FINAL YEAR PROJECT REPORT

BS Electrical Engineering

Batch 2019-2023

Portable Diabetes Type 1 Solution (OpenAPS)

DEPARTMENT OF ELECTRICAL ENGINEERING AND TECHNOLOGY

GOVERNMENT COLLEGE UNIVERSITY, FAISALABAD

April, 2023

Submitted by

M Abu Bakar Shafique	5609
Muhammad Talha	5625
Abu Bakar	5675
Muhammad Anas	5677

Project Supervisor

Name: Prof. Dr. Abdul Rauf Bhatti

Signature: ___________________________

DEPARTMENT OF ELECTRICAL ENGINEERING AND TECHNOLOGY

GOVERNMENT COLLEGE UNIVERSITY, FAISALABAD

August, 2023

DECLARATION

We attest that the **"Portable Diabetes Type 1 Solution (OpenAPS)"** final year project is our own work. The proposal has not been published somewhere else for evaluation. The usage of the content from other sources has been fully acknowledged & documented.

Name: **M Abu Bakar Shafique**	Roll No.: 5609	Signature: __________
Name: **Muhammad Talha**	Roll No.: 5625	Signature: __________
Name: **Abu Bakar**	Roll No.: 5675	Signature: __________
Name: **Muhammad Anas**	Roll No.: 5677	Signature: __________

COPYRIGHT STATEMENT

ACKNOWLEDGEMENTS

We are thankful to Allah Almighty, our creator, for guiding us through this project at every step and for each new thought he put in our thoughts to improve it. Indeed, without His invaluable assistance and direction, we would have been powerless. It was Allah's will that everyone who assisted us with our project—whether they were our parents or someone else—so nobody else deserves recognition but Him.

We are grateful beyond measure to our devoted parents, who reared us from the time we were unable to walk and have supported us in every aspect of our lives. Additionally, we would like to express our gratitude to our supervisor for his assistance with our capstone project.

In addition, we would like to thank Prof. Dr. Abdul Rauf Bhatti for his outstanding help and collaboration. He or they always had the answer when we were stuck on something. We would not have been able to finish our senior project without his or her assistance. Throughout the entire project, we are grateful for his or her/their patience and direction.

Moreover, the research project titled " Portable Diabetes Type 1 Solution (OpenAPS)" was successfully completed in the FYP project Lab of the Government College University Faisalabad under the Pakistan Engineering Council (PEC) Annual Award of Final Year Design Projects (FYDPs) for the year 2022-2023. The project was supervised by Prof. Dr. Abdul Rauf Bhatti

Finally, I want to thank everyone who has offered any kind of support to me.

ABSTRACT

Artificial pancreas devices are used to treat type 1 diabetes (T1D), which signifies a shift in how complicated dynamics involving glucose and insulin are managed. Compared to manual alterations, higher degrees of safety, accuracy, and dependability are offered by automated functions. In nontribal real-world T1D management, fewer commercial solutions and more open-source, hybrid closed loop, and Do-It-Yourself Artificial Pancreas technologies (DIY APS) have been employed thus far. As far as this work is concerned, it collects information in the beginning from a variety of sources, including research papers, assessments, observations, and opinion pieces published by DIY APS users and healthcare professionals (HCPs).

It contains details on the origins of the DIY APS movement, how it originated through online diabetic message boards, and how it is altering T1D self-management in real-world circumstances. It also provides an overview of the expanding body of clinical data supporting DIY APS. The post also presents ideas that consider how DIY APS can influence medical practices. DIY APS is fundamentally altering T1D management. The automation of the process of consistently measuring glucose levels and successfully titrating insulin administration relieves part of the demands of intense management for people with T1D (PWD). DIY APS users know more about this extremely specialized area of T1D therapy than many HCPs do. Challenges with the legislation, ethics, and education need to be resolved.

In order to improve policy and practice on DIY APS, more research is required. HCPs are still picking up tips from PWDs hands-on DIY APS experiences to improve metabolic and psychosocial outcomes.

Key Words: Type 1 diabetes, AndroidAPS, DIY artificial pancreas systems, Hybrid closed loop, OpenAPS.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

FYP	Final Year Project
FEA	Finite-element analysis
DIY	Do-It-Yourself
APS	Artificial Pancreas Systems
BG	Blood glucose
T1D	Type 1 diabetes
HCPs	Healthcare professionals
PWD's	Practical experiences with DIY APS
CSII	Continuous subcutaneous insulin infusion
CGM	Continuous glucose monitoring
CSII	Continuous subcutaneous insulin infusion
T1DM:	Type 1 diabetes mellitus
T2DM:	Type 2 diabetes mellitus
CL:	Closed loop
SMBG:	Self-monitoring of blood glucose
BGL:	Blood glucose levels
SAP:	Sensor-augmented pump

CHAPTER 1: INTRODUCTION

1.1 Introduction

Insulin-dependent diabetes, also referred to as type 1 diabetes. Juvenile diabetes and diabetes type 1 are both chronic autoimmune diseases that impact millions of individuals globally. It happens when the beta cells in the pancreas that make insulin are unintentionally attacked and destroyed by the immune system. A hormone called insulin controls blood sugar levels and permits glucose to enter cells of the body where it is used as fuel. In the absence of insulin, glucose builds up in the blood, resulting in high blood sugar levels, which can result in a variety of health issues.

Although it can happen at any age, type 1 diabetes is typically diagnosed in children, teenagers, and young adults. Although the precise etiology of this autoimmune reaction is not entirely understood, genetic and environmental factors are thought to be involved. Type 1 diabetes has no known cure, therefore those who have it must carefully control their blood sugar levels to prevent problems like heart disease, kidney damage, nerve damage, and blindness. Insulin medication, blood sugar monitoring, a nutritious diet, and frequent exercise are common treatment components. People with type 1 diabetes can live healthy, active lives with adequate care.

Proper management of diabetes requires a comprehensive approach that involves the patient, healthcare provider. Here are some tips for creating an effective diabetes patient management system:

1. **Education and self-management support**: Providing education and self-management support to patients is essential for successful diabetes management. The significance of keeping an eye on blood sugar levels, taking medications as directed, and leading a healthy lifestyle must be emphasized to patients.
2. **Regular monitoring**: Patients and healthcare professionals can follow progress and make necessary adjustments to treatments by routinely measuring blood pressure, cholesterol, and blood sugar levels.
3. **Team-based care**: Diabetes management is complex and requires a team-based approach. Patients should work with their primary care provider, endocrinologist, and other healthcare professionals to manage their diabetes effectively.

4. **Technology**: Technology can help patients manage their diabetes more effectively. Continuous glucose monitoring systems, insulin pumps, and other devices can help patients keeping an eye on their blood sugar levels and modifying their insulin dosage as necessary.
5. **Lifestyle changes:** Patients can better control their diabetes and lower their risk of complications by making lifestyle changes like managing their weight, eating healthfully, and engaging in regular physical activity.

By implementing these strategies, patients with diabetes can achieve better blood sugar control and reduce the risk of complications. But we have use two approaches the technology and regular monitoring. The technology, collect the samples and in regular monitoring we monitor the sample data and perform tasks.

