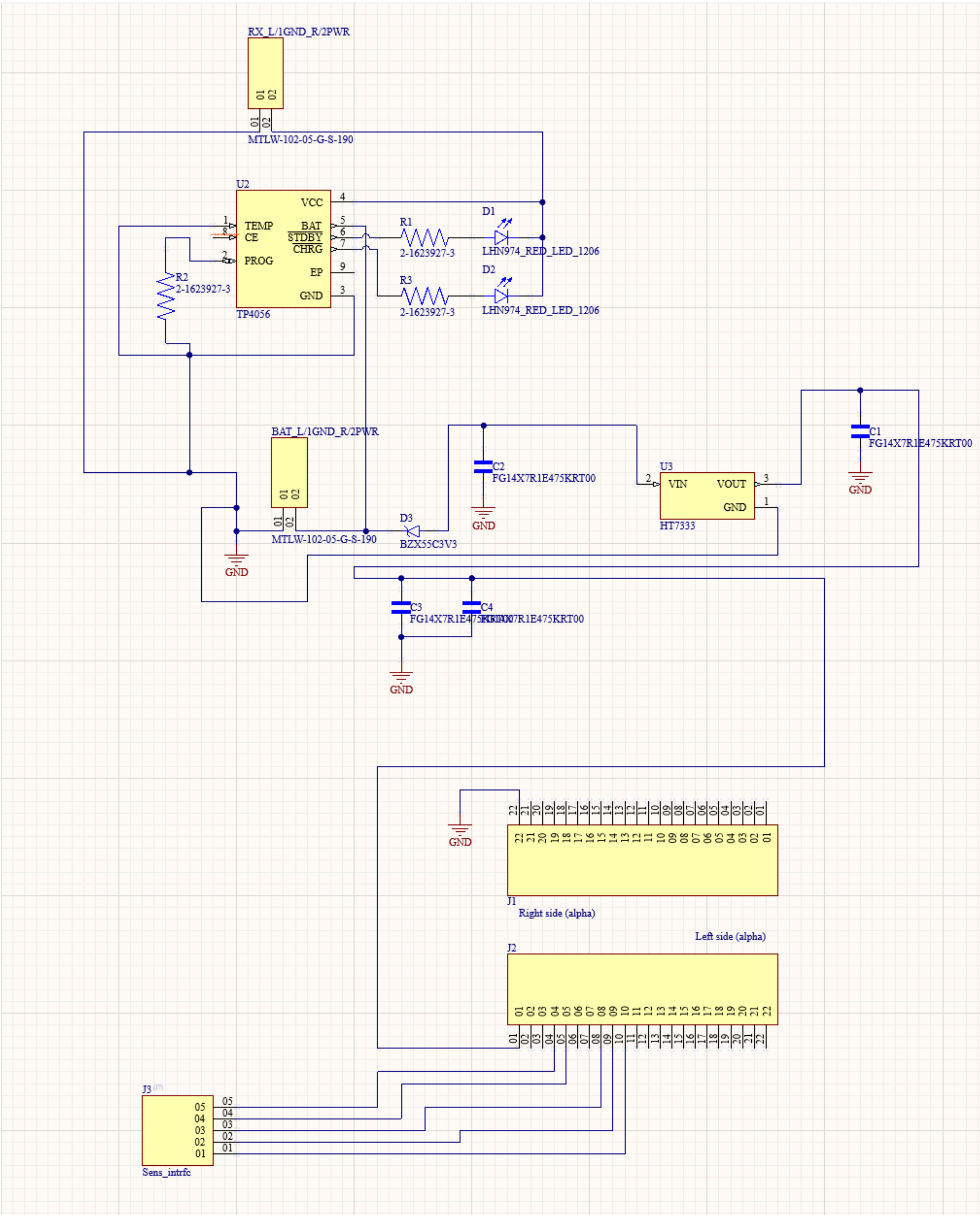

Fig 5.26: Final Schematics Design

The final schematics shown above in figure 5.26 shows the appropriate header implementation for ESP32-S3 board since the original vision for the PCB was not realized. This happened due to multiple reasons which include the discrepancy we observed during testing the Arduino Uno R3 SMD where the ATMega328P chip showed errors while handling all the processing, and the discrepancy we observed with Kingsense 1082 signal processor which we could not implement due to its high accuracy auto-reset nature where it automatically sets the voltage levels obtained from ECG signals, which in our case is detrimental as it breaks our ECG signal monitoring (shown in figure). Therefore, we have implemented a simple design for our PCB that will make use of the wireless charging feature and the ESP32-S3 board for signal processing and data management.

5.2.4 Designing PCB layout in Altium Designer:

Our Initial PCB Design and its improvements

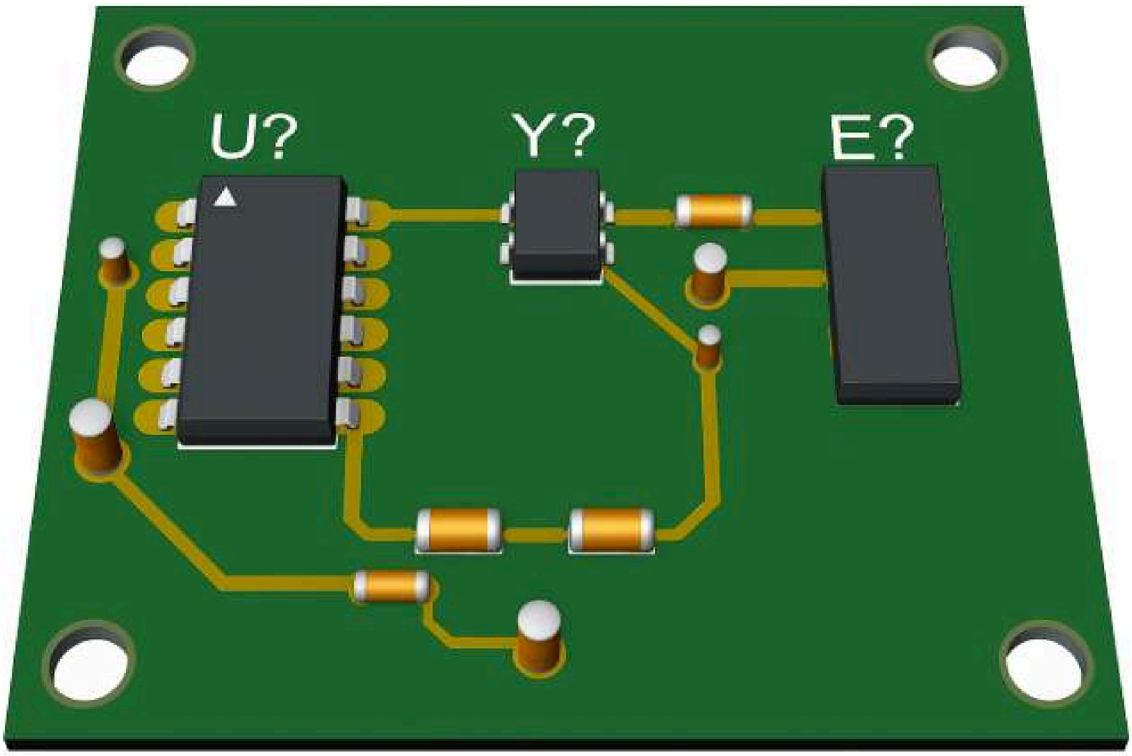

Figure 5.27: The initial simplified PCB design

To develop a basic and functional PCB prototype that supports core signal processing and communication features for the hydrogel-based cardiac pacemaker, enabling early testing and validation shown in fig 5.27.

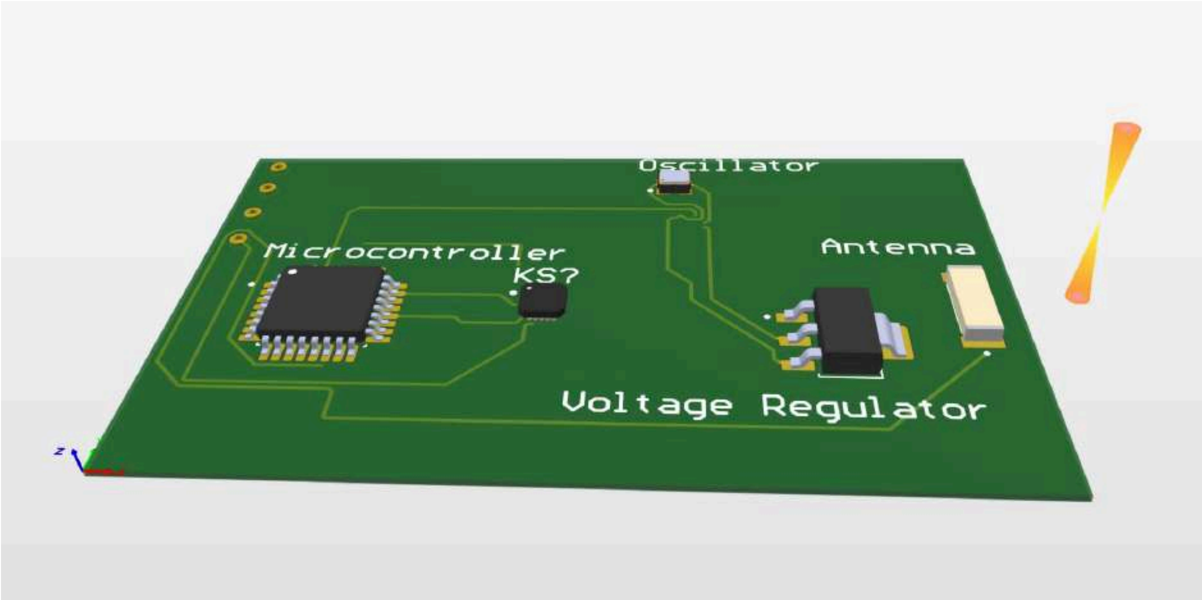

Figure 5.28: PCB making in process (2nd iteration)

The second iteration is using the signal processor model (KS) shown below, we have progressed on our design and development of our printed circuit board (PCB) which integrates key components microcontroller, oscillator, voltage regulator, and antenna for wireless communication and power management, as part of the second iteration of hardware prototyping as shown above fig 5.28.

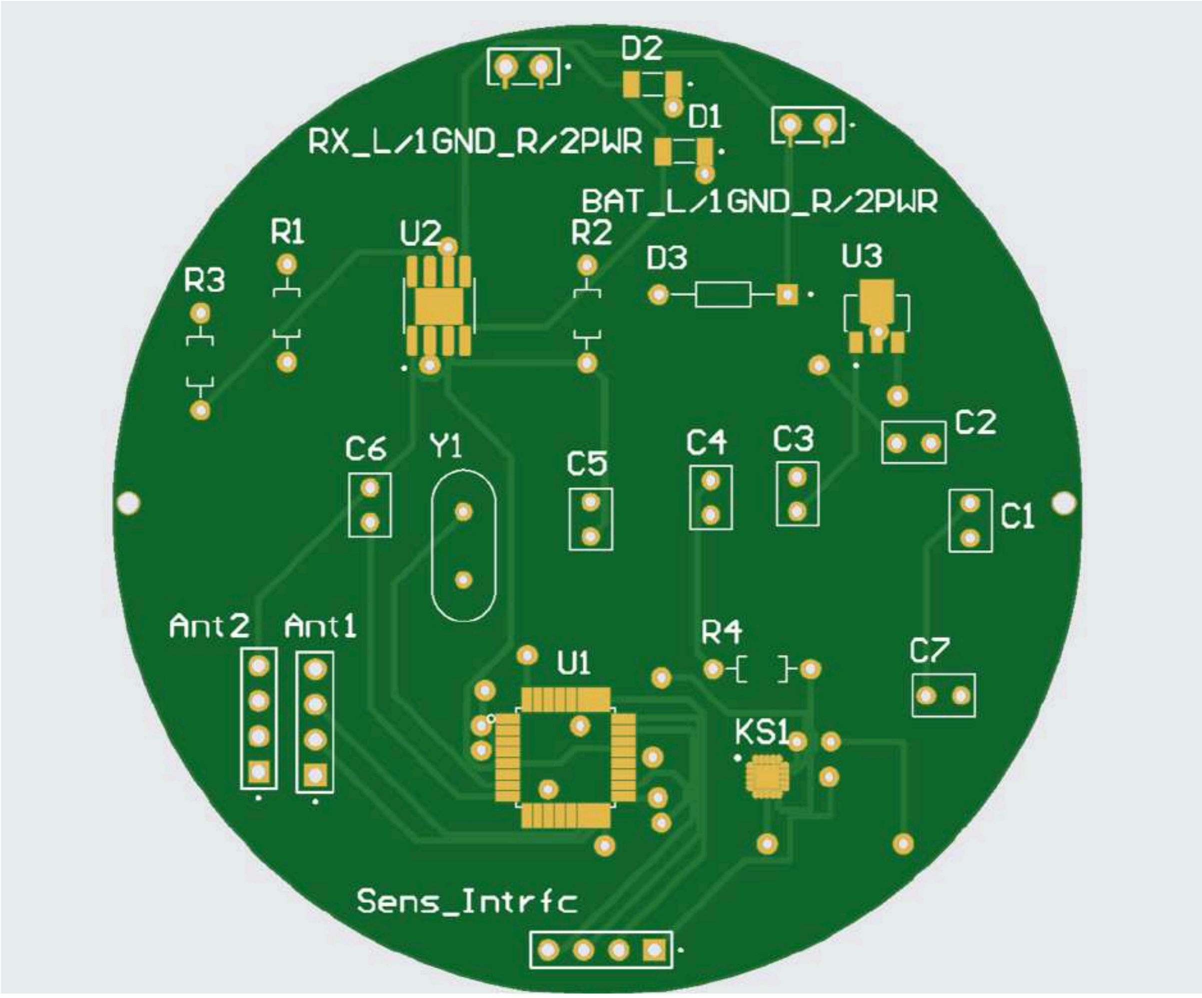

Fig 5.29: Revised PCB Design

The above figure 5.29 shows the PCB design of the HydroPace pacemaker in which we will solder the necessary components. The PCB design was done by Altium software. This is the revised version of the previous PCB design and it includes the operations that we desired to implement using ATMega328P microcontroller.

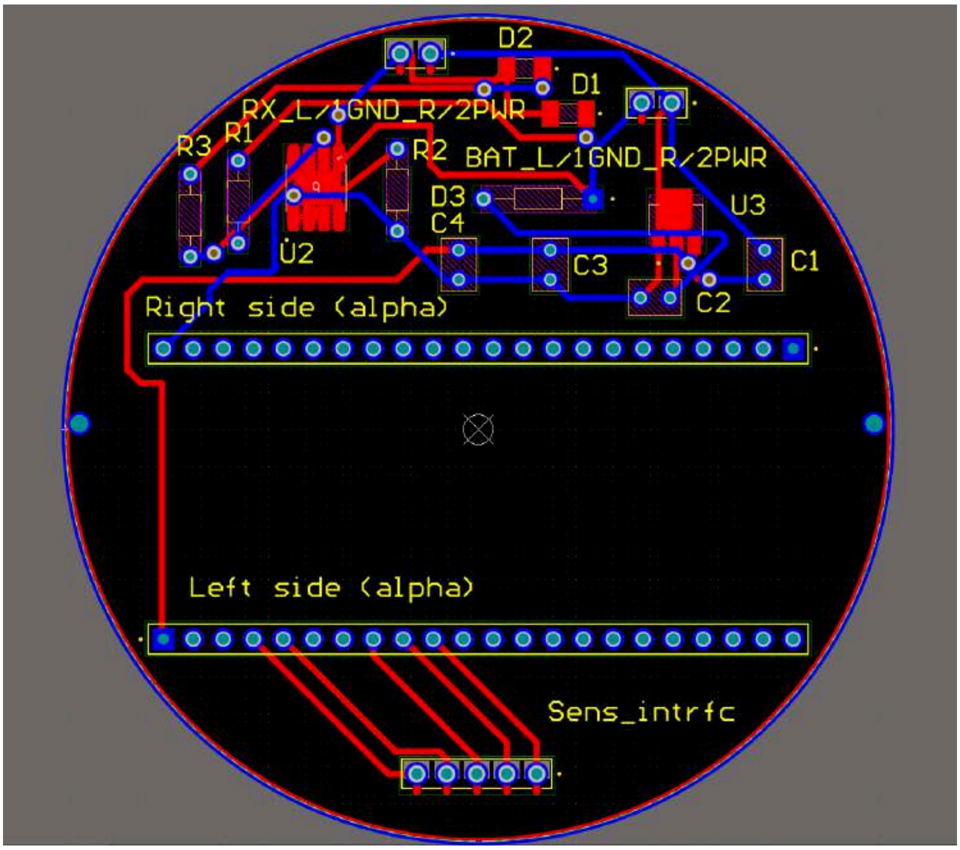

Fig 5.30: Final PCB Design

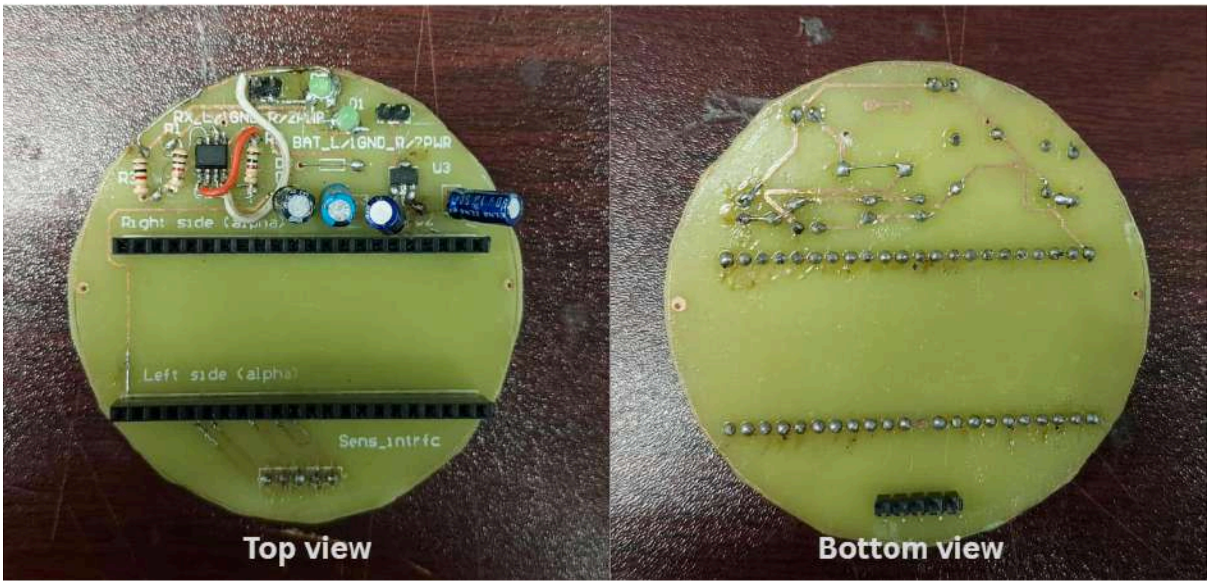

Fig 5.31: Final PCB board

Fig 5.32: Final PCB board with ESP32-S3 attached

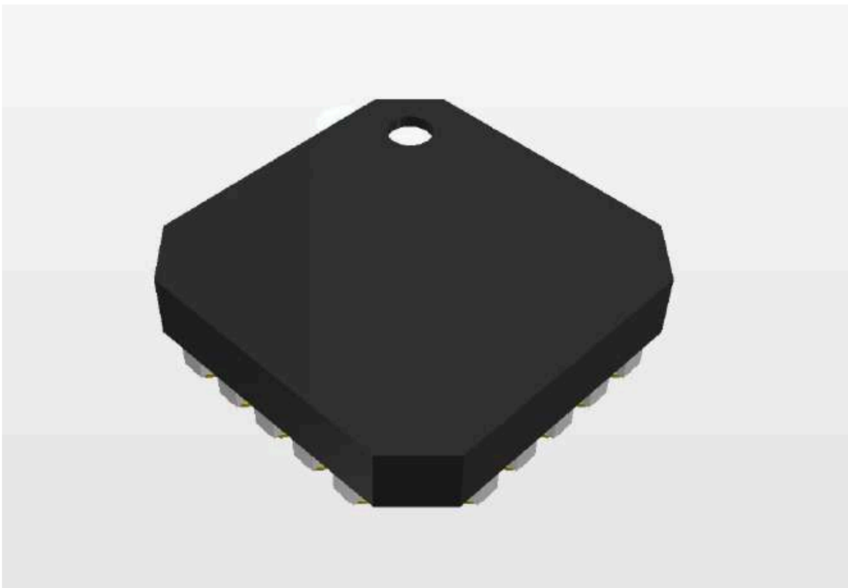

Figure 5.33: 3D IC model for signal Processor

The fig. 5.30 shows the final PCB design based on the final schematics design, and the real PCB board that arrived has been shown in fig. 5.31. Figure 5.32 shows the PCB board with the ES32-S3 attached as intended. We made a 3D IC of the Kingsense signal processor in order to implement it in the pacemaker as shown in fig. 5.33, but due to various constraints, it remained unimplemented. The PCB will sit inside the pacemaker case that has been 3D printed as shown in figure 5.72.

5.2.5 Supporting Equipment for Hydrogel:

Figure 5.34: Deep Freezer

Figure 5.34 shows a deep freezer, which is used to preserve materials at very low temperatures. It plays an important role in laboratories and medical facilities by storing sensitive biological samples, medicines, and equipment that require strict temperature control. The deep freezer ensures long-term stability of these items by maintaining a constant cold environment, making it essential for research, experiments, and medical applications where preservation of temperature-sensitive materials is critical.

Figure 5.35: Normal Freezer

The normal freezer also plays an important role in laboratories and medical facilities by storing sensitive biological samples, medicines, and equipment that require strict temperature control that is shown in the fig 5.35.

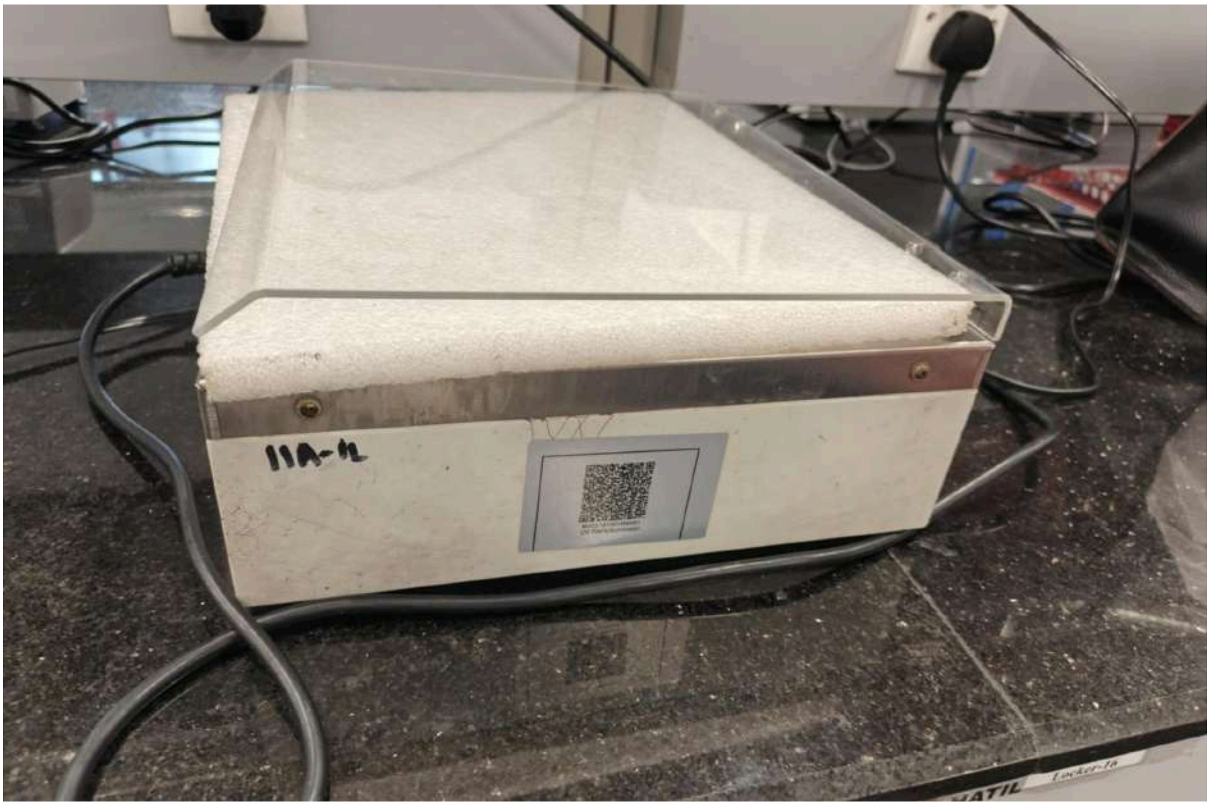

Figure 5.36: UV treatment machine

This mentioned fig 5.36 shows a UV treatment machine, which is commonly used for sterilization and disinfection purposes. It utilizes ultraviolet (UV) light to eliminate or inactivate microorganisms such as bacteria, viruses, and fungi on surfaces or within samples. This type of machine is widely applied in laboratories and healthcare settings to ensure contamination-free environments and to maintain the sterility of sensitive materials and equipment.

Figure 5.37: Vortex mixer

Vortex mixer is a laboratory device used to mix small liquid samples quickly and efficiently shown in fig 5.37. It works by creating a rapid circular motion that generates a vortex within the container, ensuring uniform mixing of solutions. This equipment is commonly used in biological, chemical, and clinical laboratories for tasks such as mixing reagents, suspensions, or cell samples.

5.2.6 Component testing:

We have chosen standard methods to test our components which include the following:

1. Isolation: This is a component-level testing where each component is separately tested for its operation. It is seen whether any components show any form of output for any input. We have chosen to supply recommended voltage to each component and see if they turn on or give any output.

2. Verification: Each component is tested by running and obtaining the desired outcomes for given inputs, either individually or in a group as per requirements.

3. Mocking and stubbing: Testing the entire setup by providing a mock code into the system.

4. Debugging: After mocking and stubbing, implementation of the actual code is done and any errors are distinguished and corrected.

During component testing, we have seen that all of our components work well except the LEDs most of which do not turn on.

- **Investigating a traditional pacemaker:**

Figure 5.38: Opening the pacemaker

To disassemble the pacemaker device for component analysis and reverse engineering. Key objectives include accessing internal electronics and battery components, studying the device's construction and design principles, extracting useful components for the HydroPace project, and understanding miniaturization techniques used in implantable cardiac devices for research and development purposes that was done in fig 5.38.

- **Testing the transmitter and receiver coils:**

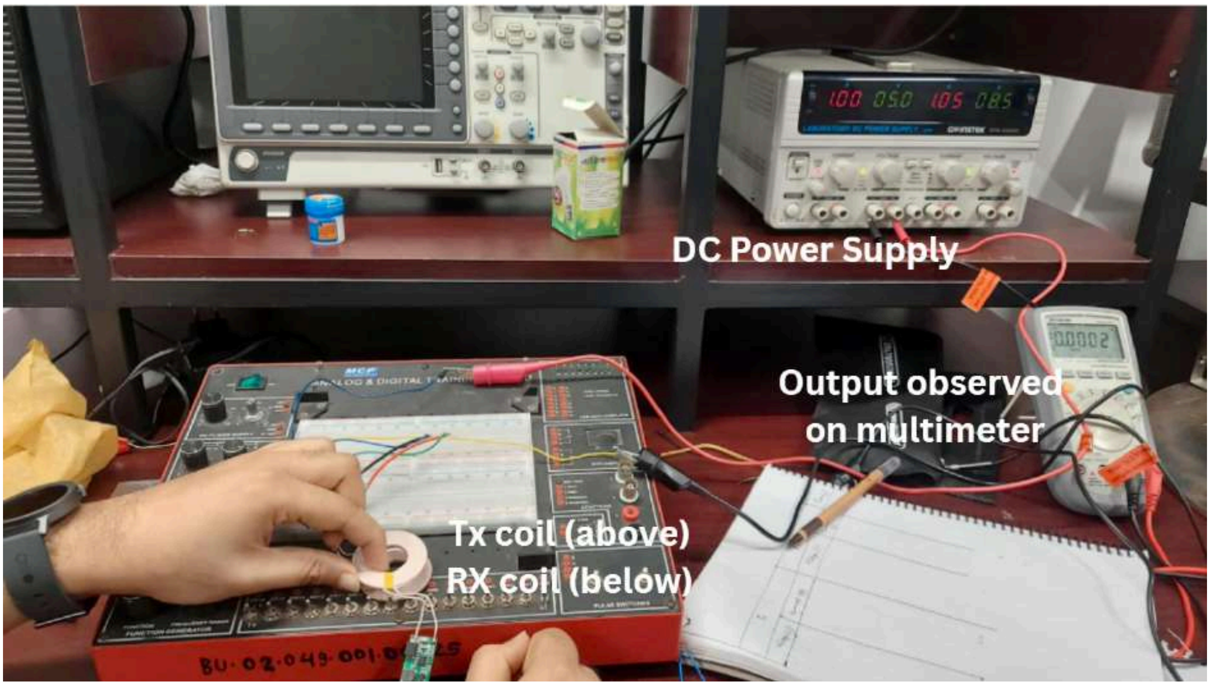

Figure 5.39: Working on the RF Tx and Rx coils

This setup aims to test and optimize the wireless power transfer system for the cardiac monitoring device in fig 5.39. Key objectives include measuring RF transmission efficiency between transmitter and receiver coils, calibrating power transfer distances and coupling alignment, testing wireless charging performance using oscilloscopes and power supplies, and validating the RF energy harvesting capabilities for powering the HydroPace system wirelessly.

Tested for R = 0.9835~1kΩ, Distance tested 0-5cm between the Tx and Rx coils:

SL. no.	T_X (V,A)	R_X (V)	Distance (cm)
1	5V 1.2A	3.851	0.5
2	6V 1.2A	5.2	0.55
3	9V 1.2A	5.2	0.6
4	10V 1.2A	5.2	0.5
5	12V 1.2A	5.2	1.6
6	5V 1.4A	3.59	0.5
7	6V 1.4A	5.2	0.55
8	7V 1.4A	5.2	0.8

9	5V 1.8A	3.79	0.55
10	5V 2A	3.75	0.55
11	12V 2A	5.2	1.85

It can be observed from the table above that for Input voltage greater than 5 (>5V) provided in the T_X we obtain 5.2V as output from the R_X coil of our module. For Input voltage of 5V (=5V) in the T_X coil we get variation in the output voltage from the R_X coil. The variation then depends on the current value ranging from 3.3V~3.9V. The distance for the proper functioning of T_X-R_X module is proportional to increment of Voltage as well current as input for which we obtain a working range of 0.5cm-1.85cm (~2cm approx.).

- **Designing the voltage regulator circuit:**

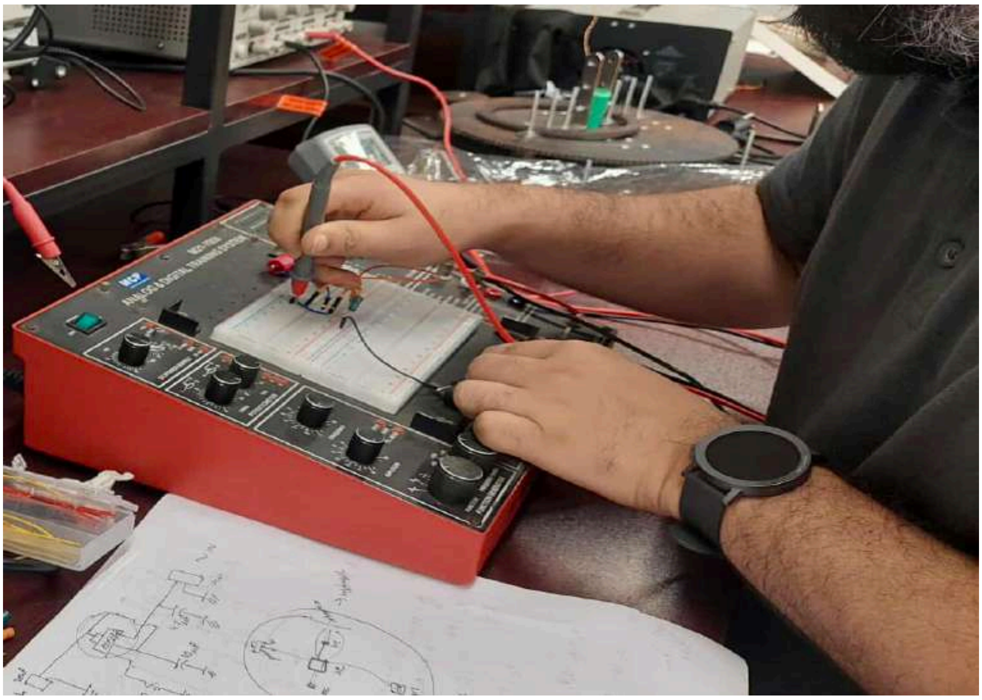

Figure 5.40: Initial implementation of the voltage regulator circuit which produced errors

The initial implementation of the voltage regulator circuit on a trainer board shown in the fig 5.40. The circuit was tested using measurement probes, but errors were observed in the output, indicating the need for adjustments and further refinement in the design.

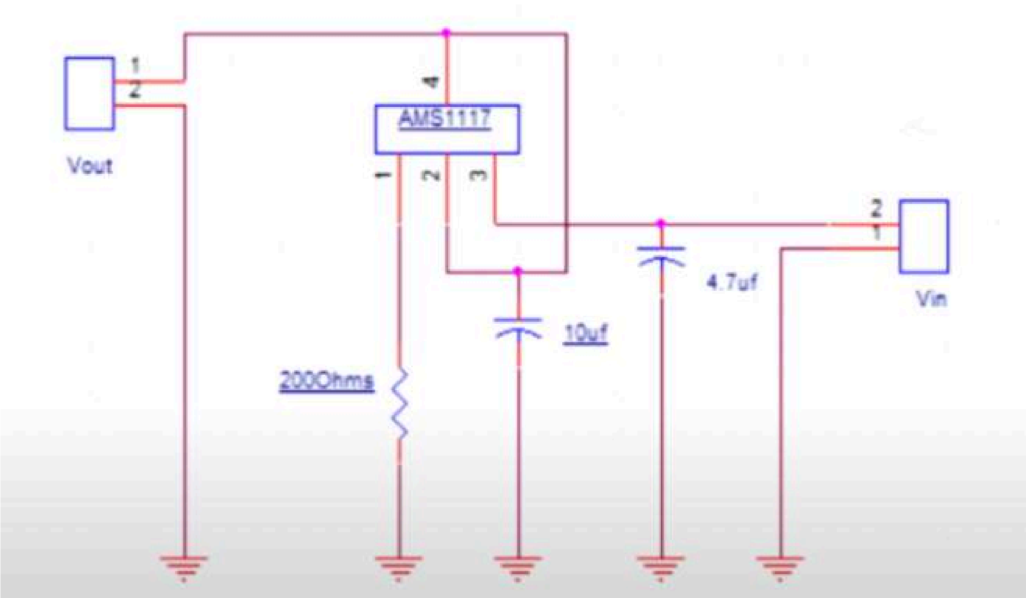

Figure 5.41: Schematic of the circuit implemented here

To work with and analyze the performance of the AMS1117 voltage regulator, we built and tested a circuit as shown in Figure 5.40 and Figure 5.41, ensuring proper assembly and functionality on the breadboard using the training system. However, the results were unsatisfactory, which have been tabulated below:

Error in output:

Input Voltage (V)	Output Voltage (V)
2	1.56
3	2.53
4	3.49
5	4.5
6	5.47
7	6.48

The results produced in this test show erroneous values. After investigating, the circuit was discarded as we deduced that the circuit might have shorted itself due to connection in the fourth pin. We found out that the fourth pin should be left disconnected in order to get the desired stable output results. Therefore, the first run of this test is invalid and we made another attempt.

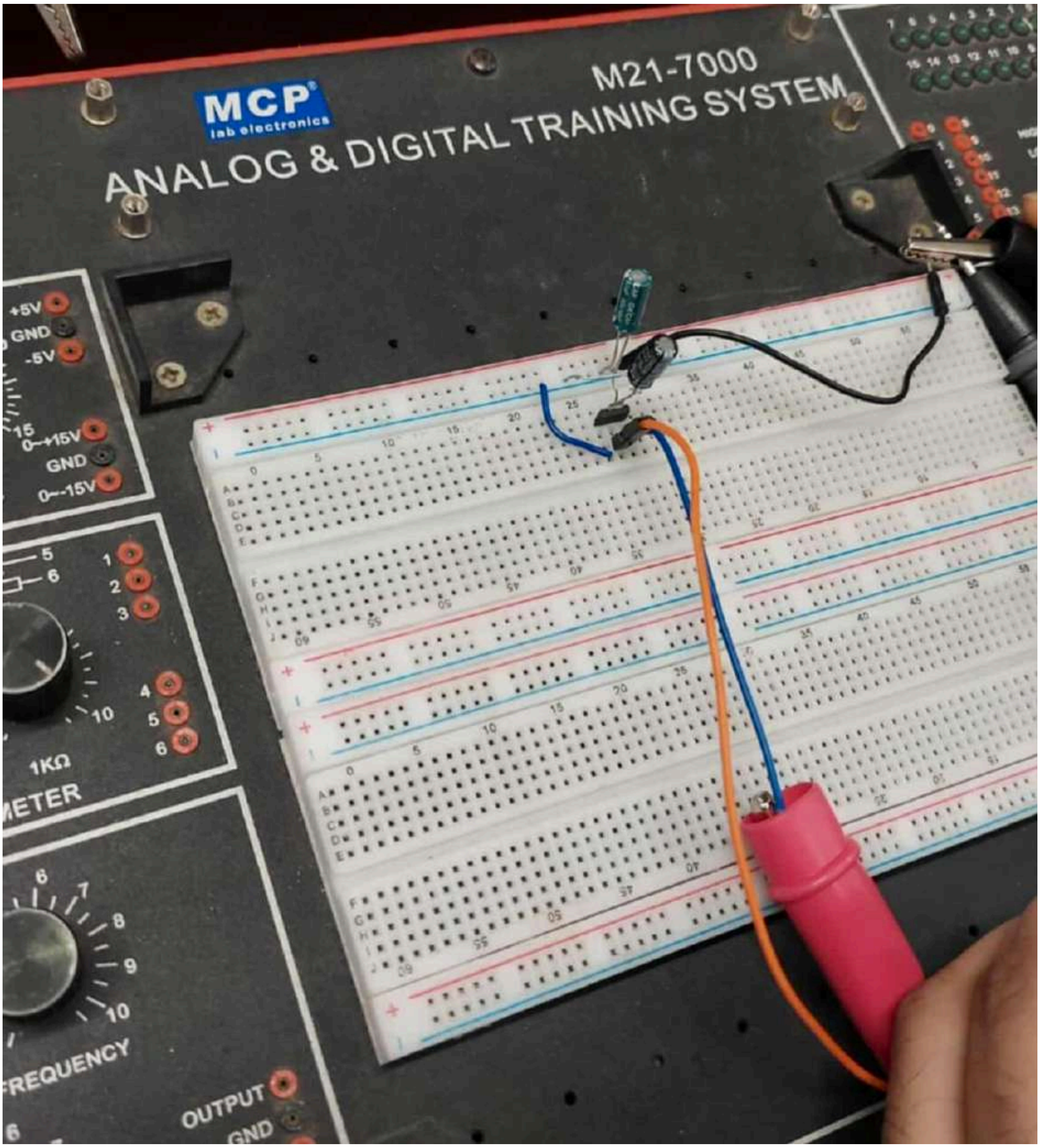

Figure 5.42: Working with the error-corrected circuit for voltage regulator

In this figure 5.42, it shows the error-corrected implementation of the voltage regulator circuit on a breadboard. After resolving the issues from the initial setup, the circuit was successfully reconfigured with proper connections and components, ensuring stable operation. This stage demonstrates the functional testing of the corrected design.

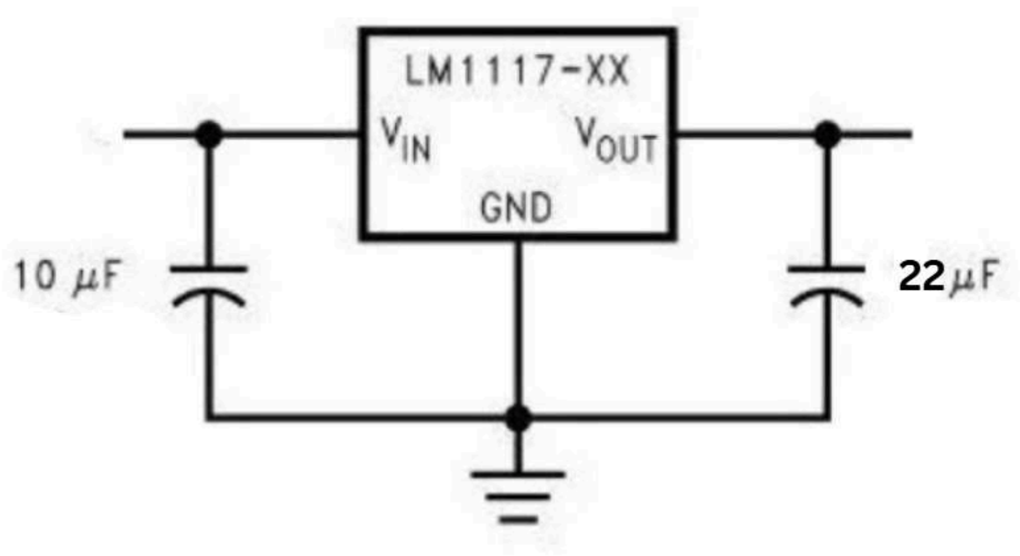

Figure 5.43: Schematic of the error-corrected circuit for voltage regulator

Here we have decided on the correct version of the voltage regulator circuit that we would be required to use for our PCB. In this standalone testing for the AMS117 IC, we have implemented the circuit in figure 5.42, as shown in figure 5.43. The values have been tabulated below:

Corrected Value:

Input Voltage (V)	**Output Voltage (V)**
2	1.183
3	2.132
4	3.103
5	3.294
6	3.295
7	3.296
8	3.297
9	3.298
10	3.298
11	3.299
12	3.301

The above test results are produced from the circuit build displayed in the figure's second implementation. The circuit is for a fixed output test. We have tested for input values ranging from 2-12V and obtained output ranging from 1.183-3.301V. The output voltage for this device (AMS1117) is 3.3V, which is gradually achieved above 2V to the safe maximum level of 12V. Any higher could potentially damage the AMS1117. We have achieved the desired results for the voltage regulator thus validating our isolation test.

- **Pacemaker battery testing:**

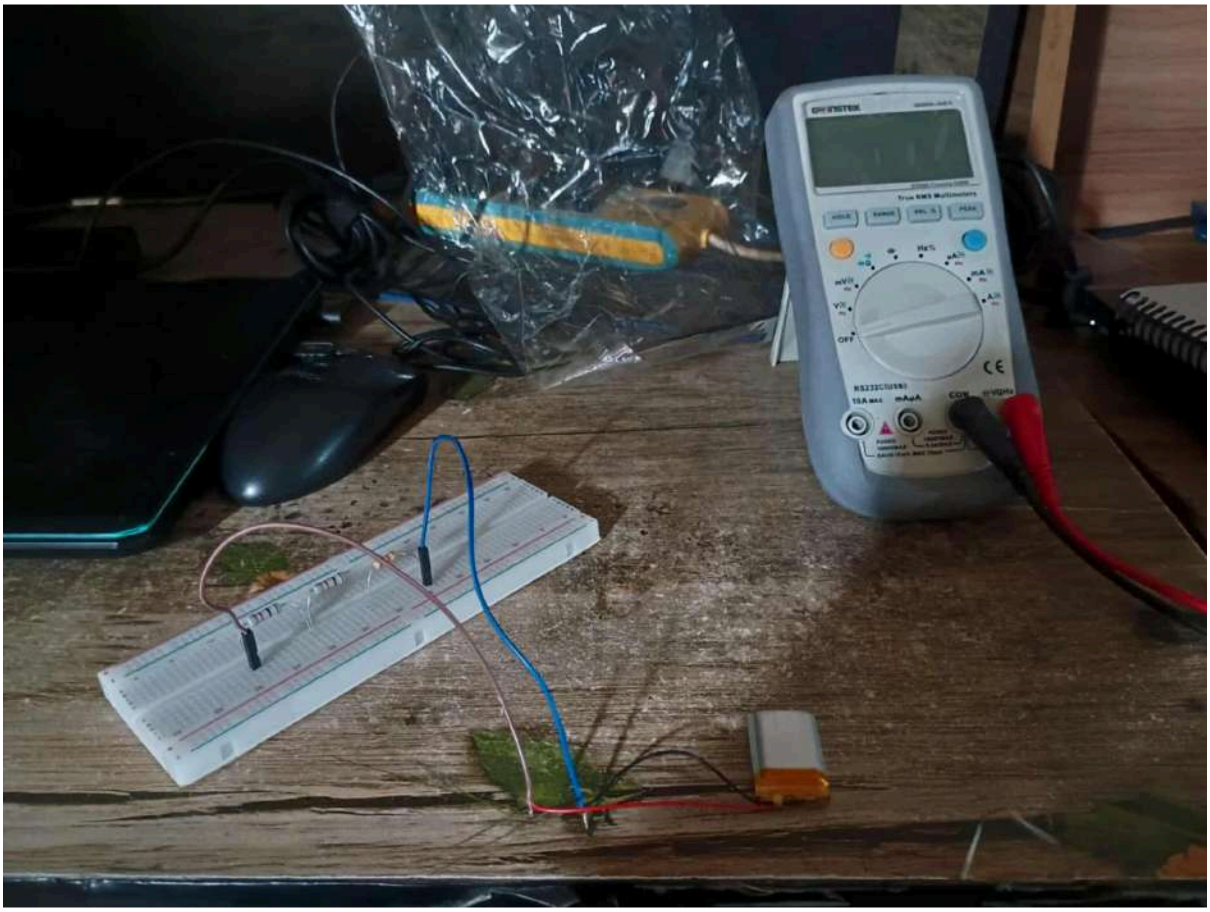

Figure 5.44: Testing the battery (discharging)

To test the discharging characteristics of a battery by measuring its voltage over time using a digital multimeter, as illustrated in Figure 5.44, in order to evaluate its performance and capacity.

- Initial V_1=3.708
- Final V_2=3.694
- After Time, t=5.0 hr = 5.0 hr
- Load R=2.9442 kΩ=2944.2 ΩR
- Current = I=V/R. Because the voltage barely changed, the best single estimate is to use the average voltage $\bar{V}=(V_1+V_2)/2=3.701V$

I_{avg}=V/R=3.701/2944.2=1.257×10^{-3} A≈1.26 mA.
(If you use the initial voltage you get I≈1.259 mA; using the final gives I≈1.255 mA.)

Capacity delivered in 5 hours
Capacity (Ah) = I×t.

Using the average current:

Q=1.257×10−3 A×5 h=6.285×10−3 Ah=6.29 mAh.
(Using the initial-voltage current gives ≈6.30 mAh; using the final-voltage current gives ≈6.27 mAh.)

- Discharge current ≈ **1.26 mA**
- Capacity delivered in 5 h ≈ **6.29 mAh** (≈0.00629 Ah)

Initial Terminal Voltage (V)	Final Terminal Voltage (V)	Discharge Current (mA)	Capacity (mAh)
3.708	3.694	1.26	6.29

Discussion:
The voltage drop for the battery terminals are very insignificant to produce any meaningful results therefore the current results do not validate the product specifications. The battery has a labeled capacity of 400 mAh but in the long time interval due to lack of sufficient load the battery drain did not occur. Without voltage drop recorded and accounted for properly this produced poor results.

LED:
LED testing was successfully completed, identifying and discarding faulty devices. Working LEDs were tested in different configurations, showing that red and green LEDs do not operate properly in parallel due to their different forward voltage drops (red: ~1.8V, green: ~2.4V), with red LEDs drawing most of the current.

- **Testing with a thermocouple:**

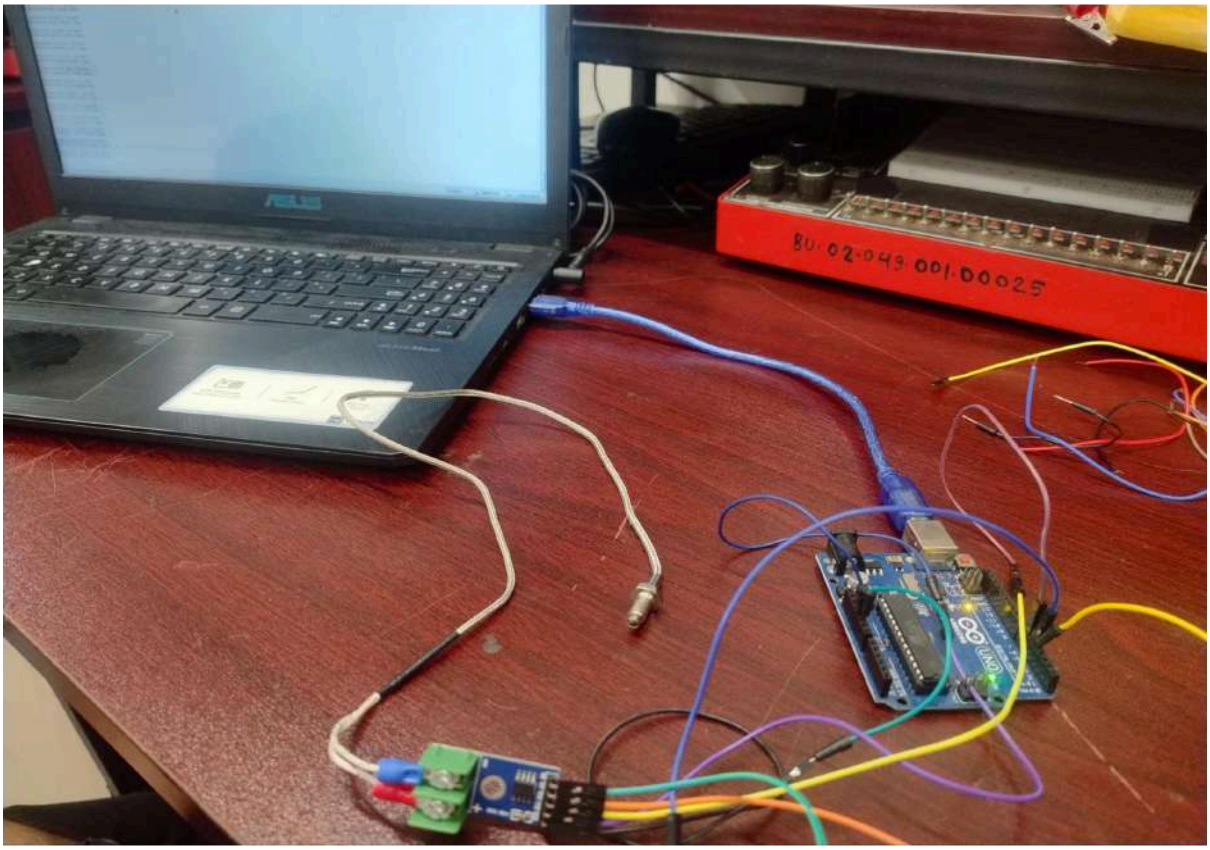

Figure 5.45: Testing the thermocouple

The test and validation of the performance of the thermocouple sensor by interfacing it with an Arduino through a dedicated amplifier module, enabling accurate acquisition and monitoring of real-time temperature readings via the Serial Monitor on a connected computer given in the above fig 5.45.

Input Temp. (℃)	Initial Output Temp. (℃)	Final Output Temp. (℃)	Time (Sec)
300	37	94	300
350	30	97	300
400	29.75	98	300
480	29.75	110.75	300

Discussion:
These tests were performed within 300 seconds for each input recording. The heat source was used from soldering iron. Thermocouple testing was successful and proved to have huge time complexity. The difference of input to output temperature especially for the final recorded temperature ranges from (57℃) ~ (81℃). This huge discrepancy in the recorded temperature values indicates that the thermocouple is subject to atmospheric loss. Although the controlled environment testing conditions were sub optimal, it does show the lack of precision and time complexity of recording temperatures, Hence, it is not suitable for time-sensitive projects which also have very low temperament for lack of precision.

- **Simulating sensing and pacing with both Arduinos:**

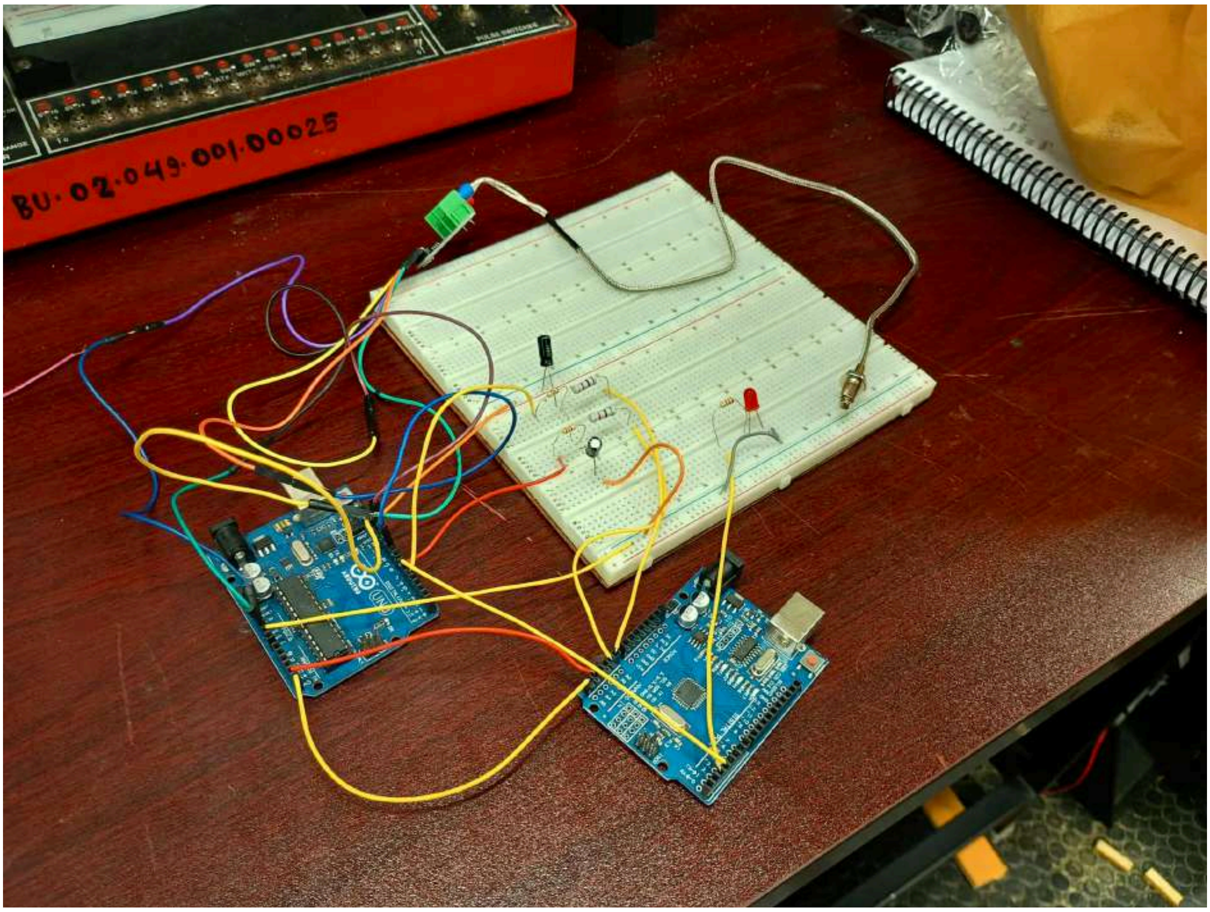

Figure 5.46: Heart simulator and Pacemaker simulator hardware test

There are two Arduino boards connected to a breadboard to simulate heart electrical pulses and pacemaker response fig 5.46. One Arduino generates heartbeat signals, while the other detects and delivers pacing, with LEDs providing visual indication of signal generation, detection, and response.

- **Simulating temperature values of heart:**

Figure 5.47: Heart Temperature simulation

The experimental setup for heart temperature simulation is shown in fig 5.47. An Arduino board is connected with a breadboard circuit and interfaced to a laptop for monitoring and analysis. A heat source is applied to mimic temperature changes, allowing the system to demonstrate its capability in detecting and responding to variations relevant to biomedical conditions.

- **Analysing two of the three cardiac health parameters:**

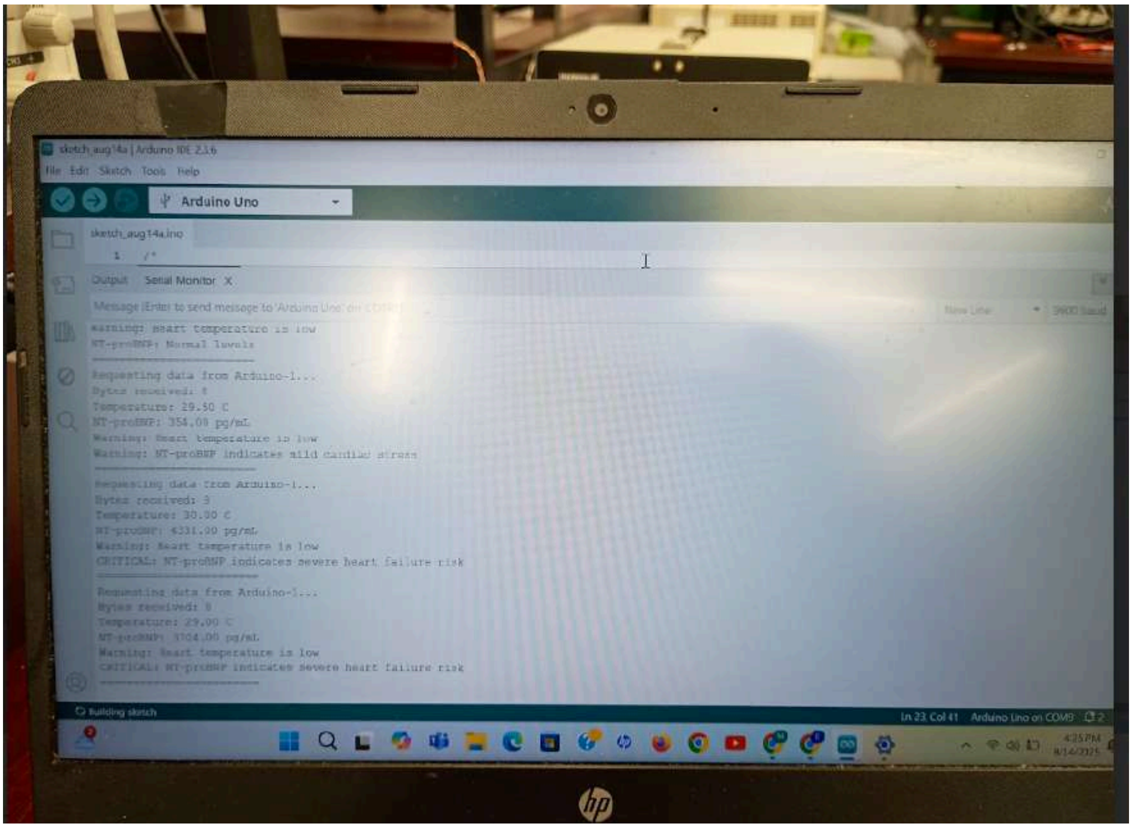

Figure 5.48: Temperature and Biochemical data analysis of Pacemaker

Figure 5.48 shows the Arduino Serial Monitor displaying real-time temperature and biochemical data from the pacemaker. The system processes these inputs to identify abnormal conditions, provide alerts, and assess potential risks such as heart failure. This demonstrates the pacemaker's ability to integrate multiple health parameters for improved monitoring and diagnosis.

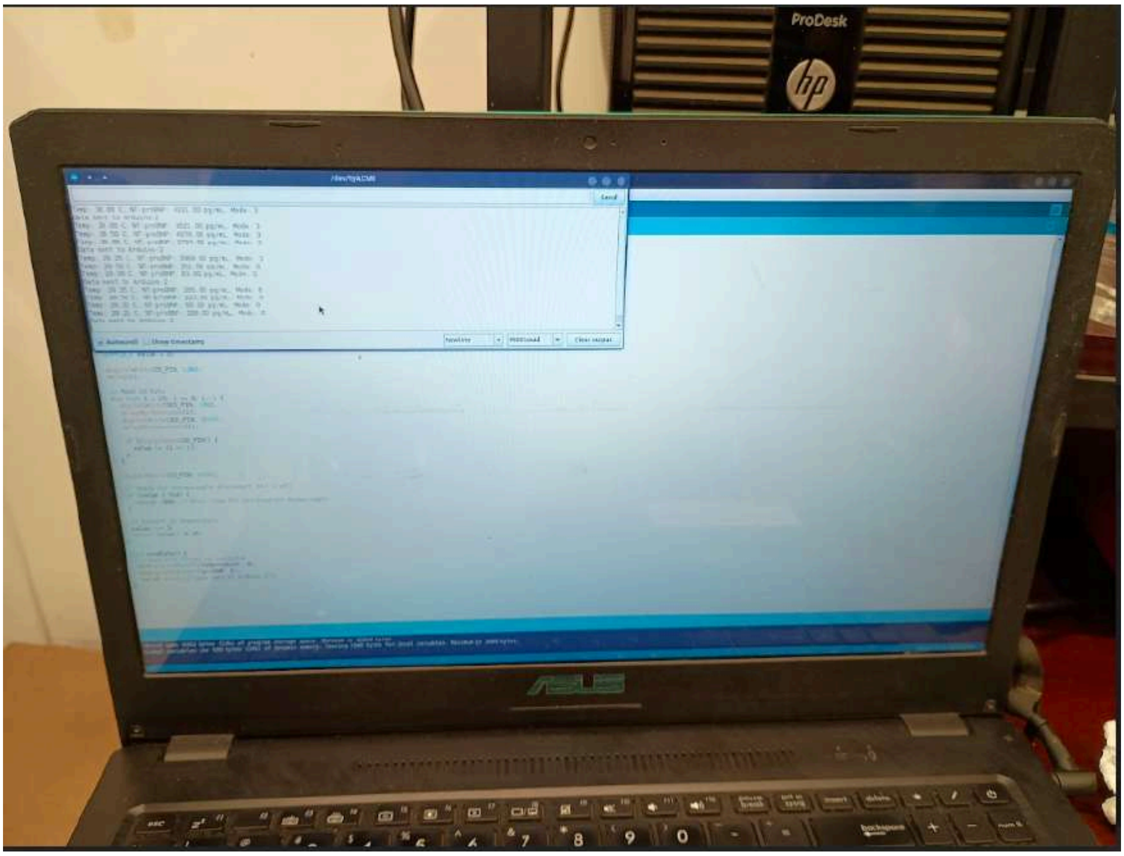

Figure 5.49: Temperature and Biochemical reading of Heart simulator

Arduino Serial Monitor presenting temperature and biochemical readings generated from the heart simulator in the above fig 5.49. These simulated values serve as input data for testing the pacemaker's functionality, allowing validation of how the device responds to different physiological conditions. It ensures that the pacemaker can reliably interpret sensor data and provide accurate analysis for patient monitoring.

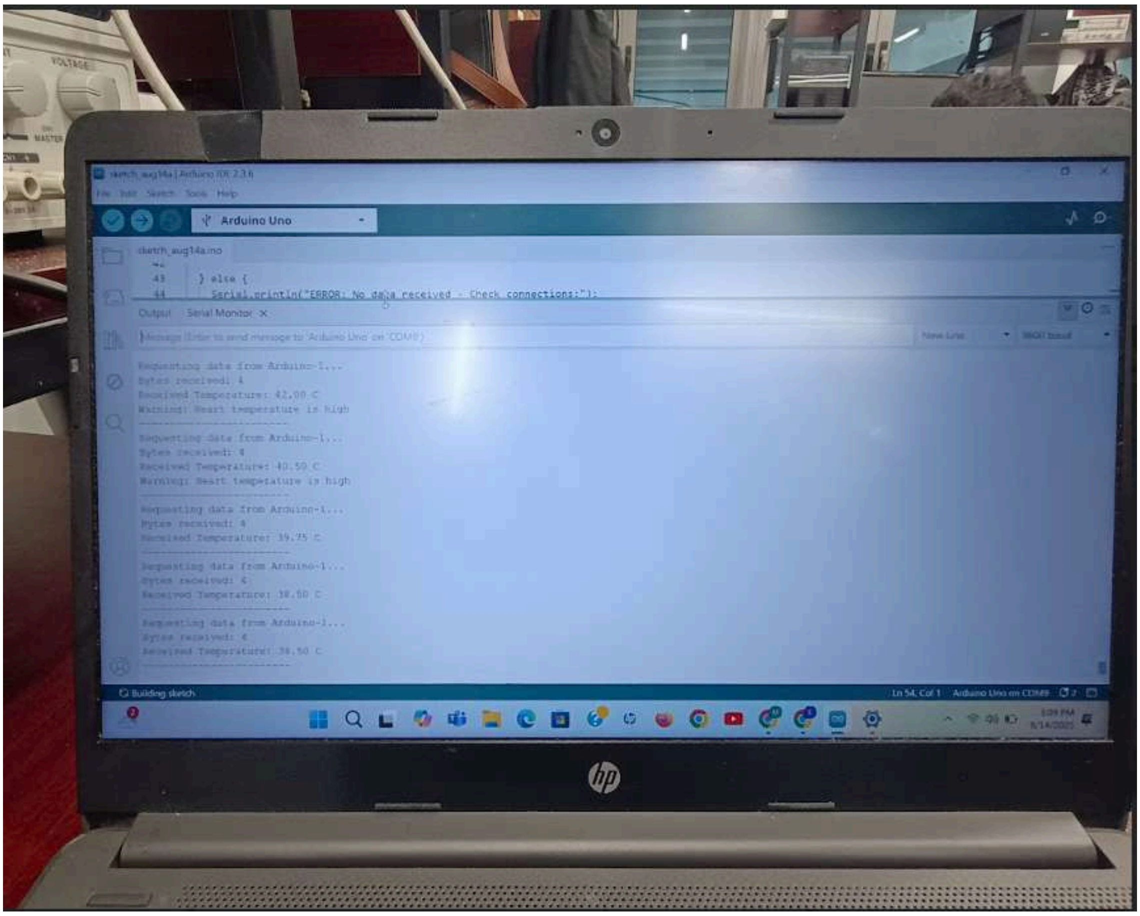

Figure 5.50: Temperature reading of Pacemaker

Arduino Serial Monitor output, where the pacemaker continuously records temperature values. Such monitoring is essential for detecting unusual temperature changes in the body, providing early warnings of possible complications and supporting better patient care that is shown in the fig 5.50. Here, real-time temperature values are monitored, which helps in checking whether the simulator operates properly within the expected safe range. This step is important to confirm the accuracy of the readings before further analysis.

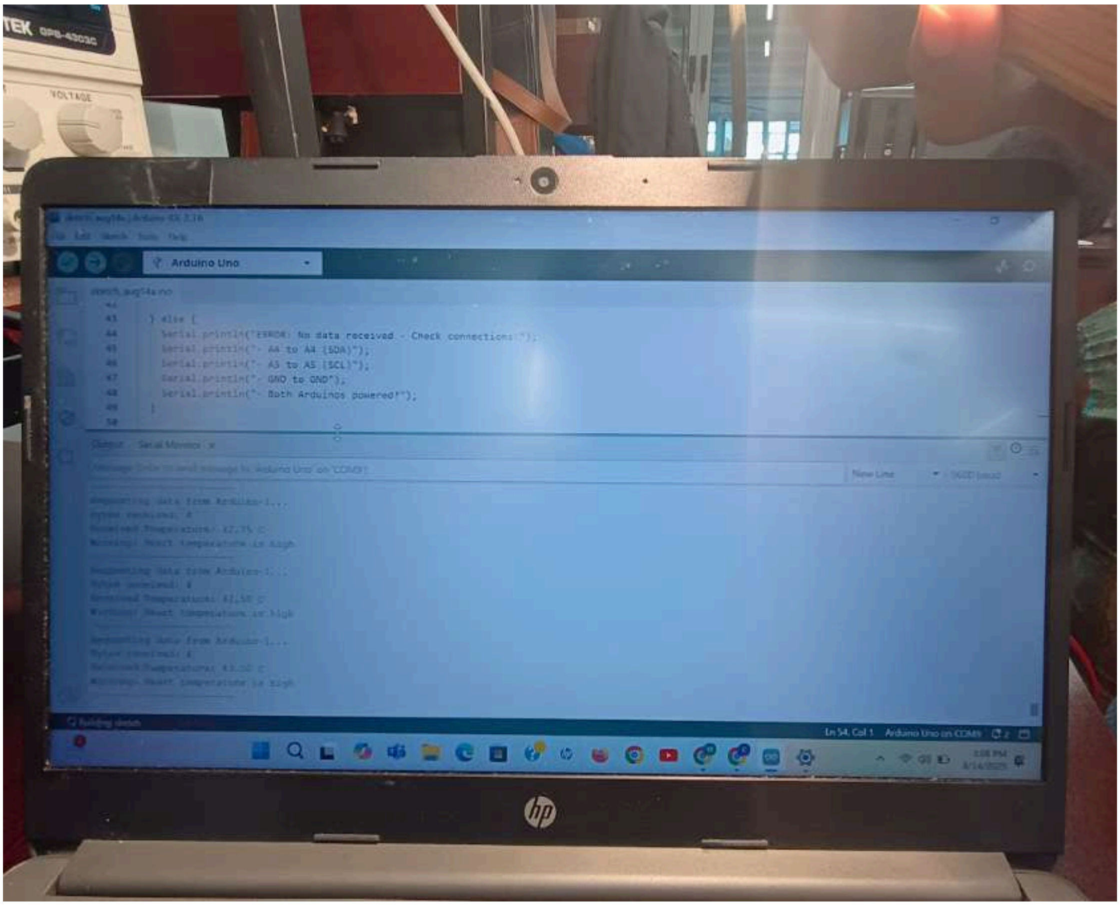

Figure 5.51: Temperature reading of Pacemaker simulator

Figure 5.51 shows the temperature reading of the pacemaker simulator displayed through the Arduino IDE. Here, some synthetic temperature values are monitored, which helps in checking whether the simulator operates properly within the expected safe range. This step is important to confirm the accuracy of the readings before further analysis.

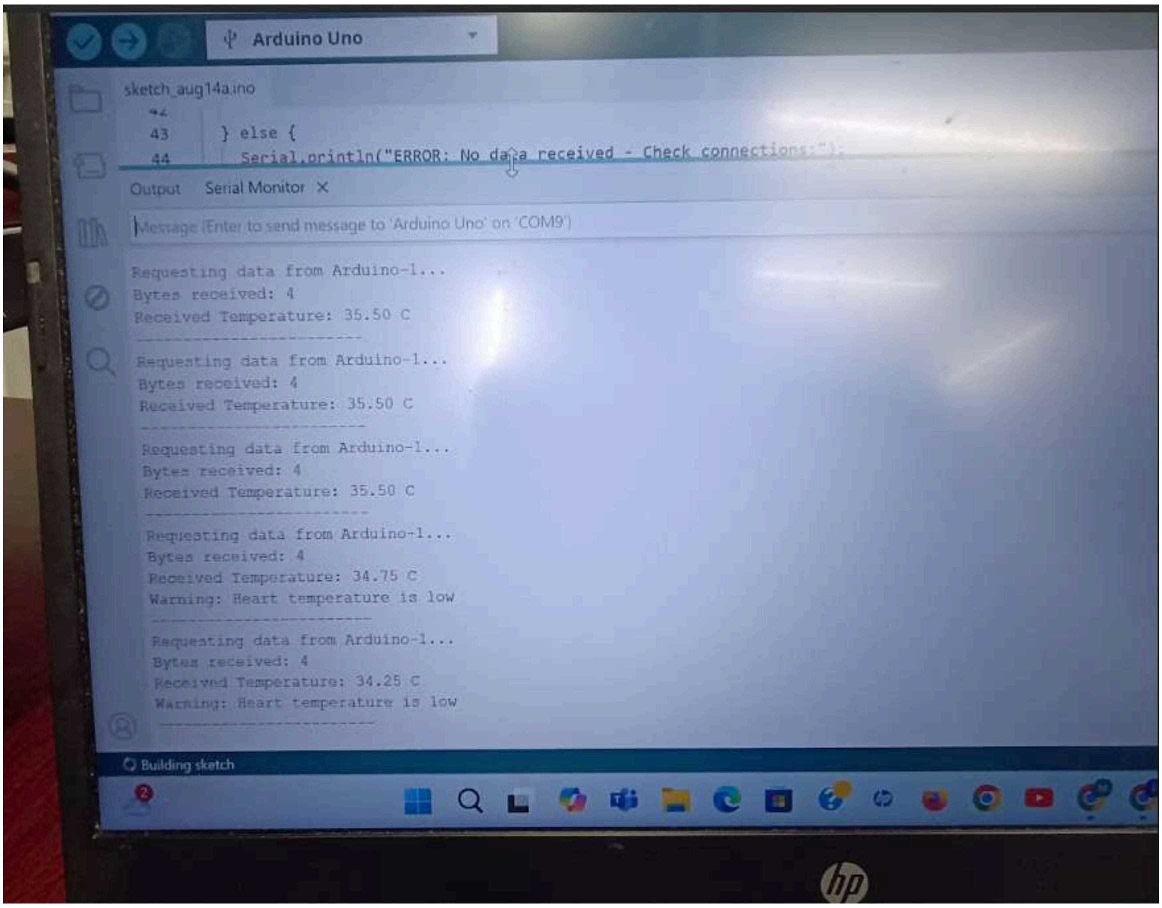

Figure 5.52: Temperature threshold analysis of pacemaker

The temperature threshold analysis of the pacemaker, where the system evaluates if the measured values go beyond or below the defined safety limits in the fig 5.52. The output highlights warnings or messages when abnormal conditions are detected, ensuring that the pacemaker simulator can respond reliably to unsafe temperature levels.

- **Preparing the hydrogel:**

Figure 5.53: Microbiology lab workstation with necessary equipment at hand

The figure 5.53 shows the work station in the microbiology lab that was used to prepare the hydrogel necessary to make the electrodes.

Figure 5.54: Distilled water reserved in a 450 ml beaker

The figure 5.54 shows distilled water in a plastic 450 ml beaker being reserved with an aluminium foil cover to prevent dust from accumulating on its surface. Distilled water was used many times during the making of the hydrogel.

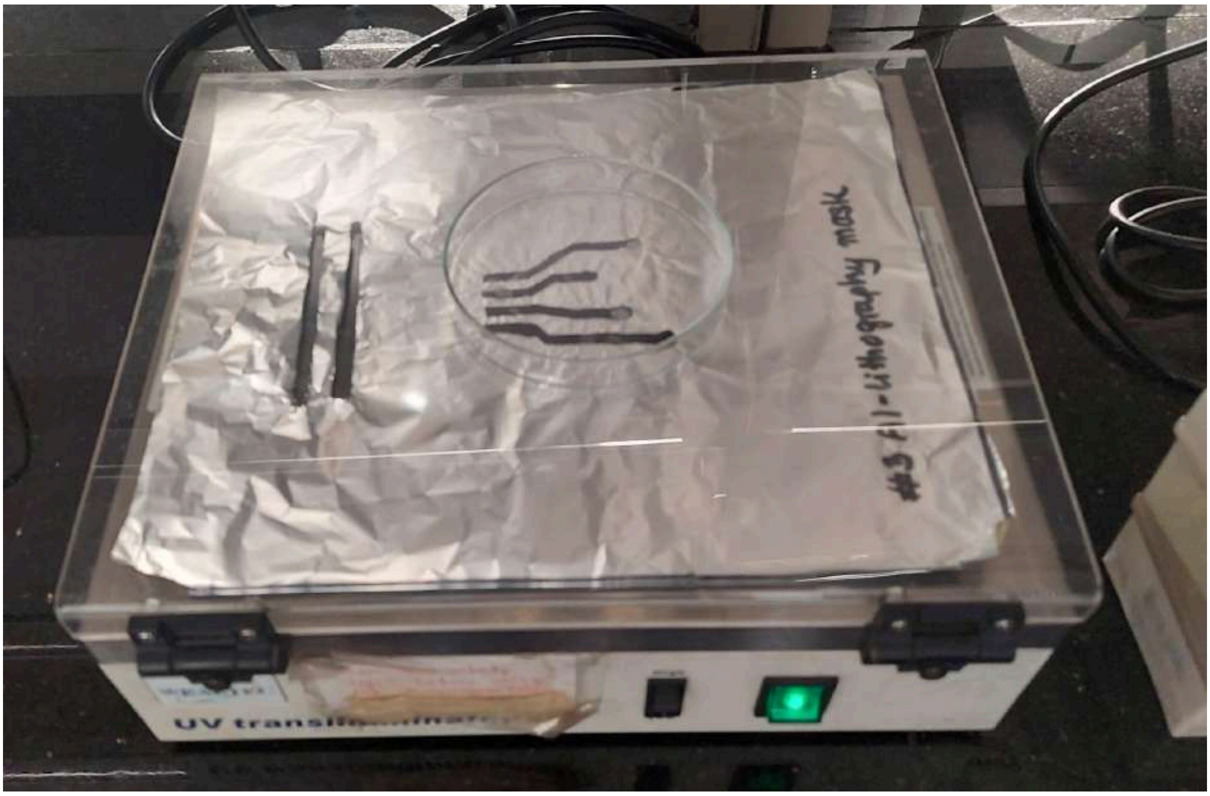

Figure 5.55: Clear hydrogel in a petri dish inside the UV machine

Here in figure 5.55 we can see a petri dish inside an UV machine. The petri dish has been placed on an aluminium foil cutout. The foil prevents UV light from escaping as the light is blasted from underneath. The cutout allows the light to escape, which imprints the shape of the cutout on the hydrogel above, thus polymerizing specific parts of the hydrogel, much like photolithography. Unexposed parts of the hydrogel remain as clear liquid and can be later recycled.

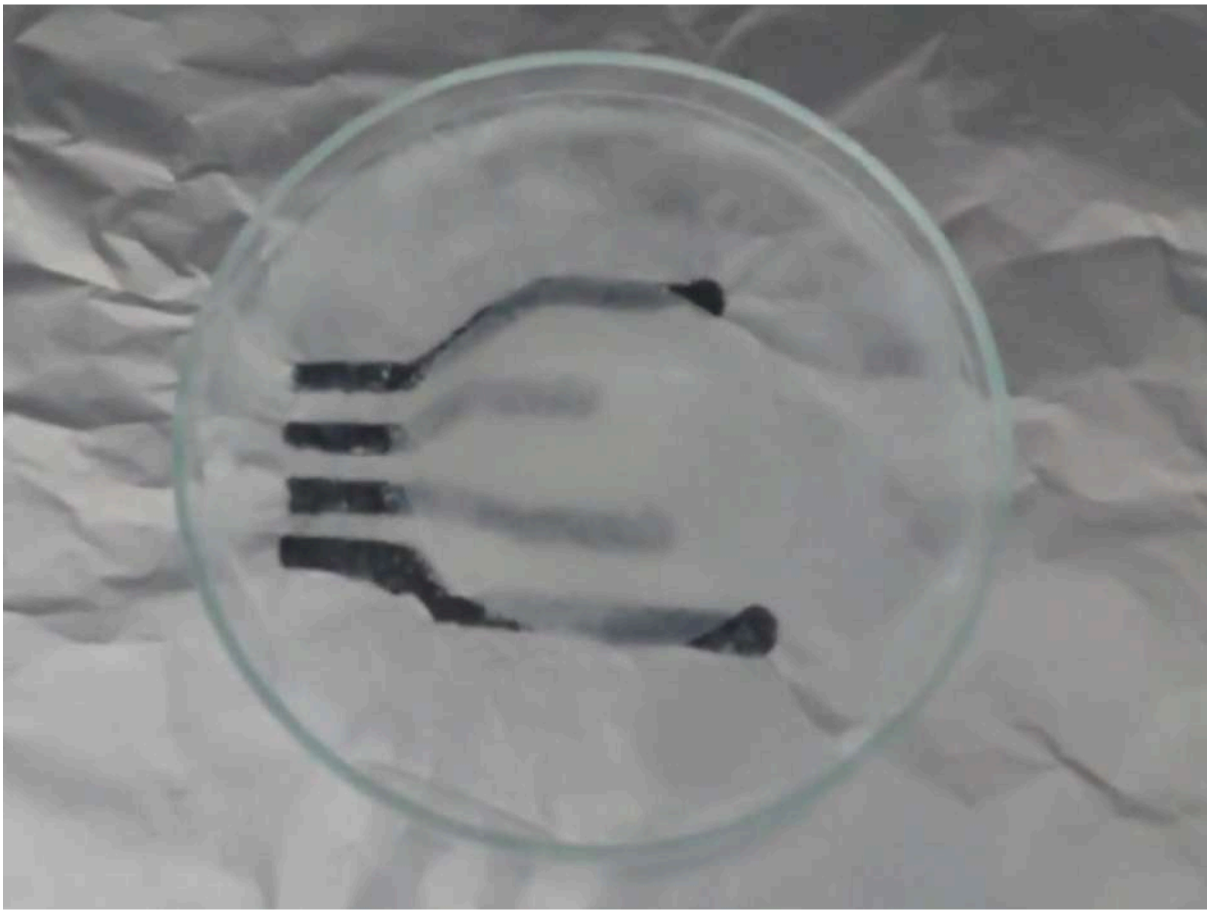

Figure 5.56: First batch of gel was transparent and unusable

However, we had found the first batch of the hydrogel unchanging and unusable after following all the steps. We concluded that because of our chemical constraint, we might have made a blunder in one of the stages. Therefore, we revised our plans to gear up to prepare our next batch of hydrogel. The obscure gel is shown in the above figure 5.56.