1.1.1 What is OpenAPS?

A free and open initiative called OpenAPS (which stands for "open source artificial pancreas system") aims to make basic Artificial Pancreas System (APS) technology widely accessible, secure, and effective in order to save as many lives as possible, improve healthcare, and lessen the burden of Type 1 diabetes. In order to keep blood glucose levels within a safe range throughout the night and between meals, the community has developed a reference implementation of an overnight closed loop APS system that uses CGM sensors to measure blood glucose (BG) levels and insulin pumps to automatically adjust basal insulin levels..

1.2 Literature Review:

After getting dissatisfied with the sluggish development of artificial pancreas systems, a community of diabetic patients (PWD) and their families/caregivers joined together online under the hashtag "#WeAreNotWaiting" to encourage the development of open-source diabetes management solutions. The Do-It-Yourself (DIY) APS movement began in 2013 through social media. A small number of people produced and shared computer codes from various applications to run their CGMs and insulin pumps in the beginning.9 Over the course of the next year, they collaborated to create the first open-source artificial pancreas system (OpenAPS). The DIY APS movement has expanded quickly since that time. [1].

Using these technologies of Artificial Pancreas System (Open APS) some sensors are developed like Medtronic Mini Med Continuous Glucose Monitoring System e.g. These sensors can sense glucose levels for three to seven days. But the main problem with these sensors are that they don't alarm the patient when they fail to sense. The use of available Glucose Monitoring sensors is still limited some patients have started to use these devices. To achieve glucose control level self-monitoring of glucose is carried out multiple times a day. This is done by Glucose Monitoring Sensor. There are varieties of technologies that have been developed for Continuous Glucose Monitoring like infrared, mid-infrared, thermos optical technologies, etc. But many technologies are in the developing stage [2].

A 2014 article by Francis J. Doyle III, Lauren M. Huyett, Joon Bok Lee, Howard C. Zisser, and Eyal Dassau describes how the artificial pancreas (AP) was developed in preclinical and clinical environments. The study offers a thorough examination of the altered glucose regulation physiology connected to type 1 diabetes (T1D), which will improve future AP methods. The experiments conducted in a closed-loop hospital setting in the 1970s led to the normalization of glycemia in diabetics during meals with the supply of insulin and glucagon by an artificial pancreas. For the artificial pancreas (AP), a treatment option for type 1 diabetes, the automation of blood glucose (BG) management has presented a serious difficulty.

The challenge of measuring blood glucose in veins 4 and Subcutaneous (SC) and continuous SC insulin infusion (CSCII) pumps, which are continuous glucose monitors that can be positioned beneath the epidermis, continue to be the most often used platforms for AP development. This article discusses the engineering design required for the AP to move from bench to clinic. Making the design problem requires figuring out important components including medical objectives, physiological considerations, subject challenges, and system limits. Most engineering issues lack a perfect answer and instead have a number of viable options, each of which has merits and downsides.

This paper also has a design with advantages and disadvantages. The design used in this paper also some limitations that include, even though additional sensors for use in daily life, it is inconvenient to attach more than one to a person. To utilize the controller, one must have access to laptops, tablets, cellphones, or other small computers. In particular when Bluetooth or other wireless communication is essential, all of these solutions should consider battery life. Due to the fact that existing AP designs rely on commercially accessible products. These are the main shortcomings of this strategy [3].

A ground-breaking DIY mobile technology device for type 1 diabetes was the Night Scout Project in 2014. In February 2013, when the parents of a 4-year-old child with type 1 diabetes started utilizing continuous glucose monitoring sensors, the night scout experiment got underway. But because there is no mobile technology to retrieve the data, they were unable to measure his blood glucose levels while he was at school. As a software developer and the child's father, he began to create a code that would allow anyone to read data from the CGM and upload it to the cloud. Parents might view the glucose level with ease once the data is on the cloud. When the father transmitted his child's BG data to the cloud, he sent a tweet about his success. When his tweet had gone viral, he was approached by technical programmers. He shared his program with them. They developed a Smartphone application that transfers the data from CGM to the cloud [4].

Diabetes technology has made a huge progress aiming for the benefit of patient with diabetes (PWD). Diabetes technology started developing their own do-it-yourself artificial pancreatic system like continuous glucose monitoring, insulin pumps and Smartphone technology to for glycemic control and improving quality of life. Online social networks like GitHub. CGM in the cloud provide platform to share open-source technologies for further innovation on it [5].

1.3 Problem Statement:

Managing Type 1 diabetes while leading an active lifestyle is a constant problem for those who have it. The current standard of care for diabetes management involves frequent blood glucose monitoring, insulin administration, and meticulous tracking of carbohydrate intake. However, these tasks often require carrying bulky and inconvenient equipment, making it difficult for individuals to manage their diabetes discreetly and effectively outside of their homes.

The objective is to develop a comprehensive and compact portable diabetes management system that incorporates advanced technologies such as miniaturized glucose monitoring sensors, insulin delivery mechanisms, and smart tracking capabilities. This solution should be lightweight, user-friendly, and allow patients to easily check their glucose levels, give insulin, and track their progress regardless of their location or activity. and seamlessly integrate into the daily lives of people with Type 1 diabetes.

1.4 Objective:

- To develop a Portable Diabetes Type 1 Solution (Open APS).
- To proper supply of Insulin to maintain Blood Glucose (BG) level.
- To give proper supply of Insulin to prevent overdose.
- To reduce burden of insulin delivery manually.
- To monitor blood pressure level continuously.
- To monitor oxygen level continuously.

CHAPTER 2: PROJECT METHODOLOGY

2.1 Methodology

Build a functional prototype of the portable diabetes system based on the design specifications. Develop detailed design specifications based on the identified needs and concepts. The methodology we are using to measure glucose in the bloodstream of a patient. Normal range is 4-7.8 mmol/L. The error or difference should pass through some control Controller of the Processing unit that contains the data regarding the normal BG level and if there is the difference it produces a control signal to allow inject the specific value of insulin into the body of the patient. Develop a user-friendly mobile application to inject required insulin dosage.

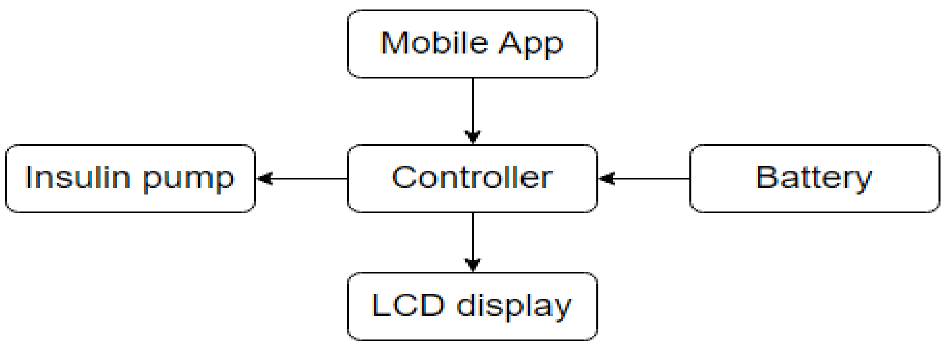

Figure 2. 1 Methodology of project

2.2 How does OpenAPS work?

In order to keep blood sugar (BG) within a safe range throughout the night and between meals, OpenAPS, a compressed Artificial Pancreas System (APS), automatically changes insulin administration. In order to cure Type 1 diabetes, modern technology known as the Open APS (Artificial Pancreas System) is used. By continuously tracking glucose levels and modifying insulin doses in real-time, it is intended to treat the time of the delivery of insulin. Open APS can also be incorporated into a portable diabetes management system to enhance its capabilities. Here's how Open APS works in the context of portable diabetes type 1.