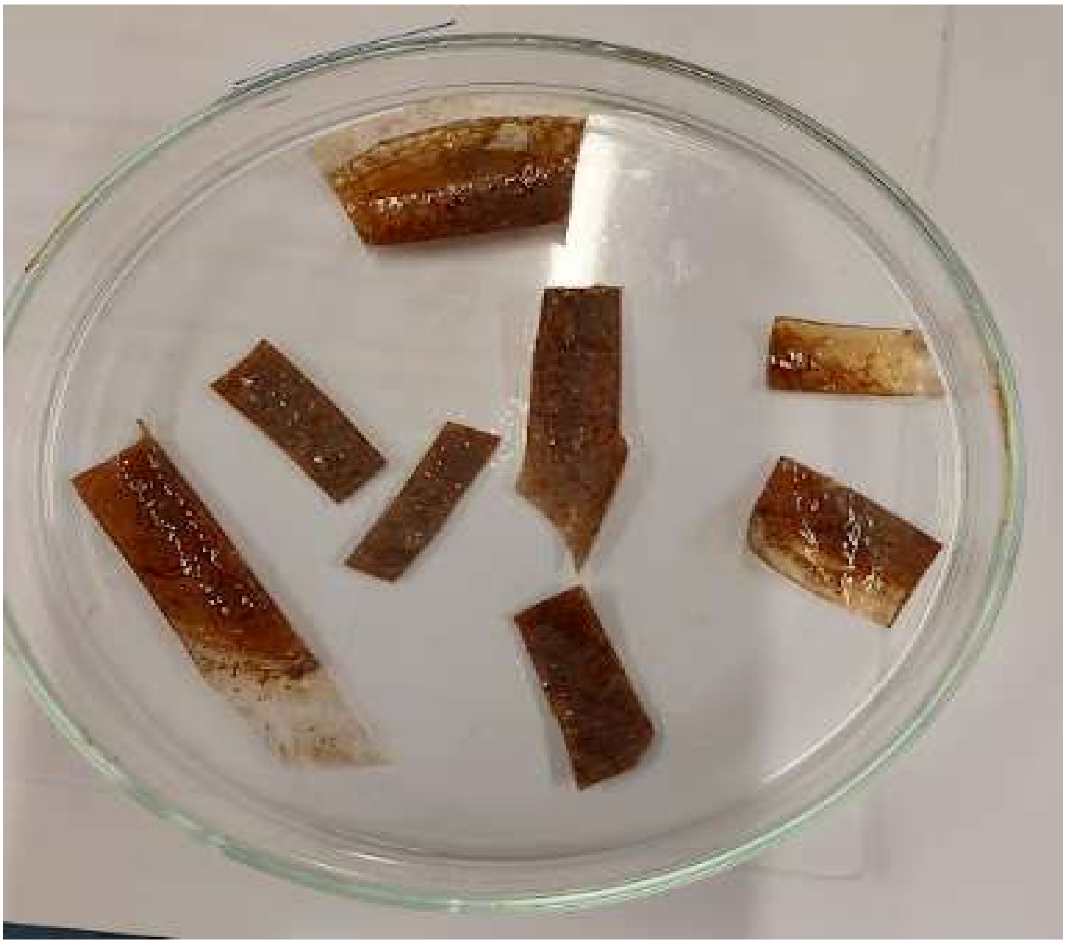

Figure 5.57: Second and final batch of hydrogel cut into strips

Here in figure 5.57 we can see the final stage of our hydrogel that we could prepare with our time and chemical constraints. The brown colour is due to Silver precipitate along the length of the hydrogel. Although the Silver Nitrate has made the hydrogel conductive, it has also left the gel very brittle, as small cracks had already appeared after finalizing the hydrogel. Using PEDOT:PSS as the core conducting chemical would have prevented the brittleness and added elasticity alongside excellent conductivity. However, the Silver-based hydrogel did show some conductivity and slight elasticity, thus fulfilling our hydrogel objective.

Figure 5.58: Placing hydrogel sample under the microscope

Here in figure 5.58 we can see the microscope that was used and the sample being placed under the microscope glass slide that has been illuminated from below.

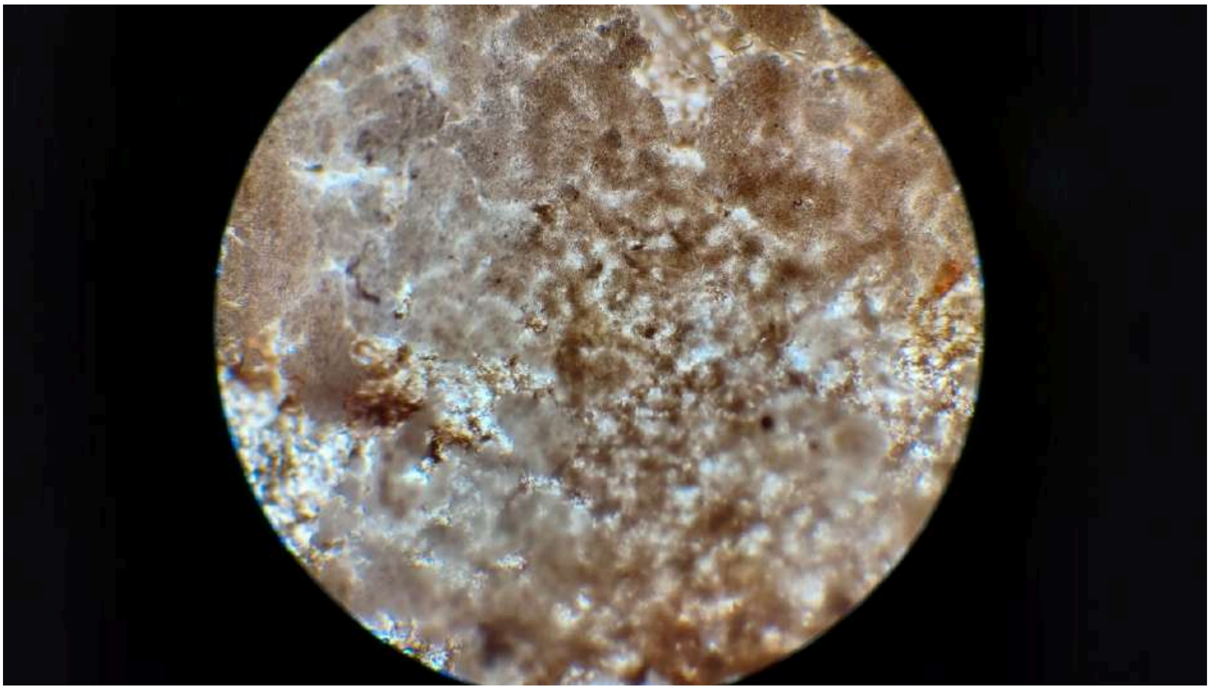

Figure 5.59: Final batch of hydrogel as seen under the microscope

This is what the hydrogel looks like under the microscope. The figure 5.59 shows that there are cross-linkages between the polymer compounds inside the hydrogel shown by the thin white lines strewn all around, but the presence of brown Silver in concentrated patches shows the uneven distribution likely caused by various factors such as the UV light intensity, thickness of Aluminium foil, etc. The Silver has been deposited almost everywhere, and we deduced that the concentrated patches of Silver could be mainly responsible to prevent proper cross-linkage between the hydrogel polymer compounds that form the backbone of the gel, thus making the hydrogel brittle.

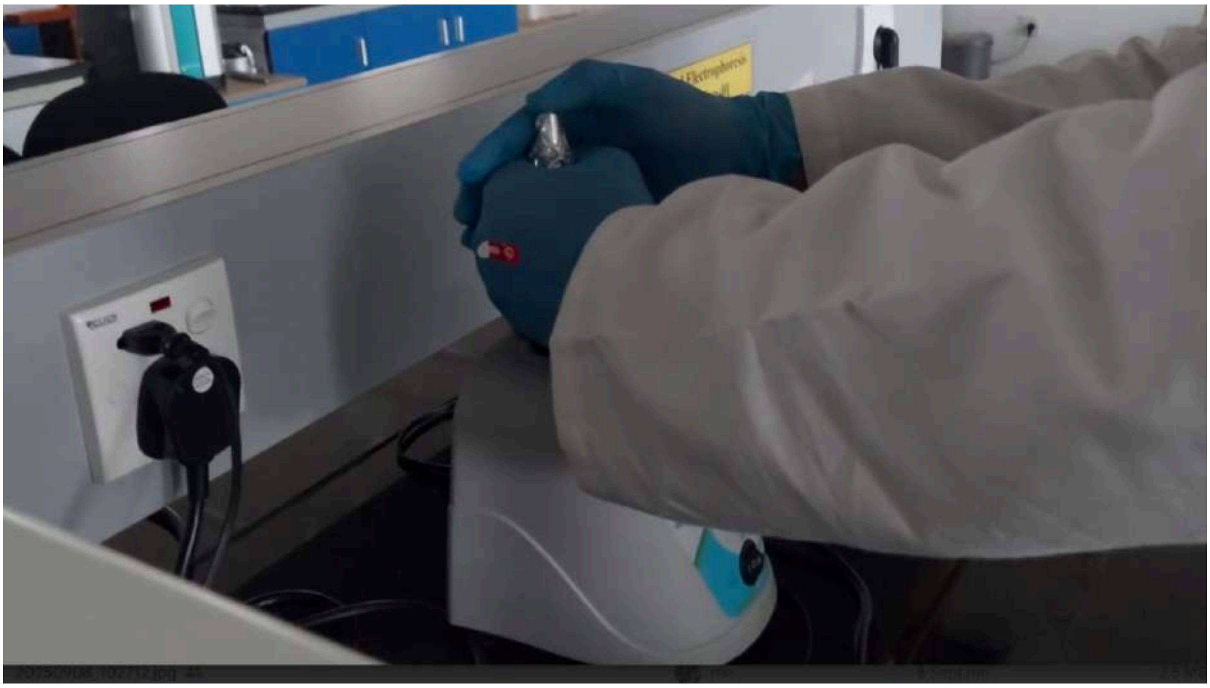

Figure 5.60: Using the vortex mixer

Here in figure 5.60 we can see the usage of the vortex mixer that was used to mix all chemical components that would make the hydrogel.

Figure 5.61: Taking mass measurement

Precise mass measurements were taken of each chemical compound. Here in figure 5.61 we can see the mass of Silver Nitrate that we used to make the second batch of hydrogel. The room was dark because Silver Nitrate decomposes even under a mild light source, and it is imperative that we reduce as many variables or factors affecting our results as possible.

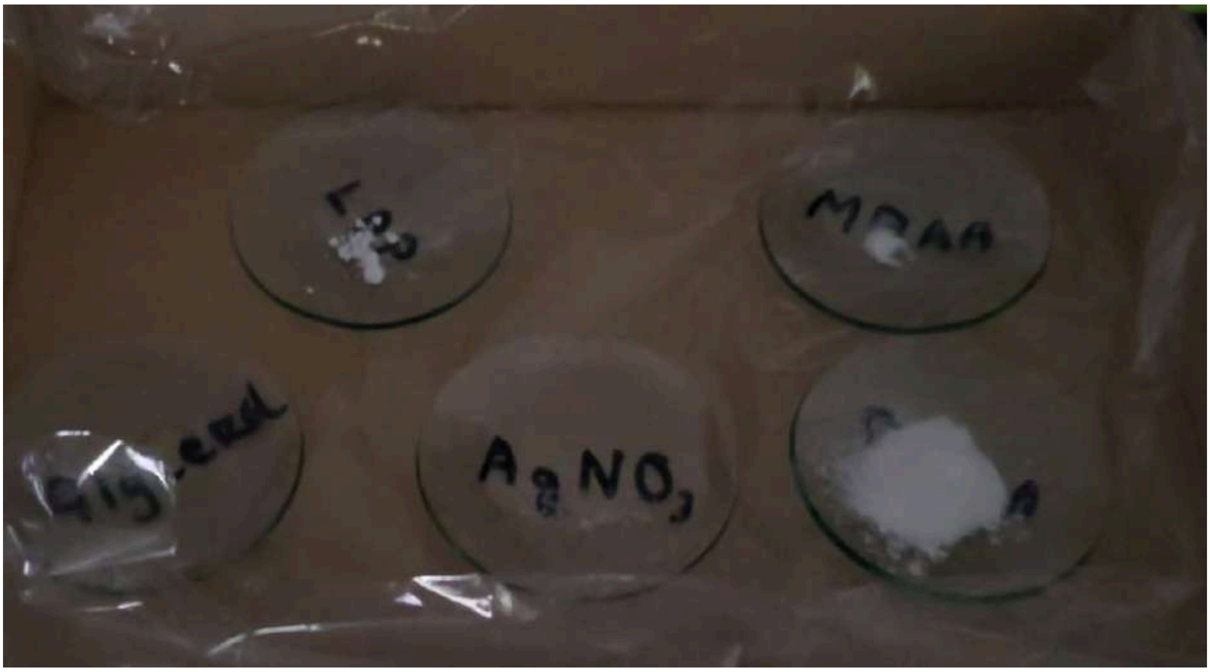

Figure 5.62: Each chemical reagent after taking precise measurements

Here in figure 5.62 we can see all the chemical reagents that were measured being placed on their respective labelled watch glasses in order to further increase the precision of mass measurement and avoid any mistakes recognizing the chemicals later on. The room was still dark due to LAP (Lithium Phenyl) and Silver Nitrate being able to decompose easily under mild light.

Figure 5.63: Testing the conductivity of hydrogel

After the hydrogel was prepared, we tested for the conductivity. Here in figure 5.63 we can see the conductivity tests. Details of the tests have been given in the later part of this section.

- **Obtaining real-life ECG value:**

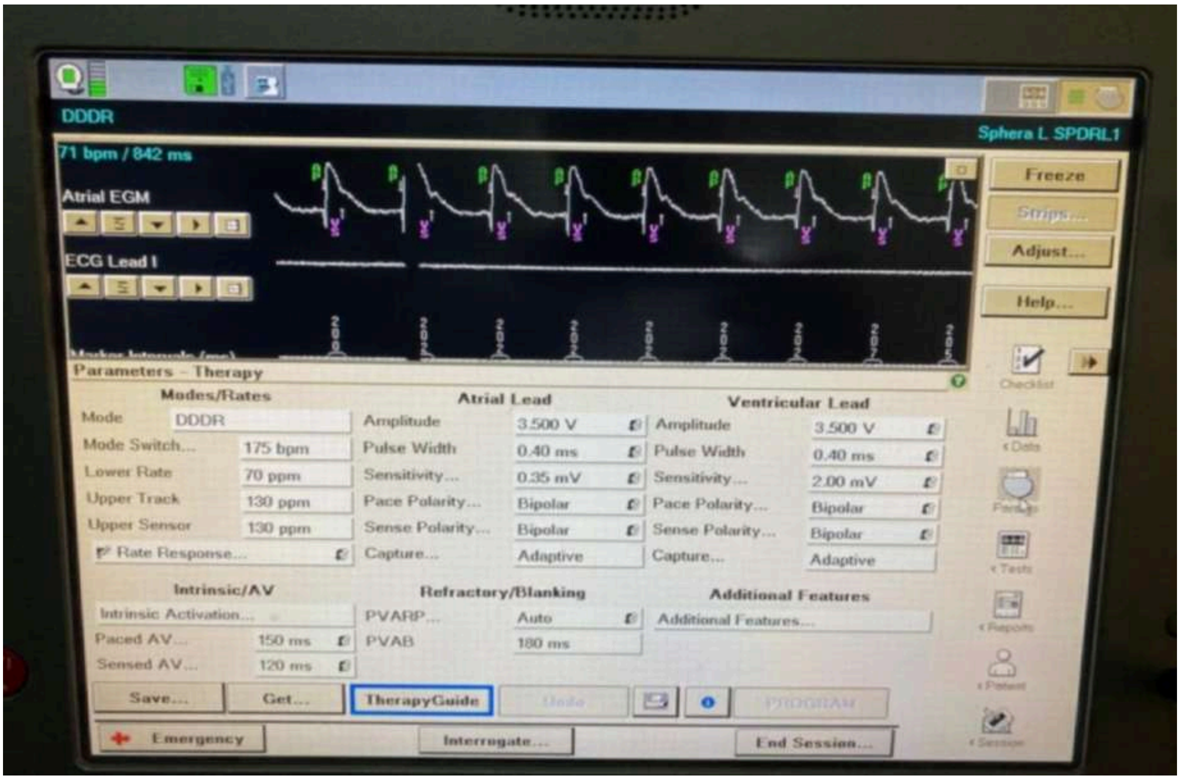

Figure 5.64: ECG heart rate graph data taken from hospital database

The figure 5.64 shows the hospital actual patient ECG dual chamber heart rate graph. It estimated the y axis value from the milli volts. Much of the data obtained is unusable in our case due to heavy noise distortion, but we have used the ones suitable for our purpose. Since the hospitals are reluctant on delivering a larger size of patient data, we coded our ECG arrays with the slightly modified usable data in hand.

- **Using Op-Amp to amplify signals obtained through hydrogel:**

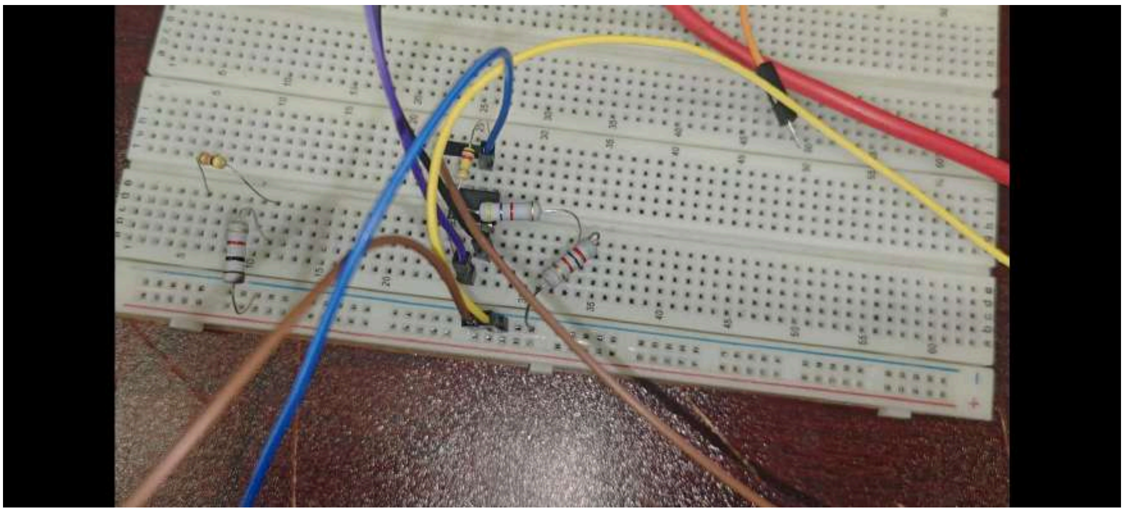

Figure 5.65: A non-inverting amplifier is used to amplify the conduction of hydrogel electrodes.

This figure 5.65 demonstrates the use of an operational amplifier (Op-Amp) configured as a non-inverting amplifier to enhance weak signals obtained from hydrogel electrodes. Hydrogels, known for their conductive and biocompatible properties, can capture low-level electrical signals, but these signals are often too small for direct analysis. By employing an Op-Amp, the circuit effectively increases the signal strength while maintaining its original polarity, making it more suitable for further processing, measurement, or biomedical applications. This approach highlights the practical integration of electronic amplification with soft, bio-friendly materials.

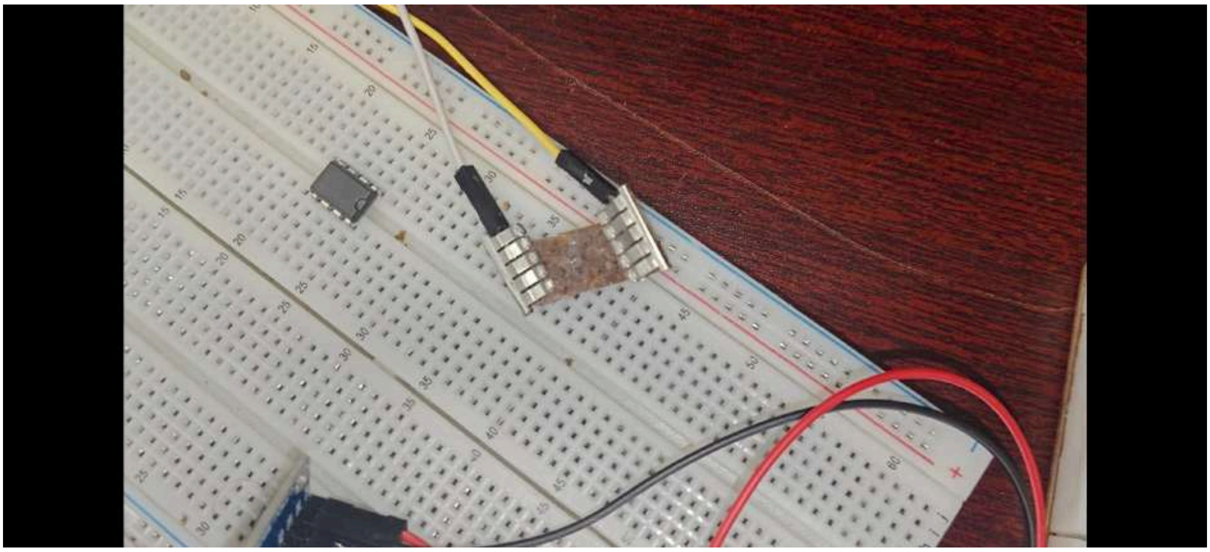

Figure 5.66: Hydrogel electrode connection is used between pacemaker and the led that blinks when heart rate goes below 60 bpm.

The integration of hydrogel electrodes with a pacemaker system to monitor heart rate and trigger an alert mechanism that is shown in the figure 5.66. The hydrogel electrodes act as conductive interfaces that detect bioelectric signals from the body and relay them to the pacemaker circuit. When the heart rate drops below 60 beats per minute (bpm), the system activates an LED indicator, which blinks to signal a low heart rate condition. This setup demonstrates how hydrogel-based electrodes can be effectively used in biomedical applications to provide real-time monitoring and feedback, enhancing patient safety and reliability in cardiac care.

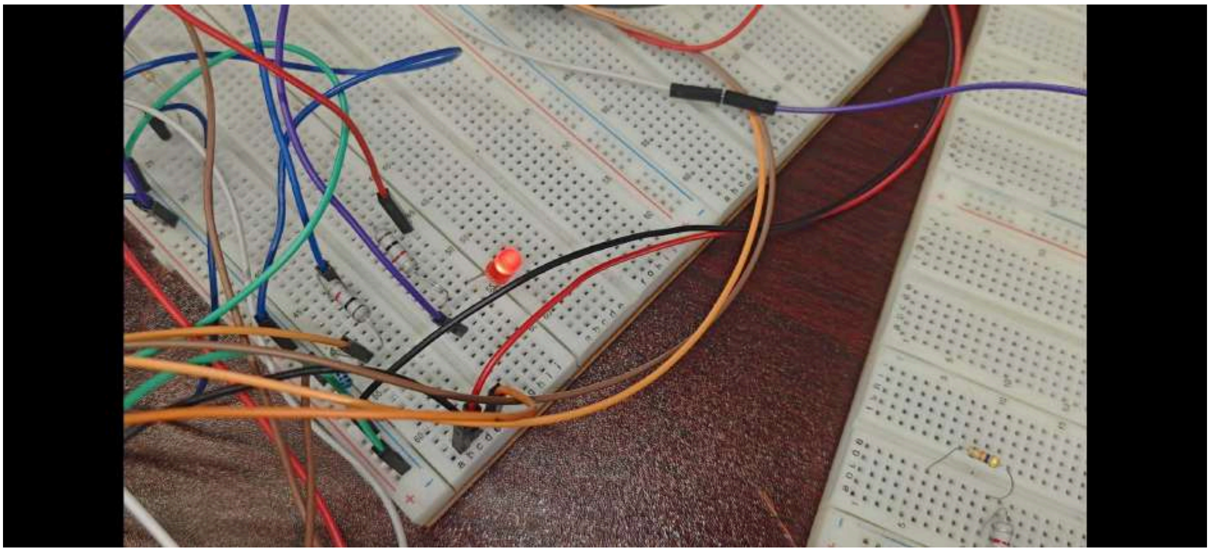

Figure 5.67: LED is blinked when heart rate is below 60 bpm.

The figure 5.67 demonstrates a simple alert mechanism where an LED is programmed to blink whenever the heart rate falls below 60 beats per minute (bpm). The system processes the input signals, likely obtained through hydrogel electrodes or a heart rate sensor, and compares the detected pulse rate with the threshold value. If the heart rate is too low, the circuit activates the LED as a visual warning, indicating a possible case of bradycardia. Such an arrangement is useful in biomedical monitoring systems, as it provides a clear and immediate indication of abnormal heart conditions that require attention.

Hydrogel conductivity graph:

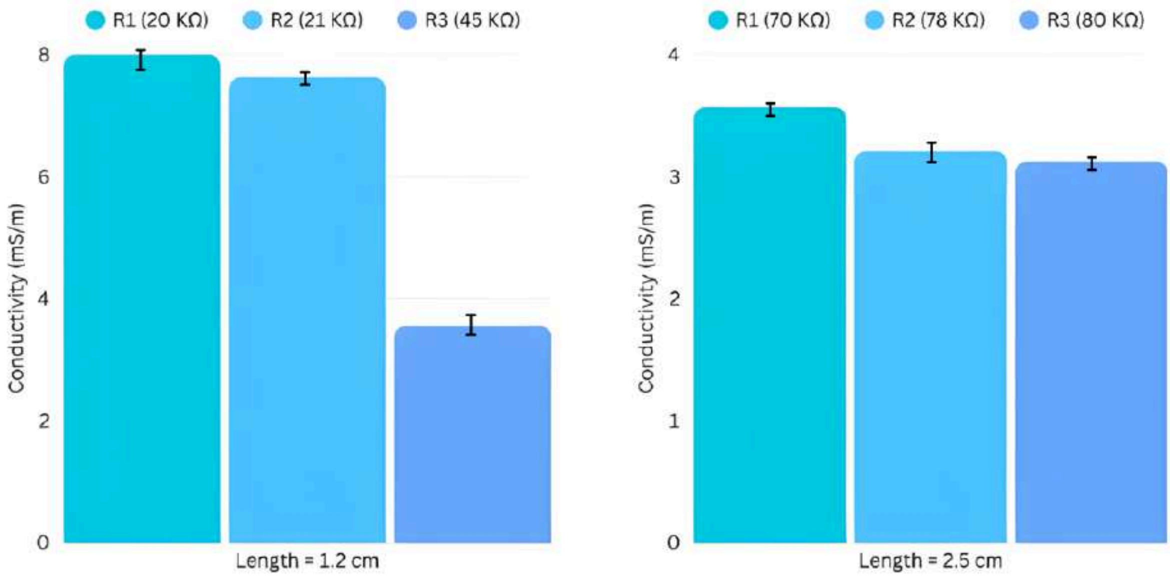

Figure 5.68: Conductivity of Hydrogel vs Length of hydrogel strips

In order to measure conductivity, we have measured the resistances of each of the hydrogel strips and their respective areas. We have divided each strip according to their lengths. The average length of a group of three hydrogel strips were measured to be of 1.2 cm while the other three were averaged around 2.5 cm. There were six hydrogel strips in total. Resistances of each strip were measured and averaged. Then we used the formula for conductivity $\rho = (R.A)/L$ where R is resistance, A is area of each of the hydrogel strips and L is the length of each hydrogel strip. After calculating the conductance, we have seen that the conductivity is much worse compared to the literature. In the figure 5.68 we can see the conductivity of our produced hydrogel to be in the milliSiemens per meter range, whereas in the literature the hydrogel conductivity is in Siemens per meter, three orders greater than our obtained results. The results from the literature were not compared here due to the obvious differences as a result of our constraints.

Calculation of the data error was done using the following formulae:

1. **Absolute Difference Error measurement:** This is the absolute difference between both the columns for the first set of values for resistance, length and area of the hydrogel strips (C) and the second set of the same values that were taken again on a different day in order to ensure accuracy of data (A).

   $$ABS = |C - A|$$

2. **ABS(%):**

   ABS Error= $(|A(i) - B(i)| / B(i)) * 100\%$

3. **Relative Error (RE):** It compares the values for both the sets C and A, and quantifies the magnitude of error compared to set A.

   $$RE = \frac{ABS}{\text{True Value}\,(A)}$$

4. **Root Mean Square Error:** It serves as the measure of average magnitude of the differences between our measured values and the predicted values. Because the error margin becomes more than three orders of magnitude greater, further comparison with the literature was no longer necessary.

   $RMSE = \sqrt{[(\sum(Di - Li)^2) / n]}$

   where Di is the set of measured data and Li is the set of data from the literature, and n is the number of data to be calculated.

- **Simulating ECG signals and pacing:**

Figure 5.69.1: Acquired ECG signal shown in Serial Monitor

Figure 5.69.2: Pacing for ECG signal shown in Serial Monitor

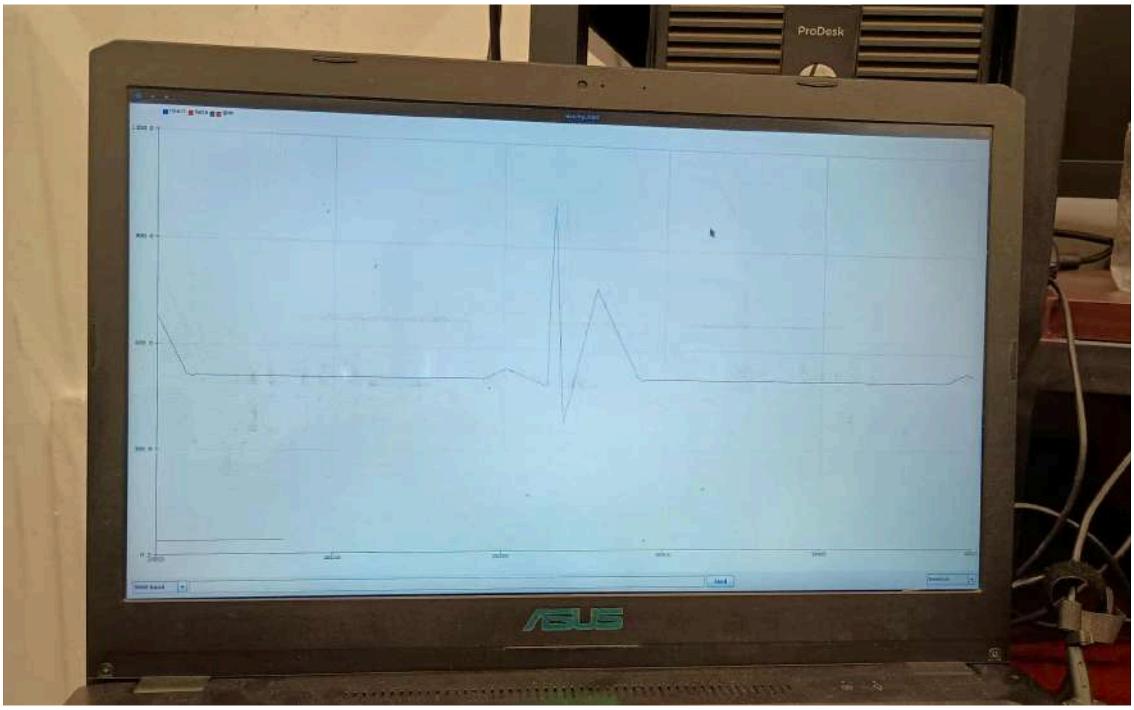

Figure 5.69.3: Trying out ECG signal with another dataset

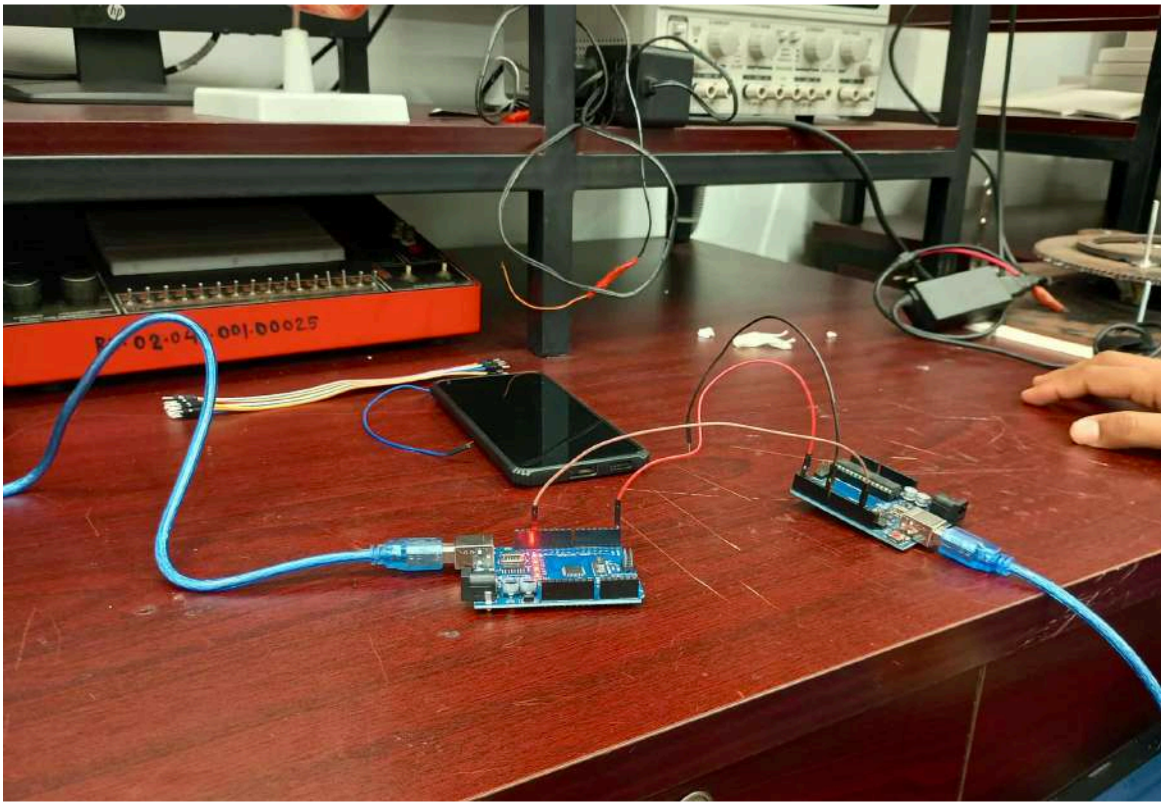

Figure 5.69.4: Direct ECG signal testing

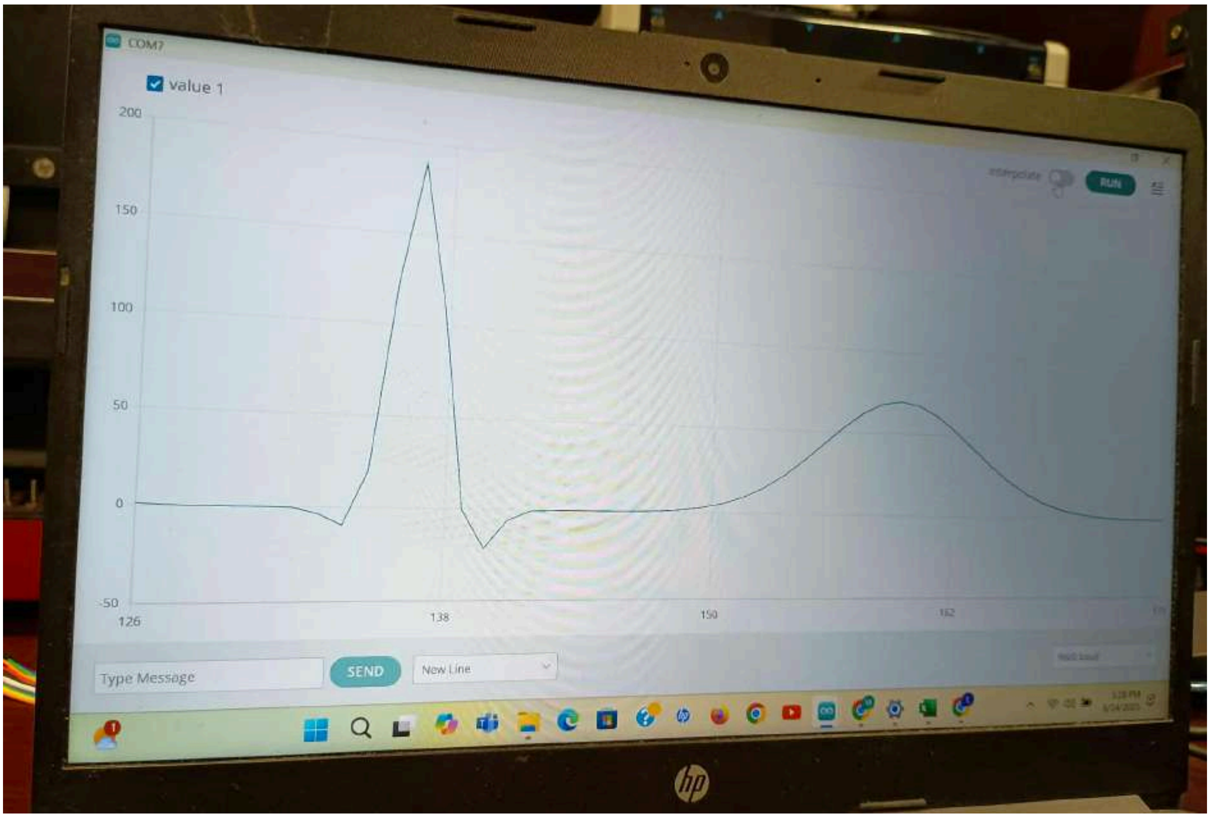

Figure 5.69.5: Pacing signal

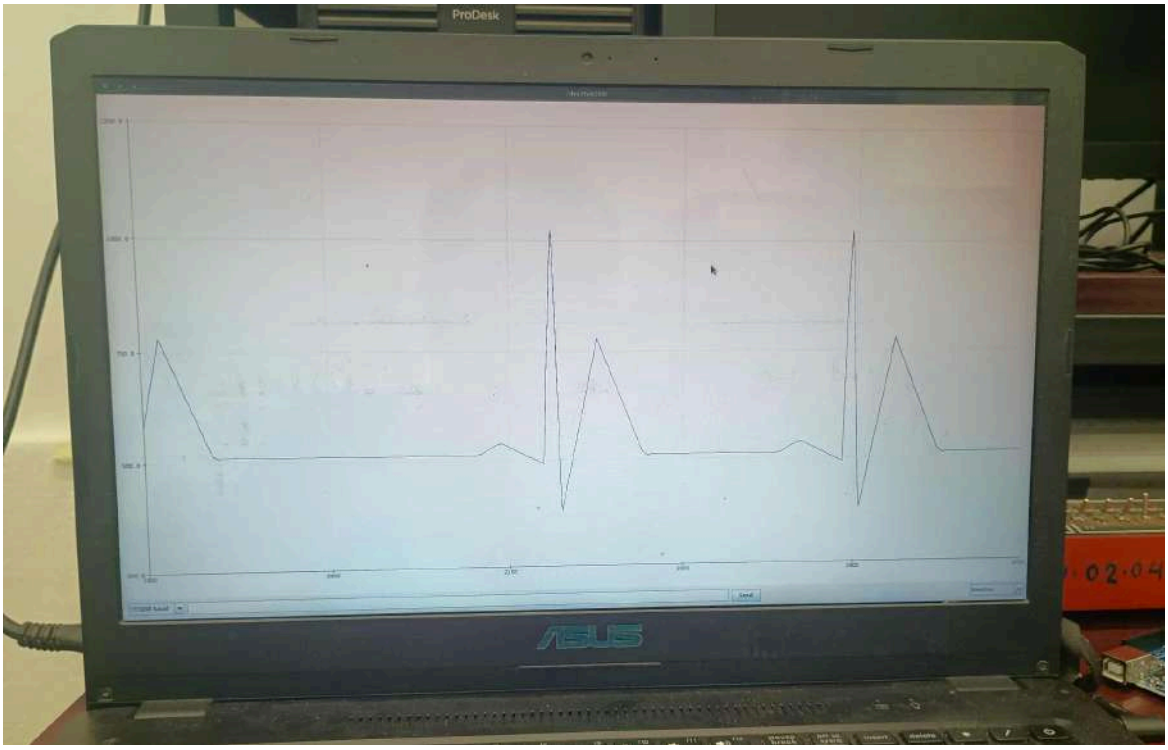

Figure 5.69.6: ECG signals as corrected by the single pacing signal on the far left