2.3 Proposed Model:

The open APS mainly consists of two parts: Controller, Insulin Pump. It sense manually the glucose level in the blood. When there is a variation in BG (Blood Glucose) it will send the information to the controller.

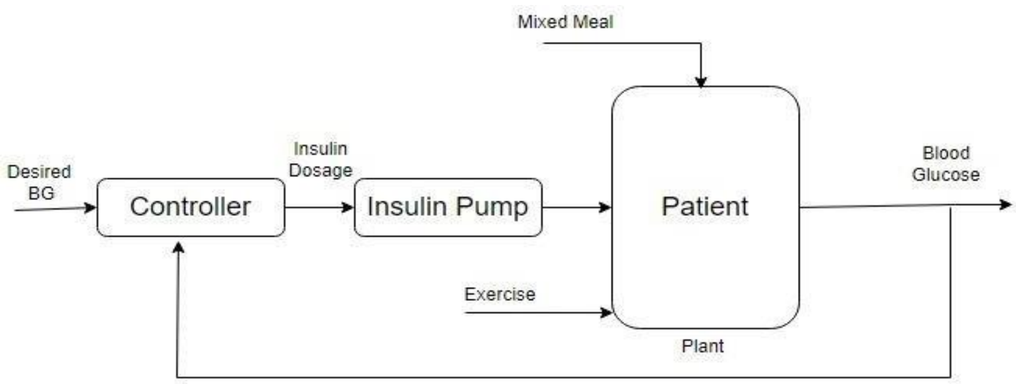

Figure 2. 2 Proposed Model

Flow Chart:

When we restart our device, it takes input from mobile and at that point controller takes decision rather the insulin required or not. If insulin in not required it go back and check for new information and if insulin is required it will check the how much insulin is required. If insulin in required then it will inject the insulin.

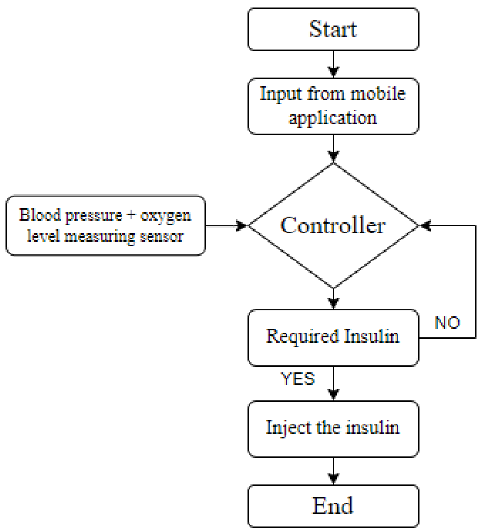

Figure 2. 3 Flowchart

2.3 Hardware:

The hardware needed to implement OpenAPS is described in this section. The following components will be required for the development of the prototype:

2.3.1 Insulin pump:

An insulin pump is utilized to deliver precise insulin doses. The APS communicates with the insulin pump to adjust basal insulin rates and deliver bolus doses based on the user's glucose readings and system algorithms. It is a device that continuously supplies insulin all the time whenever it'll be needed.

2.3.2 Voltage regulator:

Voltage regulators are crucial parts of electrical and electronic equipment. They are essential for preserving a constant voltage level, guaranteeing the appropriate operation of electronic circuits, and assuring their protection. This note aims to provide a basic understanding of voltage regulators, their types, and their significance in various applications. In this project voltage regulator is used for provide a proper voltage to the motor.

A regulator of voltage is a circuit that generates and maintains a constant output voltage regardless of changes in the input voltage or load conditions.

Figure 2. 4 Voltage regulator

2.3.3 Resistor:

The amount of electrical current that may flow through a circuit in an electronic device is controlled or limited by a resistor. Resistors can be used to deliver a certain voltage to an active device like a transistor. Use a 10 K ohm pull-up resistor so that when the button is not depressed, the input pin reads high. In other words, there is only a very modest circulation flowing.

Figure 2. 5 Resistor

2.3.4 Metal gear motor:

The micro DC gear motor is a micro gear motor that works in the form of DC. It is a combination of a DC motor and a reducer. It is widely used in industrial applications because its physical characteristics determine that it can be used in different industries.

Figure 2. 6 Metal gear motor

2.3.6 Motor driver L293D:

The L293D is a dual-channel H-Bridge motor driver that has the ability to operate either one stepper motor or two DC motors. The shield can control up to four DC motors or two stepper motors because it comes with two of these motor drivers.

Figure 2. 7 Motor driver L293D

Driver Configuration:

1. Enable 1 (EN1): This pin enables or disables the motor connected to outputs 1 and 2. Providing a logical high (usually +5V) to this pin enables the motor, and a logical low (usually 0V or ground) disables it.
2. Input 1 (IN1): This pin controls the direction of rotation for motor 1. By providing different logic states (high/low) to this pin in combination with Input 2 (IN2), you can control the motor's direction and speed.
3. The motor's output number one (OUT1) connection is connected to this pin. 1. To enable the motor to run, the other terminal must be linked to the positive supply voltage (VCC2). Ground (GND): This pin should be connected to the ground reference of your system.
4. VCC2: This is the motor supply voltage pin. It typically ranges from 4.5V to 36V and is used to power the motors connected to the outputs (OUT1 and OUT2).
5. Enable 2 (EN2): Similar to Enable 1 (EN1), this pin enables or disables the motor connected to outputs 3 and 4.

6. VCC1: This is the logic supply voltage pin. It typically ranges from 4.5V to 7V and powers the internal logic circuitry of the L293D IC.
7. Ground (GND): Another ground pin that should be connected to the ground reference of your system.

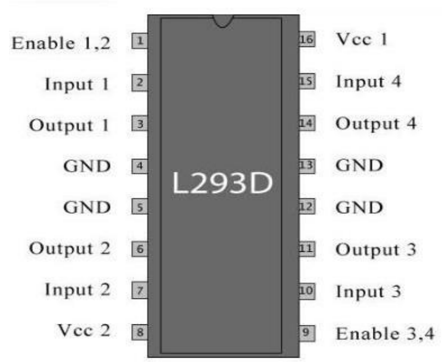

Figure 2. 8 Driver Configuration

2.3.7 Syringe:

An extremely small hollow tube used to inject or remove liquids. It might be connected to a needle so that fluids or medications could be injected into the body.

Figure 2. 9 Syringe

2.3.8 Node MCU:

It will be used as a controller in our device. That will get input data from CGM and gives the command to the insulin pump to work accordingly.

The ESP8266 Wi-Fi System-on-Chip (SoC) is the foundation of the open-source electronics platform known as NodeMCU. It offers a cheap and simple Internet of Things (IoT) development and prototyping solution. NodeMCU makes it simple to program and connect to Wi-

Fi networks by combining the ESP8266 chip with firmware that is based on the Lua scripting language.