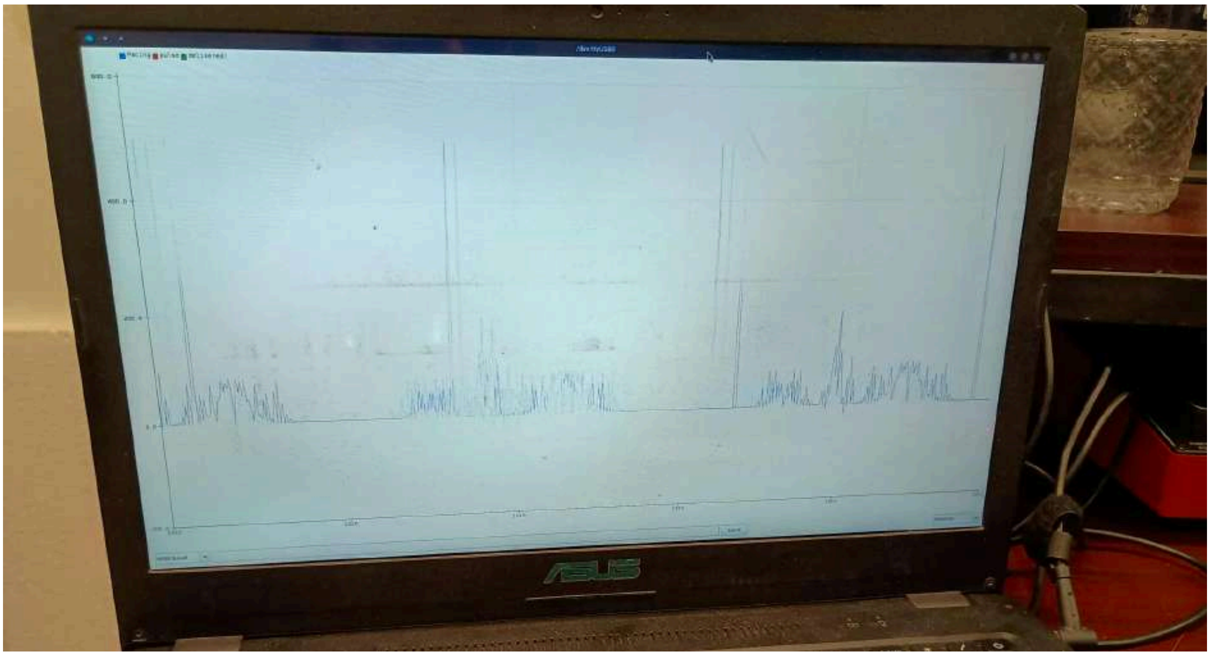

Figure 5.69.7: Sensing and pacing signal with a larger dataset that showed erroneous ECG signals

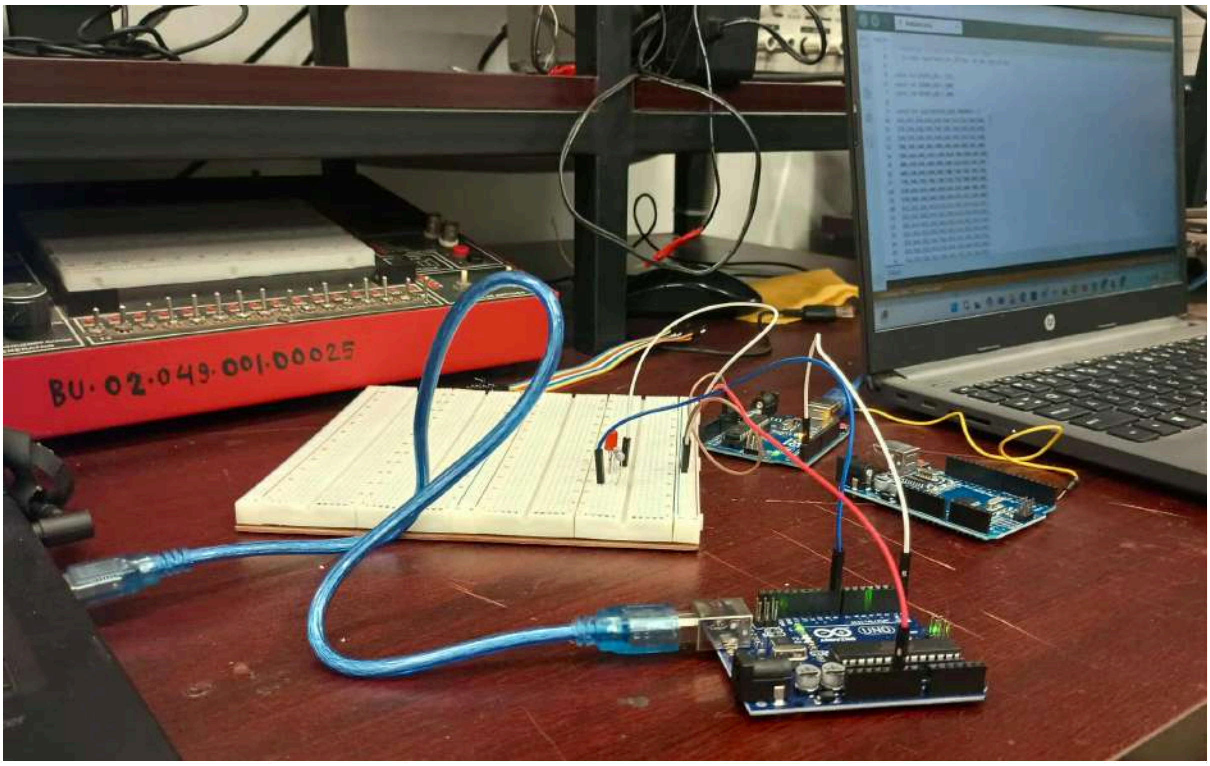

Figure 5.69.8: Circuit built during pacing signal testing

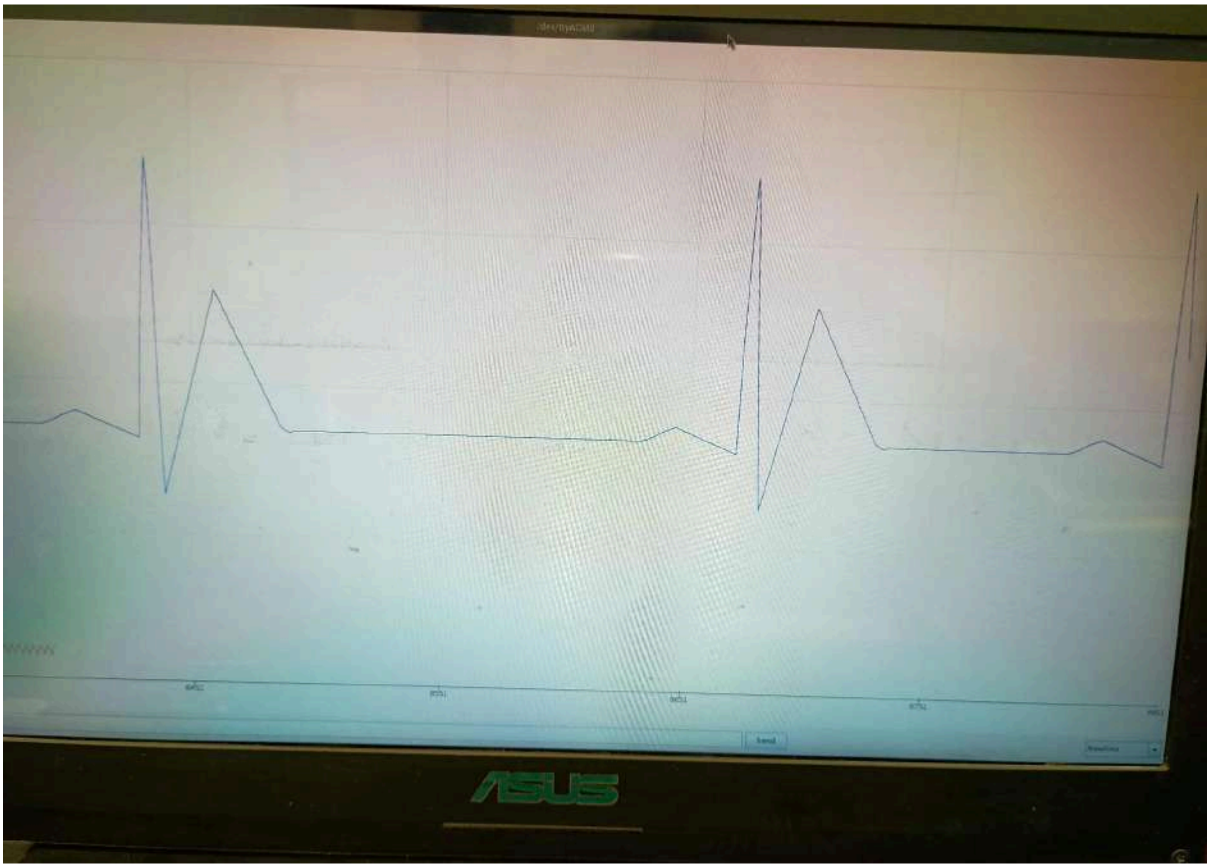

Fig 5.69.9: Pacing signal (the pacing itself is not showing up here due to errors)

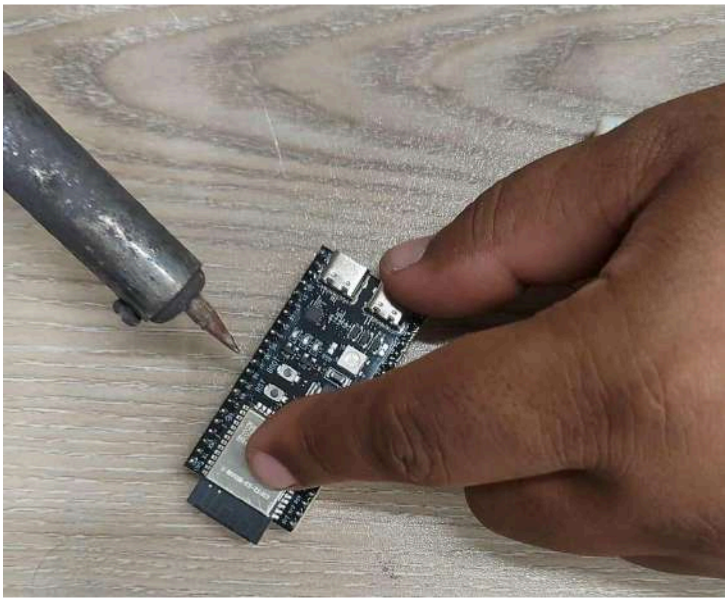

Fig 5.69.10: Soldering two 20-pin headers on each side of the ESP32-S3

Fig 5.69.11: ECG monitoring and pacing signal (error-fixed in the web serial plotter)

In this part of the section, first we start from the figure 5.69.1. Here figure 5.69.11 shows the ECG monitoring and pacing signal successfully displayed on the web serial plotter after fixing earlier errors. Firstly we acquired an ECG signal in the serial monitor in figure 5.69.1 and then its pacing is shown in figure 5.69.2. The waveform clearly demonstrates the characteristic ECG pattern with sharp peaks corresponding to ventricular activity, along with pacing spikes that indicate artificial stimulation in figure 5.69.6. We also tried out the ECG signal with another dataset through direct signal testing and we found out the pacing signal in figure 5.69.3. After that, sensing and pacing signals with a larger dataset obtained from the hospital showed erroneous ECG signals in figure 5.69.7. This could be due to incomplete voltage data per period of time that could be due to data with restricted completeness as it was being shared with individuals outside the organization. As a result, we merged the dataset with synthetic data to produce normal and abnormal ECG signals that a real heart would produce. The consistent periodicity of the signals obtained after this, shown in figure 5.69.9 suggests proper synchronization between natural cardiac activity. Proper pacing events can be observed in figure 5.69.11, which shows the complete functionality of ECG signal monitoring and pacing treatment of the pacemaker. By soldering two 20-pin headers on each side of the ESP32-S3 in figure 5.69.10, we get the microprocessor to process the ECG monitoring and pacing signals. This error-free visualization confirms that the system is accurately acquiring, processing, and displaying ECG data in real time, making it reliable for monitoring cardiac behavior and validating the pacing functionality.

Fig 5.69.12: ECG monitoring without pacing signal

The ECG monitoring without pacing signal, showing the natural cardiac waveform without any external stimulation. The signal presents clear P-QRS-T complexes, with distinct peaks representing the electrical activity of the heart. Unlike the previous paced ECG, no artificial pacing spikes are observed, indicating that the heart's rhythm is entirely intrinsic. This highlights the system's capability to differentiate between normal ECG activity and paced signals, ensuring accurate monitoring of both natural and assisted cardiac conditions that showed in the figure 5.69.12.

Fig 5.70: ECG signals, pacing, temperature readings and biomarker level readings being displayed on the app dashboard

The figure 5.70 shows an ESP32-based medical monitoring dashboard that displays real-time physiological parameters. It shows body temperature (35.4 °C), heart rate (50 bpm), biomarker levels such as NT-proBNP (391.7 pg/mL), and packet count, along with pacing status. The central section provides a live ECG signal visualization, allowing continuous cardiac monitoring. Additionally, a system log tracks incoming data packets and device activity, ensuring accurate and transparent communication between the monitoring device and the application. This interface highlights the integration of multiple health metrics into a single, user-friendly platform for real-time patient monitoring.

Fig 5.71: All cardiac parameters being shown with different values for each parameter

ESP32 medical monitor dashboard displaying updated cardiac and physiological parameters in the figure 5.71. It shows a body temperature of 39.0 °C, heart rate of 70 bpm, and NT-proBNP level of 515.6 pg/mL, indicating mild stress. The packet count is also tracked to ensure reliable data transmission. In the middle section, the real-time ECG monitor visualizes continuous heart activity, providing an accurate representation of cardiac signals. The system log below records detailed information about incoming data and device performance. This interface highlights how different parameter values can be monitored simultaneously, giving a comprehensive overview of the patient’s cardiac health in real time.

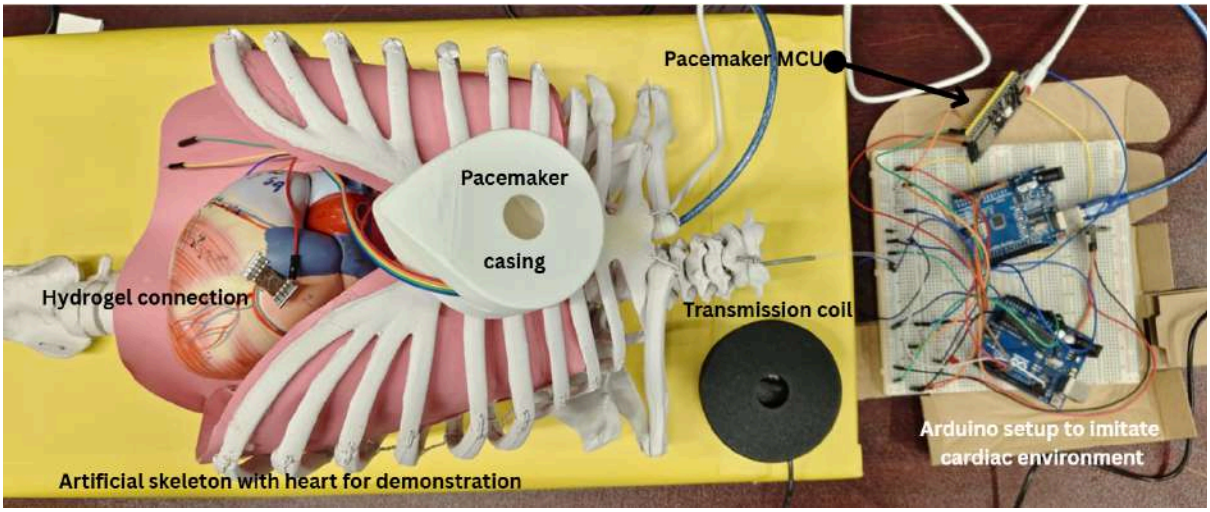

Fig 5.72: Final setup

The figure 5.72 shows the final experimental setup, where an artificial skeleton with a heart model is used to demonstrate heart and pacemaker placement. The transmission coil enclosed in a black cylinder enables wireless power transfer once placed above the pacemaker casing. The pacemaker PCB is inside the pacemaker casing, while an Arduino-based system is connected to the heart to simulate the cardiac environment. The pacemaker is connected to the heart via the hydrogel in order to monitor the cardiac parameters and provide cardiac pacing. Note that there is only one hydrogel connection instead of separated ones due to several constraints discussed previously. Here only the ECG monitoring is being accomplished. The rest of the cardiac parameter monitoring and pacing is occurring via direct connection from pacemaker to the Arduino setup that represents the heart. Nevertheless, our objectives were fulfilled. This setup effectively demonstrates the integration of hardware for testing pacemaker functionality in a controlled environment.

5.3 Evaluate the solution to meet the desired need

5.3.1 Alignment with Project Objectives

The HydroPace project was planned to meet a number of fundamental biomedical engineering goals: continuous ECG signal recording, temperature and biochemical measurements, real-time cardiac abnormalities (e.g. bradycardia) detection, adaptive pacing, and biocompatibility with hydrogel-based electrodes. The majority of these goals were successfully accomplished and there were minor constraints that could be overcome in the next versions.

All the individual components worked as desired when the tests were conducted in isolation. The performance of the wireless power transmission system was stable, which allowed transferring the inductive energy of low range. The bradycardia detector and ECG sensing system performed well and pacing signals were initiated at reasonable levels. Latency was found to be about 30 ms compared to simulation results that were not out of control in the biomedical application.

The hydrogel electrodes that were developed were poor conductors as they produced about 200 mV rather than 3.3 V as desired. A part of this was alleviated by use of an amplifier circuit. The temperature and biochemical sensors were also working properly and they generated real time notifications on breach of preset thresholds.

The mobile application dashboard, though functionality, had periods of lag because it had errors of misinterpreting data and poor way of handling packets, which led to misses in ECG data packets. However, the essence of the concomitant monitoring, signal evaluation and responsive pacing was accomplished. Generally, the solution was comparable to the original goals and indicated the correctness of the feasibility of a soft-material and sensor-imbedded pacemaker prototype.

5.3.2 Functional Verification of Key Modules

- **Pacing System and ECG Monitoring:** In the early days, there were significant difficulties with ECG signal capture on Arduino in the form of data loss, freezing, and arbitrary drops in the baseline (i.e. back to 0 instead of expected 512) as a result of the serial buffers and parsing latency. This had the effect of disrupting R-peak detection and pacing decisions. Software optimization helped to reduce these problems but eventually these problems were resolved by switching to the ESP32-S3 that is better in data processing and processing speed and has a stable signal acquisition.

  The RR interval was used to identify R-peak and bradycardia. This latency between the simulated and real detection was around 30 ms (theoretical: 1000 ms, experimental: 1030 ms). This was fine in the generation of bradycardia alerts. The LED alarm (LED) and pacing signal (GPIO 5) were also observed to work correctly as the pacing system was noticed to function successfully as the LED alert mechanism was always activated when the heart rate was below the 60 bpm range.

- **Temperature Sensing and simulation:** The MCP9808 temperature sensor, connected through Arduino Uno, provided readings on temperatures consistently. The sensor had limits of delay (around 30 seconds) and precision (in 2.5°C) however, which included delays a bit. It was not applicable to the high-precision real-time response, but in the simulation, it was effective in the detection of febrile episodes and signs of inflammation.

  The difference in voltages between the Arduino 5V and ESP32 (3.3V) sometimes disturbed communication. This was in part solved by internal pull-up resistors and voltage divider circuits, the latter being more useful in the serial communication. The endurance test revealed constant temperature data communication and real-time threshold analysis in the ESP32 dashboard.

- **Biomarker (NT-proBNP) Simulation and Detection:** Simulation of NT-proBNP levels which is important to detect heart failure early was carried out by creating randomized biomarker values based on clinically relevant categories: normal (<300 pg/mL), mild stress (300-800 pg/mL), moderate risk (800-1800 pg/mL), severe (>1800 pg/mL). This information was sent to ESP32, where threshold based interpretations and alerts were shown through the serial monitor and the app dashboard.

  Although there were some communication mistakes in the initial trials, the final implementation enabled real time monitoring of both temperature and biochemical indicators, which demonstrate the capability of the system to monitor multi-parameter cardiac health. Combined electrical, thermal, and biochemical anomalies detection make this prototype consistent with the practical, clinically oriented diagnostic systems.

5.3.3 Integration and System-Level Performance

The final HydroPace design successfully demonstrated the ability to simultaneously acquire, process, and display cardiac parameters including ECG, temperature, and NT-proBNP biochemical markers. Results from comparing the two design approaches in a simulated environment as discussed in section 4, Compact HydroPace achieved higher ECG accuracy (96.5% vs 91.8%) and SNR (~28 dB vs ~22 dB) compared to Accessible HydroPace.

Wireless communication was validated using the ESP32-S3 board (Fig. 5.44), which offered stable Bluetooth Low Energy (BLE) transmission to the custom application. This was intended to be done using a smaller antenna and bridges to connect with the app, but due to various constraints, this solution at hand was successfully implemented. The app (Fig. 5.67) displayed continuous ECG signal, pacing spikes, biomarker concentration, and temperature in real time, confirming synchronization between simulated heart output, pacing logic, and monitoring.

However, latency was influenced by wireless bandwidth and cable connections between the Arduino Unos (simulating the heart) and the ESP32 (the pacemaker MCU). From simulation results, Compact HydroPace maintained a pacing response of 2.3 ms, while Accessible HydroPace showed 2.5 ms. Visualizations on the app dashboard were clear in the hardware implementation, but intermittent Bluetooth packet loss introduced minor delays in multi-parameter streaming in Compact HydroPace.

5.3.4 Innovation in Electrode Design (Hydrogel Evaluation)

Hydrogel electrodes were prepared using $AgNO_3$ as a substitute for PEDOT:PSS due to sourcing issues as discussed previously in the report. Conductivity tests showed that silver-reduced hydrogels could conduct current, but the conductivity was much less compared to the practical data from the literature that used PEDOT:PSS. Silver deposition through reduction reaction varied depending on UV exposure uniformity and water evaporation from the gel. Microscopy revealed brittle morphology and uneven silver deposition (Fig. 5.55–5.56), confirming structural inconsistency in large samples.

Compared with PEDOT:PSS, silver-based hydrogels demonstrated initially higher conductivity but significantly lower elasticity and durability under mechanical stress. Literature confirms PEDOT:PSS offers repeatable elasticity and long-term ionic conduction, whereas silver hydrogels risk cracking and loss of continuity under bending. Thus, the current electrode design demonstrates proof-of-concept feasibility but limited real-world implant durability. Moreover, silver nitrate-reduced hydrogel is toxic for the human body, whereas PEDOT:PSS has been proven to be completely safe and non-toxic. Thus, from our point of view, we have only been able to show the conductivity and bendability of hydrogel in our project. The comparison between the two types of hydrogel has been shown in the radar chart in the figure 5.70 below (note that the figure does not display toxicity in the biocompatibility comparison between the two hydrogels):

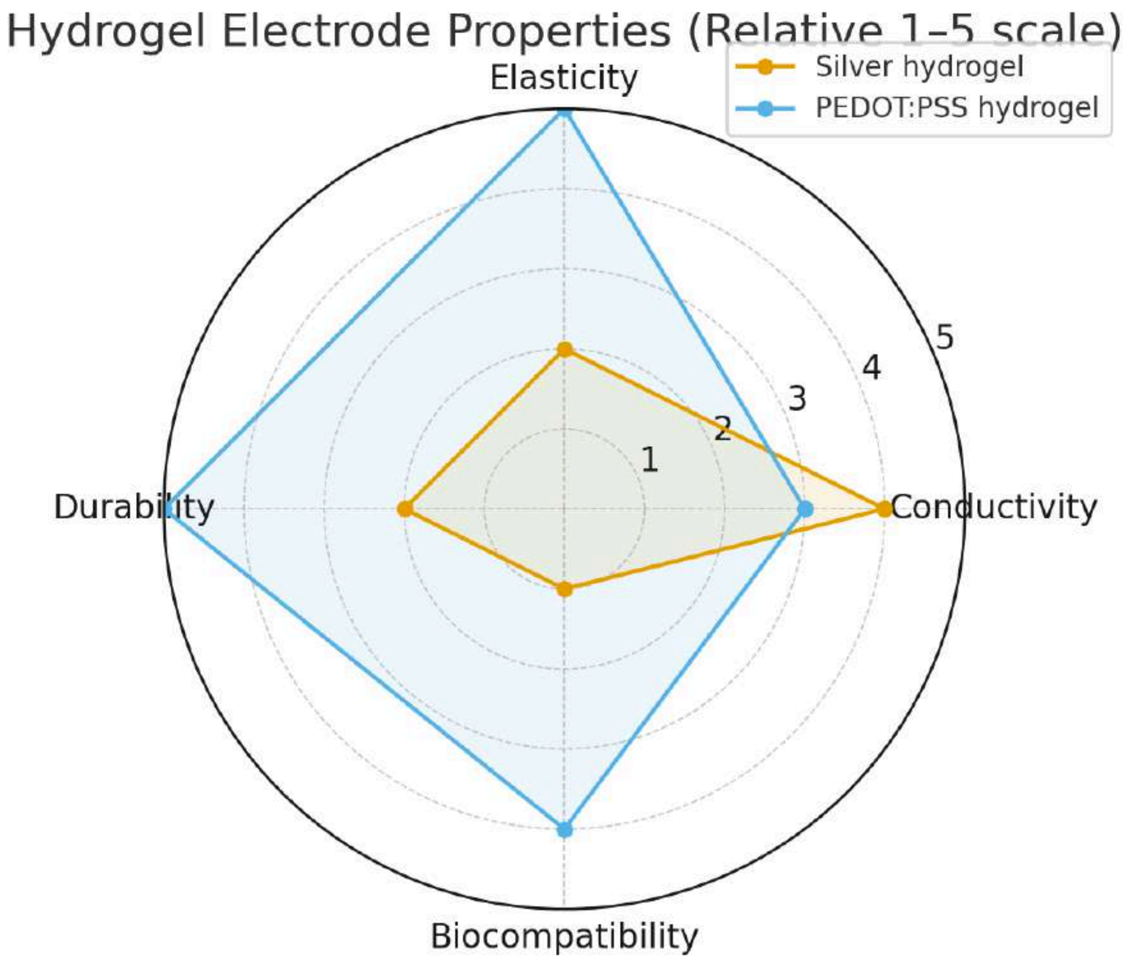

Fig 5.73: Comparison between the hydrogel we produced and the hydrogel suggested in the literature

5.3.5 Validation through Simulation and Hardware Testing

Proteus simulations demonstrated pacing logic, biomarker input, and wireless transmission, but faced CPU-load limitations leading to instability in larger integrated circuits .

Arduino-based hardware validation confirmed ECG acquisition and pacing spikes using a dual-Arduino system. Serial plotter outputs (Figs. 5.51–5.54) clearly showed paced ECGs with synchronized spikes. After debugging, the web serial plotter displayed accurate synchronization between intrinsic cardiac rhythm and artificial pacing, validating timing and control algorithms .

Hardware validation with ESP32 further ensured real-time communication, and dashboard visualization confirmed multi-parameter streaming and pacing correction.

5.3.6 Limitations Encountered

Although the HydroPace prototype met its primary goals in cardiac monitoring and pacing, there were a number of limitations that were found during the development process, both in hardware and software capability, material constraints, and data constraints.

1. **Hydrogel Material and Integration Problems:** One of the greatest limitations was the development and integration of hydrogel based electrodes. The target conductive material PEDOT:PSS with usage in the biomedical sphere because of its biocompatibility and high conductivity was unavailable because of the restrictions in supply and regulations. In place of this, silver nitrate was utilized. Nonetheless, this replacement produced a fragile, low-conducting gel that could not be reliable in pacing, especially electrically. In addition, silver nitrate is both toxic and not suitable for human use, nor does it fit a real prototype of an implantable object. Its use in this project was solely demonstrative, to demonstrate the potential of hydrogel as a medium of electrode or pacemaker casing in chemistry should the appropriate biocompatible materials be employed at a later date.

   The mechanical durability of the hydrogel was also poor. With a little stress the gel broke down and became unfunctional, it could be reused and be more stable under the electrode interface. The lack of complete incorporation of this hydrogel platform into the pacemaker prototype is also a major limitation towards proving the long term feasibility of the device.

2. **Limits in Hardware Resources:** There was a lack of necessary elements to biomedical testing in the project such as access to artificial heart hardware and implant-level pacemaker-grade electronics. Moreover, wireless transmission of power, although tried in isolated settings, still needs more trials with biological tissue simulation to determine the interference, heating and possible abrasion of surrounding human tissues.

   Furthermore, the system could only work with ESP32-S3 module which, though valid in simpler communication solutions, is not suited in the medical grade of implantable Bluetooth or RF transmission. Future iterations should incorporate certified low-energy, biocompatible wireless modules so as to make sure it is safe and regulatory compliant.

3. **Limitations in Software and Signal Processing:** Software development was faced with many problems particularly in its initial phases. The original ECG pacing spikes were too wide (as in Fig. 5.52.1) to cause true-negative responses. Although this was subsequently streamlined, the data parsing errors and lag on serial communications continued to reduce data by occasional instances. These were only compounded when

trying to control temperature, biochemical and ECG streams concurrently on small memory and processing platforms.

Moreover, bradycardia could be detected reliably, because no sophisticated ECG datasets were available, therefore, the system would not have detected other conditions. It could not verify answers to other conditions like tachycardia, atrioventricular blocks or ventricular fibrillations which were initially in the scope of the project. The absence of annotated and varied real-world ECG records curtailed the full diagnostic capabilities of the monitoring module.

4. **Electromagnetic Vulnerability:** The prototype lacks electromagnetic shielding (a Faraday cage or EMI filters). Consequently, the system still is susceptible to the external electromagnetic interference (EMI) that may break internal circuits or misinterpret physiological information. This is of great concern especially in a patient who has been subjected to high-field conditions (i.e. MRI, CT scan, industrial machinery). To assure safety and reliability of operation in real-life conditions, any further clinical adaptation should incorporate EMI protection.

5. **General System Limitation:** The pacing controlling functionality has worked well in the conditions of bradycardia detection, but the monitoring unit performed poorly because of the fact that optimization of the code and real-time processing was not effective. Another flaw in the system was that it was not fault tolerance, i.e., any delay or error in one of the modules could cause a problem in the entire signal chain, and in this case, the future version of the system should also be implemented through the use of multi-threaded processing and error-handling protocols.

5.3.7 Meeting the Biomedical Need

HydroPace demonstrates feasibility as a low-cost, portable, non-invasive prototype for cardiac health monitoring. The system integrates hydrogel-based sensing, real-time data transmission, and pacing intervention, aligning with the biomedical need for remote patient monitoring and early detection of heart failure indicators.

The ability to monitor ECG, temperature, and biomarkers simultaneously—while triggering pacing in arrhythmia—positions HydroPace as a multi-parameter academic prototype. While our findings and prototype are not clinically deployable yet, it provides a foundation for heart failure prediction, pacing interventions, and low-cost cardiac data tracking as well as extremely durable pacemakers that last for decades.

5.3.8 Recommendations and Future Improvements

In order to address the existing shortcomings and to bring the HydroPace system out of the prototype stage and into its clinical use, there are a number of strategic suggestions that would be applied both at the material, hardware, software, and system-level design.

1. Innovation in Biocompatible Materials: The toxicity, brittle characteristics, and the lack of conductivity were also major weaknesses in the use of silver nitrate as a temporary replacement of conductive hydrogel. It should be given more focus in the future to integrate biocompatible conductive polymers like the PEDOT:PSS that have a better electrical conductivity, mechanical flexibility and compatibility with biological tissues.

Furthermore, there should be comparative research to assess the emerging materials which are flexible, stretchable, non-toxic and can be stable in the long-term. These materials can not only make the process of pacing more efficient, but they can also make life easier and safer to patients. This type of research is in line with the greater healthcare objectives of promoting implantable technologies in the society.

2. Improved Hardware Integration: The system ought to be scaled down in size and functionality by designing smaller but powerful microcontrollers that have the ability to perform real-time processing and handle data efficiently in the future. It is suggested to use devices like ARM Cortex-M-based with low power consumption and high speed communication.

Wireless communication will also be safe, stable, and free of interference and the incorporation of Bluetooth Low Energy (BLE) modules that have been developed to be used in the medical field will make sure that wireless communication is able to proceed without interruptions. Also, there should be an effort to integrate long-lasting, rechargeable or bioenergy-compatible power systems which are medically safe to be used as implantables.

Moreover, the system must make use of medical-grade sensors of temperature, biochemical and other vital signs to monitor. These sensors have to be very small, very precise and able to last long without excessive drift or failure.

3. Signal Intelligence and Software Optimization: The current prototype had a problem of optimization of the software because of the lack of knowledge in the field and time constraints. Future work should focus on:

- Refactoring the codebase to be fast, modular and fault tolerant.
- Application of sophisticated signal processing techniques to find the accurate R-peaks, filter noise and interpolate the data.

- Integrating machine learning models developed on real-world ECG data to improve the detection of a wider variety of cardiac diseases, such as tachycardia, atrioventricular (AV) blocks and arrhythmias.
- Better data parsing and better buffer management to avoid signal loss, in particular, when monitoring several parameters at the same time.

Cooperation with the domain specialists in the field of biomedical software and clinical cardiology will also improve the decision-making and the accuracy of the diagnostic system.

4. Efficient and Safe Wireless Power Transfer: Although early experiments on wireless energy transfer are encouraging, further testing is required to make sure that there is safety in the implanted use of human beings. Future work should evaluate:

- Heat impacts of biological tissues.
- Energy saving at varying depths of tissues.
- Electromagnetic interference (EMI) on other devices.

Provided that it is effective, wireless charging would remove the necessity of battery replacement operations which would greatly enhance the quality of life of patients.

5. Shielding and Strength of Devices: A consequence of this is that patients with implantable devices are highly susceptible to outside magnetic fields, including those produced by the MRI machines, CT scanners, or industrial machines. The prototype at hand has none of the electromagnetic shielding, which is a very critical risk.

To overcome this, the subsequent design step shall involve coming up with a smaller Faraday cage or embedded EMI shielding layer in the hydrogel-based casing. This would safeguard internal circuitry against adverse interference and assure safe operation in high field conditions, a necessary measure towards clinical preparation.

Altogether, with the introduction of both innovative biomaterials and miniaturised hardware, highly resilient software architecture, tested wireless charge-up and electromagnetic compatibility (EMI) protection, the HydroPace system can become a secure, effective, and life-saving cardiac management system that can be implemented in practice.

5.4 Conclusion

The HydroPace project is near completion of the final design and validation stage and this is one of the milestones in the history of creation of a new hydrogel-based pacemaker system. Although it had a number of hardware, material, and software-related limitations, the major objectives were met. The system had proven to be reliable in monitoring of ECG, temperature and biochemicals with responsive pacing through the use of a hydrogel electrode interface. All important modules were tested, and optimization and testing performed through numerous tests. Although certain elements, including the conductive hydrogel and wireless data transfer were limited, they did have some useful lessons on how they can be improved in future. This stage justified the technical capacity and conceptual soundness of the HydroPace system as a possible answer to real-time, multi-parameter monitoring and intervention of the heart. All in all, the results of Chapter 5 set a good ground upon clinical development, further research, and industry implementation, which makes the project consistent with the greater objective to enhance human health due to the innovative biomedical engineering.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

The project that we are developing must go beyond its technical design and take into consideration the broader impact it may have on patients, the medical community and society as a whole. Impact analysis and sustainability evaluation are especially important for our Hydrogel Cardiac Pacemaker (HydroPace) because it is designed to directly affect human lives. This chapter describes how our proposed solution influences patients and medical practice, evaluates its long-term sustainability, and reflects on the social, ethical, and environmental aspects of our design.

6.2 Assess the impact of the solution

HydroPace is expected to bring meaningful changes to the following areas:

- **Medical Impact:** Compared to the current industry standard pacemakers, the hydrogel-based solution provides greater flexibility, better comfort, and a reduced need for multiple surgeries. Patients suffering from conditions such as arrhythmia and heart blocks will have the freedom for more natural movement, fewer complications, and improved recovery.

- **Patient Experience:** Since the device is designed to be lightweight, compact, and less invasive, patients will have more comfort in their daily activities. This solves one of the biggest issues that users face with traditional devices. Discomfort and limited mobility often degrade the quality of life.

- **Healthcare System Impact:** By significantly reducing the number of surgeries and increasing device lifespan, the hydrogel pacemaker cuts healthcare costs and eases the load on hospitals. Doctors also gain from precise real-time data, which helps them make reliable and more accurate clinical decisions.

- **Societal Impact:** If the device is mass produced, it could make cardiac healthcare management more affordable and accessible. This is especially important for communities where traditional pacemakers are too costly and generally out of reach. Such changes may reduce healthcare disparities and improve global access to life-saving technology.

- **Technical Impact:** There are impacts from a technical perspective as well. Although the use of Silver Nitrate results in conductivity limitations in the electrode due to the absence of PEDOT:PSS, signal amplification has been ensured using a non-inverting op-amp. This has resulted in effective outputs for both heartbeat sensing and pacing signals, proving that it is possible to maintain functionality even in complex situations using alternative circuit strategies. The advanced processor and Bluetooth interface have made the system more scalable. Full integration with proper chemicals to make the desired hydrogel and proper implementation of all the discussed requirements for the pacemaker, with a smartphone app in the future, patients will be able to see their health information in real-time and share it with their doctors instantly.

- **Economic Impact:** The project is also significant in terms of economic impact. The prototype has been constructed using rather expensive chemicals but available electronics parts. This is to ensure patient safety, increase reliability of HydroPace and in the long run, make up for the initial cost since there is almost no requirement for further surgical replacement due to overall longevity of HydroPace.

6.3 Evaluate the sustainability

The Hydrogel Cardiac Pacemaker project closely aligns with the United Nations Sustainable Development Goals (SDGs). It is a medical breakthrough and a significant leap toward a healthier, fairer, and more sustainable future. The project tackles patient health, affordability, technological innovation, and environmental responsibility. It helps achieve several global goals at the same time. The table below shows the specific SDGs related to this project and explains how the pacemaker supports each one.

SDG Goal	Relevance to the Project	Contribution of Hydrogel Cardiac Pacemaker
SDG 3: Good Health and Well-being	Ensures healthy lives and promotes well-being for all.	Provides a safer, more flexible, and long-lasting pacemaker to improve patient health, reduce complications, and enhance quality of life.
SDG 9: Industry, Innovation, and Infrastructure	Encourages innovation and resilient infrastructure.	Promotes biomedical innovation through hydrogel-based flexible electronics and supports advancement in medical device technology.
SDG 10: Reduced Inequalities	Aims to reduce disparities in access to healthcare.	Offers a more affordable and accessible pacemaker solution, helping patients in low-income communities access life-saving technology.
SDG 12: Responsible Consumption and Production	Focuses on sustainable production and reducing waste.	Uses flexible, durable, and partially biodegradable materials, which reduce electronic waste and promote responsible biomedical production.
SDG 16: Peace, Justice, and Strong Institutions	Promotes strong institutions and ethical practices.	Ensures patient safety, data privacy, and ethical compliance with international medical standards and regulations.

SDG 17: Partnerships for the Goals	Strengthens global partnerships to achieve SDGs.	Encourages collaboration among engineers, doctors, researchers, and policymakers to ensure safe, affordable, and widespread adoption of the technology.

6.3.1 SWOT Analysis

The hydrogel based cardiac pacemaker represents a commitment to resilience while redefining the standards for breakthroughs in medical therapy by addressing these elements.

Strengths	Weakness
• **Biocompatibility:** The hydrogel ensures reduced infection risk and enhanced patient safety. • **Energy Efficiency:** Prolonged lifespan and reduced surgical needs lower costs and resource use. • **Real-Time Monitoring:** Advanced monitoring capabilities improve healthcare outcomes and patient management.	• **Reliance on Material Stability:** The secondary performance of the pacemaker is highly dependent on the long-term stability of the hydrogel components. • **Implementation Challenges:** Large-scale adoption may require significant adjustments in clinical protocols.
Opportunities	**Threats**
• **Global Accessibility:** Potential to provide life-saving technology to remote or underserved areas. • **Technological Integration:** Compatibility with future advancements, such as AI-driven diagnostics and telemedicine, enhances its relevance.	• **Competitive Market:** Technologies like bio-compatible conductive polymers and piezoelectric biomedical devices present direct competition, challenging our hydrogel-based solution's market positioning and differentiation. • **Regulatory Hurdles:** Strict approval processes for medical devices could delay deployment.

6.4 Conclusion

Taking everything into account, the hydrogel-based cardiac pacemaker project is a comprehensive illustration of technical innovation, patient-centered safety and reliability. It is capable of overcoming the limitations of conventional pacemakers and bringing clinical impact and socio-economic benefits in the long term. It is also strong in terms of sustainability, as its modular architecture, readily available components and the opportunity to improve power management. With further iterative research and responsible implementation, this technology can play a vital role in shaping the next generation of biomedical devices and making advanced healthcare more inclusive worldwide.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1 Introduction:

Effectively managing a project from start to finish requires the application of appropriate skills and expertise to ensure it meets all requirements, remains within budget, and adheres to the schedule. At the early stages of development, it's crucial to clearly define the project's goals and strictly follow a set timeline. Project management enables us to outline the plan for achieving these goals, along with the specific processes and expected outcomes. In addition to handling project tasks, it also involves maintaining regular communication among team members and relevant stakeholders. The next important step is to prepare contingency plans to address any unforeseen issues. Strong project management skills are demonstrated when the project is successfully presented within the scheduled timeframe.

7.2 Define, plan and manage an engineering project:

Gantt Chart FYDP-P

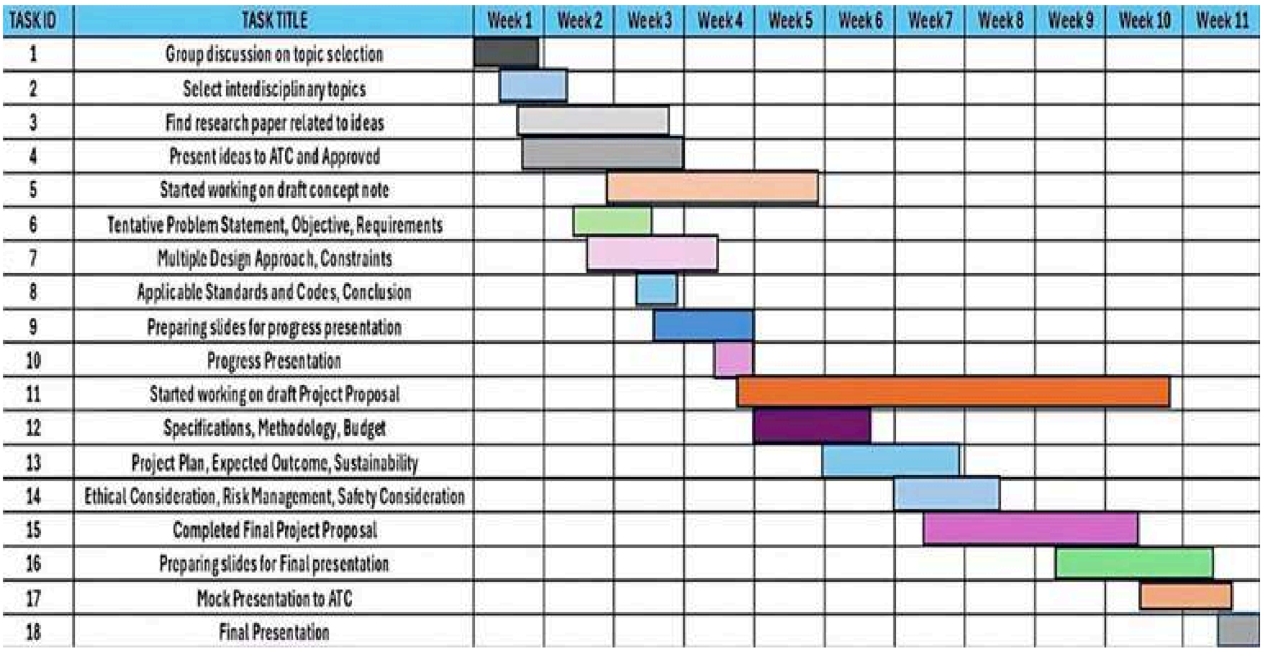

Figure : Gantt Chart for FYDP-P

EEE499P Project Plan

TASK ID	TASK TITLE	START DATE	END DATE	DURATION
1	Group discussion on topic selection	22/10/2024	28/10/2024	6 DAYS
2	Select interdisciplinary topics	31/10/2024	02/11/2024	2 DAYS
3	Find research papers related to ideas	03/11/2024	06/11/2024	3 DAYS
4	Present ideas to ATC and Approved	07/11/2024	07/11/2024	1 DAY
5	Started working on the draft concept note	09/11/2024	01/12/2024	22 DAYS
6	Problem Statement, Objectives, Requirements	10/11/2024	13/11/2024	3 DAYS
7	Multiple Design Approach, Constraints	14/11/2024	18/11/2024	4 DAYS
8	Applicable Standards and Codes, Conclusion	16/11/2024	16/11/2024	1 DAY
9	Preparing slides for progress presentation	19/11/2024	20/11/2024	1 DAY
10	Progress Presentation	21/11/2024	21/11/2024	1 DAY
11	Started working on draft Project Proposal	28/11/2024	05/01/2025	38 DAYS
12	Specifications, Methodology, Budget	01/12/2024	05/12/2024	4 DAYS
13	Project Plan, Expected Outcome, Sustainability	07/12/2024	13/12/2024	6 DAYS
14	Ethical Consideration, Risk Management and Safety Considerations	15/12/2024	18/12/2024	3 DAYS
15	Completed Final Project Proposal	19/12/2024	03/01/2025	15 DAYS
16	Preparing slides for the Final Presentation	04/01/2025	06/01/2025	2 DAYS
17	Mock Presentation to ATC	07/01/2025	07/01/2025	1 DAY
18	Final Presentation	09/01/2025	09/01/2025	1 DAY
Total Days				114 DAYS

Gantt Chart FYDP-D

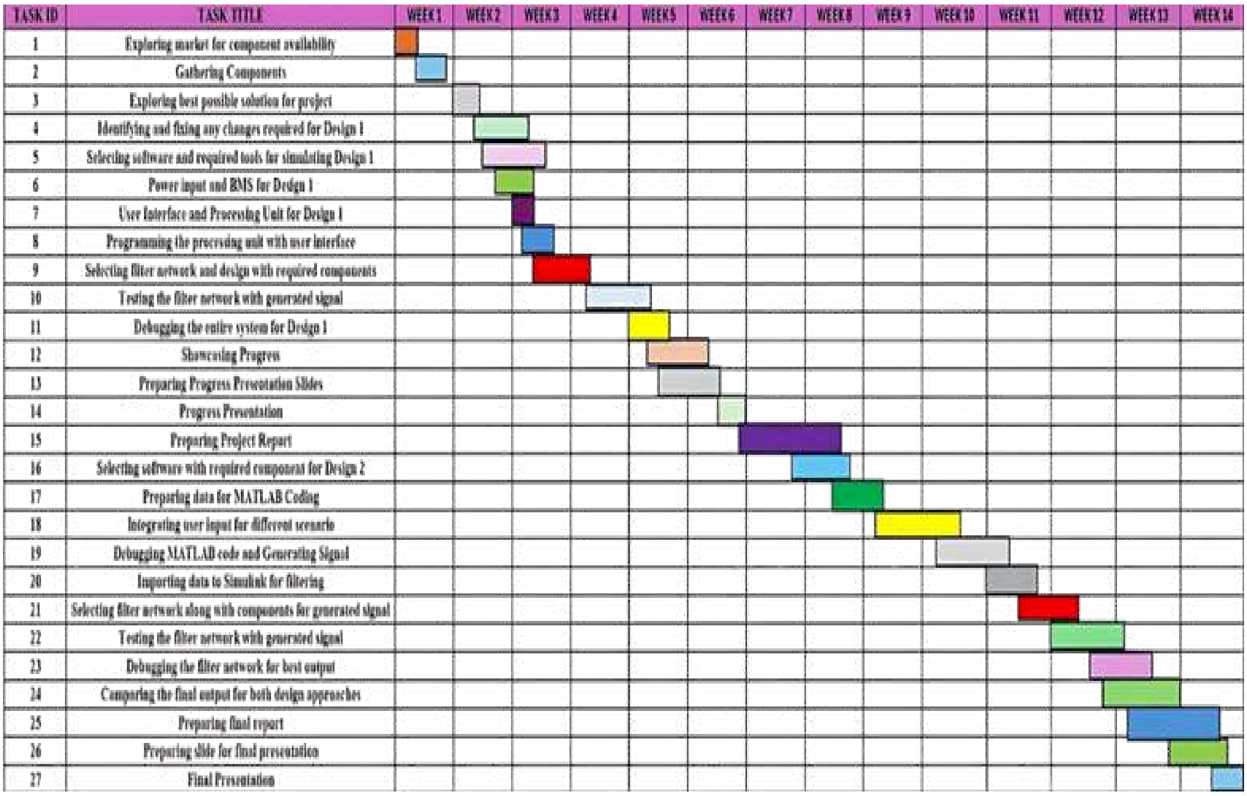

Figure : Gantt Chart for FYDP-D

EEE499D Project Plan

TASK ID	TASK TITLE	START DATE	END DATE	DURATION
1	Exploring the market for component availability	20/01/2025	22/01/2025	3 DAYS
2	Gathering Components	23/01/2025	25/01/2025	3 DAYS
3	Exploring best possible solution for project	26/01/2025	27/01/2025	2 DAYS
4	Identifying and fixing any changes required for Design 1	28/01/2025	29/01/2025	2 DAYS
5	Selecting software and tools for simulating Design 1	30/01/2025	04/02/2025	6 DAYS
6	Power input and BMS for Design 1	05/02/2025	08/02/2025	4 DAYS

7	User Interface and Processing Unit for Design 1	09/02/2025	14/02/2025	6 DAYS
8	Programming the processing unit with user interface	15/02/2025	17/02/2024	3 DAYS
9	Selecting filter network and required components	18/02/2025	22/02/2024	5 DAYS
10	Testing the filter network with generated signal	23/02/2025	25/02/2025	3 DAYS
11	Debugging the entire system of Design 1	27/02/2025	27/02/2025	1 DAY
12	Showcasing Progress	28/02/2025	01/03/2025	2 DAY
13	Preparing Progress Presentation Slides	02/03/2024	04/03/2025	3 DAYS
14	Progress Presentation	05/03/2025	05/03/2025	1 DAY
15	Preparing Project Report	06/03/2025	07/03/2025	2 DAY
16	Selecting software and components for Design 2	08/03/2025	13/03/2025	6 DAYS
17	Preparing data for MATLAB Coding	14/03/2025	17/03/2025	4 DAYS
18	Integrating user input for different scenario	18/03/2025	21/03/2025	4 DAYS
19	Debugging MATLAB code and Generating Signal	22/03/2025	24/03/2025	3 DAYS
20	Importing data to Simulink for filtering	25/03/2025	28/03/2025	4 DAY
21	Selecting filter network and components for signal	29/03/2024	01/04/2025	4 DAYS
22	Testing the filter network with the generated signal	02/04/2025	08/04/2025	7 DAYS
23	Debugging the filter network for best output	09/04/2025	13/04/2025	5 DAYS
24	Comparing final output for both Design Approaches	14/04/2025	17/04/2025	4 DAYS
25	Preparing final report	18/04/2025	22/04/2025	5 DAYS
26	Preparing slides for final presentation	23/04/2025	25/04/2025	3 DAYS
27	Final Presentation	26/04/2025	28/04/2025	3 DAY
Total Days				98 DAYS

Gantt Chart FYDP-C

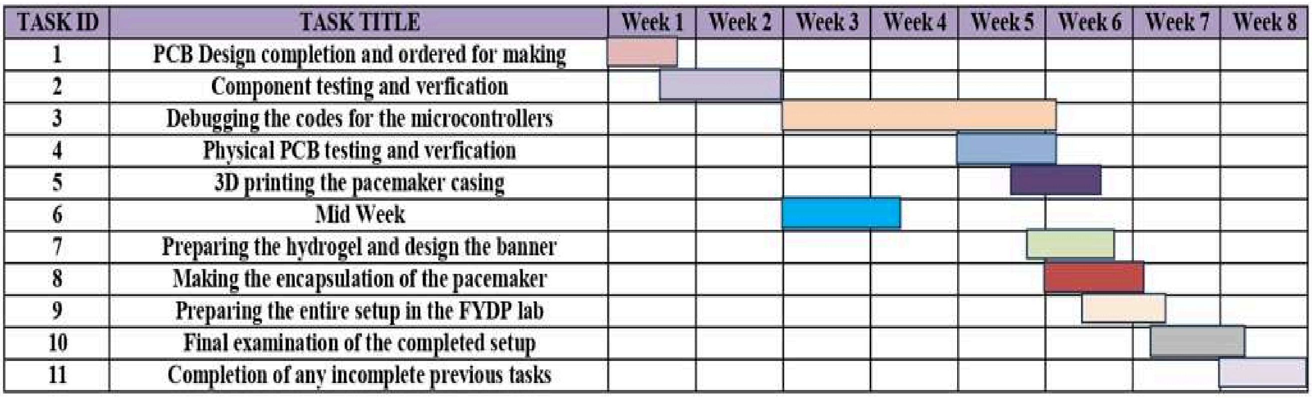

Figure: Gantt Chart for FYDP-C

EEE499C Project Plan

TASK ID	TASK TITLE	START DATE	END DATE	DURATION
1	PCB Design completion and ordered for making	25/06/2025	12/07/2025	17 DAYS
2	Component testing and verification	13/07/2025	16/07/2025	4 DAYS
3	Debugging the codes for the microcontrollers	18/07/2025	13/08/2025	26 DAYS
4	Physical PCB testing and verification	28/07/2025	14/08/2025	17 DAYS
5	3D printing the pacemaker casing	16/08/2025	20/08/2025	4 DAYS
6	Mid Week	26/07/2025	03/08/2025	8 DAYS
7	Preparing the hydrogel and design the banner	15/08/2025	27/08/2025	12 DAYS
8	Making the encapsulation of the pacemaker	18/08/2025	28/08/2025	10 DAYS
9	Preparing the entire setup in the FYDP lab	30/08/2025	02/09/2025	3 DAYS
10	Final examination of the completed setup	03/09/2025	05/09/2025	2 DAYS
11	Completion of any incomplete previous tasks	05/09/2025	07/09/2025	2 DAYS
Total Days				105 DAYS

7.3 Evaluate project progress

The general development of the project can be deemed to be satisfactory, and significant breakthroughs in all three phases of the project, which are; FYDP-P, FYDP-D and FYDP-C, were recorded despite a number of challenges being encountered especially in the latter phases.

The FYDP-P (Planning Phase) was carried out in an effective manner. The project proposal was done within its time frame as all the project documents were submitted within the stipulated time frame, including problem definition, objectives, design approaches, and risk analysis. This stage exhibited the excellence of coordination within the team members and clarity in planning the project. This period did not have any significant challenges and the background framework of the project was well established.

The FYDP-D (Development Phase) was a more dynamic situation. Although the preliminary activities like the component acquisition, system design and the simulation planning were done as per the schedule, the team also faced a number of technical challenges in debugging and system integration. These problems led to certain delays especially in the process of simulating signal filtering and integrating the user input. However, a series of troubleshooting processes resulted in the successful simulation of individual modules. Despite the constraint of full system integration, namely, the limitation in terms of runtime, which was limited to about three seconds because of resource limitations, the basic functional points were obtained. The stage proved to be successful in the validation of the main design concepts and the feasibility of the individual subsystems.

The FYDP-C (Construction and Testing Phase) was the most time- and resource-constrained. A number of hardware elements, especially those needed in order to apply the hydrogel based system, were either delayed or not obtainable at all. It is noteworthy that one of the key raw materials, namely a specialized conducting agent of the hydrogel electrodes, was unavailable because of the import restrictions. Regardless of these failures, the team adopted dynamic approaches, such as fast decision making and improvising on the spot, to guarantee further development. We had lagged behind schedule by a month, but we had later simplified some aspects of our work like the PCB to make more time to focus on the main objectives of our project. As a result, we were able to achieve a satisfactory result regardless of some incomplete processes like the wireless charging system. All the subsystems (ECG, temperature, and biochemical monitoring and the pacing module) were tested successfully. Although the complete process of all system integration into one unified system was achieved only partially, the main goals of the project, which were the monitoring and pacing with hydrogel electrodes, as well as the demonstration of hydrogel and its capabilities, and usage of an external application to demonstrate the measured parameters, were achieved.

7.4 Conclusion

The project is an important step on the path to the creation of a next-generation hydrogel-based pacemaker that is able to monitor the heart and activate it in real-time. The project journey involved a lot of teamwork, flexibility, and engineering capabilities as seen in terms of first planning and proposal in FYDP-P, development and simulation in FYDP-D, and eventual construction and testing in FYDP-C. Even though there were difficulties associated with the availability of hardware, time, and integration, the central functionalities, such as ECG surveillance, temperature, and biochemical sensing and cardiac pacing with the help of hydrogel electrodes were obtained. The construction and testing of individual subsystems had been done and shown to be viable. The results of the full integration though it was not completely realized in the case because of resource constraints offer a great basis on which further improvements can be made in future. This paper provides a basis on further biomedical developments and proves that hydrogel-based solutions can be used in implantable heart devices, serving the overall objective of enhancing patient care and technology to save lives.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

Any product analysis is an essential aspect of evaluating the feasibility of any biomedical device. For HydroPace, the primary considerations involve material costs, manufacturing complexity, wireless communication modules, hydrogel preparation, and sensor integration. Since cardiac pacemakers are life-saving devices, cost-effectiveness must be balanced with safety, reliability, and compliance with medical standards. The economic viability of HydroPace depends on minimizing production costs while ensuring durability, biocompatibility, and advanced features such as wireless monitoring.

8.2 Economic analysis

The cost structure of HydroPace can be divided into several categories: hydrogel materials, sensors (ECG, biochemical, temperature, pH), microcontroller, wireless communication unit, power transfer coils, and packaging for implantation. Hydrogel preparation and embedding of electrodes represent a moderately high cost due to the requirement for biocompatibility and precision manufacturing. However, bulk production and scalable synthesis of hydrogel can significantly reduce expenses. Compared to traditional pacemakers that rely on costly batteries and invasive replacement surgeries, HydroPace offers long-term economic benefits by reducing battery replacement needs through wireless powering. Additionally, the use of off-the-shelf microcontrollers and Bluetooth-enabled modules makes the system more affordable without compromising performance. Thus, the initial development cost may be high, but widespread adoption and scaled production are expected to reduce unit costs, making HydroPace a cost-effective and sustainable cardiac pacing solution.

8.3 Cost benefit analysis

The feasibility of HydroPace as a cardiac pacing solution is determined through a thorough cost-benefit analysis. While developing biomedical devices, both advantages and trade-offs must be carefully weighed, as safety, precision, and durability are as important as affordability. The benefits of HydroPace lie in its ability to provide wireless powering, eliminate frequent surgical interventions for battery replacement, and integrate real-time monitoring of ECG, biochemical, temperature, and pH data. These features collectively improve patient outcomes and reduce long-term healthcare costs.

It is not always the case that the lowest-cost design is the most economical choice in biomedical engineering. For HydroPace, critical considerations include the reliability of hydrogel electrodes, stability of wireless communication, accuracy of sensors, and biocompatibility of the materials. While certain components—such as conductive hydrogels and RF coil systems may be more expensive compared to alternatives, their inclusion ensures long-term safety and functionality, making the overall design more cost-effective in the long run.

The two design approaches proposed have been analyzed: Compact HydroPace and Accessible HydroPace. Some modules in Compact HydroPace, such as RF coupling for coil-based wireless powering, are more costly and complex, while Accessible HydroPace, which relies mainly on WiFi-based communication, reduces cost but may sacrifice certain functionalities. As engineers, it is our responsibility to select components and design paths that balance cost with performance, ensuring that HydroPace remains both economically feasible and clinically effective. The figure 8 below shows the calculation of our produced hydrogel, the capital expenditure, operational expenditure, the benefit we can provide and the net gain we can achieve in the course of a year:

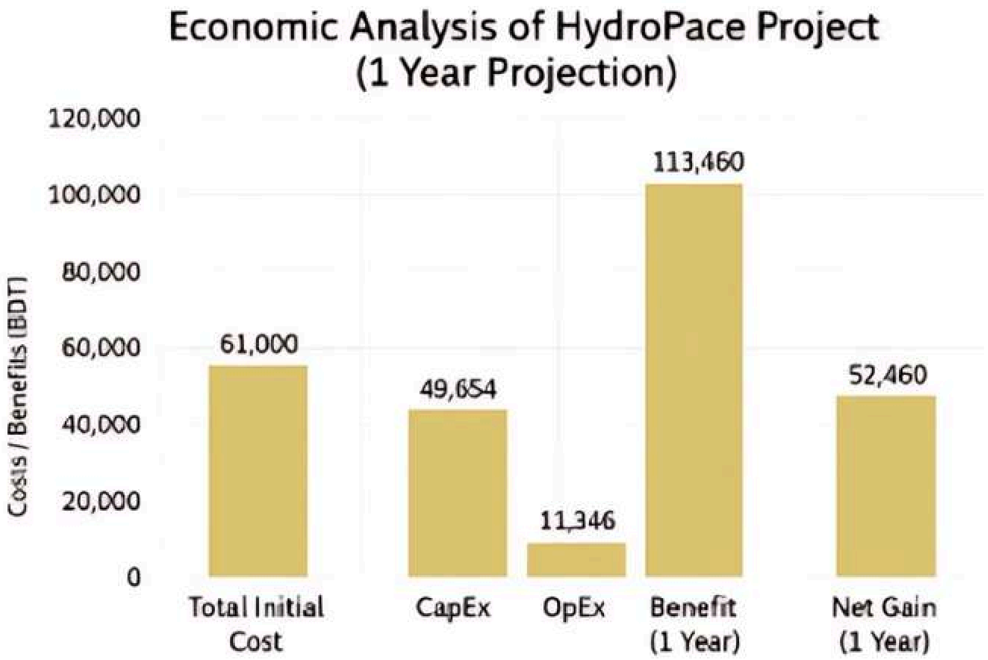

Figure 8: Economic analysis of hydropace

- The initial cost shows the total spent on building the prototype.
- ROI = (Net Return/ Net investment) x 100

= (52,460/ 61,000) x 100

= 86%

However, if we are to produce HydroPace on a large scale, with our available options, the production cost will largely decrease due to the amount of hydrogel being actually used, and with the cost of the pacemaker electronics being similar to that of conventional pacemakers, we anticipate that we can produce HydroPace with less cost compared to the greater benefit we can achieve in return, leading to more net gain. One chemical mentioned in section 8.4.2 is Neostigmine Methylsulphate. Based on the supplier, its price drastically changes. It was initially valued at 4000 taka for 5 grams while having to be imported, but in the local market it was found to be only 10 taka for the same amount. In the comparatively short time period allocated to our FYDP project, there are such offers that we might miss. Therefore, with adequate preparation, it is possible to enhance the long-term cost effectiveness and increase economic feasibility.

8.4 Evaluate economic and financial aspects

8.4.1 Initial Components Budget for Design Approach 1 (Compact HydroPace)

Component's Name	Details	Unit	Price (BDT)	Product Link
Lithium battery	100mAh, 3.7V LiPO4 battery	10 (fixed quantity)	955	https://siruituo.en.made-in-china.com/product/UQhYoLTuvSWg/China-3-7V-Lithium-Polymer-Battery-Cell.html
Microcontroller	ATMega328-AU	1	277	https://www.snapeda.com/parts/ATMEGA328-AU/Microchip%20Technology/view-part/?ref=search&t=ATmega%20328
Oscillator	SPXO crystal oscillator	1	15	https://store.roboticsbd.com/components/1977-12mhz-crystal-oscillator-robotics-bangladesh.html
ECG sensor (ECG acquisition unit)	AD8232 ECG measurement module kit	1	790	https://store.roboticsbd.com/sensors/391-ad8232-ecg-measurement-module-kit-robotics-bangladesh.html
Biochemical sensor	Hydrogel-based	1	8685	https://www.ubuy.com.bd/en/product/1QG4ZSUM-chitosan-powder-90-deacteylated-100g?srsltid=AfmBOor-cGxEshnHFXaCVJnfdnLskU-zdNogX2ZS7eQeXKA0DSvelucB
Temperature Sensor	RTD PT-100 Temp. sensor	1	490	https://store.roboticsbd.com/sensors/2056-pt-100-rtd-temperature-sensor-3-wire-50cm-robotics-bangladesh.html

Signal Amplifiers	UA741CN Op-Amp	1	30	https://store.roboticsbd.com/analog-ics-/1025-ua741cn-operational-amplifier-robotics-bangladesh.html
Signal Processor	dsPIC30F2010-20E/SP Digital Signal Processors & Controllers	1	617	https://www.bdtronics.com/dspic30f2010-20e-sp-digital-signal-processors-controllers-dsp-dsc-16b-mcu-dsp-28ld-30mips-12kb-flash-pdip-28.html?srsltid=AfmBOooNotKH_4gLnHL5RF-gmVxXujqfNpGzsElipMtM_sldEG5HAMv9 1
Analog to Digital converter and vice versa	PCF8591 module (Dual ADC/DAC)	1	390	https://store.roboticsbd.com/arduino-shield-module/2216-pcf8591-module-analog-to-digital-digital-analog-converter-module-robotics-bangladesh.html
Energy harvesters 9dp2)	AEM30940 RF Energy Harvesting	1	500	https://e-peas.com/product/aem30940/ https://www.mouser.in/c/?m=e-peas&_gl=1%2Aiqwwk4%2A_ga%2AMTQ2Njg1MDkuMTcxMjkxNzk2Nw..%2A_ga_15W4STQT4T%2AMTczNTc0MDM3OS4zLjEuMTczNTc0MDQ4NC4zNC4wLjA.
Hydrogel substrate	Poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate)	1g	600	https://www.bldpharm.com/products/155090-83-8.html
Hydrogel encapsulation	Chitosan, alginate and silk fibroin based hydrogels.	100g	8026	https://www.ubuy.com.bd/en/product/1QG4ZSUM-chitosan-powder-90-deacteylated-100g?srsltid=AfmBOor-cGxEshnHFXaCVJnfdnLskU-zdNogX2ZS7eQeXKA0DSvelucB
Hydrogel conduction additive material	Neostigmine Methylsulphate	0.5mg	10	https://medex.com.bd/generics/803/neostigmine-methylsulphate
Wireless module (Bluetooth or NFC) (Arduino)	HM-10 BLE Bluetooth 4.0	1	470	https://store.roboticsbd.com/robotics-parts/439-arduino-android-ios-hm-10-ble-blu

	cc2540 (Model name)			etooth-40-cc2540-cc2541-serial-wireless-module-robotics-bangladesh.html
Antenna	M177 NRF24L01 (Model name) Antenna Wireless Transceiver (Attribute)	1	199	https://store.roboticsbd.com/robotics-parts/103-m177-nrf24l01-24ghz-antenna-wireless-transceiver-module-robotics-bangladesh.html
Wires	M - M/ F - F/ M - F Copper wires (enamelled)	3 1 unit	165 50	https://store.roboticsbd.com/cables-wire/2639-male-to-male-jumper-wires-20-pcs-20cm-robotics-bangladesh.html https://www.electronics.com.bd/Copper-wire-22-SWG-Magnet-enameled-Copper-motor-coil-wire-22-SWG-Magnet-enameled-Price-in-online-BD-Bangladesh?route=product/product&srsltid=AfmBOoo-KfgVI8x4YHUazXl-0BwpLbXqRFGLyB45W3c75nWnNIjx8Xnt
Resistor	Normal resistors	2	30	https://store.roboticsbd.com/resistor/243-10k-ohm-14w-carbon-film-resistor-pack-of-10-robotics-bangladesh.html
Capacitor	Normal and micro Aluminium electrolytic capacitors	1	7	https://store.roboticsbd.com/capacitor/1493-22uf-50v-capacitor-pack-of-5-robotics-bangladesh.html
Diode	1N4001	10	40	https://store.roboticsbd.com/components/1360-1n4007-diode-robotics-bangladesh.html
Inductor	Colour ring inductors	10	100	https://store.roboticsbd.com/components/2000-10uh-05w-color-ring-inductor-robotics-bangladesh.html

Voltage Regulator	AMS1117 Voltage rating- 5.0 V Current rating- 1A Model: SOT-223 IC	1	49	https://store.roboticsbd.com/components/2109-ams1117-50v-1a-sot-223-voltage-regulator-ic-robotics-bangladesh.html
Total			22,495 BDT	

8.4.2. Latest Implemented Components Budget for Design Approach 1

Component's Name	Details	Unit	Price (BDT)	Product Link
Lithium battery	500mAh, 3.7V LiPO4 battery	1	274	https://www.electronics.com.bd/batteries-chargers/li-ion-battery-500mah-3-7v-1-cell
	600mAh, 3.7V Lithium Ion battery	2	300	Patuatuli
	1500mAh, 3.7V Lipo battery 5.55Wh	1	620	https://store.roboticsbd.com/battery/3564-37v-1500mah-lipo-battery-555wh-with-jst-connector-robotics-bangladesh.html
Microcontroller	Arduino Uno R3	1	988	https://store.roboticsbd.com/development-boards/94-8-arduino-uno-r3-robotics-bangladesh.html
	ESP32 S3 Wroom Micropython Board	2	1880	https://store.roboticsbd.com/development-boards/2367-esp32-s3-wroom-1-dual-type-c-usb-n16r8-micropython-board-robotics-bangladesh.html
	Arduino uno R3 SMD(Atmega 328P)	1	483	https://www.electronics.com.bd/microcontroller/arduino-uno-r3-smd-atmega328-ic

Oscillator	8 MHz Crystal Oscillator 16 MHz Crystal Oscillator	2 1	26 18	https://store.roboticsbd.com/components/1981-8-mhz-crystal-oscillator-robotics-bangladesh.html https://store.roboticsbd.com/components/1356-16mhz-crystal-oscillator-robotics-bangladesh.html
Hydrogel-based	N,N'-Methylenebisacrylamide)	5gm	7000	https://www.facebook.com/sulfochems.bd.page
Hydrogel-based	Sulfobetaine Methacrylate	5gm	4000	https://www.facebook.com/sulfochems.bd.page
Signal Processor	KS1082 signal processor chip	5	2590	https://www.taobao.com/list/item/621844771640.htm
Solder Paste	MECHANIC XG-50 Solder Paste	1	290	https://www.electronics.com.bd/power-tools/mechanic-solder-paste
Battery Charger	Tp4056 lithium battery charger	1	32	https://store.roboticsbd.com/robotics-parts/919-tp4056-lithium-battery-charger-module-with-protection-dual-functions-robotics-bangladesh.html
Hydrogel substrate	Lithium Phenyl (2,4,6 - Trinethylbenzoyl)	1gm	10500	https://www.facebook.com/sulfochems.bd.page
Hydrogel encapsulation	3-(Trimethoxsilyl) Propyl Methacrylate	100ml	5000	https://www.facebook.com/sulfochems.bd.page
Hydrogel conduction additive material	Neostigmine Methylsulphate	0.5mg	10	https://medex.com.bd/generics/803/neostigmine-methylsulphate
Antenna	M177 NRF24L01 2.4GHz Antenna Wireless Transceiver	1	195	https://store.roboticsbd.com/communication-module/103-m177-nrf24l01-24ghz-an

	Module			tenna-wireless-transceiver-module-robotics-bangladesh.html
Wires	M - M	1	160	https://store.roboticsbd.com/connector/2105-male-to-male-jumper-wires-40-pin-30cm-robotics-bangladesh.html
	M-M	1	55	https://store.roboticsbd.com/cables-wire/2639-male-to-male-jumper-wires-20-pcs-20cm-robotics-bangladesh.html
	M-F	1	150	https://store.roboticsbd.com/connector/2104-male-to-female-jumper-wires-40-pin-30cm-robotics-bangladesh.html
	Breadboard Jumper Wire Set	1	190	https://store.roboticsbd.com/cables-wire/1153-breadboard-jumper-wire-set-robotics-bangladesh.html
	Solderless Copper wires	1 unit	50	https://www.electronics.com.bd/Copper-wire-22-SWG-Magnet-enameled-Copper-motor-coil-wire-22-SWG-Magnet-enameled-Price-in-online-BD-Bangladesh?route=product/product&srsltid=AfmBOoo-KfgVI8x4YHUazXl-0BwpLbXqRFGLyB45W3c75nWnNIjx8Xnt
	M-F	1	100	https://store.roboticsbd.com/robotics-parts/31-1-jumper-wire-40-pcs-set-20cm-robotics-bangladesh.html#/2-jumper_wire_type-male_to_female
Desoldering braid	0.7m 2mm Desoldering Braid Solder Remover Wick Wire	1	62	https://www.electronics.com.bd/soldering-equipment/0-7m-2mm-desoldering-braid-solder-remover-wick-wire-repair-cable
Wireless Charger Module	5V 2A wireless charger module	1	830	https://store.roboticsbd.com/power-module-adapter/1723-5v-2a-large-current-wireless-charger-module-wireless-power-supply-module-robotics-bangladesh.html

Voltage Regulator	AMS1117 Voltage rating- 5.0 V Current rating- 1A Model: SOT-223 IC HT7333A Voltage Regulator	1 3	49 90	https://store.roboticsbd.com/components/2109-ams1117-50v-1a-sot-223-voltage-regulator-ic-robotics-bangladesh.html https://leetechbd.com/product/7333-a-sot89-3-smd-voltage-regulator-chip/
Lab Coat	For Lab Purpose	1	350	Trade Hunt Scientific Bd(patuatuli)
Human Skeleton	5ft Human Skeleton	1	3500	https://labtexbd.com/product/human-skeleton-5-feet-indian/
Power Adapter	ac/dc power adapter 12v	1	350	https://store.roboticsbd.com/power-module-adapter/1876-acdc-power-adapter-12v-18a-robotics-bangladesh.html
LED	5mm LED (Red+ Green)	4	20	https://store.roboticsbd.com/components/768-5-mm-red-led-robotics-bangladesh.html
Human heart prop	Human Heart Model	1	800	https://labtexbd.com/product/human-heart-model/
OP Amp	JFET Dual Op-Amp	2	70	https://store.roboticsbd.com/analog-ics-/1026-tl072cp-jfet-dual-op-amp-robotics-bangladesh.html
Cable	50 cm Cable For Arduino UNO/MEGA (USB A to B) Shielded Blue USB Type-C cable for arduino Cable for arduino 3.2feet	1 2 1	130 440 195	https://store.roboticsbd.com/programmer/2196-50-cm-cable-for-arduino-unomega-usb-a-to-b-robotics-bangladesh.html https://store.roboticsbd.com/cables-connectors/2425-shielded-blue-usb-type-c-cable-30cm-for-arduino-robotics-bangladesh.html https://store.roboticsbd.com/programmer/1761-cable-for-arduino-unomega-usb-a-t

				o-b-32-feet1meter-robotics-bangladesh.html
Aluminium Sheet	For Hydrogel	1	150	Local Store, Dhanmondi
Sand Paper	For Hydrogel	1	30	Local Store, Uttara
Electronics Box	Tool	1	450	Local Store, Uttara
Foam	Square Foam	1	100	Local Store, Badda
Wrapper	Color Paper Wrapper	1	120	Local Store, Badda
Small Cloth	For Hydrogel making	1	80	Local Store, Uttara
Small Piece of Wood	For Hydrogel making	1	70	Local Store, Uttara
Temperature Sensor	LM35 Temperature Sensor MCP9808 High Accuracy I2C Temperature Sensor Breakout Board	2 1	310 680	https://store.roboticsbd.com/sensors/241-lm35-temperature-sensor-robotics-bangladesh.html https://store.roboticsbd.com/sensors/3402-mcp9808-high-accuracy-i2c-temperature-sensor-breakout-board-robotics-bangladesh.html?srsltid=AfmBOorEI7f9C1eCtV9TZpSWBQudOgSrAqsfFqXjxjYV8ndt4PBsVRQT
Electric mini drill	Tool	1	1150	https://store.roboticsbd.com/tools-accessories/670-electric-mini-drill-robotics-bangladesh.html
Chemical	Silver Nitrate	50gm	8000	Trade Hunt Scientific Bd(patuatuli)
Bulb	For temperature test	1	40	Local Store, Badda
Duct Tape	Tool	1	60	Local Store, Badda
Balloon	Tool	6	30	Local Store, Badda

Tweezer	Anti-Static Stainless Steel Tweezer	1	170	https://store.roboticsbd.com/tools-accessories/1169-88-anti-static-stainless-steel-high-precision-professional-tweezers-robotics-bangladesh.html#/58-tweezers_type-esd_14
Xanthan gum	For Hydrogel	50gm	100	https://www.daraz.com.bd/products/xanthan-gum-50gm-food-grade-made-in-malaysia-i478805242.html
3D Model	3D Model Print	1	950	https://www.facebook.com/EvoTechBD22
PCB	Pacemaker PCB	1	3000	https://www.facebook.com/PCBExpertBD
Pipe	Clear PVC pipe	5ft	50	Local Store, Uttara
Poster	Poster Print	1	2000	Local Store, Mohakhali
Total			59337 BDT	

8.4.3 Components Budget for Design Approach 2 (Accessible HydroPace)

Component's Name	Details	Unit	Price (BDT)	Product Link
Lithium battery	3-15 years, 3.3V LiSOCl2 battery	1	2530	https://www.daraz.com.bd/products/saft-ls33600-d-size-36v-lithium-thionyl-chloride-battery-i168302792.html
Microcontroller	Arduino Mega 2560 R3	1	1895	https://store.roboticsbd.com/development-boards/9-arduino-mega-2560-r3-robotics-bangladesh.html

ECG sensor (ECG acquisition unit)	AD8232 ECG measurement module kit	1	790	https://store.roboticsbd.com/sensors/391-ad8232-ecg-measurement-module-kit-robotics-bangladesh.html
Temperature Sensor	RTD PT-100 Temp. sensor	1	490	https://store.roboticsbd.com/sensors/2056-pt-100-rtd-temperature-sensor-3-wire-50cm-robotics-bangladesh.html
Signal Amplifiers	UA741CN Op-Amp	1	30	https://store.roboticsbd.com/analog-ics-/1025-ua741cn-operational-amplifier-robotics-bangladesh.html
Signal Processor	Kingsense KS1082	1	2500	https://www.tradeeasy.com/supplier/692932/kingsense-sourcing-china.html
Analog to Digital converter	ADS1115	1	440	https://store.roboticsbd.com/arduino-shield-module/3165-ads1115-4-channel-16-bit-precision-analog-to-digital-converter-adc-module-china-robotics-bangladesh.html
Digital to Analog converter	MCP4725	1	300	https://store.roboticsbd.com/arduino-shield-module/2740-mcp4725-12-bit-dac-module-robotics-bangladesh.html
Energy harvesters 9dp2)	AEM30940 RF Energy Harvesting	1	500	https://e-peas.com/product/aem30940/ https://www.mouser.in/c/?m=e-peas&_gl=1%2Aiqwwk4%2A_ga%2AMTQ2Njg1MDkuMTcxMjkxNzk2Nw..%2A_ga_15W4STQT4T%2AMTczNTc0MDM3OS4zLjEuMTczNTc0MDQ4NC4zNC4wLjA.
Antenna	M177 NRF24L01	1	199	https://store.roboticsbd.com/robotics-parts/103-m177-nrf24l01-24ghz-antenna-wireless-transceiver-module-robotics-bangladesh.html
Wireless module (Bluetooth or NFC) (Arduino)	HM-10 BLE Bluetooth 4.0 cc2540 (Model name)	1	470	https://store.roboticsbd.com/robotics-parts/439-arduino-android-ios-hm-10-ble-bluetooth-40-cc2540-cc2541-serial-wireless-module-robotics-bangladesh.html

pH sensor	Microelectrode-based	1	1325	https://www.volza.com/p/ph-electrodes/import/import-in-bangladesh/
Hydrogel Substrate	Chitosan, alginate, PSBMA and silk fibroin-based hydrogels.	100g	8026	https://www.ubuy.com.bd/en/product/1QG4ZSUM-chitosan-powder-90-deacteylated-100g?srsltid=AfmBOor-cGxEshnHFXaCVJnfdnLskU-zdNogX2ZS7eQeXKA0DSvelucB
Heart rate pulse sensor module for Arduino	RBD-0348	1	309	https://store.roboticsbd.com/sensors/348-heart-rate-pulse-sensor-module-for-arduino-robotics-bangladesh.html
Breadboard	Medium	1	150	https://store.roboticsbd.com/breadboard-prototype/1886-gl-12-breadboard-full-size-bare-830-tie-points-robotics-bangladesh.html
Wires	M - M/ F - F/ M - F	3	165	https://store.roboticsbd.com/cables-wire/2639-male-to-male-jumper-wires-20-pcs-20cm-robotics-bangladesh.html
	Solderable wires	3	12	https://store.roboticsbd.com/cables-wire/904-solderable-cable-red-and-black-pair-robotics-bangladesh.html
	Copper wires (enamelled)	1	50	https://www.electronics.com.bd/Copper-wire-22-SWG-Magnet-enameled-Copper-motor-coil-wire-22-SWG-Magnet-enameled-Price-in-online-BD-Bangladesh?route=product/product&srsltid=AfmBOoo-KfgVI8x4YHUazXl-0BwpLbXqRFGLyB45W3c75nWnNIjx8Xnt
	Solderless breadboard cables	3	25	https://store.roboticsbd.com/connector/772-75mm-u-shaped-solderless-breadboard-jumper-cable-pack-of-5-robotics-bangladesh.html

Resistor	Normal resistors	2	30	https://store.roboticsbd.com/resistor/243-10k-ohm-14w-carbon-film-resistor-pack-of-10-robotics-bangladesh.html
Capacitor	Normal and micro Aluminium electrolytic capacitors	1	7	https://store.roboticsbd.com/capacitor/1493-22uf-50v-capacitor-pack-of-5-robotics-bangladesh.html
Diode	1N4001	10	40	https://store.roboticsbd.com/components/1360-1n4007-diode-robotics-bangladesh.html
Inductor	Colour ring inductors	10	100	https://store.roboticsbd.com/components/2000-10uh-05w-color-ring-inductor-robotics-bangladesh.html
Voltage Regulator	AMS1117 Voltage rating- 5.0 V Current rating- 1A Model: SOT-223 IC	1	49	https://store.roboticsbd.com/components/2109-ams1117-50v-1a-sot-223-voltage-regulator-ic-robotics-bangladesh.html
Total			20,432 BDT	

8.5 Conclusion

In conclusion, based on the above discussion regarding economic analysis and budget considerations, we can say that our selected design approach offers a more cost-effective and sustainable solution compared to traditional pacemakers. While conventional devices rely heavily on rigid structures and batteries that require frequent surgical replacement, HydroPace minimizes such limitations by incorporating hydrogel materials, wireless powering, and integrated sensors. This not only reduces long-term costs but also enhances patient safety and comfort.