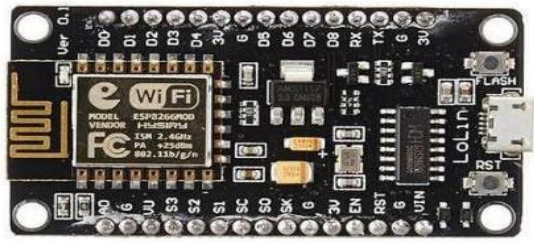

Figure 2.10 Node MCU

Difference between Arduino and Node MCU

Table 1. 1 Difference between Arduino and NodeMCU

Feature	ESP32	Arduino Uno
Microcontroller	Dual-core Tensilica LX6 32-bit processors	ATmega328P 8-bit processor
Clock Speed	160 MHz	16 MHz
Memory (RAM)	520 KB SRAM	2 KB SRAM
Analog Inputs	18	6
I2C	2	1
Wi-Fi	Built-in Wi-Fi (802.11 b/g/n)	Not built-in (may require an additional shield/module)
Bluetooth	Built-in Bluetooth (Classic and BLE)	Not built-in (may require an additional shield/module)
Operating Voltage	3.3V	5V
USB Interface	Micro USB	USB Type-B
Additional Features	- Dual-core processor	- Lower power consumption
	- More GPIO pins	- Simplicity and ease of use
	- Wi-Fi and Bluetooth built-in	- Wide range of shields and accessories

Key Features of NodeMCU:

- **ESP8266 SoC**: NodeMCU is built around the ESP8266 chip, which integrates a microcontroller and Wi-Fi capabilities. This compact and powerful chip enables IoT projects to connect to the internet wirelessly.

- **Wi-Fi Connectivity:** NodeMCU provides built-in Wi-Fi connectivity, allowing devices to connect to the internet, interact with cloud services, and communicate with other devices on the network.
- **GPIO Support**: NodeMCU features General Purpose Input/Output (GPIO) pins that can be utilized to link and manage a variety of electronic parts, including sensors, actuators, and displays. This flexibility enables users to build a wide range of IoT applications.

2.3.9 Push Button:

A push button switch mechanically controls an electrical circuit; to engage the internal switching mechanism, the user must press the button. They come in a wide range of forms, dimensions, and configurations depending on the demands of the design.

Figure 2.11 Push button

2.3.10 Battery:

A battery is a device that stores electrical energy and consists of one or more electrochemical cells with external connections for powering electrical equipment. When a battery is supplying electricity, its positive terminal serves as the cathode and its negative terminal as the anode. An external electric circuit is the source of the electrons that will flow from the terminal marked "negative" to the terminal marked "positive". When a battery is connected to an external electric load and the free-energy difference is transferred to the external circuit as electrical energy, redox processes convert high-energy reactants into lower-energy products.

Figure 2. 10 Battery

2.3.11 MAX30100:

The MAX30100 is a very beneficial and adaptable sensor module that is mostly used for non-invasively measuring blood oxygen saturation levels and heart rate. Its integrated pulse oximeter and heart-rate sensor make it a useful tool for a variety of applications, including fitness trackers, medical equipment, and wearable technology.

The module uses a pair of LEDs—typically red and infrared—along with a photodetector to measure the amount of light absorbed by the blood vessels. The MAX30100 is able to gauge the blood's oxygen saturation levels and heart rate by examining the light's intensity as it is reflected back. To keep track of people. For general health and well-being, it is essential to have this information

Figure 2. 11 MAX30100

2.4 Results:

2.4.1 Insulin Pump Results:

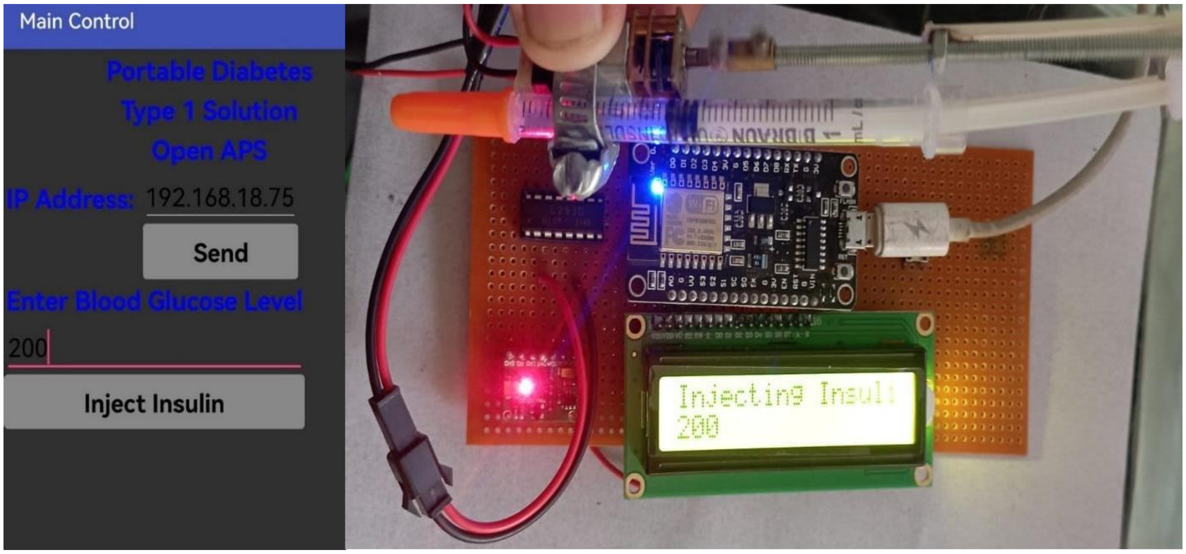

Figure 2. 12 Injecting of insulin at 200

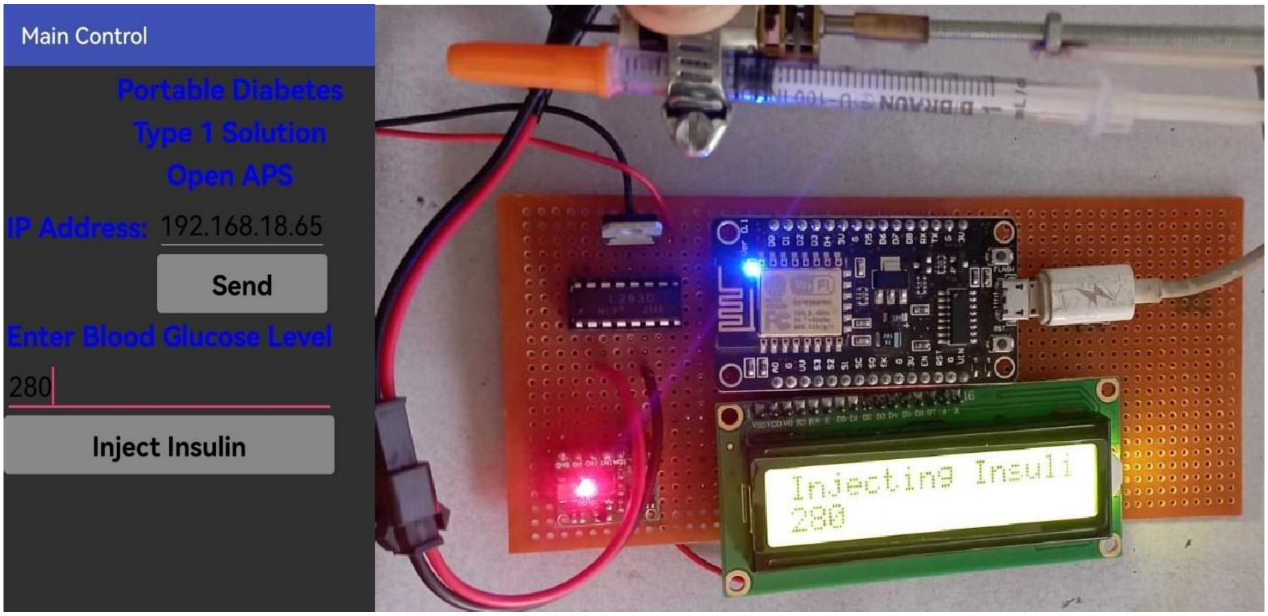

Figure 2. 13 Injecting of insulin at 280

2.4.2 MAX30100 Results:

Figure 2. 14 Measurement of person one

Figure 2. 15 Measurement of second person

2.4.3 Parameters:

Table 1. 2 Defined Parameters

Glucose Level	Injected insulin
<80	0
<110	1
<130	2
<150	3
<170	4
<190	5
<210	6
<230	7
<250	8
<270	9
<290	10
<310	11
<330	12
<350	13
>350	14