Through this economic evaluation, we can better assess the trade-offs between cost, performance, and durability, ensuring that HydroPace remains both affordable and clinically effective. Therefore, it is essential that a thorough economic assessment continues to guide the development of the device, so that the final product achieves sustainability, accessibility, and practical impact in the healthcare sector.

Chapter 9: Ethics and Professional Responsibilities CO13, CO2

9.1 Introduction

The integration of advanced biomedical technologies, such as hydrogel-based cardiac pacemakers, demands strong ethical foundations and a commitment to professional responsibility. These responsibilities include ensuring patient autonomy, safety, data security, and regulatory compliance. As such innovations become more embedded in patient care, both designers and healthcare professionals must uphold these ethical standards to maintain trust and deliver equitable, effective, and respectful care.

9.2 Identify ethical issues and professional responsibility

Several ethical concerns arise in the development and deployment of HydroPace, a hydrogel-based cardiac pacemaker:

- **Patient Consent and Autonomy:** Patients must provide informed consent regarding device implantation, usage, and data collection. Respecting their autonomy ensures that participation is voluntary and well-understood.

- **Sensitivity to Patient Well-Being:** The device must be designed with a focus on minimizing discomfort, both physically and psychologically. Professional responsibility includes maintaining patient dignity and emotional safety throughout the treatment process.

- **Ownership and Control of Health Data:** Ethical practice demands that patients maintain control over their health data. Any modifications or sharing of this data should require explicit permissions and follow privacy standards.

- **Inclusive Design:** The pacemaker must consider diverse patient populations with varying levels of literacy, tech skills, and cultural backgrounds. Ensuring accessibility is a professional obligation.

- **Regulatory Compliance:** Professionals are ethically responsible for adhering to national and international regulations set by medical and ethical boards, ensuring device safety and effectiveness.

- **Transparency in Data Use:** Full disclosure of how data is collected, processed, stored, and used is a key ethical requirement.

- **Data Privacy and Security:** Health data must be anonymized and encrypted to prevent misuse or unauthorized access.

- **Ongoing Ethical Audits:** Continuous review and updates based on emerging ethical concerns and technological advancements reflect a professional duty toward ethical integrity.

9.3 Apply ethical issues and professional responsibility

To ensure that ethical considerations and professional responsibilities are effectively translated into real-world implementation, several strategic actions should be adopted throughout the lifecycle of the hydrogel-based cardiac pacemaker:

- **Implement User-Friendly Consent Processes:** Healthcare providers must develop clear, accessible, and user-oriented consent models that explain the implications of using the pacemaker. This includes detailing how the device functions, what data it collects, and how it is stored or shared. Patients should be able to make informed decisions without pressure, fully understanding the benefits and risks.

- **Design with Empathy and Comfort in Mind:** Engineering teams should focus on minimizing both physical and psychological discomfort associated with the implantation and long-term use of the pacemaker. This includes using biocompatible and flexible materials like hydrogel to reduce tissue irritation, and ensuring procedures are conducted with minimal invasiveness. Psychological support should also be available for patients who may have anxiety about having a medical device implanted.

- **Secure Patient Data with Strict Access Controls:** All cardiac data collected must be protected with modern encryption techniques, ensuring confidentiality and preventing misuse. Access to data should be role-based—only qualified healthcare professionals with proper authorization should view or make recommendations based on the data. Any changes to health records must follow strict protocols and require medical justification.

- **Promote Inclusive Design Across Demographics:** Ethical responsibility includes designing technology that serves a wide range of patients regardless of age, gender, cultural background, or technological literacy. Interfaces should be simple and customizable, and alert systems should be adapted for users with different needs. Educational materials and tutorials must also be available in multiple languages and formats.

- **Ensure Regulatory Alignment and Continuous Oversight:** Developers and healthcare providers must ensure the pacemaker is in full compliance with medical device regulations and ethical standards. This includes obtaining approval from ethical review boards, conducting risk assessments, and staying updated with international standards to maintain legal and ethical credibility.

- **Maintain Transparency with Stakeholders:** Patients, caregivers, and healthcare professionals should be regularly informed about how data is being used, processed, and stored. Clear communication builds trust and allows patients to feel more secure in their treatment. Features such as opt-in/opt-out options for certain types of data sharing can enhance transparency and control.

- **Conduct Periodic Ethical and Technological Audits:** Regular assessments should be performed to review whether ethical standards are being met and if the technology needs to be updated. These audits may include patient feedback, technical evaluations, and policy reviews, helping the team respond to new ethical challenges and advances in medical innovation.

By implementing these practical steps, the development and deployment of the hydrogel cardiac pacemaker can remain ethically sound, patient-centered, and professionally responsible at every stage.

9.4 Conclusion

Ethical considerations and professional responsibilities play a vital role in the development and use of hydrogel-based cardiac pacemakers. Ensuring patient autonomy, data privacy, comfort, and inclusivity are key to building trust and promoting safe, patient-centered care. Adhering to regulatory standards and maintaining transparency in data use help strengthen ethical integrity. Regular ethical audits and updates ensure the device remains aligned with both technological advancements and evolving patient needs. Overall, a strong ethical foundation ensures that such innovations serve the public good responsibly and effectively.

Chapter 10: Conclusion and Future Work

10.1 Project summary/Conclusion

The project focuses on designing a compact, hydrogel-based cardiac pacemaker that addresses the limitations of conventional pacemakers by incorporating modern advancements in biomedical sensing and wireless technologies. The device integrates real-time cardiac monitoring features such as ECG, temperature sensing, and cardiac fitness detection, all within a fully implantable and Bluetooth enabled framework. Among the two design approaches considered, the wireless-powered version shows greater potential in terms of sustainability, biocompatibility, and long-term performance. Through intelligent design and interdisciplinary coordination, the system ensures continuous health monitoring with minimal need for invasive procedures, thus enhancing patient comfort and reducing medical costs. Despite limitations in simulation software (e.g., Proteus CPU load), the human faculty simulations confirmed the practical viability and impact of the design. The project aligns strongly with Complex Engineering Problems (CEP) and Complex Engineering Activities (CEA) attributes by involving cross-disciplinary knowledge, novel biomedical integration, real-time sensing, and ethical design thinking. Overall, the HydroPace pacemaker is a novel contribution to biomedical innovation, promising greater longevity, safety, and global accessibility in cardiac care.

10.2 Future work

While the current prototype and simulation confirm the functional promise of the hydrogel-based pacemaker, several areas remain open for further development:

- **Implementation of compact Faraday Cage:** The incorporation of a compact Faraday cage in the implant construction will be considered to protect sensitive electronic devices against external electromagnetic interference (EMI), providing the continuity of signal in a wide range of environments and reliability of the devices.

- **Hardware Integration and Miniaturization:** Future iterations will focus on physically assembling all components hydrogel electrodes, wireless modules, and biosensors into a miniaturized, implantable form suitable for clinical trials.

- **Biocompatibility and Long-Term Testing:** Extensive biological testing, including animal trials, will be required to evaluate the hydrogel's long-term interaction with human tissue, degradation patterns, and immune responses.

- **Power Management and Wireless Charging:** The wireless energy transfer system must be refined for stability, safety, and efficiency. Research will also explore energy harvesting from body motion or thermoelectric sources.

- **AI-Driven Data Analysis:** Integration of machine learning algorithms for anomaly detection and predictive alerts will be explored to provide early warnings to both patients and healthcare providers.

- **Compliance and Certification:** Future work must ensure compliance with international medical device regulations (FDA, CE) and ethical standards for data privacy, especially for real-time patient monitoring systems.

- **User Interface Development:** A user-friendly mobile or wearable interface for patients and physicians will be designed to display cardiac data, receive alerts, and track overall health trends.

Through these developments, the HydroPace project aims to transition from a simulated concept to a clinically approved, real-world medical solution capable of saving lives and advancing cardiac healthcare.

Chapter 11: Identification of Complex Engineering Problems and Activities.

11.1: Identify the attribute of complex engineering problem (EP)

Attributes of Complex Engineering Problems (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	✓
P2	Range of conflicting requirements	
P3	Depth of analysis required	✓
P4	Familiarity of issues	✓
P5	Extent of applicable codes	
P6	Extent of stakeholder involvement and needs	
P7	Interdependence	

11.2: Provide reasoning how the project address selected attribute (EP)

In this project, we identified three attributes of Complex Engineering Problems: depth of knowledge required, depth of analysis required, and familiarity of issues. The project demands a wide range of knowledge, including biomedical devices and their functionalities, embedded systems, IoT, sensors, wireless communication, the design process, and the necessary development tools. A strong depth of analysis is also needed to evaluate different alternative solutions and select the most optimal one. Furthermore, the project involves issues that are not commonly encountered, as biomedical devices and their applications are not usually part of the standard EEE/ECE curriculum. This means we must independently learn and understand these unfamiliar topics while designing the solution.

11.3 Identify the attribute of complex engineering activities (EA)

Attributes of Complex Engineering Activities (EA)

	Attributes	Put tick (√) as appropriate
A1	Range of resource	✓
A2	Level of interaction	
A3	Innovation	
A4	Consequences for society and the environment	✓
A5	Familiarity	✓

11.4 Provide reasoning how the project address selected attribute (EA)

Three characteristics of complex engineering activities were chosen for this project: range of resources, consequences for society and the environment, and familiarity. Coordination and communication are necessary to mobilize a variety of resources, including funds, individuals, equipment, and information, in order to carry out the project. By making sure that their development complies with societal needs, ethical norms, and environmental restrictions, the initiative also emphasizes the critical role biomedical devices play in sustainability and public health. Furthermore, as EEE and ECE students typically lack knowledge in this biological sector, it is critical to comprehend and use principle-based approaches that may satisfy the particular needs of the project.

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Appendices

Related code/theory:

It is to note that during coding in Codevision AVR, numerous types of files are produced. We opened the c files in Visual Studio Code and copied the codes here. The codes for the simulation for design approach 1 (Compact HydroPace) have been given below:

1. The code for the simulated heart (Arduino Uno):

```
// ECG Simulator with Arduino Serial Plotter
// Generates synthetic ECG with P-QRS-T waves
// Includes heartbeats at ~70 bpm, 60 bpm, and 50 bpm

const int ECG70_LEN = 173;
const int ECG60_LEN = 200;
const int ECG50_LEN = 240;

const int ecg70[ECG70_LEN] PROGMEM = {
512,513,514,516,518,520,523,525,528,530,
532,534,536,538,540,538,536,534,532,530,
528,526,524,522,520,518,516,514,512,510,
508,506,504,502,500,498,496,494,492,490,
700,820,940,1023,940,820,700,580,460,380,
400,420,440,460,480,500,520,540,560,580,
600,620,640,660,680,700,720,740,760,780,
770,760,750,740,730,720,710,700,690,680,
670,660,650,640,630,620,610,600,590,580,
570,560,550,540,530,520,515,512,510,508,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,
};

const int ecg60[ECG60_LEN] PROGMEM = {
512,513,514,516,518,520,523,525,528,530,
532,534,536,538,540,538,536,534,532,530,
528,526,524,522,520,518,516,514,512,510,
508,506,504,502,500,498,496,494,492,490,
```

```
700,820,940,1023,940,820,700,580,460,380,
400,420,440,460,480,500,520,540,560,580,
600,620,640,660,680,700,720,740,760,780,
770,760,750,740,730,720,710,700,690,680,
670,660,650,640,630,620,610,600,590,580,
570,560,550,540,530,520,515,512,510,508,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
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512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
};

const int ecg50[ECG50_LEN] PROGMEM = {
512,513,514,516,518,520,523,525,528,530,
532,534,536,538,540,538,536,534,532,530,
528,526,524,522,520,518,516,514,512,510,
508,506,504,502,500,498,496,494,492,490,
700,820,940,1023,940,820,700,580,460,380,
400,420,440,460,480,500,520,540,560,580,
600,620,640,660,680,700,720,740,760,780,
770,760,750,740,730,720,710,700,690,680,
670,660,650,640,630,620,610,600,590,580,
570,560,550,540,530,520,515,512,510,508,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
};
```

```
int mode = 0;  // 0: 70 bpm, 1: 60 bpm, 2: 50 bpm
int index70 = 0;
int index60 = 0;
int index50 = 0;

void setup() {
  Serial.begin(115200);  // Increased baud rate
  Serial.println("ECG Simulator: 70 bpm → 60 bpm → 50 bpm");
}

void loop() {
  if (mode == 0) {
    Serial.println(pgm_read_word(&ecg70[index70]));
    index70++;
    if (index70 >= ECG70_LEN) {
      index70 = 0;
      mode = 1;
      Serial.println("// Switching to 60 bpm pattern");
    }
  } else if (mode == 1) {
    Serial.println(pgm_read_word(&ecg60[index60]));
    index60++;
    if (index60 >= ECG60_LEN) {
      index60 = 0;
      mode = 2;
      Serial.println("// Switching to 50 bpm pattern");
    }
  } else {  // mode == 2
    Serial.println(pgm_read_word(&ecg50[index50]));
    index50++;
    if (index50 >= ECG50_LEN) {
      index50 = 0;
      mode = 0;
      Serial.println("// Switching to 70 bpm pattern");
    }
  }
  delay(10);  // Increased to 10 ms to slow down the graph
}
```

2. The temperature and biochemical data code for Arduino Uno (simulated heart):

```
#include <Adafruit_MCP9808.h>

// Create MCP9808 sensor object
Adafruit_MCP9808 tempsensor = Adafruit_MCP9808();

int mode = 0;
float proBNP;
float temperature;

void setup() {
  Serial.begin(115200);     // Hardware serial - both debug AND ESP32 communication

  // Initialize MCP9808 sensor
  if (!tempsensor.begin()) {
    // Can't use Serial.println here since Serial is used for ESP32 communication
    // If sensor fails, the loop will send error data
  }

  // Send initialization message to ESP32
  Serial.println("Arduino Uno: Heart Simulator Ready");
  delay(2000); // Give ESP32 time to initialize
}

void loop() {
  // Check if sensor is working
  if (!tempsensor.begin()) {
    // Send error message to ESP32 if sensor fails
    Serial.println("ERROR:SENSOR_NOT_FOUND");
    delay(5000);
    return;
  }

  // Read temperature from MCP9808
  temperature = tempsensor.readTempC();

  // Update heart condition every 5 seconds
  static unsigned long lastChange = 0;
  if (millis() - lastChange > 5000) {
    mode = random(0, 4);
    lastChange = millis();
  }
```

```
  // Generate NT-proBNP value based on mode
  switch (mode) {
    case 0: proBNP = random(50, 301); break;    // Normal
    case 1: proBNP = random(300, 801); break;   // Mild stress
    case 2: proBNP = random(800, 1801); break;  // Moderate risk
    case 3: proBNP = random(1800, 5001); break; // Severe
  }

  // Send formatted data to ESP32 via hardware TX pin
  Serial.print("TEMP:");
  Serial.print(temperature, 2);  // 2 decimal places
  Serial.print(",BNP:");
  Serial.print(proBNP, 1);       // 1 decimal place
  Serial.println();              // Send newline

  delay(1000); // Send every 1 second
}
```

3. The pacemaker code for pacing treatment (ESP32-S3):

```
#define LED_PIN 4            // GPIO 4 for LED
#define PACING_PIN 5         // GPIO 5 for pacing output
#define ECG_RX_PIN 16        // GPIO 16 as RX for ECG signal

int prevVal = 0;
int currVal = 0;
int nextVal = 0;

unsigned long t_prevR = 0;
unsigned long t_currR = 0;

bool peakFound = false;

void setup() {
  pinMode(LED_PIN, OUTPUT);
  pinMode(PACING_PIN, OUTPUT);
  digitalWrite(LED_PIN, LOW);
  digitalWrite(PACING_PIN, LOW);

  Serial.begin(115200);     // Serial Monitor
```

```
  Serial2.begin(115200, SERIAL_8N1, ECG_RX_PIN, -1);  // ECG signal on RX (GPIO 16),
TX not used
}

void loop() {
  static int buffer[3] = {0, 0, 0};  // Sliding window for ECG values

  if (Serial2.available()) {
    char lineBuffer[10];  // Buffer for one ECG value as string
    int index = 0;
    unsigned long timeout = millis() + 50;

    while (millis() < timeout && index < sizeof(lineBuffer) - 1) {
      if (Serial2.available()) {
        char c = Serial2.read();
        if (c == '\n' || c == '\r') {
          lineBuffer[index] = '\0';
          break;
        } else if (isDigit(c) || c == '-') {
          lineBuffer[index++] = c;
        } else {
          // Skip bad line
          while (Serial2.available() && Serial2.peek() != '\n' && millis() < timeout) {
            Serial2.read();
          }
          if (Serial2.available()) Serial2.read();  // Consume newline
          return;
        }
      }
    }
    lineBuffer[index] = '\0';

    if (index > 0 && isDigit(lineBuffer[0])) {
      int ecgValue = atoi(lineBuffer);
      Serial.println(ecgValue);  // Print to Serial Plotter

      // Update buffer
      buffer[0] = buffer[1];
      buffer[1] = buffer[2];
      buffer[2] = ecgValue;

      // Peak detection
      if (buffer[1] > buffer[0] && buffer[1] > buffer[2]) {
        unsigned long now = millis();
```

```
      if (!peakFound || (now - t_currR > 300)) {
        t_prevR = t_currR;
        t_currR = now;
        peakFound = true;

        unsigned long rrInterval = t_currR - t_prevR;

        if (rrInterval > 1030) {  // BPM < ~58
          digitalWrite(LED_PIN, HIGH);
          digitalWrite(PACING_PIN, HIGH);
          delay(50);
          digitalWrite(LED_PIN, LOW);
          digitalWrite(PACING_PIN, LOW);
        }
      }
    }
  } else {
    while (Serial2.available()) Serial2.read();  // Clear bad data
  }
 }
}
```

4. The pacemaker code for displaying temperature and biochemical data (ESP32-S3):

```
float temperature = 0.0;
float proBNP = 0.0;

void setup() {
  pinMode(17, INPUT_PULLDOWN);
  Serial.begin(115200);     // USB Serial Monitor
  Serial2.begin(115200, SERIAL_8N1, 17, -1);  // RX on GPIO17, TX unused

  Serial.println("ESP32 Cardiac Monitor Ready");
  Serial.println("Monitoring: Temperature + NT-proBNP");
  Serial.println("Receiving data on GPIO17 from Arduino D7");
  Serial.println("========================================");

  delay(2000);
}

void loop() {
```

```
  // Check if data is available from Arduino
  if (Serial2.available()) {
    String receivedData = Serial2.readStringUntil('\n');
    receivedData.trim(); // Remove whitespace

    // Parse the received data
    if (parseData(receivedData)) {
      Serial.println("========================");
      Serial.print("Temperature: ");
      Serial.print(temperature, 2);
      Serial.println(" °C");

      Serial.print("NT-proBNP: ");
      Serial.print(proBNP, 1);
      Serial.println(" pg/mL");

      // Analyze temperature (36-39°C normal range)
      if (temperature < 36.0) {
        Serial.println("Warning: Heart temperature is LOW!");
      } else if (temperature > 39.0) {
        Serial.println("Warning: Heart temperature is HIGH!");
      } else {
        Serial.println("Heart Temperature is Normal.");
      }

      // Analyze NT-proBNP levels
      if (proBNP < 300) {
        Serial.println("NT-proBNP: Normal levels");
      } else if (proBNP >= 300 && proBNP < 800) {
        Serial.println("Warning: NT-proBNP indicates mild cardiac stress");
      } else if (proBNP >= 800 && proBNP < 1800) {
        Serial.println("Warning: NT-proBNP indicates moderate cardiac risk");
      } else if (proBNP >= 1800) {        Serial.println("CRITICAL: NT-proBNP indicates
severe heart failure risk");
      }


      Serial.println("========================");
    } else {
      Serial.println("ERROR: Failed to parse data");
      Serial.print("Received: ");
      Serial.println(receivedData);
    }
  }
```

```
  delay(10);
}

bool parseData(String data) {
  // Expected format: TEMP:xx.xx,BNP:xxx.x
  int tempIndex = data.indexOf("TEMP:");
  int bnpIndex = data.indexOf("BNP:");

  if (tempIndex == -1 || bnpIndex == -1) {
    return false;
  }

  // Extract temperature
  int tempStart = tempIndex + 5; // After "TEMP:"
  int tempEnd = data.indexOf(",", tempStart);
  if (tempEnd == -1) return false;

  String tempStr = data.substring(tempStart, tempEnd);
  temperature = tempStr.toFloat();

  // Extract NT-proBNP
  int bnpStart = bnpIndex + 4; // After "BNP:"
  String bnpStr = data.substring(bnpStart);
  proBNP = bnpStr.toFloat();

  // Validate parsed values
  if (temperature < -40 || temperature > 100 || proBNP < 0 || proBNP > 10000) {
    return false; // Invalid values
  }

  return true;
}
```

5. The merged code for pacemaker (ESP32-S3):

```
#include <Arduino.h>
#include <BLEDevice.h>
#include <BLEServer.h>
#include <BLEUtils.h>
#include <BLE2902.h>
```

```
#include <pgmspace.h>

// BLE UUIDs (Nordic UART style)
#define SERVICE_UUID        "6E400001-B5A3-F393-E0A9-E50E24DCCA9E"
#define CHARACTERISTIC_UUID "6E400002-B5A3-F393-E0A9-E50E24DCCA9E"

// STX/ETX markers for stream reassembly
#define STX 0x02
#define ETX 0x03

// pins
#define PACE_LED_PIN 4   // pulse when pacing occurs (HIGH briefly)
#define PACE_OUT_PIN 5   // optional pacing output pin (mirrors LED short pulse)

// Timing
const unsigned long SEND_INTERVAL_MS = 40; // send one JSON every 40 ms (~25
packets/sec)
                                    // you can increase/decrease as desired

// ---------------- ECG arrays (copied from your uploaded doc) ----------------
const int ECG70_LEN = 173;
const int ECG60_LEN = 200;
const int ECG50_LEN = 240;
const int ECG80_LEN = 150;
const int ECG80_PACED_LEN = 150;

const uint16_t ecg70[ECG70_LEN] PROGMEM = {
512,513,514,516,518,520,523,525,528,530,
532,534,536,538,540,538,536,534,532,530,
528,526,524,522,520,518,516,514,512,510,
508,506,504,502,500,498,496,494,492,490,
700,820,940,1023,940,820,700,580,460,380,
400,420,440,460,480,500,520,540,560,580,
600,620,640,660,680,700,720,740,760,780,
770,760,750,740,730,720,710,700,690,680,
670,660,650,640,630,620,610,600,590,580,
570,560,550,540,530,520,515,512,510,508,
```

```
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512
};

const uint16_t ecg60[ECG60_LEN] PROGMEM = {
512,513,514,516,518,520,523,525,528,530,
532,534,536,538,540,538,536,534,532,530,
528,526,524,522,520,518,516,514,512,510,
508,506,504,502,500,498,496,494,492,490,
700,820,940,1023,940,820,700,580,460,380,
400,420,440,460,480,500,520,540,560,580,
600,620,640,660,680,700,720,740,760,780,
770,760,750,740,730,720,710,700,690,680,
670,660,650,640,630,620,610,600,590,580,
570,560,550,540,530,520,515,512,510,508,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512
};

const uint16_t ecg50[ECG50_LEN] PROGMEM = {
512,513,514,516,518,520,523,525,528,530,
532,534,536,538,540,538,536,534,532,530,
528,526,524,522,520,518,516,514,512,510,
508,506,504,502,500,498,496,494,492,490,
```

```
700,820,940,1023,940,820,700,580,460,380,
400,420,440,460,480,500,520,540,560,580,
600,620,640,660,680,700,720,740,760,780,
770,760,750,740,730,720,710,700,690,680,
670,660,650,640,630,620,610,600,590,580,
570,560,550,540,530,520,515,512,510,508,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512
};

const uint16_t ecg80[ECG80_LEN] PROGMEM = {
512,513,514,516,518,520,523,525,528,530,
532,534,536,538,540,538,536,534,532,530,
528,526,524,522,520,518,516,514,512,510,
508,506,504,502,500,498,496,494,492,490,
700,820,940,1022,940,820,700,580,460,380,
400,420,440,460,480,500,520,540,560,580,
600,620,640,660,680,700,720,740,760,780,
770,760,750,740,730,720,710,700,690,680,
670,660,650,640,630,620,610,600,590,580,
570,560,550,540,530,520,515,512,510,508,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512
```

```
};

const uint16_t ecg80_paced[ECG80_PACED_LEN] PROGMEM = {
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,1023,
512,700,820,940,1023,940,820,700,580,460,
380,400,420,440,460,480,500,520,540,560,
580,600,620,640,660,680,700,720,740,760,
780,770,760,750,740,730,720,710,700,690,
680,670,660,650,640,630,620,610,600,590,
580,570,560,550,540,530,520,515,512,510,
508,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512,
512,512,512,512,512,512,512,512,512,512
};

// ---------------- mode & playback state ----------------
enum ECGMode { MODE_70, MODE_60, MODE_50, MODE_PACE_INSERT };
ECGMode currentMode = MODE_70;

int idx70 = 0, idx60 = 0, idx50 = 0;
int idx80_paced = 0;
bool pacedPending = false;      // set to true when we should insert paced waveform after a
50-cycle

// Medical values (stored in the ESP32 as requested)
float currentTemp = 36.8f;       // will vary 35.0 - 40.0
float currentProBNP = 420.5f;    // will vary 100 - 1000
int   currentECG = 512;
float currentHR = 70.0f;
bool  pacingActive = false;

// BLE objects
```

```
BLECharacteristic *pCharacteristic = nullptr;
BLEServer *pServer = nullptr;
bool deviceConnected = false;

// timing
unsigned long lastSend = 0;
unsigned long packetCount = 0;

// forward declarations
int getNextEcgSample();
void updateMedicalData(); // vary temp & BNP
String makeJsonPacket(int ecgSample);
void sendJsonChunked(const String &payload);

// BLE callbacks
class MyServerCallbacks: public BLEServerCallbacks {
  void onConnect(BLEServer* pServer) override {
    deviceConnected = true;
    Serial.println("✓ BLE client connected");
  }
  void onDisconnect(BLEServer* pServer) override {
    deviceConnected = false;
    Serial.println("✗ BLE client disconnected");
    delay(1000);
    pServer->getAdvertising()->start();
    Serial.println("↻ BLE advertising restarted");
  }
};

// ---------------- setup ----------------
void setup() {
  Serial.begin(115200);
  delay(200);

  pinMode(PACE_LED_PIN, OUTPUT);
  pinMode(PACE_OUT_PIN, OUTPUT);
  digitalWrite(PACE_LED_PIN, LOW);
```

```
  digitalWrite(PACE_OUT_PIN, LOW);

  Serial.println("=== ESP32S3 BLE Cardiac Monitor (single-sample JSON) ===");

  // BLE init
  BLEDevice::init("ESP32S3-ECG-Monitor");
  BLEDevice::setMTU(517); // try to raise MTU for larger chunks

  pServer = BLEDevice::createServer();
  pServer->setCallbacks(new MyServerCallbacks());

  BLEService *pService = pServer->createService(SERVICE_UUID);

  pCharacteristic = pService->createCharacteristic(
     CHARACTERISTIC_UUID,
     BLECharacteristic::PROPERTY_READ |
     BLECharacteristic::PROPERTY_WRITE |
     BLECharacteristic::PROPERTY_NOTIFY
  );
  pCharacteristic->addDescriptor(new BLE2902());
  pService->start();

  BLEAdvertising *adv = pServer->getAdvertising();
  adv->addServiceUUID(SERVICE_UUID);
  adv->setScanResponse(true);
  adv->start();

  Serial.println("BLE advertising started - waiting for client.");
  randomSeed(analogRead(0));

  // initialize variation values
  currentTemp = 36.8;
  currentProBNP = 420.5;
  currentHR = 70.0;
  lastSend = millis();
}
```

```
// ---------------- main loop ----------------
void loop() {
 unsigned long now = millis();
 if (now - lastSend >= SEND_INTERVAL_MS) {
  // 1) update medical values (temp, proBNP)
  updateMedicalData();

  // 2) get next ECG sample (based on arrays & state machine)
  int sample = getNextEcgSample();
  currentECG = sample;

  // pacingActive flag is set when sample indicates pacing spike (>=1000)
  pacingActive = (sample >= 1000);

  // if pacing sample, pulse the LED/out pin briefly
  if (pacingActive) {
   digitalWrite(PACE_LED_PIN, HIGH);
   digitalWrite(PACE_OUT_PIN, HIGH);
  }

  // 3) create JSON & send via chunked notify
  String json = makeJsonPacket(sample);
  if (deviceConnected && pCharacteristic) {
   sendJsonChunked(json);
   Serial.print("SENT #"); Serial.print(packetCount);
   Serial.print(" ecg="); Serial.print(sample);
   Serial.print(" hr="); Serial.print(currentHR);
   Serial.print(" temp="); Serial.print(currentTemp,1);
   Serial.print(" bnp="); Serial.println(currentProBNP,1);
  } else {
   Serial.print("NO_CLIENT -> would send: ");
   Serial.println(json);
  }

  // turn pacing LED off (keep short)
  if (pacingActive) {
   delay(30); // short blink visible
```

```
    digitalWrite(PACE_LED_PIN, LOW);
    digitalWrite(PACE_OUT_PIN, LOW);
   }

   packetCount++;
   lastSend = now;
  }

  // light yield
  delay(1);
}

// ---------------- ECG playback & pacing insertion ----------------
int readProgmemValue(const uint16_t *arr, int idx) {
  return (int)pgm_read_word(&(arr[idx]));
}

int getNextEcgSample() {
  // returns next sample and advances indices/mode
  int val = 512;

  switch (currentMode) {
   case MODE_70:
    val = readProgmemValue(ecg70, idx70);
    idx70++;
    currentHR = 70.0;
    if (idx70 >= ECG70_LEN) {
     idx70 = 0;
     currentMode = MODE_60;
     idx60 = 0;
    }
    break;

   case MODE_60:
    val = readProgmemValue(ecg60, idx60);
    idx60++;
    currentHR = 60.0;
```

```
    if (idx60 >= ECG60_LEN) {
      idx60 = 0;
      currentMode = MODE_50;
      idx50 = 0;
    }
    break;

  case MODE_50:
    val = readProgmemValue(ecg50, idx50);
    idx50++;
    currentHR = 50.0;
    if (idx50 >= ECG50_LEN) {
      idx50 = 0;
      // after finishing a 50-cycle block, schedule a paced insertion
      pacedPending = true;
      currentMode = MODE_PACE_INSERT;
      idx80_paced = 0;
    }
    break;

  case MODE_PACE_INSERT:
    // Play the paced 80 waveform once, then resume MODE_70
    val = readProgmemValue(ecg80_paced, idx80_paced);
    idx80_paced++;
    currentHR = 80.0; // paced beat apparent rate locally
    if (idx80_paced >= ECG80_PACED_LEN) {
      // after paced waveform play normal 80 twice? to mimic earlier code we go to
MODE_70
      idx80_paced = 0;
      pacedPending = false;
      currentMode = MODE_70;
      idx70 = 0;
    }
    break;
 }

 return val;
```

```
}

// ---------------- vary temp & proBNP smoothly ----------------
void updateMedicalData() {
  // small random walk + bounding
  float dt = (random(-20, 21) / 100.0f); // -0.2 .. +0.2
  currentTemp += dt;
  if (currentTemp < 35.0f) currentTemp = 35.0f;
  if (currentTemp > 40.0f) currentTemp = 40.0f;

  float db = (random(-50, 51) / 20.0f); // -2.5 .. +2.5
  currentProBNP += db;
  if (currentProBNP < 100.0f) currentProBNP = 100.0f;
  if (currentProBNP > 1000.0f) currentProBNP = 1000.0f;
}

// ---------------- JSON creation (standard format used previously) ----------------
String makeJsonPacket(int ecgSample) {
  String json = "{";

  // device info
  json += "\"device_id\":\"ESP32S3_ECG_001\",";
  json += "\"device_type\":\"ECG_Monitor\",";
  json += "\"firmware\":\"1.0.0\",";

  // packet info
  json += "\"timestamp\":" + String(millis()) + ",";
  json += "\"packet_number\":" + String(packetCount) + ",";

  // medical_data
  json += "\"medical_data\":{";
  json += "\"ecg_value\":" + String(ecgSample) + ",";
  json += "\"ecg_unit\":\"ADC_counts\",";
  json += "\"temperature\":" + String(currentTemp, 1) + ",";
  json += "\"temperature_unit\":\"celsius\",";
  json += "\"nt_probnp\":" + String(currentProBNP, 1) + ",";
  json += "\"nt_probnp_unit\":\"pg_mL\",";
```

```
  json += "\"heart_rate\":" + String(currentHR, 0) + ",";
  json += "\"heart_rate_unit\":\"bpm\",";
  json += "\"pacing_active\":" + String(pacingActive ? "true" : "false");
  json += "},";

  // system_status (no battery)
  json += "\"system_status\":{";
  json += "\"connected_clients\":" + String(deviceConnected ? 1 : 0) + ",";
  json += "\"signal_quality\":" + String(random(85, 101)) + ",";
  json += "\"memory_free\":" + String(ESP.getFreeHeap());
  json += "}";

  json += "}";
  return json;
}

// ---------------- chunked notify (STX/ETX) ----------------
void sendJsonChunked(const String &payload) {
  if (!pCharacteristic) return;

  // conservative chunk (MTU - overhead)
  const uint16_t CHUNK = 180;

  // STX
  uint8_t stx = STX;
  pCharacteristic->setValue(&stx, 1);
  pCharacteristic->notify();
  delay(3);

  // body
  size_t len = payload.length();
  for (size_t i = 0; i < len; i += CHUNK) {
    size_t n = (i + CHUNK <= len) ? CHUNK : (len - i);
    String part = payload.substring(i, i + n);
    pCharacteristic->setValue((uint8_t*)part.c_str(), part.length());
    pCharacteristic->notify();
    delay(3);
```

```
  }

  // ETX
  uint8_t etx = ETX;
  pCharacteristic->setValue(&etx, 1);
  pCharacteristic->notify();
  delay(2);
}
```

6. Python code used to build and run the app:

```python
import json
import threading
import time
import sqlite3
from datetime import datetime
import tkinter as tk
from tkinter import ttk, messagebox, filedialog
import queue
import matplotlib.pyplot as plt
from matplotlib.backends.backend_tkagg import FigureCanvasTkAgg
from collections import deque


import serial
import serial.tools.list_ports


class ESP32DataReceiver:
  def __init__(self):
      self.root = tk.Tk()
      self.root.title("ESP32 Pressure Sensor Data Receiver")
      self.root.geometry("900x700")


      # Data storage
      self.data_queue = queue.Queue()
      self.pressure_data = deque(maxlen=50)
      self.time_data = deque(maxlen=50)
```

```
        self.all_data = []

        # Connection variables
        self.is_connected = False
        self.ser = None
        self.receive_thread = None
        self.port_map = {}

        # Database
        self.init_database()

        # Setup GUI
        self.setup_gui()

        # Start GUI update loop
        self.update_display()

    def init_database(self):
        self.conn = sqlite3.connect('esp32_data.db', check_same_thread=False)
        cursor = self.conn.cursor()
        cursor.execute('''
            CREATE TABLE IF NOT EXISTS sensor_data (
                id INTEGER PRIMARY KEY AUTOINCREMENT,
                device_id TEXT,
                timestamp INTEGER,
                packet_number INTEGER,
                pressure REAL,
                temperature REAL,
                battery_level INTEGER,
                received_at TEXT
            )
        ''')
        self.conn.commit()

    def setup_gui(self):
        title_label = tk.Label(self.root, text="ESP32 Pressure Sensor Monitor",
                               font=('Arial', 16, 'bold'))
        title_label.pack(pady=10)
```

```python
# Connection Frame
conn_frame = ttk.LabelFrame(self.root, text="Connection", padding=10)
conn_frame.pack(fill='x', padx=10, pady=5)


# Scan button
ttk.Button(conn_frame, text="Scan Ports",
        command=self.scan_ports).pack(side='left', padx=5)


# Device selection
ttk.Label(conn_frame, text="Port:").pack(side='left', padx=5)
self.device_var = tk.StringVar()
self.device_combo = ttk.Combobox(conn_frame, textvariable=self.device_var,
                              width=35, state='readonly')
self.device_combo.pack(side='left', padx=5)


# Baud rate
ttk.Label(conn_frame, text="Baud:").pack(side='left', padx=5)
self.baud_var = tk.StringVar(value="115200")
self.baud_entry = ttk.Entry(conn_frame, textvariable=self.baud_var, width=8)
self.baud_entry.pack(side='left', padx=5)


# Connect/Disconnect
self.connect_btn = ttk.Button(conn_frame, text="Connect",
                            command=self.connect_device)
self.connect_btn.pack(side='left', padx=5)


self.disconnect_btn = ttk.Button(conn_frame, text="Disconnect",
                              command=self.disconnect_device, state='disabled')
self.disconnect_btn.pack(side='left', padx=5)


# Status
self.status_var = tk.StringVar(value="Ready to scan ports")
ttk.Label(conn_frame, textvariable=self.status_var).pack(side='right', padx=5)


# Data Display Frame
```

```
data_frame = ttk.LabelFrame(self.root, text="Current Data", padding=10)
data_frame.pack(fill='x', padx=10, pady=5)


readings_frame = tk.Frame(data_frame)
readings_frame.pack(fill='x')


# Pressure
pressure_frame = tk.Frame(readings_frame)
pressure_frame.pack(side='left', fill='x', expand=True)
tk.Label(pressure_frame, text="Pressure:", font=('Arial', 12)).pack()
self.pressure_var = tk.StringVar(value="-- hPa")
tk.Label(pressure_frame, textvariable=self.pressure_var,
        font=('Arial', 20, 'bold'), fg='blue').pack()


# Temperature
temp_frame = tk.Frame(readings_frame)
temp_frame.pack(side='left', fill='x', expand=True)
tk.Label(temp_frame, text="Temperature:", font=('Arial', 12)).pack()
self.temp_var = tk.StringVar(value="-- °C")
tk.Label(temp_frame, textvariable=self.temp_var,
        font=('Arial', 20, 'bold'), fg='red').pack()


# Battery
battery_frame = tk.Frame(readings_frame)
battery_frame.pack(side='left', fill='x', expand=True)
tk.Label(battery_frame, text="Battery:", font=('Arial', 12)).pack()
self.battery_var = tk.StringVar(value="-- %")
tk.Label(battery_frame, textvariable=self.battery_var,
        font=('Arial', 20, 'bold'), fg='green').pack()


# Statistics
stats_frame = tk.Frame(data_frame)
stats_frame.pack(fill='x', pady=5)
self.packets_var = tk.StringVar(value="Packets received: 0")
tk.Label(stats_frame, textvariable=self.packets_var).pack(side='left')
self.last_update_var = tk.StringVar(value="Last update: Never")
tk.Label(stats_frame, textvariable=self.last_update_var).pack(side='right')
```

```
    # Graph Frame
    graph_frame = ttk.LabelFrame(self.root, text="Real-time Pressure Graph", padding=5)
    graph_frame.pack(fill='both', expand=True, padx=10, pady=5)


    self.fig, self.ax = plt.subplots(figsize=(8, 4))
    self.ax.set_title('Pressure Over Time')
    self.ax.set_xlabel('Time (seconds)')
    self.ax.set_ylabel('Pressure (hPa)')
    self.ax.grid(True)


    self.canvas = FigureCanvasTkAgg(self.fig, graph_frame)
    self.canvas.get_tk_widget().pack(fill='both', expand=True)


    # Control Frame
    control_frame = ttk.LabelFrame(self.root, text="Controls", padding=10)
    control_frame.pack(fill='x', padx=10, pady=5)


    ttk.Button(control_frame, text="Save Data",
            command=self.save_data).pack(side='left', padx=5)
    ttk.Button(control_frame, text="Clear Data",
            command=self.clear_data).pack(side='left', padx=5)
    ttk.Button(control_frame, text="View All Data",
            command=self.view_all_data).pack(side='left', padx=5)


def scan_ports(self):
    """Scan available serial/COM ports (including Bluetooth SPP COM ports)"""
    self.status_var.set("Scanning ports...")
    self.root.update()
    ports = list(serial.tools.list_ports.comports())
    self.port_map.clear()
    labels = []


    for p in ports:
        label = f"{p.device} — {p.description}"
        labels.append(label)
        self.port_map[label] = p.device
```

```
        if labels:
            self.device_combo['values'] = labels
            self.device_combo.current(0)
            self.status_var.set(f"Found {len(labels)} port(s)")
        else:
            self.device_combo.set('')
            self.device_combo['values'] = []
            self.status_var.set("No ports found")
            messagebox.showinfo("Scan Result",
                                "No serial/Bluetooth (COM) ports found.\n"
                                "• If using Bluetooth SPP: pair ESP32 first, then try again.\n"
                                "• If using USB: connect the cable and install drivers.")


    def connect_device(self):
        """Open the selected serial port"""
        if not self.device_var.get():
            messagebox.showwarning("No Port", "Please scan and select a port first")
            return


        port_label = self.device_var.get()
        port = self.port_map.get(port_label)
        try:
            baud = int(self.baud_var.get())
        except ValueError:
            messagebox.showerror("Invalid Baud", "Baud rate must be an integer (e.g., 115200)")
            return


        def connect_thread():
            try:
                self.status_var.set("Connecting...")
                self.ser = serial.Serial(port=port, baudrate=baud, timeout=1)
                time.sleep(0.2)  # small settle time


                self.is_connected = True
                self.status_var.set(f"Connected to {port}")
                self.connect_btn.config(state='disabled')
                self.disconnect_btn.config(state='normal')


                self.receive_thread = threading.Thread(target=self.receive_data, daemon=True)
```

```python
            self.receive_thread.start()


            messagebox.showinfo("Connected", f"Successfully connected to {port_label}")
        except Exception as e:
            self.status_var.set("Connection failed")
            messagebox.showerror("Connection Error", f"Failed to connect:\n{e}")


    threading.Thread(target=connect_thread, daemon=True).start()


def disconnect_device(self):
    """Close serial port"""
    self.is_connected = False
    if self.ser:
        try:
            self.ser.close()
        except:
            pass
        self.ser = None


    self.status_var.set("Disconnected")
    self.connect_btn.config(state='normal')
    self.disconnect_btn.config(state='disabled')


def receive_data(self):
    """Receive newline-delimited JSON lines from serial"""
    buffer = ""
    while self.is_connected and self.ser:
        try:
            raw = self.ser.readline()  # reads until \n or timeout
            if not raw:
                continue
            chunk = raw.decode('utf-8', errors='ignore')
            buffer += chunk


            while '\n' in buffer:
                line, buffer = buffer.split('\n', 1)
                line = line.strip()
                if line:
```

```
                    self.process_data(line)
            except Exception as e:
                if self.is_connected:
                    print(f"Receive error: {e}")
                break


    def process_data(self, data_string):
        """Process received JSON data"""
        try:
            data = json.loads(data_string)
            data['received_at'] = datetime.now().isoformat()


            cursor = self.conn.cursor()
            cursor.execute('''
                INSERT INTO sensor_data
                (device_id, timestamp, packet_number, pressure, temperature, battery_level,
received_at)
                VALUES (?, ?, ?, ?, ?, ?, ?)
            ''', (
                data.get('device_id', ''),
                data.get('timestamp', 0),
                data.get('packet_number', 0),
                data.get('pressure', 0.0),
                data.get('temperature', 0.0),
                data.get('battery_level', 0),
                data['received_at']
            ))
            self.conn.commit()


            self.data_queue.put(data)
        except json.JSONDecodeError:
            print(f"Invalid JSON: {data_string}")
        except Exception as e:
            print(f"Process error: {e}")


    def update_display(self):
        updated = False
        while not self.data_queue.empty():
            try:
                data = self.data_queue.get_nowait()
```

```
            self.pressure_var.set(f"{data.get('pressure', 0):.1f} hPa")
            self.temp_var.set(f"{data.get('temperature', 0):.1f} °C")
            self.battery_var.set(f"{data.get('battery_level', 0)} %")


            self.packets_var.set(f"Packets received: {data.get('packet_number', 0)}")
            self.last_update_var.set(f"Last update: {datetime.now().strftime('%H:%M:%S')}")


            current_time = time.time()
            if not hasattr(self, 'start_time'):
                self.start_time = current_time


            relative_time = current_time - self.start_time
            self.time_data.append(relative_time)
            self.pressure_data.append(float(data.get('pressure', 0)))
            self.all_data.append(data)


            updated = True
        except queue.Empty:
            break


    if updated and len(self.pressure_data) > 1:
        self.ax.clear()
        self.ax.plot(list(self.time_data), list(self.pressure_data), 'b-o', markersize=3)
        self.ax.set_title('Pressure Over Time')
        self.ax.set_xlabel('Time (seconds)')
        self.ax.set_ylabel('Pressure (hPa)')
        self.ax.grid(True)
        self.canvas.draw()


    self.root.after(100, self.update_display)


def save_data(self):
    if not self.all_data:
        messagebox.showinfo("No Data", "No data to save")
        return
```

```
    filename = filedialog.asksaveasfilename(
        defaultextension=".csv",
        filetypes=[("CSV files", "*.csv"), ("All files", "*.*")],
        initialname=f"esp32_data_{datetime.now().strftime('%Y%m%d_%H%M%S')}.csv"
    )

    if filename:
        try:
            with open(filename, 'w', encoding='utf-8') as f:
                f.write("Timestamp,Packet,Pressure,Temperature,Battery,ReceivedAt\n")
                for d in self.all_data:
                    f.write(f"{d.get('timestamp', 0)},{d.get('packet_number', 0)},"
                            f"{d.get('pressure', 0)},{d.get('temperature', 0)},"
                            f"{d.get('battery_level', 0)},{d.get('received_at', '')}\n")
            messagebox.showinfo("Saved", f"Data saved to {filename}")
        except Exception as e:
            messagebox.showerror("Save Error", f"Failed to save data:\n{e}")

def clear_data(self):
    if messagebox.askyesno("Clear Data", "Are you sure you want to clear all data?"):
        self.all_data.clear()
        self.pressure_data.clear()
        self.time_data.clear()
        self.ax.clear()
        self.ax.set_title('Pressure Over Time')
        self.ax.set_xlabel('Time (seconds)')
        self.ax.set_ylabel('Pressure (hPa)')
        self.ax.grid(True)
        self.canvas.draw()
        if hasattr(self, 'start_time'):
            delattr(self, 'start_time')

def view_all_data(self):
    if not self.all_data:
        messagebox.showinfo("No Data", "No data to display")
        return

    data_window = tk.Toplevel(self.root)
```

```
        data_window.title("All Received Data")
        data_window.geometry("800x400")


        frame = tk.Frame(data_window)
        frame.pack(fill='both', expand=True, padx=10, pady=10)


        text_widget = tk.Text(frame, wrap='none')
        scrollbar_y = ttk.Scrollbar(frame, orient='vertical', command=text_widget.yview)
        scrollbar_x = ttk.Scrollbar(frame, orient='horizontal', command=text_widget.xview)
        text_widget.configure(yscrollcommand=scrollbar_y.set,
xscrollcommand=scrollbar_x.set)


        scrollbar_y.pack(side='right', fill='y')
        scrollbar_x.pack(side='bottom', fill='x')
        text_widget.pack(side='left', fill='both', expand=True)


        text_widget.insert('1.0', "All Received Data:\n" + "="*50 + "\n\n")
        for i, d in enumerate(self.all_data, 1):
            text_widget.insert('end', f"Packet {i}:\n")
            text_widget.insert('end', json.dumps(d, indent=2) + "\n\n")


        text_widget.config(state='disabled')


    def run(self):
        try:
            self.root.mainloop()
        finally:
            self.disconnect_device()
            if self.conn:
                self.conn.close()


if __name__ == "__main__":
    print("Starting ESP32 Data Receiver (Serial/COM mode)...")
    print("Install: pip install pyserial matplotlib")
    app = ESP32DataReceiver()
    app.run()
```

FYDP (P) Fall 2024 Summary of Team Log Book/ Journal

Group No - 03

Project Title:

HydroCP: Developing a hydrogel-based cardiac pacemaker.

	Final Year Design Project (P) Fall 2024		
Student Details	**NAME & ID**	**EMAIL ADDRESS**	**PHONE**
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Member 2	Sheikh Md. Nazmus Sadath (21110001)	md.nazmus.sadath@g.bracu.ac.bd	01624818533
Member 3	Md. Emran Hossen (20221011)	md.emran.hossen@g.bracu.ac.bd	01770127056
Member 4	Istiaq Mohammad (21321036)	Istiaq.mohammad@g.bracu.ac.bd	01648250771
Member 5	Sk. Zayed Mahmood (22121116)	sk.zayed.mahmood@g.bracu.ac.bd	01851902090

ATC Details:		
ATC 3		
Chair	Prof. Dr. AKM Abdul Malek Azad	a.azad@bracu.ac.bd
Member 1	MD. Rafiqul Islam Rafi	rafiqul.rafi@bracu.ac.bd
Member 2	Ihteyaz Aqaid Avash	ihteyaz.avash@bracu.ac.bd

General Notes:

1. In addition to detail journal/logbook fill out the summary/key steps and progress of your work
2. Reflect planning assignments, who has what responsibilities.
3. The logbook should contain all activities performed by the team members (Individual and team activities).

FYDP (P) Fall 2024 Summary of Team Log Book/Journal

Group No - 03

Date/Time /Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
24.11.2024 (FYDP Committee) Class - 1	**Faculty member** Mohaimenul Islam **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	**Overview of the Final Year Design Project Course.**		
31.11.2024 (FYDP Committee) Class - 2	**Faculty member** Dr. Mosaddequr Rahman **Students:** 1. Nazmus 2. Emran 3. Zayed 4. Istiaq	**Class on Complex Engineering Problem, Finding Solution as an Engineer, Creating a Problem Statement, Finding multiple Design approach based solutions.**		
06.11.2024 Group Meeting 1 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. FYDP topic selection. 2. Presentation slides preparation for ATC Meeting 1. 3. Finalize additional details regarding each topic.	Task 1: Everyone Task 2: Everyone Task 3: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed	

FYDP (P) Fall 2024 Summary of Team Log Book/Journal

Group No - 03

07.11.2024 (FYDP Committee) Class - 3	**Faculty member** Dr. Abu S.M. Mohsin **Students:** 1. Rafiul 2. Emran 3. Zayed	**Complex Engineering Problem Identification, EP and EA.**		
07.11.2024 ATC Meeting 1 (Online)	**Faculty member** 1. Chair- Prof. Dr. AKM Abdul Malek Azad 2. MD. Rafiqul Islam Rafi 3. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. ATC Introduction. 2. Presentation on FYDP topic selection. 3. Topic selection and finalization by ATC.	Task 1: Everyone Task 2: Everyone Task 3: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed	1. Finalize the weekly meeting schedule.
07.11.2024 Group Meeting 2 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Discussion on finalizing the topic. 2. ATC meeting and group meeting schedule finalized. 3. Working on the logbook.	Task 1: Everyone Task 2: Everyone Task 3: Emran Progress: Task 1: Completed Task 2: Completed Task 3: Completed	

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09.11.2024 Group Meeting 3 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Prepare two design approaches, problem statements and objectives. 2. Identify all relevant constraints of the project 3. Specify components and their details. 4. Address codes and standards, complex engineering attributes.	Task 1: Nazmus, Rafiul Task 2: Zayed Task 3: Istiaq Task 4: Emran Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	
13.11.2024 ATC Meeting 2 (Offline)	**ATC Members** 1. MD Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Zayed 4. Istiaq 5. Emran (Absent—went to hometown due to unavoidable circumstances.)	1. Review and provide feedback on the proposed design approaches. 2. Review and ensure all references are accurately cited and formatted in compliance with IEEE standards.	Task 1: Nazmus Task 2: Everyone Progress: Task 1: Completed Task 2: Completed	
14.11.2024 (FYDP Committee) Class - 4	**Faculty member** Professor Arshad M. Chowdhury **Students:** 1. Nazmus 2. Emran 3. Zayed 4. Istiaq 5. Rafiul	**Complex Engineering Problem Identification, EP and EA. Real-world examples are provided. Every group's ideas were discussed.**		

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14.11.2024 ATC Meeting 3 (Online)	**ATC Members** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Evaluation of log book and draft concept note (referred to ATC comment). 2. Feedback on design approach (referred to ATC comment). 3. Update concept note and log book (referred to ATC comment).	Task 1: Everyone Task 2: Everyone Task 3: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed	1. Fix the writing error in the concept note and log book. 2. Work on design approaches such as sensor output should go to MC-unit. 3. Work on project title. 4.Add References.
14.11.2024 ATC Meeting 4 (Online)	**ATC Members** 1. Ihteyaz Aqaeed Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Provide a project overview during the meeting. 2. Finalize the concept note and prepare a presentation summarizing the key aspects of the project. 3. Create a dedicated drive folder for references, including research papers used in the project.	Task 1: Nazmus Task 2: Everyone Task 3: Rafiul Progress: Task 1: Completed Task 2: Completed Task 3: Completed	1. Encouraged us to keep up our work and instructed us to finish the concept note and prepare for the presentation.
19.11.2024 Group Meeting 4 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Create and divide presentation slides among the team to complete for the progress presentation.	Task1: Everyone Progress: Task1: Completed	

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20.11.2024 ATC Meeting 5 (Offline)	**ATC Members** 1. MD Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Zayed 4. Istiaq 5. Emran	1. Feedback on presentation slide (referred to ATC comment).	Task1: Everyone Progress: Task1: Completed	1. Fix the error in the slides and add the missing information according to the rubrics.
20.11.2024 Group Meeting 5 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Slide completion and presentation speech division.	Task 1: Everyone Progress: Task 1: Completed	
21.11.2024 (FYDP Committee) Class - 5	**Faculty member** ALL ATC **Students:** 1. Nazmus 2. Emran 3. Zayed 4. Istiaq 5. Rafiul	**1. Conducted the progress presentation.**	Task 1: Everyone Progress: Task 1: Completed	1. We were asked to explain the design approaches, component specifications, and our concept further. No discrepancies were reported by any ATC.

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21.11.2024 ATC Meeting 6 (Online)	**ATC Members** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Review of Concept Note. 2. Discussion on Progress Presentation. 3. Work on project title. 4. Feedback on presentation slide information (referred to ATC comment). 5. Follow sequential order for references. 6. Explanation of complex engineering attributes.	Task 1: Everyone Task 2: Everyone Task 3: Nazmus Task 4: Everyone Task 5: Everyone Task 6: Emran Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed Task 5: Completed Task 6: Completed	1. Fix the error of the presentation slide, such as adding the name of design approaches. 2. Final concept notes must have references in proper sequence. 3. Start work on the project proposal.
04.12.2024 ATC Meeting 7 (Offline)	**ATC Members** 1. MD Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Zayed 4. Istiaq 5. Emran	1. Implement the required header format in the logbook to maintain consistency and professionalism.	Task 1: Rafiul Progress: Task 1: Completed	1. Examine the sample provided and update the headers accordingly to align with the required format and standards.

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05.12.2024 (FYDP Committee) Class - 7	**Faculty member** Mohaimenul Islam **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	**Ethical implications along with risk analysis, identification, solution processes, safety and cultural aspects were overviewed with examples.**		
05.12.2024 ATC Meeting 8 (Online)	**ATC Members** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Feedback on log book (referred to ATC comment). 2. Feedback on the project proposal (referred to ATC comment).	Task 1: Everyone Task 2: Everyone Progress: Task 1: Completed Task 2: Completed	1. Fix the errors of the log book, such as alignment problems and spacing problems.Also mention to add ATC comments. 2. Fix and add information in the concept note, such as: point out specific problems in the problem statement; review some literature review to add statistics and case studies.

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05.12.2024 ATC Meeting 9 (Offline)	**ATC Members** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Continue work on the project proposal to ensure steady progress. 2. Improve time management for the presentation to ensure adherence to allocated time. 3. Develop a tentative Gantt chart to organize tasks parallel to the logbook.	Task 1:Everyone Task 2:Everyone Task 3:Nazmus Progress: Task 1: Completed Task 2: Completed Task 3: Completed	1. The design approaches need to be more vivid and clearer. 2. Presentation skills need to be improved.
07.12.2024 Group Meeting 7 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Discuss and refine the content of the project proposal. 2. Work on organizing and formatting references properly. 3. Correct alignments and standardize font sizes throughout the document. 4. Enhance the design approaches to make them more detailed and visually clear.	Task 1:Everyone Task 2:Nazmus Task 3:Emran Task 4:Zayed Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	
11.12.2024 ATC Meeting 10 (Offline)	**ATC Members** 1. MD Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Zayed 4. Istiaq 5. Emran	1. Work on design approach in the project proposal (referred to ATC comment). 2. Include FYDP-P class entries for the last two classes, one on 5.12.24 and the other on 14.11.24.	Task 1:Nazmus Task 2:Istiaq Progress: Task 1: Completed Task 2: Completed	1. Fix the design approach: arrows and words should be more clear and visible.

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12.12.2024 (FYDP Committee) Class - 8	**Faculty member** Dr. A. S. Nazmul Huda **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	**Ethics of engineering projects, Engineering project canons, how a project should say an engineering students projects, Code and conduct of engineering project.**		
12.12.2024 ATC Meeting 11 (Online)	**ATC Members** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Feedback on project log book (referred to ATC comment). 2. Feedback on project proposal (referred to ATC comment). 3. Divided the work between group members 4. Every group member should go through with 5 reference papers.	Task 1:Emran Task 2:Everyone Task 3:Everyone Task 4:Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	1. The new entry should be colored blue in the log book, and the task progress notification should be updated as to whether it was done. 2. In design approach 1, the hydrogel electrodes have to be separated from sensors and the provided diagram and its associated caption have to be on the same page. 3. Some writing needs to be rephrased. 4. Functional requirements need to be more specific.

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12.12.2024 ATC Meeting 12 (Offline)	**ATC Members** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Some modifications are needed on design approaches (referred to ATC comment). 2. Ensure the references are related to our project and read thoroughly. 3. Divide the remaining work of the project proposal and complete it as early as possible. 4. Start early planning for simulation.	Task 1: Nazmus, Rafiul Task 2: Everyone Task 3: Everyone Task 4: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	1. Arrows used in the design approach 1 should be bigger and in the design approach 2, the block diagram needs to be more legible by using a lighter colour such as blue.
14.12.2024 Group Meeting 8 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Istiaq 4. Zayed 5. Emran	1. Modify the design approach according to feedback and correct any identified errors. 2. Outline and finalize the methodology for the project. 3. Develop and finalize the project plan. 4. Complete and present a detailed budget. 5. Elaborate on expected outcomes, impact, sustainability, and safety considerations. 6. Add more references to ensure thorough sourcing for the project.	Task 1: Nazmus Task 2: Emran Task 3: Rafiul Task 4: Istiaq Task 5: Zayed Task 6: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed Task 5: Completed Task 6: Completed	

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19.12.2024 (FYDP Committee) Class - 9	**Faculty Members** 1. Taiyeb Hasan Sakib **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	**Review of Project Proposal Preparation, Report Writing and Presentation Techniques.**		
19.12.2024 ATC Meeting 14 (Offline)	**ATC Members** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Make a summary of ATC comments and clearly mention the task name and then divide the work. 2. Discussion on project title (referred to ATC comment). 3. Referencing needs to be standardized as per guidelines. 4. Feedback on design approach: in design approach 2, ADC being part of MCU should not be shown separately. 5. The methodology flowchart must represent the workings of the system. 6. Create two budgets for two design approaches. 7. Gantt charts must be adjusted for better clarity. 8. Download all reference papers, upload to a shared google drive, organize folders by student name, upload papers accordingly and select the best paper from the collection.	Task 1: Emran Task 2: Nazmus Task 3: Everyone Task 4: Rafiul Task 5: Emran Task 6: Istiaq Task 7: Zayed Task 8: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed Task 5: Completed Task 6: Completed Task 7: Completed Task 8: Completed	1. We need to work on our project title. 2. Focus on consistency and precision in references and project documentation. 3. Need to conduct four group meetings in the next two weeks following provided guidelines. 4. Maintain proper teamwork in tasks, making good use of scheduled meetings.

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19.12.2024 ATC Meeting 15 (Offline)	**ATC Members** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Discussion on final presentation: distribution of work for the final presentation. 2. Modifications required for the Gantt chart font. 3. Budgeting for two design approaches.	Task 1: Everyone Task 2: Rafiul Task 3: Istiaq Progress: Task 1: Completed Task 2: Completed Task 3: Completed	1. Ensure timely completion of tasks to avoid delays and maintain quality.
21.12.2024 Group Meeting 9 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Istiaq 4. Zayed 5. Emran	1. Create two budgets for the two different design approaches, covering all potential costs. 2. Complete the project methodology. 3. Finish the writeup on risk management and ethical considerations. 4. Modify the project title and correct inconsistencies, including in-text citations. 5. Revise the Gantt charts and project plans.	Task 1: Nazmus Task 2: Emran Task 3: Zayed Task 4: Istiaq Task 5: Rafiul Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed Task 5: Completed	
24.12.2024 Group Meeting 10 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Istiaq 4. Zayed 5. Emran	1. Working on reference papers: every member should download at least 5 reference papers and upload them in the shared google drive. 2. Selection of the best papers from all the downloaded papers.	Task 1: Everyone Task 2: Everyone Progress: Task 1: Completed Task 2: Completed	

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28.12.2024 Group Meeting 11 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Istiaq 4. Zayed 5. Emran	1. Discussion on the project presentation, including the division of work and slide creation.	Task 1: Everyone Progress: Task 1: Completed	
31.12.2024 Group Meeting 12 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Istiaq 4. Zayed 5. Emran	1. Discussed the modification of certain components in both design approaches and the necessity of preparing a budget for these modifications. 2. Reviewed the overall progress of the work.	Task 1: Nazmus Task 2: Everyone Progress: Task 1: Completed Task 2: Completed	
02.01.2025 ATC Meeting 16 (Online)	**ATC Members** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Fix the logbook errors; ensure writing consistency. 2. Revise the methodology, making the flowchart clear and meaningful. 3. Conduct a deeper review of relevant literature and incorporate more sources. 4. Revise the relevant sections of the project proposal, rephrase unclear sentences, and ensure consistent numbering for all tables. 5. Modify Design Approach 2 based on insights from research papers.	Task 1: Nazmus Task 2: Emran Task 3: Everyone Task 4: Zayed Task 5: Rafiul Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed Task 5: Completed	1. This is not about inventing something new; instead, conduct a more in-depth literature review, study relevant research papers, and align your work with established approaches from those sources.

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02.01.2025 ATC Meeting 17 (Offline)	**ATC Members** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Modify the final presentation: Ethical considerations and impact should be presented on separate slides; use keywords rather than descriptive sentences on the slides.	Task 1: Everyone Progress: Task 1: Completed	
04.01.2025 Group Meeting 13 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Istiaq 4. Zayed 5. Emran	1. Modify the presentation slide as per the instructions: use keywords instead of long descriptive sentences. 2. Make text more visible and improve slide alignment and spacing. 3. Complete the methodology section with clear and concise information.	Task 1: Nazmus,Istiaq Task 2: Zayed,Rafiul Task 3: Emran Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
06.01.2025 Group Meeting 14 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Istiaq 4. Zayed 5. Emran	1. Divide the presentation slides into sections and assign specific parts to each team member to speed up slide completion as well as ensure proper presentation.	Task 1: Everyone Progress: Task 1: Completed	

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08.01.2025 ATC Meeting 18 (Offline)	**ATC Members** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Review the presentation slides, providing guidance on how to present effectively, which parts to emphasize, and which parts can be summarized or skipped.	Task 1: Everyone Progress: Task 1: Completed	
08.01.2025 Group Meeting 15 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Istiaq 4. Zayed 5. Emran	1. Conducted a mock presentation to identify areas of improvement and discussed how to enhance the overall delivery and content.	Task 1: Everyone Progress: Task 1: Completed	
09.01.2025 (FYDP Committee) Class - 10	**Faculty members:** 1. Taiyeb Hasan Sakib 2. Ihteyaz Aqaid Avash 3. Md. Saif Kabir 4. Saad Mahbub Chowdhury 5. Dr. Mohammed Belal Hossain Bhuian **Students:** 1. Rafiul 2. Nazmus 3. Istiaq 4. Zayed 5. Emran	**1. Presented the project for the final presentation.**	Task 1: Everyone Progress: Task 1: Completed	1. Provide background information on hydrogels, covering their properties, uses, and how they function, as it is an unfamiliar topic, all in one separate slide. 2. Problem statement slide is too wordy, So use bullet points instead of statements.

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09.01.2025 Group Meeting 16 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. FYDP final presentation introspection and brainstorming ideas for improvement. 2. Discussion on ideas to improve the project proposal with inclusion of context on hydrogel substance and its pacemaker incorporation. 3. Discussion on anticipated hurdles of the project and brainstorming solutions for smooth workflow. 4. Discussion of further research areas of the project and division of specified research work (e.g., power source, simulation, biochemical synthesis etc).	Task 1: Everyone Task 2: Nazmus, Zayed, Emran Task 3: Istiaq, Rafiul Task 4: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task: In progress	
11.01.2025 Group Meeting 17 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. FYDP-P project proposal font, alignment, grammatical error correction. 2. Adding context for hydrogel in the proposal. 3. Adding more references to the proposal. 4. Further updating the proposal with corrections as instructed by the ATC.	Task 1: Rafiul Task 2: Nazmus Task 3: Istiaq Task 4: Zayed, Emran Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	

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Group No - 03

Project Title:

HydroCP: Developing a hydrogel-based cardiac pacemaker.

	Final Year Design Project (D) Spring 2025		
Student Details	**NAME & ID**	**EMAIL ADDRESS**	**PHONE**
Member 1	Rafiul Alam (21321019)	rafiul.alam@g.bracu.ac.bd	01980482956
Member 2	Sk. Md. Nazmus Sadath (21110001)	md.nazmus.sadath@g.bracu.ac.bd	01624818533
Member 3	Md. Emran Hossen (20221011)	md.emran.hossen@g.bracu.ac.bd	01770127056
Member 4	Istiaq Mohammad (21321036)	Istiaq.mohammad@g.bracu.ac.bd	01648250771
Member 5	Sk. Zayed Mahmood (22121116)	sk.zayed.mahmood@g.bracu.ac.bd	01851902090

ATC Details:		
ATC 3		
Chair	Prof. Dr. AKM Abdul Malek Azad	a.azad@bracu.ac.bd
Member 1	MD. Rafiqul Islam Rafi	rafiqul.rafi@bracu.ac.bd
Member 2	Ihteyaz Aqaid Avash	ihteyaz.avash@bracu.ac.bd

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Group No - 03

Date/Time /Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
12/02/2025 ATC Meeting 1 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Selected the ATC meeting routine schedule for Rafi sir as per sir's and everyone else's agreement. 2. We should use previous Gantt charts and research to create streamlined plans for simulation design for both of our design approaches. 3. Instructed to make our free time schedule within 18/02/2025.	Task 1: Everyone Task 2: Everyone Task 3: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed	1. Select and finalize a suitable time slot for regular meetings, as done in FYDP-P. 2. Submit the proposed ATC meeting schedule by 18th February so that all ATC-3 members can review and confirm their availability. 3. Ensure the schedule aligns with the group's academic routine and is feasible for consistent progress tracking.

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13/02/2025 (FYDP Committee) Class - 1	**Faculty Member** Tasfin Mahmud **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	**Overview of the second phase of the Final Year Design Project Course (FYDP-D). Discussed key changes for Spring 2025, including a more rigorous final presentation with reduced emphasis on the mid-presentation**		
16/02/2025 Group Meeting 1 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Identify and finalize simulation tools and techniques for FYDP-D. 2. Develop flowcharts for both design approaches to guide the simulation process, using insights from FYDP-P research. 3. Analyze the components selected during FYDP-P, ensuring proper model availability, feasibility, and accuracy in the simulation process. 4. Make our schedule as instructed by Rafi sir and email in the same thread as instructed by Azad sir.	Task 1: Emran, Zayed Task 2: Nazmus, Rafiul, Istiaq Task 3: Everyone Task 4: Everyone Progress: Task 1: Completed Task 2: Partially done Task 3: Partially done Task 4: Completed	
23/02/2025 ATC Meeting 2 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We are to do two group meetings this week and ensure this is maintained throughout the semester. 2. This task pertains to working on the simulation design as instructed, using literature, research materials, etc. and	Task 1: Everyone Task 2: Everyone Task 3: Everyone Progress: Task 1: Completed Task 2: Completed	1. Attach the updated logbook at the end of the FYDP-D report for documentation and evaluation purposes. 2. Maintain a minimum of two group meetings per

		creating flowcharts for a streamlined approach. 3. We need to prepare simulation module by module and divide the modules between us in order to ease our burden while taking less time to complete simulation. Module division and design work is to be finalized in the next group meeting.	Task 3: Completed	week to ensure continuous progress and coordination. 3. Use the same simulation tools for both design approaches to maintain consistency and enable effective comparison of performance and feasibility. 4. Work sincerely and stay committed to the timeline, as PCB design is scheduled for FYDP-C. 5. In FYDP-D, strictly follow relevant literature and references to support design decisions and ensure academic integrity.

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23/02/2025 ATC Meeting 3 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Simulate using appropriate softwares and update the progress.	Task 1: Everyone Progress: Task 1: Completed	1. Encouraged us to stay motivated and maintain steady progress throughout the semester. 2. Advised to show tangible progress to ensure alignment with project goals and expectations.
25/02/2025 Group Meeting 2 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. This task is to dedicate making flowcharts and using reference materials to create the overall design of Compact HydroCP (design approach 1). 2. Beginning our simulation work in the proteus software.	Task 1: Nazmus, Rafiul Task 2: Istiaq, Emran, Zayed Progress: Task 1: Completed Task 2: Completed	
26/02/2025 ATC Meeting 4 (Online)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Instructed to look for more softwares for our simulation since we are making a biomedical device. Xcos could be one such software.	Task 1: Everyone Progress: Task 1: Completed	1. Approved the design concept and instructed the team to explore alternative simulation software options, as Proteus may lack certain biomedical components required for accurate modeling.

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				2. Ensure that the selected tools support all essential modules for seamless simulation and validation.
01/03/2025 Group Meeting 3 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Identified limitations in Proteus, including the unavailability of the ECG sensor and certain components. Decided to proceed with modules that can be fully implemented in Proteus this week. 2. Identified limitations in Xcos, Proteus, and Simulink for accurately representing biomedical techniques. Decided to explore alternative software that better aligns with project requirements.	Task 1: Istiaq, Zayed, Emran Task 2: Nazmus, Rafiul Progress: Task 1: Completed Task 2: Not Done	
02/03/2025 ATC Meeting 5 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Perform a comprehensive analysis of potential simulation tools, assessing their compatibility with biomedical applications, accuracy, and integration feasibility.	Task 1: Everyone Progress: Task 1: Not Done	1. Instructed us to identify and list the specific software tools required for the simulation and development of the project.

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04/03/2025 Group Meeting 4 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	Defined the workflow and divided the project into key modules. The task is to work on the modules divided: **1. Power Supply Unit** **2. Central Processing Unit** **3. Signal Processing Unit** **4. Sensors and Pacing Unit** **5. Wireless communication module** **6. Coding**. Each team member will be responsible for designing and developing their assigned module. Coding part is to be done if required for the respective module.	Module 1: Zayed Module 2: Emran Module 3: Rafiul Task 4: Nazmus Task 5: Istiaq Task 6: Everyone Progress (only for this week): Task 1: Partially completed Task 2: Partially completed Task 3: Not Done Task 4: Partially completed Task 5: Not Done Tssk 6: Not Done	
05/03/2025 ATC Meeting 6 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Researched offline versions of Proteus and alternative software solutions for circuit and biomedical device simulation. Evaluating tools that provide necessary features without online dependencies.	Task 1: Everyone Progress: Task 1: Completed	1. Agreed to assist in exploring alternative software options that better support biomedical simulations.

				2. Provided guidelines for building or extending the Proteus library to include additional components if required. 3. Advised us to document component requirements clearly to facilitate efficient library development and integration.
06/03/2025 Group Meeting 5 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1.Reviewed the simulation progress of Design Approach 1, assessing challenges and required improvements. Improvements such as design, components and extra library build are to be worked on next week. 2. Worked on the simulation of the Power Supply Module, verifying component functionality and stability.	Task 1: Everyone Task 2: Zayed Progress: Task 1: Completed Task 2: Completed	
09/03/2025 ATC Meeting 7 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran	1. Start writing the FYDP-D report using the given template. 2. Istiaq has been instructed to build a small custom component	Task 1: Nazmus, Rafiul, Emran Task 2: Istiaq Task 3: Zayed	1. Advised us to resume and maintain the weekly project report, similar to the approach

	4. Zayed 5. Istiaq	in proteus and show it to sir through recording. 3. Zayed has been instructed to simulate the completed design of the power supply in proteus and show sir through recording. 4. Nazmus, Rafiul and Emran have been instructed to start writing the report, as well as continue building the proteus library for the required components and building their own modules. This array of tasks is to be divided as shown in the next column. 5. Everyone will back up each other in order to contribute to each others' tasks and make the work progress smoothly.	Task 4: Nazmus (new component library coding), Emran (CPU module), Rafiul (Sensing and pacing unit) Task 5: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed Task 5: Completed	followed in FYDP-P. 2. Emphasized the importance of parallel progress on software simulations while updating the report. 3. Stressed on equal work distribution, all members should contribute across tasks and support each other. 4. Instructed to clearly document the development process of the custom Proteus library. 5. Recommended using pre-recorded simulation clips for demonstrations to avoid real-time technical difficulties.

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09/03/2025 ATC Meeting 8 (Online)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We are to start working on the proteus custom library starting with PSPice and/or LTSpice.	Task 1: Nazmus Progress: Task 1: Completed	1. Instructed the team to continue with the coding that has already been initiated by one of the members, ensuring consistent development.
11/03/2025 Group Meeting 6 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Looked for a new version of Proteus software (8.17 SP2 build) and tested it to see if it works. 2. We took updates of each other's work that was divided during ATC meeting 7. 3. Everyone's workflow was updated, such as, some components were shifted to another module, etc. to ensure quick completion of design and simulation.	Task 1: Nazmus Task 2: Everyone Task 3: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
12/03/2025 ATC Meeting 9 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Agreed to let us use Proteus 8.17 SP2 version to do the simulation. Also create the custom libraries for the missing components. Try to complete the design approach 1 simulation as soon as possible.	Task 1: Everyone Task 2: Nazmus, Rafiul,Emran Progress:	1. Agreed to use Proteus 8.17 due to its larger library, which may include more required components for the project.

		2. Start writing the report in the given template by the FYDP committee.	Task 1: Completed Task 2: Completed	2. Advised us to start working on the report and aim to complete as much as possible to ensure timely progress.
13/03/2025 Group Meeting 7 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We took updates of our progress in this meeting to ensure finding any problems we are facing. 2. One of the problems we found is that some parts of the report seem to be very similar to that during FYDP-P, so we decided one of us will complete that first by copying from our FYDP-P project proposal. 3. Research on the new library for proteus has to be included in the report.	Task 1: Everyone Task 2: Rafiul Task 3: Nazmus Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
16/03/2025 ATC Meeting 10 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We need more familiarization with biomedical devices and practices, such as, where they differ from normal electronic devices, what the medical terms involved with cardiac pacing are, etc. 2. Specify the details of the previous online	Task 1: Everyone Task 2: Nazmus Task 3: Everyone Task 4: Everyone Task 5: Everyone Progress:	1. Instructed us to become more familiar with biomedical terms and practices to improve domain understanding. 2. Emphasized the need to

		meeting, which sounds very generalized. 3. We should update in one of our weekly group meetings which members are doing what part of the FYDP-D report. 4. We have to properly simulate every module, record the proteus simulation and share with sir. 5. We are to never change what has been done in 499P, but we must add to the new work for 499D.	Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed Task 5: Completed	update the logbook with specific details, especially elaborating on tasks discussed in the meeting. 3. Required that the logbook clearly indicate which member completed which section of the report each week. 4. Directed us to properly simulate and record outputs, avoiding the use of static images of component connections.
16/03/2025 ATC Meeting 11 (Online)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	We corresponded with sir by mail and whatsapp. We had let sir know our progress.		1. Sir suggested we continue with our progress.
18/03/2025 Group Meeting 8 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Removed energy harvester from the component list as we figured we have no use for it.	Task 1: Rafiul Task 2: Istiaq Task 3: Everyone	

		2. Troubleshooting of custom-made antenna and wireless receiver done. 3. We updated our work that had been divided previously. We made some progress but we decided to continue with our work so we could simulate them and look for any bugs.	Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
22/03/2025 Group Meeting 9 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. From our work update, the CPU module needs coding to be done. 2. Another work update was to decide that the power module will not have two separate schematics, but will be merged into one containing all the required components. 3. The ECG sensor is to be built and biochemical sensor has to be made, and their simulation will have to be done after completion of the Signal Processing Unit (SPU) module. 4. The SPU module has to be done in conjunction with miscellaneous circuit components such as RLC components. 5. Project title, background survey and	Task 1: Emran Task 2: Zayed Task 3: Nazmus Task 4: Rafiul Task 5: Rafiul Task 6: Nazmus Task 7: Emran Task 8: Istiaq Task 9: Zayed Progress: Task 1: Completed Task 2: Completed Task 3: Completed	

		research, objectives, specifications, constraints and requirements as well as the project plan in the report are to be updated. 6. The design approaches, selection of modern engineering tools and references are to be updated in the report. 7. The methodologies and complex engineering and attribute problems in the report have to be updated, but the standard codes were not included as no separate section for the codes and standards were given with the template of the report. 8. The budget and component list have to be changed as per our update with the completion of design approach 1 simulation. So this task will take longer to complete. 9. Expected impact of our optimal design and ethical considerations were added to the report.	Task 4: Completed Task 5: Completed Task 6: Completed Task 7: Completed Task 8: Not Done Task 9: Completed	
06/04/2025 ATC Meeting 12 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus	1. Update the simulation in the report. 2. Email the report and logbook early on Saturday.	Task 1: Code for the heart (Rafiul), Power module (Zayed), CPU (Emran), Sensing and pacing unit	1. Instructed us to submit the report and logbook earlier, preferably by Saturday,

	3. Emran (could not attend due to unavoidable circumstances while travelling home after eid) 4. Zayed 5. Istiaq		(Nazmus), Wireless module (Istiaq). Task 2: Nazmus Progress: Task 1: Completed Task 2: Completed	instead of waiting until the Sunday meeting. 2. Advised to include updated simulation progress in the weekly report to reflect ongoing technical development.
13/04/2025 ATC Meeting 13 (Online)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Continuation of our progress with our simulation.	Task 1: Everyone Progress: Task 1: Completed	1. Updated sir on our progress online. Sir approved of our progress.
12/03/2025 ATC Meeting 14 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Components such as temperature sensor can be taken from the proteus library, for eg. LM35. Other components such as wireless transceivers are unavailable and have to be custom-built as we work on our simulation design.	Task 1: Everyone Progress: Task 1: Completed	1. Recommended using similar alternative components if exact components are unavailable in the Proteus library. 2. Advised that custom component development in Proteus may be necessary for certain modules.

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07/04/2025 Group Meeting 10 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Coding for the heart simulator debugging. 2. Coding for the CPU. 3. Testing the wireless module.	Task 1: Rafiul Task 2: Emran Task 3: Istiaq Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
10/04/2025 Group Meeting 11 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Compilation of all the modules into one file. 2. There were some problems found in the wireless module which are the malfunctioning of the antenna and some errors in the codes. This task is to find the solution to these problems. 3. Since the simulation of the device was divided into modules, progress of each individual module is to be reflected in the report. 4. Start working on the design approach 2.	Task 1: Nazmus Task 2: Istiaq Task 3: Everyone Task 4: Emran, Zayed Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Partially Done (for this week only)	

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13/04/2025 ATC Meeting 15 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. The first task is to change the tone of some of the previous tasks mentioned in this report as per the standards of maintaining tasks, since these are tasks and not orders. 2. Some of the other tasks mentioned in this report have some ambiguity around them. Therefore this task is to make them more specific. 3. We have to rewrite the title of our project in the Title case as per instructions. 4. This task is to make appropriate referencing in a few places in the report. 5. Instead of having figure captions under a large group of figures, each figure should have its own captions underneath. 6. In our report on page 15 the second picture from above was taken from the literature. We are to make some changes to the image to reflect our purpose. Since the image shows the breakdown of the pacemaker device, we	Task 1: Rafiul Task 2: Rafiul Task 3: Rafiul Task 4: Nazmus Task 5: Zayed Task 6: Nazmus Task 7: Emran, Istiaq Task 8: Nazmus, Zayed, Istiaq Task 9: Nazmus Task 10: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed Task 5: Completed	1. Noted that some logbook entries read like directives, not tasks; these need to be rephrased more clearly as actionable items. 2. Emphasized that completed tasks must be reflected in the report, along with updated simulation progress. 3. Pointed out the need to correct referencing throughout the report and place figure captions directly under each figure. 4. Recommended working in parallel to speed up progress and meet the timeline. 5. Directed us to compare both design approaches

		have to make some changes that show how our device breakdown would look. 7. In our report, we compared the two design approaches, but unlike FYDP-P, now we have to compare them before and after simulation. The comparison will have to be reflected in the report. Full comparison of both design approaches can be achieved after their total completion. Therefore, this task is to make the most recent updates in the comparison table in the report. 8. All necessary figures in the report will have to be given explanation and description in the larger body paragraphs as per instructions. 9. The simulation video shown during the ATC Meeting 14 has to be given in our official mail thread as per instructions. 10. Proper simulation updates such as the codes are to be given in the appendix section after the references.	Task 6: Completed Task 7: Completed Task 8: Completed Task 9: Completed (immediately as per instructions) Task 10: Completed	before and after simulation, including proper referencing and clear explanations. 6. Stressed the importance of maintaining high standards in both logbook and report documentation. 7. Noted that the group is falling behind the Gantt chart schedule and encouraged faster progress. 8. Instructed to send the simulation video for further review.