CHAPTER 3: WORKING

3.1 Working:

An insulin pump is a medical device used to deliver insulin to individuals with diabetes. It is a small device that is typically worn on the body, such as on a belt or in a pocket, and it consists of following components: the pump itself, controller, injection to inject and to store inulin.

Firstly, we will measure the diabetes level with the help of glucometer. Then enter the value received from glucometer to the mobile application which develop for insulin pump then from this application data will be sent to controller. Controller will take decision accordingly, howmuch insulin required for body. For example, if insulin level is greater than the moderate value the controller will take decision and inject the insulin.

3.1.1 Features and Benefits:

- Customizable insulin dosage: The system allows users to input their specific insulin requirements, which the microcontroller uses to calculate and administer the appropriate dosage.
- Data-driven decision-making: The ESP32 microcontroller analyzes data from the mobile application, such as blood glucose levels, and adjusts the insulin dosage accordingly to ensure precise and timely delivery.
- Enhanced user experience: The intuitive mobile application provides a user-friendly interface for inputting data and monitoring insulin delivery, enhancing patient engagement and empowerment.
- Compact and portable design: The insulin pump will have a compact form factor, making it convenient to wear or carry discreetly.
- Notifications and alarms: The system can provide timely alerts, reminders, and alarms to ensure patients adhere to their prescribed insulin regimen and avoid missed doses.