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13/04/2025 ATC Meeting 16 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Make the perfect font and line spacing in each paragraph of the report. 2. Start working on the design approach 2 by this week. 3. Update the design approach with 2 simulations in the report.	Task 1: Rafiul Task 2: Emran Task 3: Everyone Progress Task 1: Completed Task 2: Completed Task 3: Completed	1. Sir, reviewed our report and advised us to give more attention to line spacing and try not to overlap any topic. 2. Instructed us to start working on design approach 2 by this week.
16/04/2025 ATC Meeting 17 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We had to quickly make presentation slides from our existing work and report and gave sir a small presentation to update on our progress. 2. Proteus has limitations in antenna implementation which was unknown to us before. Therefore according to sir's suggestion, we planned to use wired connection between the bluetooth modules to simulate instead.	Task 1: Everyone Task 2: Istiaq Progress: Task 1: Completed Task 2: Completed	1. Due to unresolved issues with the wireless module, sir permitted the use of wired communication for the module simulation as an alternative. 2. Progress presentation was delivered to sir, who approved the simulation development.

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16/04/2025 Group Meeting 12 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Final update in the design approach 1 (Compact HydroCP) simulation design. Some changes were made in the design of CPU, power and communication modules. 2. Debugging of the simulation codes were done, but full debugging is yet to be achieved. 3. Using the completed design of Compact HydroCP, design approach 2 (Accessible HydroCP) is to be started.	Task 1: Emran, Zayed, Istiaq Task 2: Rafiul, Nazmus, Emran Task 3: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
17/04/2025 Group Meeting 13 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. The final design approach 1 updates are to be included in the report. 2. Debugging and final design of design approach 1 is to be completed and updated in the report. 3. Updates of design approach 2 were taken. Progression of design approach 2 is to be included in the report.	Task 1: Rafiul, Nazmus Task 2: Everyone Task 3: Zayed, Istiaq, Emran Progress: Task 1: Completed Task 2: Partially completed (codes show much fewer errors than before.)	

			Task 3: Completed	
19/04/2025 Group Meeting 14 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. The antenna issue was solved and we finalized the making of wireless communication between the transmitter and receiver. 2. Updating our presentation slides as we have done more work after giving a presentation to Rafi sir.	Task 1: Istiaq Task 2: Everyone Progress: Task 1: Completed Task 2: Completed	
20/04/2025 ATC Meeting 18 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Progress Presentation given. 2. We need to make a deep analysis of the HydroCP (Hydrogel pacemaker) to see how much edge it has over traditional pacemakers. 3. We have to put the power supply annotations appropriately.	Task 1: Everyone Task 2: Nazmus, Rafiul Task 3: Zayed Progress: Task 1: Completed Task 2: Completed Task 3: Completed	1. Advised not to assign the same presenter for multiple sections. 2. Instructed to include slide page numbers. 3. Emphasized the need to clearly explain how the hydrogel pacemaker offers a significant improvement.

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20/04/2025 ATC Meeting 19 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Before the presentation, we were to follow the feedback instructions given by Azad Sir after our presentation with sir. 2. We should be structuring our slides such that each person does not have to present twice.	Task 1: Everyone Task 2: Everyone Progress: Task 1: Completed Task 2: Completed	1. Instructed us to make the necessary changes instructed by ATC members.
22/04/2025 Group Meeting 15 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Presentation slide power module section annotation. 2. Adding more content to the slide to reflect what we have done so far. 3. Finding and fixing any font issues in the slides that could have been missed previously. 4. All the simulation result images are placed enlarged to be easily visible.	Task 1: Zayed Task 2: Nazmus, Rafiul Task 3: Istiaq Task 4: Emran Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	
23/04/2025 ATC Meeting 20 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed	1. Update all the outputs of the design approach 1 in the report. 2. Continuing our work on the design approach 2. 3. For stable output, we should use the Voltage	Task 1: Nazmus, Rafiul Task 2: Everyone Task 3: Zayed Progress:	1. Sir, check our report and satisfy our work on the design approach 1. 2. Also advised us to fix some

	5. Istiaq	regulator IC LM7805 in both design approaches, since we were facing problems with running of the simulation for design approach 1.	Task 1: Completed Task 2: Ongoing Task 3: Completed	minor errors. Also, discuss with us on design approach 2. 3. We proposed to use the Voltage regulator IC LM7805 in both design approaches. So, sir told us to see this update next week.
23/04/2025 ATC Meeting 21 (Online)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Progress Presentation given. 2. We have to use a bar chart instead of a pie chart to present the conventional pacemakers and hydrogel pacemakers data for better understanding. 3. We need to continue working on Design Approach 2 and provide an update in next week's meeting.	Task 1: Everyone Task 2: Nazmus, Rafiul Task 3: Emran, Istiaq, Zayed Progress: Task 1: Completed Task 2: Completed Task 3: Partially Completed	1. Progress presentation taken. Sir has advised us that all the content should be written in short phrases, not full sentences. 2. Use a bar chart rather than a pie chart to explain any graph. 3. Do not just add a single image to a slide. Rather than give a caption and explain accordingly. 4. All the image alignments

				need to be perfect, so that it will be visible clearly. 5. During our presentation, give a short explanation of why our design approach 1 budget is more than the design approach 2 budget. Sir also said that no slide should be only full of words or only full of images, then there will not be proper understanding. 6. Lastly, sir advised us to send the final presentation slides one week before the final presentation to receive better feedback.
24/04/2025 Group Meeting 16 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. As we modify the design approach 2, we are to update any progress in the report accordingly. 2. We are to use a pH sensor in design approach 2 instead of a biochemical sensor.	Task 1: Everyone Task 2: Istiaq Task 3: Emran Task 4: Nazmus, Rafiul Task 5: Zayed	

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		3. We are to change some parts from our compiled design approach 1 such as the wireless module and some parts of the power module so that it is easier to make design approach 2. The CPU’s oscillator has to be changed for the purpose as well. 4. We plan to use a Heart rate pulse sensor module for Arduino in design approach 2. 5. For the power module in design approach 1, we use stable output Voltage regulator IC LM7805 and it has been utilised for both design approaches, addressing the issues caused by zener diodes. 6. Simulation of design approach 1 caused an issue of CPU overloading. As such, we had to remove all other root sheets and have all components in one root sheet.	Task 6: Nazmus, Rafiul Progress: Task 1: Partially completed Task 2: Ongoing Task 3: Ongoing Task 4: Ongoing Task 5: Completed Task 6: Completed	
25/04/2025 ATC Meeting 22 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Modifications to be done in the report which include: clearly mentioning which parts have been mentioned by other papers, not writing our plans for the project in background research, changing some figures, modifying the appendix and making the	Task 1: Nazmus, Rafiul, Emran Task 2: Everyone Progress: Task 1: Completed	1. Sir reviewed our report and found more points to be corrected. Sir told us not to include our plans in the background section. Sir told us to

		references more in incremental sequence instead of sudden jumps. 2. We are to continue our work on the simulation for both the design approaches.	Task 2: Partially completed	modify some figures and make the in-text citations more sequential and not to jump drastically between references. The codes in the appendix have to have white background as sir instructed us. 2. The simulation work is to be carried on and sir wanted to see the simulation progress in the next meeting.
25/04/2025 ATC Meeting 23 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We are to make corrections in our presentation slides incorporating all feedback provided by our ATC members. 2. Submitting the draft to sir several days prior to the final presentation for review and correction. In this case, we would give the slides prior to our meeting on Sunday.	Task 1: Everyone Task 2: Rafiul Progress: Task 1: Completed Task 2: Completed	1. Sir told us to modify the presentation slides. 2. Sir told us to send the slides earlier in order to do final review so that we can make our final corrections in the slides.

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26/04/2025 Group Meeting 17 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Identified issues in the Bluetooth module during simulation. Assigned task to debug the problem, identify the root cause, and implement an appropriate solution. 2. Initiated development of the code for Design Approach 2. 3. Updating the report according to ATC feedback, including all the corrections 4. Errors such as excessive CPU load and GMIN timestep are too small have to be fixed so that running the simulation do not show these errors anymore.	Task 1: Istiaq Task 2: Emran, Rafiul Task 3: Nazmus Task 4: Zayed Progress: Task 1: Completed Task 2: Partially completed Task 3: Completed Task 4: Completed	
28/04/2025 ATC Meeting 24 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq			1. Due to the BSRM inauguration event, sir was not able to give us any detailed feedback on our work.
01/05/2025 Group Meeting 18 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. After solving the previous sets of errors, which was done by rebuilding the power module, using an external application to connect the bluetooth components properly and modifying the codes further, another set of	Task 1: Everyone Task 2: Zayed, Istiaq Task 3: Emran, Nazmus, Rafiul Progress:	

		errors was displayed. Logic contention error showed up while the simulation was running, thereby preventing the display of the simulation data. We started working on fixing this error. 2. Making corrections in the presentation slides. 3. We are to update the report and logbook of our current progress.	Task 1: Partially completed Task 2: Completed Task 3: Completed	
04/05/2025 ATC Meeting 25 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Correction of the presentation slides. 2. Fixing link issue in the design report. 3. Inclusion of all simulation results in the report and slides.	Task 1: Rafiul, Zayed, Nazmus Task 2: Istiaq Task 3: Emran, Nazmus, Zayed Progress: Task 1: Completed Task 2: Completed Task 3: Completed	1. Sir reviewed our presentation slide first. Sir raised issues with fonts, alignment, space utilization and proper placement of certain slide contents. Sir told us to fix these issues. 2. Sir also pointed out our mistake in the report where we had biochemical sensor online buying link in the hydrogel section and instead we gave pH sensor link in the place of

				biochemical, which should be fixed. 3. Since we did not include results in our report, sir wanted to see all the details as soon as possible.
04/05/2025 Group Meeting 19 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Since our simulation results for design approach 1 would only run for 3 seconds in real time and design approach 2 results had not yet been achieved, we decided that we would submit our report and slides the next day after ATC meeting 25 so that sir can get a complete view of our work. This task was to decide when we would submit our report and slides again to the ATC after simulation results were updated. 2. Design approach 1 simulation results are to be included in the report and slides. 3. Design approach 2 simulation results are to be obtained from simulation and then updated in the report and slides. 4. If there are any problems with the	Task 1: Everyone Task 2: Nazmus, Rafiul Task 3: Emran, Istiaq, Zayed Task 4: Zayed Progress: Task 1: Completed Task 2: Completed Task 3: Not Done Task 4: Completed	

		simulation, all of the issues have to be included in the report, but we decided that the presentation slides will only contain the desired outcomes. Hence for any simulation issues, the slides will have blank spaces for the simulation results.		
08/05/2025 ATC Meeting 26 (Offline)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We have to keep working diligently towards our successful implementation of this design project.	Task 1: Everyone Progress: Task 1: In progress	1. We asked sir about any feedback on our presentation and our journey ahead for FYDP-C. 2. Sir encouraged us to keep up with our work and provided feedback on our presentation. We needed more practice, keeping time and presenting ourselves neatly.
21/05/2025 Group Meeting 20 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. FYDP-D final report font, alignment, grammatical error correction. 2. Review the full report and further update with corrections as instructed by the ATC.	Task 1: Everyone Task 2: Everyone Progress Task 1: Completed Task 2: Completed	

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	Final Year Design Project (C) Summer 2025		
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General Notes:

1. In addition to detail journal/logbook fill out the summary/key steps and progress of your work
2. Reflect planning assignments, who has what responsibilities.
3. The logbook should contain all activities performed by the team members (Individual and team activities).

FYDP (C) Summer 2025 Summary of Team Log Book/ Journal

Date/Time/ Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
19/06/2025 Group Meeting 1 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Discussion for component selection, bill estimation revised. 2. Roadmap of FYDP-(C) discussed along with revised timeline. 3. Ordering of all components available locally. 4. Sensor chip (Kingsense) ordered for import.	Task 1,2, and 3: Everyone Task 4 : Nazmus, Istiaq Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	
26/06/2025 Group Meeting 2 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Acquisition of components ordered locally - microprocessor, mini drill, RLC components, wires, . 2. Task division between electronics, encapsulation and hydrogel components. Everyone will oversee electronics. Nazmus will oversee the hydrogel part. Istiaq, Rafiul, Zayed will oversee the encapsulation part. 3. Kingsense chip acquisition.	Task 1: Istiaq, Zayed Task 2: Everyone Task 3:Nazmus, Istiaq Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
02/07/2025 ATC Meeting 1 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran (Sick)	1. Order all the remaining components as early as possible. 2. Discussion for component selection and its usage.	Task 1: Everyone Task 2: Everyone Progress:	1. Sir gave emphasis on ordering the components. 2. Sir discussed component usage with us.

	4. Zayed 5. Istiaq		Task 1: Partially done Task 2: Completed	
02/07/2025 ATC Meeting 2 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran (Sick) 4. Zayed 5. Istiaq	1. FYDP-P and D materials are to be copied from the previous reports and added to the new FYDP-C report. 2. We have only to modify the FYDP-C gantt chart. 3. We are to include proper images and media of our components and progress in the report. 4. We need to include our new budget section in the report as well.	Task 1: Rafiul, Istiaq Task 2: Nazmus, Rafiul Task 3: Everyone Task 4: Istiaq, Zayed, Nazmus, Emran Progress: Task 1: In progress Task 2: Completed Task 3: In progress Task 4: Completed	1. Sir told us that we need to be mature as we correct any errors remaining within the FYDP-P and D materials when we transfer them over to FYDP-C report. 2. Sir told us that reports are very important and when we do them, we must capture images and take videos of what we have done and give weekly updates and properly include them in the reports.
02/07/2025 ATC Meeting 3 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran (Sick) 4. Zayed 5. Istiaq	1. Discussion for all the components and its usage. 2. Discussion of the roadmap with revised timeline.	Task 1: Everyone Task 2: Everyone Progress: Task 1: Completed Task 2: Completed	1. Rafi Sir gave us advice on how we should use some of our components, i.e. the microcontroller and the signal processor. 2. Sir discussed the FYDP-C roadmap with us.
02/07/2025 (FYDP Committee)	**Faculty Member** Mirza Rasheduzzaman **Students:**	1. Introduction to FYDP(C) 2. Dos and Don’ts discussed for the project completion.	Task 1: Everyone Task 2: Everyone Task 3: Everyone	

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Class - 1	1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	3. All COs explained in detail. 4. Deadlines and milestones introduced.	Task 4: Everyone	
06/07/2025 Group Meeting 3 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Commercial Pacemaker dissected for observation. 2. All of the electronic components secured and workload distributed for the week (i.e. build wireless charging radio frequency module, PCB designing). 3. Acquire the rest of the components (i.e., Dummy heart, DAC)	Task 1: Everyone Task 2: Zayed, Emran. Task 3: Istiaq, Nazmus, Rafiul. Progress: Task 1: In progress Task 2: Completed Task 3: Completed	
08/07/2025 Group Meeting 4 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Making changes in the budget by adding some chemical components. 2. Making a complete PCB design for our project 3. Report writing was done up to Chapters 1,2,3	Task 1: Nazmus Task 2: Emran, Zayed, Nazmus Task 3: Rafiul, Istiaq Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
09/07/2025 ATC Meeting 4 (Online)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Discussion of our dummy pacemaker and its PCB design. 2. Discussion of our workload distribution.	Task 1: Everyone Task 2: Everyone Progress: Task 1: Completed Task 2: Completed	1. Sir saw our dummy pacemaker and discussed its functionality of PCB design and the other component usage.

				2. Sir told us to take our meeting at the FYDP lab from next week to see our hardware update.
09/07/2025 ATC Meeting 5 (Online)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Discussion for the PCB design in an appropriate way. 2. Discussion on adding some biochemical component that is easily accessible and useful for the pacemaker. 3. Discussion on the antenna connections.	Task 1: Everyone Task 2: Everyone Task 3: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: In progress	1. Sir gave us the roadmap for the PCB design as we are stuck on it before. 2. Sir gave us a suggestion for some biochemical components that are useful and accessible to us. 3. Sir told us about a specific antenna (2.5 GHz) which is small in size and effectively used in our project.

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09/07/2025 ATC Meeting 6 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We have to modify our FYDP-C Gantt chart and proceed with our work accordingly, which is, ordering the PCB Design and completing the report and logbook. 2. We have to include our daily hardware updates in the report. 3. Our PCB design will be completed by next week. 4. We have to make a record of our PCB design work as well as our prototype updates.	Task 1: Nazmus, Rafiul, Istiaq, Emran Task 2: Rafiul, Zayed, Istiaq Task 3: Emran, Zayed, Nazmus Task 4: Istiaq, Emran Progress: Task 1: Completed Task 2: Completed Task 3: In progress Task 4: In progress	1. Sir told us to change the comments on the comment by ATC of Rafi sir. 2. Sir instructed us to send the report and logbook at least one day before the meeting. 3. Sir told us to specify in group meetings who wrote which part of the report, and allocated the chapters. 4. Sir instructs us to mention every weekly update on the hardware part, which should be included in the report and also include the page no in the report. 5. Sir told us that we need to prepare the PCB and Gantt chart by next week.
12/07/2025 Group Meeting 5 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Making a PCB design, component testing, PCB testing, coding. 2. Making a power module, building and	Task 1: Nazmus, Emran, Zayed Task 2: Zayed, Rafiul, Istiaq	

		testing, building a cover for the RF transmitter coil (3D design), and readings of the temperature values. 3. Acquiring remaining components for hydrogel, and writing steps for building the encapsulation layer. 4. Report writing has been completed for part of the following chapters: 1.1, 1.1.1, 1.1.2, 1.2, 1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.5, 2.1, 2.2, 2.2.1, 2.2.2, 2.3.1, 2.3.2, 2.4, 2.5, 3.1, 3.2.1, 4.1, 4.2, 4.3, 5.2, 7.1, 7.2.	Task 3: Nazmus, Rafiul Task 4: Rafiul, Istiaq Progress: Task 1: Completed Task 2: In progress Task 3: In progress Task 4: Completed	
16/07/2025 ATC Meeting 7 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	-	-	The meeting had been cancelled by sir.
16/07/2025 ATC Meeting 8 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We have to fix a day after the midterm exam when we will all be working in the FYDP lab and during that time, Rafi sir will come and observe our progress.	Tasks: Task 1: Everyone Progress: Task 1: In progress	1. Sir encouraged us to continue with our work. 2. Sir told us to fix a time after the midterm exam when he will go and check our progress as we work in the lab.

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16/07/2025 ATC Meeting 9 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We are to change some ATC comments in the logbook since they must involve the ATC instructing and not us initiating discussion. 2. We must separate in our report which are the components and which are the tools for use. 3. We have to change some pictures in our report as they appear blurred or unprofessional. 4. We have to implement testing of the components this week.	Tasks: 1. Rafiul 2. Istiaq, Rafiul 3. Istiaq 4. Emran, Zayed, Nazmus Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	1. Sir told us to make some changes in the logbook regarding the wordings on the ATC comment. 2. Sir told us to change some images in the report; replacing them with more appropriate images. 3. Sir instructed us to test and verify the components and our design before moving into making the final PCB. 4. Sir encouraged us to continue with our work.
19/07/2025 Group Meeting 5 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Completing the update on the report and logbook. 2. Report chapter 1.2.3, chapter 4 and chapter 5 have been updated. 3. Acquiring the necessary chemicals to make the hydrogel (delivery within 15 days). 4. Ensuring what tests to be done on the components in the FYDP lab.	Tasks: Task 1: Rafiul, Istiaq Task 2: Rafiul. Istiaq Task 3: Nazmus Task 4: Nazmus. Emran, Zayed Progress: Task 1: Completed Task 2: Completed	

			Task 3: Completed Task 4: Completed	
21/07/2025 Group Meeting 6 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Component testing in the FYDP lab. Tested components include LEDs, battery, RF transceiver coils, Arduino board. 2. Taking new pictures of components as per instructions of our ATC. 3. Updating the report and logbook as per our agreement in the group meeting 5.	Tasks: Task 1: Zayed, Emran, Nazmus Task 2: Istiaq, Rafiul Task 3: Istiaq, Rafiul Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
23/07/2025 ATC Meeting 10 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Discussion regarding our work distribution before the midterm exam-week. 2. Showing the test procedures and expected results of various components (e.g. T_X-R_X module, Battery, LM35 Temp. sensor) 3. Going over the plan for heart prop simulation.	Tasks: Task 1, and 2: Emran, Rafiul, Zayed. Task 3: Nazmus, Istiaq Progress: Task 1: Completed Task 2: In Progress Task 3: In Progress	1. Sir encouraged us to pick up our pace of work before midterm exam week with proper planning of workload until the final week. 2. Observed component testing methods and wanted an update on the test results.
23/07/2025 ATC Meeting 11 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus	1. Discussion on the sorting of each component testing. 2. Showing the testing methods and anticipated outcomes for different	Tasks: Task 1: Nazmus, Istiaq Task 2: Zayed, Emran	1. Sir told us some specific and effective ways to test the components.

	3. Emran 4. Zayed 5. Istiaq	components such as the TX-RX module, battery, and LM35 temperature sensor. 3. Discussing the advanced process of application development.	Task 3: Nazmus, Rafiul Progress: Task 1: Completed Task 2: In progress Task 3: In Progress	2. Sir instructed us on the use of some specific code to develop our application, since we failed to execute it a few times.
23/07/2025 ATC Meeting 12 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We have to revise and update the system-level specification since ours is incomplete. 2. We have to include the labelings and annotations with some explanation of the pictures, which will make the figures easier to understand. 3. We have to change the Gantt Chart style of FYDP-C.	Tasks: Task 1: Rafiul, Nazmus Task 2: Rafiul, Zayed Task 3: Rafiul, Istiaq Progress: Task 1: Completed Task 2: Completed Task 3: Completed	1. Sir commented on our progress not being significantly great. 2. Sir commended our component-level specification, but advised us to revise and update the system-level specification since ours is incomplete. 3. Sir told us to add explanations below each picture of the components and tools we have in the report. 4. In some of the pictures, sir told us to include labelings and annotations, which will make the figures easier to understand.

				5. Sir told us to change the Gantt chart of FYDP-C to match the style of the previous Gantt charts. 6. Sir gave us a task to download 3 very recent papers from 2025 for hydrogel pacemakers. Future direction in the report must be completed using the materials and directions in those papers. 7. Sir also instructed us to check with LTO Nazrul Islam of the FYDP lab to try out the thermocouple, which is said to be more accurate compared to the LM35.
25/07/2025 Group Meeting 7 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Acquisition of the 2.4 GHz antenna. 2. Attempting the application development process. 3. Prepare the programming codes for the pacemaker as well as the artificial heart.	Tasks: Task 1: Istiaq Task 2: Nazmus, Rafiul Task 3: Zayed, Emran Task 4: Rafiul, Zayed	

		4. Report chapter 2.2.1, 2.2.2, 4.2, 5.2, 9.1, 9.2, 9.3, 9.4, 10.1, 10.2, Appendix (code), Reference (22,23) have been updated.	Progress: Task 1: In progress Task 2: In progress Task 3: In progress Task 4: Completed	
03/07/2025 Group Meeting 8 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Completing the PCB design accurately. 2. Confirm the process of making hydrogel by touring the laboratory. 3. Completion of the codes. 4. Getting the heart prop and other components which include the LEDs, some more wires and a tweezer to help with the desoldering process. 5. Use the thermocouple to get temperature readings and complete testing all of the components.	Tasks: Task 1: Nazmus Task 2: Nazmus, Rafiul Task 3: Emran, Zayed Task 4: Istiaq Task 5: Everyone Progress: Task 1: In progress Task 2: In progress Task 3: In progress Task 4: In progress	
06/08/2025 ATC Meeting 13 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Discuss the process of using the heart prop accurately. 2. Showing the testing methods and anticipating the new outcomes for testing different components.	Tasks: Task 1: Namzus, Istiaq Task 2: Zayed, Emran Progress: Task 1: In progress Task 2: In progress	1. Sir, instruct us on some ways to use the heart prop by reference so that it works accurately. 2. Observed component testing methods and saw the update on the test results.

06/08/2025 ATC Meeting 14 (Offline)	**ATC Member** 1. MD. Rafiqul Islam Rafi **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed (Absent) 5. Istiaq	1. Discussion on making some changes in our PCB design in the connection between the components and adding an op-amp. 2. Discussion on updating the application development.	Tasks: Task 1: Nazmus Task 2: Nazmus, Rafiul Progress: Task 1: In progress Task 2: In progress	1. Sir told us to make changes in our PCB design in the connections part between the components and told us that it could be better to add a TL071 Low-Noise JFet-input op-amp. 2. Sir instructed us again to use some specific code to develop our application, since we had failed to execute it quite a few times.
06/08/2025 ATC Meeting 15 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed (Absent) 5. Istiaq	1. We have to label and annotate the diagram of both design approaches. 2. We have to mention the figure number in the explanation paragraph under every figure. 3. We have to mention that all the modules on page 52 have been integrated together. 4. We have to add the figure number in Chapter 5. 5. We have to put our old budget in chapter 8.3 and modify it accordingly.	Tasks: Task 1: Nazmus Task 2: Rafiul Task 3: Zayed Task 4: Istiaq Task 5: Emran Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	1. Sir commented on our PCB design testing progress lagging and the 3D printing of the pacemaker is also missing. 2. Sir told us to show the heart's demonstration in the upcoming week. 3. Sir, instruct us about some specific page no of our report to fix some specific parts.

			Task 5: In progress	4. Sir commented on our prototype design that it is important to take immediate action for significant progress. 5. Sir told us to meet and discuss with the ATC at any time if we need, no need to wait for the weekly meeting.
07/08/2025 Group Meeting 9 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Contacting the PCB makers and consulting with them on our design. 2. Changes in the PCB design by adding a connection between the components and considering the addition of an op-amp. 3. Dividing the work on code and debugging: running the code in the individual Arduino uno boards before building the circuit without PCB.	Tasks: Task 1: Nazmus, Istiaq Task 2: Nazmus, Rafiul Task 3: Emran, Zayed Progress: Task 1: Completed Task 2: In progress Task 3: In progress	
08/08/2025 Group Meeting 10 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Researching and developing the app so that it can connect to the Bluetooth antenna we have selected. 2. Touring the microbiology lab and confirming the equipment and getting familiarized with the environment while	Tasks: Task 1: Nazmus, Rafiul Task 2: Nazmus, Rafiul Task 3: Emran, Zayed	

		updating our plans for making the hydrogel. 3. Use the thermocouple to get temperature readings as per the instructions of the ATC. 4. Completion of all the component testing individually without building the circuit (for testing before PCB making). 5. Report chapter 5.2 has been updated.	Task 4: Emran, Zayed Task 5: Rafiul, Zayed, Istiaq, Nazmus Progress: Task 1: In progress Task 2: Completed Task 3: Completed Task 4: Completed Task 5: Completed	
13/08/2025 ATC Meeting 16 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq (Absent)	1. We have to add all the missing modules of the design approach 2. 2. We have to rephrase all the figure paragraph patterns in Chapter 05. 3. We have to take pictures of all the chemical testing components. 4. We have to remove all the unwanted parts from the report.	Tasks: Task 1: Rafiul, Nazmus Task 2: Rafiul, Istiaq Task 3: Rafiul, Nazmus Task 4: Rafiul, Zayed Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	1. Sir instructed us to complete our weekly work within due time, and not to worry about the Gantt chart. 2. Sir told us to delete some unnecessary figures and paragraphs in the report. 3. Sir instructed us to make a video of every type of component and chemical test.

13/08/2025 ATC Meeting 17 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq (Absent)	1. Showing the testing methods and anticipating the new outcomes for testing different components. 2. Discuss the process of chemical testing and finding the output.	Tasks: Task 1: Zayed, Emran Task 2: Nazmus, Emran Progress: Task 1: Completed Task 2: Completed	1. Observed component testing methods and saw the update on the test results. 2. Sir told us some basic concepts about chemical testing.
16/08/2025 Group Meeting 11 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Preparing to create a lively demonstration of how the pacemaker works inside the human body. Here, we aim to quickly prepare an external human thoracic cavity for the left side, where the heart resides. We plan to build a mini-automated pump to deflate and inflate a balloon attached to a hydrogel sample, demonstrating the elasticity of the hydrogel. 2. Further debugging of the PCB schematics code. Additionally, observing how to connect the battery, Rx, Tx coil, and voltage regulator provides insights into optimizing the connections on the PCB. 3. Seeing if the antenna could be brought from outside Bangladesh so that we can order a temp sensor TMP117 and	Tasks: Task 1: Everyone Task 2: Emran, Zayed Task 3: Istiaq, Zayed Task 4: Nazmus Progress: Task 1: Partially completed Task 2: In progress Task 3: In progress Task 4: Completed	

		ESP8285. If that is not possible, we will have to use the MCP temperature sensor and the M177 NRF 2.4 GHz antenna, which are readily available online at roboticsbd. 4. Making further necessary changes to the PCB design to create the final version.		
18/08/2025 Group Meeting 12 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Giving the final PCB design to the PCB maker for completion of the PCB board. 2. Completion of the coding and debugging of the PCB schematics code.	Tasks: Task 1: Nazmus Task 2: Zayed, Emran Progress: Task 1: In progress Task 2: In progress	
19/08/2025 Group Meeting 13 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Obtaining the accurate temperature and biochemical values and showing them in the serial monitor. 2. Doing tests on obtaining the ECG waveform. 3. Report chapter 1.2.3, 2.2.1, 2.2.2, 5.2 has been updated.	Tasks: Task 1: Zayed, Emran Task 2: Zayed, Emran Task 3: Rafiul Progress: Task 1: Completed Task 2: In progress Task 3: Completed	

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20/08/2025 ATC Meeting 18 (Online)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Showing the testing methods and anticipating the outcomes for testing temperature and biochemical values. 2. Discuss the result of the obtained ECG waveform.	Tasks: Task 1: Zayed, Emran Task 2: Zayed, Emran Progress: Task 1: Completed Task 2: In progress	1. Observed the testing methods and saw the update on the test results. 2. Sir told us some basic concepts about the accurate ECG waveform.
20/08/2025 ATC Meeting 19 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We have to complete our coding part and hardware part for electronics. 2. We have to fix the figure error in the report. 3. We have to solve our ECG waveform showcasing part, and all three signals need to work properly. 4. We need to start working on the application and get guidance from Annajiat sir.	Tasks: Task 1: Everyone Task 2: Rafiul Task 3: Zayed, Emran Progress: Task 1: In progress Task 2: Completed Task 3: In progress Task 4: In progress	1. Sir told us to start working on the breadboard instead of the PCB board. 2. Sir, instructed us to fix the error in the report. 3. Sir, instructed us to solve all three signals to work properly, as well as our ECG part has to be solved as soon as possible. 4. Sir told us to meet Annajiat Sir to get guidance for our application implementation.
22/08/2025 Group Meeting 14 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Doing the ECG test and obtaining the waveform. 2. Continuing the application development.	Tasks: Task 1: Zayed, Emran Task 2: Rafiul, Nazmus	

		3. Preparing the thoracic cavity, heart drill location and balloon stand as part of the prop preparation process for the showcase.	Task 3: Rafiul, Nazmus, Istiaq Progress: Task 1: Completed Task 2: In progress Task 3: Partially done	
24/08/2025 Group Meeting 15 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Completing the PCB design and finalizing it. 2. Debug the code and apply logic to understand if the code should not work and use it on Arduino boards. 3. Report Chapter 5 has been updated and all the figures in Chapter 5 have been arranged.	Tasks: Task 1: Nazmus Task 2: Zayed, Emran Task 3: Rafiul Progress: Task 1: Completed Task 2: In progress Task 3: Completed	
25/08/2025 Group Meeting 16 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We were supposed to meet Mr. Annajiat sir for the progress of our application development, but we couldn't find him. 2. Prof AKM Azad Sir instructed us to meet Prof Md Golam Rabiul Alam Sir, for our application development progress, since we couldn't find Mr. Annajiat Sir. However, he did not come to university on August 25, 2025, so we	Tasks: Task 1: Nazmus, Rafiul Task 2: Nazmus, Rafiul Task 3: Zayed, Emran Task 4: Zayed, Emran Task 5: Istiaq, Nazmus	

		have to meet him during his class time the next day. 3. Heart ECG, temperature and biochemical data have been successfully implemented using code. 4. Only the pacing of the irregular heartbeats is needed for the full realization of our sensing and pacing objective. 5. The last chemical needed for hydrogel preparation, PEDOT: PSS, is stuck in Indian customs, and it is uncertain when it will arrive. An alternative has been considered: using silver nanoparticle ink to replace PEDOT: PSS in terms of conductivity and toughness, although this will reduce the stretchability of the hydrogel. The silver ink is available in Bangladesh.	Progress: Task 1: Not done Task 2: Not done Task 3: Completed Task 4: In progress Task 5: In progress	
27/08/2025 ATC Meeting 20 (Online)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Showing the testing methods and anticipating the outcomes for testing the ECG signal and the Pacing unit. 2. Discuss the hydrogel chemical and showcase presentation.	Tasks: Task 1: Zayed, Emran Task 2: Everyone Progress: Task 1: In progress	1. Observed the testing methods and saw the update on the test results. 2. Sir gave us the idea of showing our hardware implementation in the showcase.

			Task 2: In progress	Also, instruct us to use an alternate chemical if we can't get our desired chemical in time.
27/08/2025 ATC Meeting 21 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	Meeting Cancelled		
29/08/2025 Group Meeting 17 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. After a long discussion, we decided to follow the AAI (atrial-atrial-inhibition) pacing, which uses a single lead for atrial pacing (uses the SA node). The literature had full implementation of 3-lead pacing without enough data and 1-lead pacing with minimal data, hence the change in our decision. 2. The ATMega328PB-AU microcontroller finally proved to be unable to handle much data, most likely due to a counterfeit product. That is why we decided to get ESP32-S3, which is much larger but considerably small enough for our size constraint and also has	Tasks: Task 1: Everyone Task 2: Zayed, Emran, Istiaq Task 3: Zayed, Emran Task 4: Nazmus, Rafiul Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: In progress	

		built-in Bluetooth support. 3. The code for demonstration of ECG signal processing and cardiac pacing needed little modification, but the issue of pacing lingered. Therefore, we decided that for task 3, we would solve this pacing issue with the ESP32-S3 and code for a separate ECG graph and a corresponding pacing graph. 4. The app that we plan to use is pre-built as part of Espressif's IDE platform. We need to modify the app such that the ECG and pacing signals are overlapped, such that it shows conventional sensing and pacing in real-time.		
01/09/2025 Group Meeting 18 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Testing out the ESP32-S3 and implementing our code into it to see pacing. Pacing only happens via LED blinking, not by graph in the Serial Monitor as intended. However, the temperature and biomarker data work as desired. 2. Buying Silver Nitrate as the only alternative to PEDOT: PSS available in Bangladesh.	Tasks: Task 1: Emran, Zayed Task 2: Istiaq Task 3: Nazmus Progress: Task 1: Completed Task 2: Completed	

		3. Updating plans for making the hydrogel. With the arrival of Silver Nitrate, hydrogel making will have to be initiated on 3/09/2025.	Task 3: Completed	
02/09/2025 Group Meeting 19 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. The pacing signal is not showing in the Serial Monitor, which has to be troubleshooted. 2. Preparing tools and chemicals required for making hydrogel. 3. Report Chapter 5 has been updated.	Tasks: Task 1: Emran, Zayed, Nazmus Task 2: Nazmus, Istiaq Task 3: Rafiul Progress: Task 1: In progress Task 2: Completed Task 3: Completed	
03/09/2025 ATC Meeting 22 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Showing the testing methods and anticipating the outcomes for every output. 2. Discuss the hydrogel chemical formation and the idea of presenting the hardware implementation in the showcase presentation.	Tasks: Task 1: Zayed, Emran Task 2: Everyone Progress: Task 1: Completed Task 2: Completed	1. Observed the testing methods and saw the update on the test results. 2. Sir gave us the idea of showing our hardware implementation in the showcase. Also, give us last-minute suggestions for the showcase.

03/09/2025 ATC Meeting 23 (Online)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We have to complete our full hardware implementation as soon as possible 2. We have to fix the errors in the report. 3. We have to solve our remaining work within the due time; if needed, we have to go for the ready-made versions of the materials to complete the work before the showcase. 4. We need to start working on building up the setup, which we are going to show in the showcase.	Tasks: Task 1: Everyone Task 2: Rafiul Task 3: Zayed, Emran Task 4: Everyone Progress: Task 1: In progress Task 2: Completed Task 3: In progress Task 4: In progress	1. Sir told us to start working on the breadboard instead of the PCB board. 2. Sir, instructed us to fix the error in the report. 3. Sir, instructed us to solve all the remaining work and if needed, go to buy the ready-made version of the component to show in the showcase. 4. Sir told us to start working on the setup, which we are going to present in the showcase.
05/09/2025 ATC Meeting 24 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Showing the testing methods, debugging and trouble shooting hardware setup. 2. Discuss the hydrogel chemical formation, test results and overall progress of our work.	Tasks: Task 1: Zayed, Emran Task 2: Nazmus Progress: Task 1: Completed Task 2: Completed	1. Observed the testing methods , saw the update on the test results and verified the functionality of hardware implementation. 2 Instructed to prepare a batch of hydrogel electrodes for demonstration and testing separately.

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07/09/2025 ATC Meeting 25 (Offline)	**ATC Member** 1. Prof. Dr. AKM Abdul Malek Azad **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. We showed the progress of full hardware setup completing the core objective of our project. 2. We discussed the limitation of hydrogel electrodes using alternate material for conductivity(i.e. $AgNO_3$). 3. We discussed the proposed solution for addressing the issue of limited conductivity such as designing amplifiers using OP-AMP. 4. We discussed the failure of procuring the necessary products for optimal performance and functionality, (i.e. suggested chemical compounds in literature review PEDOT:PSS).	Tasks: Task 1: Zayed Task 2: Nazmus, Istiaq Task 3: Zayed, Emran Task 4: Istiaq Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	1. Sir instructed us to complete the setup with hydrogel electrodes, addressing the issues as swiftly as possible and expressed mandatory Lab visit of ATC members for verification of work completed. 2. Sir, instructed us keep working on our reports in the report. 3. Sir reminded us to utilize the limited time we have to ensure preparation for the upcoming project showcase. 4. Sir instructed Istiaq that component procurement failure must be under investigation and clarification must be given with evidence in support of our resource limitation.

07/09/2025 ATC Meeting 26 (Offline)	**ATC Member** 1. Ihteyaz Aqaid Avash **Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Showing complete functional hardware setup of project objective. 2. Showing the test results of hydrogel electrodes, discuss the limitation of performance.	Tasks: Task 1: Zayed, Emran Task 2: Nazmus Progress: Task 1: In progress Task 2: In progress	1.Emphasized the hardware test results to be documented thoroughly and that monitored values, plots, visualising LED to be displayed in an easily comprehensible manner. 2.Sir instructed us to work on our solution of amplifiers in order to fully utilize the potential of electrodes which is required for complete hardware setup. 3. Instructed to prepare a batch of hydrogel patch for demonstration. Approved idea of using alternate materials (i.e. Xanthan Gum) for demonstration purposes only.
08/09/2025 Group Meeting 20 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Implement the application on the FYDP lab PC. 2. Fixing the position of the heart in the rib cage for the showcase.	Tasks: Task 1: Nazmus Task 2: Rafiul, Istiaq Task 3: Zayed, Emran	

		3. Working on the scaling issue for the ECG graph.	Progress: Task 1: Completed Task 2: Completed Task 3: In progress	
09/09/2025 Group Meeting 21 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Work is going on to run the application smoothly. 2. Fixing on the Biochemical reading, heart rate signal. 3. Updated the report writing.	Tasks: Task 1: Nazmus Task 2: Zayed Task 3: Rafiul Progress: Task 1: In progress Task 2: Completed Task 3: Completed	
10/09/2025 Group Meeting 22 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Work to be done for the application to connect all the signals perfectly. 2. Making the final output setup for showing in the showcase. 3. Making the poster for the showcase. 4. Using a breadboard instead of a PCB, as the PCB doesn't work at the last minute.	Tasks: Task 1: Nazmus Task 2: Everyone Task 3: Rafiul Task 4: Zayed, Emran Progress: Task 1: Partially done Task 2: Completed Task 3: Completed Task 4: Completed	

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11/09/2025 Group Meeting 23 (Offline)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Preparation for project showcase, last minute hardware setup check and troubleshooting. 2. Preparation of project demonstration equipment such as setting up PC, DC voltage regulator, Heart simulation with Prop heart and skeleton,Ballon inflation-deflation system for Hydrogel stretching, flexibility demonstration. 3. Preparing for the project showcase presentation speech, and a mock Q & A session.	Tasks: Task 1: Zayed, Emran, Nazmus Task 2: Rafiul, Istiaq, Nazmus Task 3: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed	
21/09/2025 Group Meeting 24 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Division of the report writing work. 2. Division of the logbook writing work. 3. Fixing the error that we found in the showcase. 4. Take a proper picture of all the output that we got from our work. 5. Report Chapter 1.1.3, 1.1.4, 1.3, 1.4, 5.2, 5.3, 5.4, 8.1, 8.2, 8.3, 8.4, 8.5 have been completed.	Tasks: Task 1: Everyone Task 2: Rafiul Task 3: Everyone Task 4: Everyone Task 5: Rafiul Progress: Task 1: Completed Task 2: Completed Task 3: Completed Task 4: Completed	

			Task 5: Completed	
22/09/2025 Group Meeting 25 (Online)	**Students:** 1. Rafiul 2. Nazmus 3. Emran 4. Zayed 5. Istiaq	1. Logbook writing is to be completed. 2. Completing the report write-up. 3. Fix all the errors and present them in the report as per our results.	Tasks: Task 1: Everyone Task 2: Everyone Task 3: Everyone Progress: Task 1: Completed Task 2: Completed Task 3: Completed	