3.2 Electrical design:

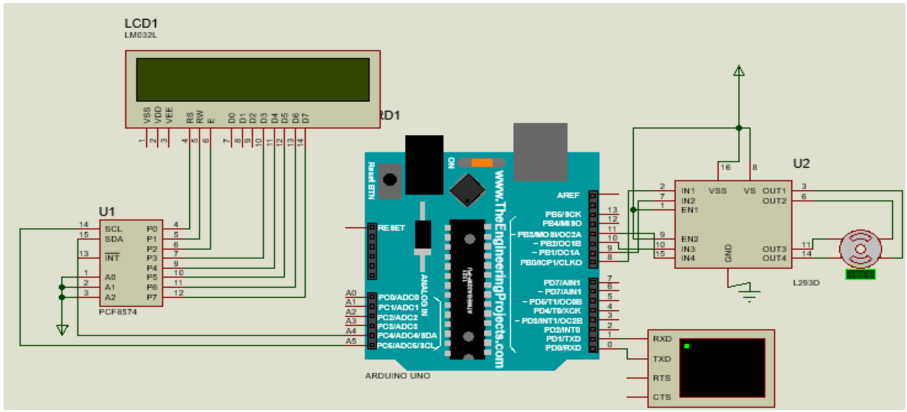

Figure 3. 1 Electrical design simulation

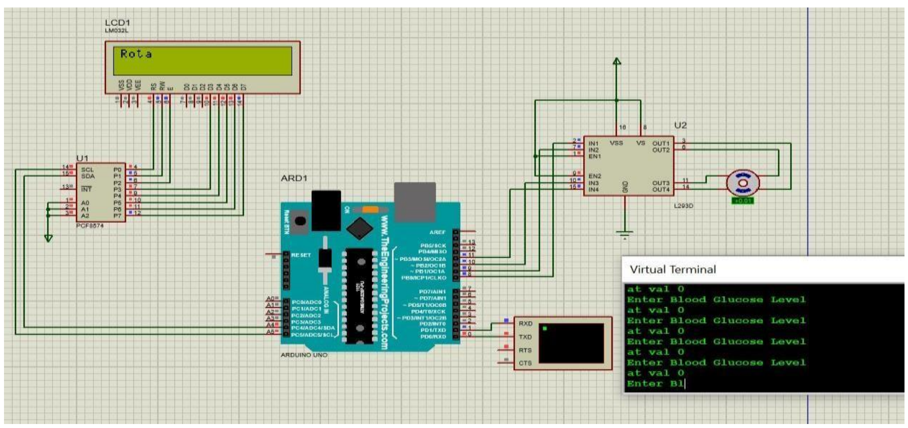

Figure 3. 2 Electrical design simulation result

3.3 Block diagram:

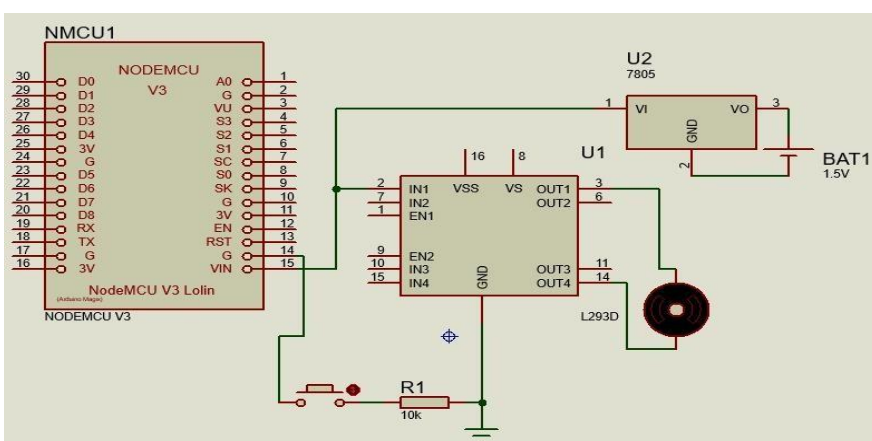

Figure 3. 3 Block Diagram

3.4 Circuit diagram:

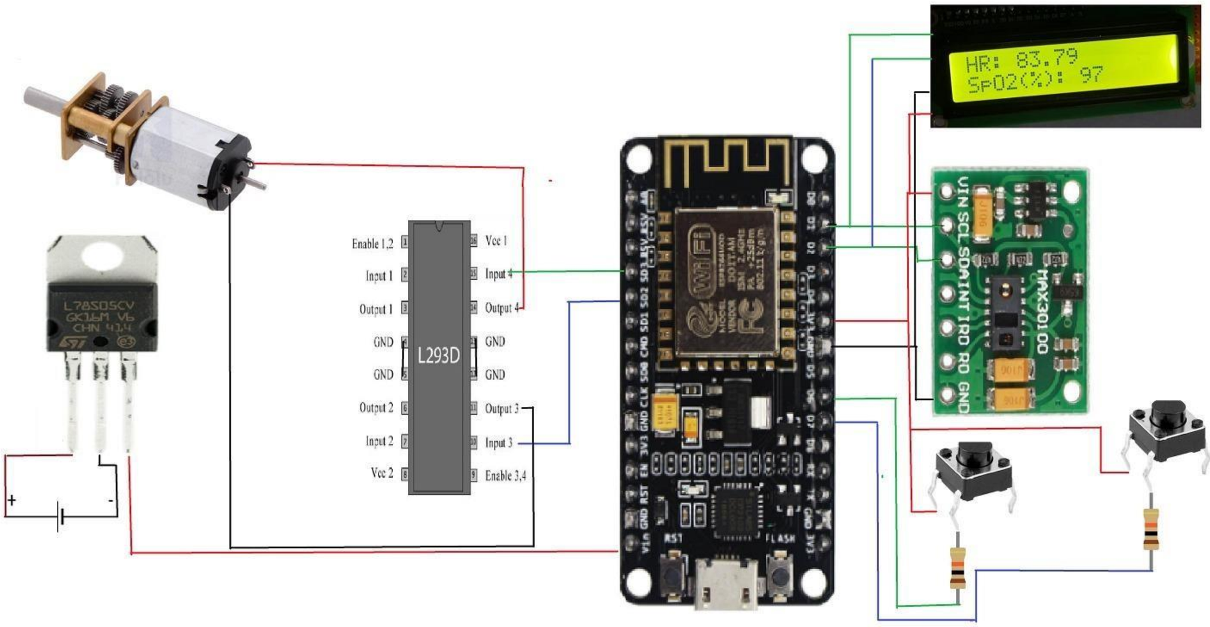

Figure 3. 4 Circuit diagram

CHAPTER 4: COMMERCIALIZATION

Executive Summary:

This proposal outlines the commercialization plan for an innovative insulin pump prototype. The product utilizes an ESP32 microcontroller to gather data from a mobile application and make informed decisions regarding insulin dosage. The system also incorporates a motor that accurately administers insulin by controlling a syringe. This comprehensive solution aims to enhance the quality of life for individuals with diabetes by providing efficient and customizable insulin delivery.

This report provides an overview of the commercialization plan for an advanced automated insulin delivery system. The project aims to develop an innovative solution that will greatly improve the management of insulin for individuals with diabetes.

The automated insulin delivery system to continuously monitor blood glucose levels and deliver precise insulin doses in real-time. By automating the insulin delivery process, the system reduces the burden on individuals with diabetes and improves the accuracy and efficiency of insulin administration.

4.1 End Product:

With an emphasis on creating an insulin pump using the ESP32 microcontroller and a syringe mechanism, our Final Year Project (FYP) ultimately produced a transportable and reasonably priced diabetes type 1 solution. Our insulin pump seeks to efficiently manage the blood sugar levels of individuals with diabetes type 1 by delivering insulin with accuracy and automation. Patients may easily carry and use the pump because of its small size, lightweight, and user-friendly design.

Our finished solution includes the MAX30100 sensor module in addition to the insulin delivery feature, making it possible to detect blood pressure and oxygen saturation. Through this connection, patients may quickly check their vital signs and learn more about their general health. Patients receive real-time feedback from the sensor's data via an easy-to-use user interface.

The insulin pump has safety features like dosage caps, alarm systems, and occlusion detection to increase user safety and reduce any potential risks related to insulin administration. Because the pump can be programmed, patients can establish custom insulin dosages based on their unique demands and medical conditions.

The ESP32 microcontroller serves as the system's central processing unit, controlling the supply of insulin, processing sensor data, and overseeing the user interface. Rechargeable batteries power the smartphone, guaranteeing extended usage and practical charging alternatives.

We also place an emphasis on user empowerment as part of our FYP. A user manual and guidelines for safe practices, maintenance, and appropriate use are included with the insulin pump. In addition, we are creating a smartphone application that will enable patients to remotely monitor their sensor readings, insulin delivery, and health information. The program will offer historical information and trends to assist patients and their healthcare professionals in making educated decisions for the management of diabetes.

Overall, our portable type 1 diabetes solution offers a vital insulin delivery system together with capabilities for blood pressure and oxygen monitoring. With the help of the ESP32 microcontroller and the MAX30100 sensor module, we were able to develop a solution that is economical and effective while still meeting resource-constrained requirements. We want to improve the quality of life for people with diabetes type 1 by giving them a dependable and practical tool for managing their illness and encouraging improved health outcomes.

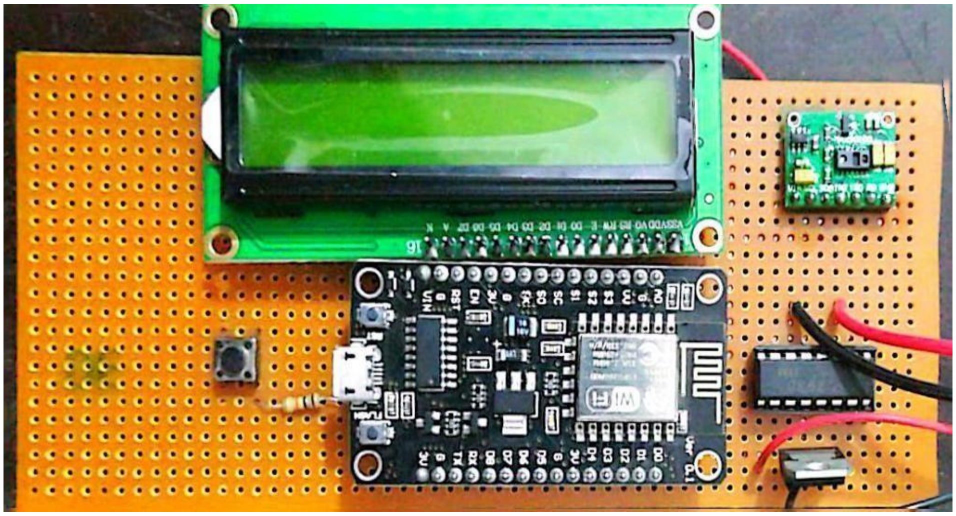

Figure 4. 1 End product

4.2 Business Model Canvas:

The insulin pump project aims to introduce an innovative medical device to the market, offering a comprehensive solution for individuals with diabetes. The business model canvas for this project can be summarized in key areas:

4.2.1 Key Partnerships:

Diabetes Associations: Collaborate with diabetes associations and organizations to raise awareness about Open APS and promote its benefits to the diabetes community.

Healthcare Providers: Partner with healthcare providers to educate and train their staff on the integration and support of Open APS for their patients.

Technological Partners:

Collaborate with technology companies to ensure compatibility with CGMs, insulin pumps, and other devices used in the closed-loop system.

4.2.2 Key Activities:

Software Development: Continuously enhance and update the Open APS platform, incorporating new features, refining algorithms, and addressing user feedback.

Community Engagement: Foster an active and supportive community around Open APS, organizing events, forums, and knowledge-sharing platforms for users and developers.

Training and Support: Provide training resources, documentation, and technical support to users and healthcare professionals for implementing and troubleshooting Open APS.

4.2.3 Key Resources:

Technology Infrastructure: Maintain servers, databases, and other technological resources required to support the Open APS platform and ensure its reliability.

Development Team: Employ skilled software developers, data scientists, and algorithm experts to continuously improve the functionality and performance of Open APS.

Community Contributors: Leverage the power of an engaged community of developers, users, and researchers to contribute to the ongoing development and enhancement of Open APS.

4.2.4 Value Propositions:

Improved Diabetes Management: Open APS empowers individuals with Type 1 diabetes to achieve better glucose control, leading to improved quality of life and reduced risk of complications.

Customizability and Openness: Open APS offers a customizable and adaptable closed-loopsystem, allowing users to tailor the settings and algorithms to their specific needs and preferences.

Community Support and Collaboration: Open APS fosters a collaborative environment where users and developers can share knowledge, experiences, and best practices, creating a supportive community.

4.2.5 Customer Segments:

Technically Savvy Individuals with Type 1 Diabetes: Target individuals who are comfortable with technology and interested in taking an active role in their diabetes management by building and using Open APS.

Healthcare Professionals: Educate and train healthcare professionals, including endocrinologists, diabetes educators, and nurses, on the implementation and support of Open APS for their patients.

Events and Conferences: Participate in diabetes-related conferences, workshops, and events to showcase Open APS, present research findings, and engage with key stakeholders.

4.2.6 Customer Relationships:

Self-Service: Provide comprehensive documentation, tutorials, and troubleshooting guides to enable users to build and implement Open APS independently.

Community Support: Foster an active and supportive community where users can seek assistance, share experiences, and learn from one another.

Direct Support: To answer particular consumer questions and technical concerns, provide responsive customer care channels like email or online chat.

4.2.7 Marketing and Distribution Strategy:

To successfully launch the insulin pump and reach the target market, the following strategies will be employed:

- Market research and segmentation: Conduct comprehensive market research to identify target demographics, assess market demand, and tailor marketing strategies accordingly.
- Branding and packaging: Create a strong brand identity and appealing packaging to create a recognizable market presence and win the trust of customers.
- Sales and distribution channels: Collaborate with medical device distributors, healthcare providers, and pharmacies to ensure widespread availability and accessibility.

4.2.8 Marketability:

The insulin pump project holds significant marketability potential due to its ability to address the needs and challenges faced by individuals with diabetes. With its user-friendly design and personalized insulin delivery, the insulin pump offers a practical and convenient solution for diabetes management. The marketability of the insulin pump project is also influenced by the growing prevalence of diabetes worldwide. With the increasing number of people diagnosed with diabetes, there is a significant market demand for advanced solutions that simplify diabetes management.

In summary, the marketability of the insulin pump project lies in its ability to improve health outcomes, offer convenience, and cater to the growing market demand for effective diabetes management solutions. By addressing the needs of individuals with diabetes through personalized insulin delivery, and connectivity features, the insulin pump project has the potential to capture a significant market share and make a positive impact on the lives of people living with diabetes.

4.2.8.1 Use of Google business:

The use of Google Business can greatly enhance the marketability of the insulin pump project. By creating a Google Business profile, the project can showcase the features and benefits of the insulin pump, including its user-friendly design and personalized insulin delivery. This profile allows individuals searching for diabetes management solutions to easily find and learn about the insulin pump. With Google Business, the insulin pump project can effectively leverage online visibility and engagement, attracting a wider audience and increasing the device's market reach and acceptance.

4.2.8.2 Compete on social media:

Virtual entertainment contests are a tomfoolery, simple method for interfacing with clients and bring more fans and brand trusts.

4.2.8.3 Use email to spread words:

This method is most effective because 82% of consumers open emails from businesses, and that email subscribers purchase through email marketing message. It is best to get word out about a new product or service. It also enables the promoter to purchase the product in advance.

4.2.8.4 Write a blog to attract customers:

Using a blog about a newly launched product is a great way to delve into all the details, features, and benefits that may be included on the landing page and a link to this post can be shared via email or social media channels.

4.2.8.5 Offer an upgrade:

If there are already such systems then some upgrades could be provided to customers.

4.2.8.6 Business Canvas Model:

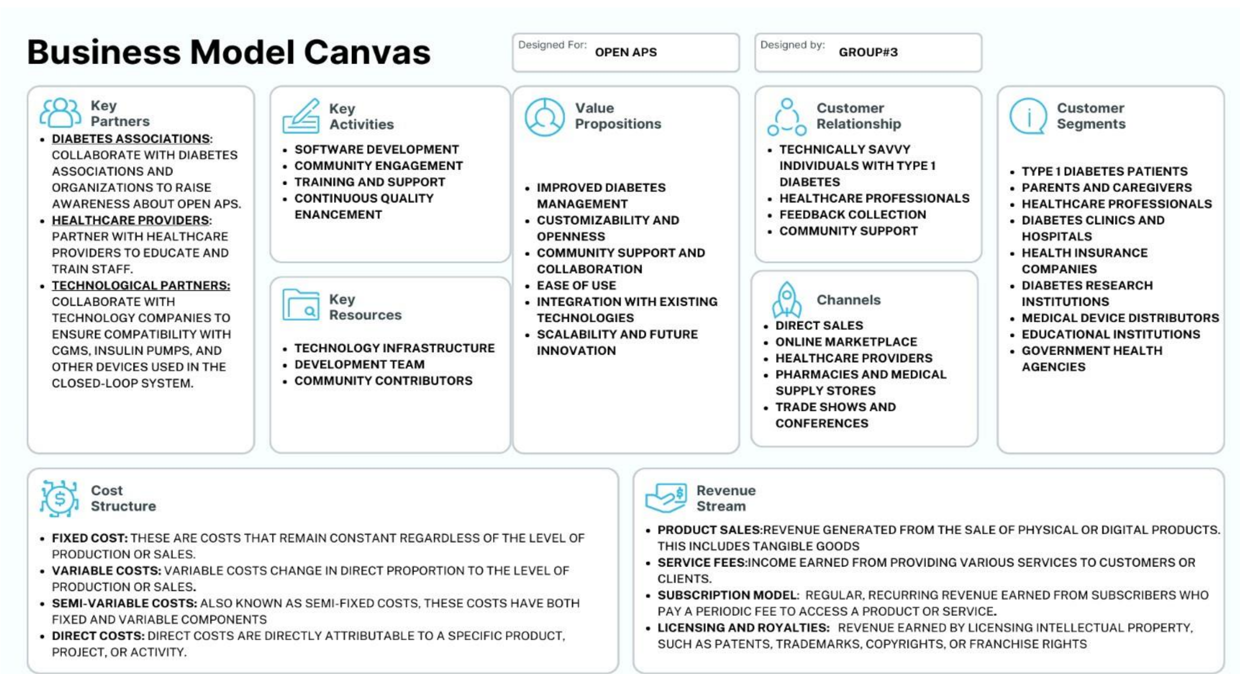

Figure 4. 2 Business Canvas Model

Chapter 5

5.1 Conclusion

APS has a promising bioelectronics solution for diabetes that is both safe and effective for the digital age. Following a thorough analysis, it was determined that APS maintains a wider norm glycemic range and shortens the duration of hypo- and hyperglycemia. [6] Evidence from a variety of clinical research studies has demonstrated that CL systems are effective in children, adolescents, adults, and pregnant women with T1DM, with better glycemic outcomes and reduced hypoglycemia, as well as having favorable end-user acceptability. [7] The current amount of scientific data on APSs is constrained by the uneven reporting of results, the small sample size, and the close spacing between individual experiments. Clinical research using CL to particular cohorts of T1DM patients will be critical in identifying individuals who stand to gain the most from this technique. Additionally, these research will offer vital proof in support of healthcare providers' payments.

We think that OpenAPS and comparable designs provide the safest and quickest means to make Artificial Pancreas technology available today for patients with type 1 diabetes because of the concepts, design limitations, and general strategy used in creating and implementing OpenAPS.

In order to realize this objective for all T1D patients, we would prefer to:

- Cooperate with producers of medical equipment who are open to using OpenAPS.
- We would like to see communication protocols that are interoperable with all diabetic devices provided by device makers.
- Collaborate with clinical researchers to plan and carry out open clinical trials for the diabetes community using open-source software.
- Develop clinically effective reporting, alerting, and management tools by collaborating with forward-thinking medical professionals who want to advance the state of type 1 diabetes therapy.

5.2 Future Work:

In developing the portable diabetes type 1 solution prototype, a significant milestone was achieved by successfully creating an insulin pump integrated with the ESP32 microcontroller. This prototype represents an essential step towards the realization of a practical and user-friendly solution for diabetes management. The insulin pump, designed to resemble a human device, serves as a critical component in the overall system, delivering precise insulin dosages as required for the management of blood glucose levels.

While this prototype showcases the potential of the portable diabetes solution, it is essential to acknowledge that there are areas for improvement and further exploration. As the sensing part was omitted from this initial iteration due to potential risks, future work should focus on reliable and glucose monitoring capabilities. Implementing a sensor-based feedback system would enhance the insulin pump's performance, allowing it to adjust insulin delivery based on real-time glucose readings.

As this project progresses, it is crucial to conduct thorough testing and validation to address any loopholes and refine the system's functionality and safety. Furthermore, expanding the capabilities of the insulin pump to incorporate smart algorithms and data-driven insights could provide personalized and efficient diabetes management. In conclusion, this prototype represents a promising first step towards a comprehensive portable diabetes type 1 solution, but further research and development are warranted to enhance its efficacy, safety, and user experience.

REFERENCES

[1] Ruffles, P.C.; 2001, “Expanding the Horizons of Gas Turbine in Global Markets”; *ISABE 2001-1010*

[2] Dring, R. P., Joslyn, H. D., Hardin, L. W., and Wagner, J. H., 1982, "Turbine Rotor-Stator Interaction," ASME Journal of Engineering for Power, vol.104, pp.729-742

[3] Arndt, N., 1993, “ Blade Row Interaction in a Multistage Low Pressure Turbine”, ASME Journal of turbomachinery, Vol. 115, pp. 370-376

[4] Denton J.D., 1993, “ Loss Mechanisms in Turbomachines:, ASME Journal of Turbomachinery, Vol.115

[5] Denton J.D., 1993, “ Loss Mechanisms in Turbomachines:, ASME Journal of Turbomachinery, Vol.115

[6] Bekiarai E, Kitsios K, Thabit H, Tauschmann M, Athanasiadou E, Karagiannis T, et al. Artificial pancreas treatment for outpatients with type 1 diabetes: systematic review and meta-analysis. BMJ 2018;361:k1310 View Article

[7] Boughton CK, Hovorka R. Is an Artificial Pancreas (Closed-Loop System) for Type 1 Diabetes Effective?. Diabet Med 2019;36(3):279-286

APPENDIX A

```
#include <ESP8266WiFi.h>


//############################## WIFI CREDENTIALS
####################################
const char* ssid = "IoT_Project";
const char* password = "ProjectIoT";

WiFiClient client;
WiFiServer server(80);

int wait30 = 30000;

char input;
String val;
int insulin = 0;
String insulinvalue ="80";
int intinsulinvalue = 0;

int motorA = 12;
int motorB = 13;
int button =  14;


void setup()
{
  Serial.begin(115200);
  Serial.println("Open APS Project");
  pinMode(LED_BUILTIN, OUTPUT);
  digitalWrite(LED_BUILTIN, HIGH); // turn the LED on (HIGH is the voltage level)
  delay(1000);                      // wait for a second
  digitalWrite(LED_BUILTIN, LOW);   // turn the LED off by making the voltage LOW
  delay(1000);
  pinMode(motorA, OUTPUT);
  pinMode(motorB, OUTPUT);
  pinMode(button, INPUT);

  Serial.println();
  Serial.println("******");
  Serial.print("Connecting to ");
  Serial.println(ssid);

  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED)
```

```
{
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());

   WiFi.mode(WIFI_STA);
  server.begin();
  Serial.println("Web Server started.");
}

void loop()
{
  Serial.println("Enter Blood Glucose Level");
  int refil = digitalRead(button);
  if (refil == 1)
  {
    digitalWrite(motorA, LOW); //clockwise
    digitalWrite(motorB, HIGH);
    Serial.println("Refilling ");
    delay(2000);
  }
  digitalWrite(motorA, HIGH); //clockwise
  digitalWrite(motorB, HIGH);

  WiFiClient client = server.available();
  if (!client) {
    return;
  }
  Serial.println("New client: ");
// Serial.println(client.remoteIP());
  String req = client.readStringUntil('\r');
  Serial.println(req);

  if (req.indexOf("Insulin") != -1)
{
  insulinvalue=req.substring(req.indexOf(":")+1, req.indexOf(","));
  Serial.print("glucose level is: ");
  Serial.println(insulinvalue);
  intinsulinvalue = insulinvalue.toInt();
  }
  int num = intinsulinvalue;
  if (num<80){
```

```
    insulin = 0;
    Serial.println("at val 0");
  }
else if (num<110)
{
    insulin = 1;
    Serial.println("at val 1");
    }
else if (num<130)
{
    insulin = 2;
    Serial.println("at val 2");
    }
else if (num<150)
 {
    insulin = 3;
    Serial.println("at val 3");
    }
else if (num<170)
{
    insulin = 4;
    Serial.println("at val 4");
    }
else if (num<190)
{
    insulin = 5;
    Serial.println("at val 5");
    }
else if (num<210)
{
    insulin = 6;
    Serial.println("at val 6");
    }
else if (num<230)
{
    insulin = 7;
    Serial.println("at val 7");
    }
else if (num<250)
{
    insulin = 8;
    Serial.println("at val 8");
    }
else if (num<270)
{
    insulin = 9;
```

```
    Serial.println("at val 9");
    }
else if (num<290)
{
    insulin = 10;
    Serial.println("at val 10");
    }
else if (num<310)
{
    insulin = 11;
    Serial.println("at val 11");
    }
else if (num<330)
{
    insulin = 12;
    Serial.println("at val 12");
    }
else if (num<350)
{
    insulin = 13;
    Serial.println("at val 13");
    }
else if (num>350)
{
    insulin = 14;
    Serial.println("at val 14");
    }

  for (int i=0; i<insulin; i++)
{
    digitalWrite(motorA, HIGH);         //COUNTER clockwise
    digitalWrite(motorB, LOW);
  delay(1000);
  int j= i+1;
  Serial.print(j);
  Serial.println(" Rotation done");
  }
  digitalWrite(motorA, HIGH);          //COUNTER clockwise
  digitalWrite(motorB, HIGH);
//  delay(5000);
  num = 0;
  insulin = 0;
  val = "0";
}
```