Hydro Pancreas : A Circuit Model Mimicking Diabetes Management

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Abstract

Currently, many people suffer from varying levels of diabetes, which is primarily categorized into Type 1, Type 2, and gestational diabetes. Type 1 diabetes requires insulin administration, while Type 2 can often be managed through diet, exercise, and medications, though insulin may be needed as the condition progress. The appropriate dosage of insulin to be administered to an individual depends on several factors, including the nutritional content of the food consumed, planned activities, and mood swings. Insulin requirements differ from person to person and are based on the individual's blood sugar levels. At present, glucose meters using finger-prick techniques are commonly used to check blood sugar levels. Recent advancements in insulin pump and glucose sensor technology have led to "hybrid loop" systems that automatically adjust and administer insulin in response to changes in blood glucose levels. These systems aim to mimic the natural function of the pancreas in regulating blood sugar, which is why they are often referred to as artificial pancreases. This project aims to build a circuit that models an artificial pancreas for the quick and safe regulation of blood sugar levels. In this project, insulin and blood are replaced by tap water and distilled water, respectively.

Key words— "Diabetes, Artificial Pancreas, Insulin, Blood glucose levels, Mimic the natural function, Hybrid loop, ."

I. INTRODUCTION

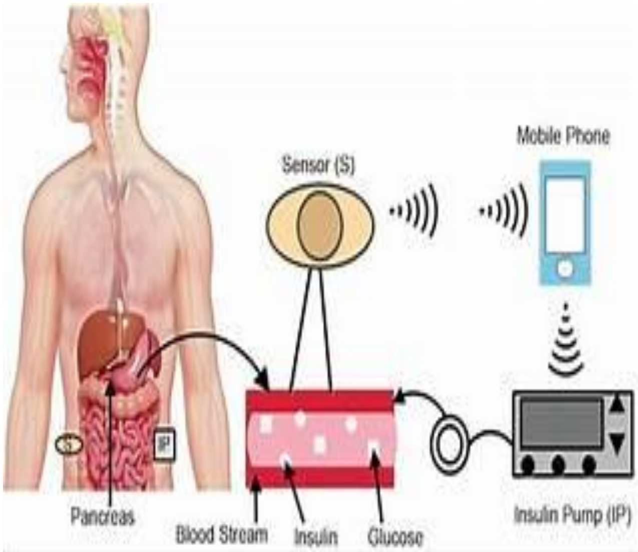


Fig.1: Artificial Pancreas System for Diabetes Management

Scientists and engineers are often motivated to do their work in order to help people out. One area in which that motivation is readily apparent is in the field of biomedical engineering, where a great deal of research focuses on creating better medical devices and equipment. For people with diabetes, smarter insulin pumps and glucose monitoring technologies can make a big difference in how effectively they manage the disease. An artificial pancreas, or insulin pump that coordinates with a continuous glucose monitor, can automate some of the maintenance and monitoring of blood glucose, including increasing or decreasing insulin, to help people control their blood glucose more effectively. These systems can take over some of the decisions and calculations involved in insulin therapy and can monitor and respond to blood glucose 24/7, often making changes every few minutes. These systems can reduce the burden of managing diabetes and may lead to better overall management, but creating devices that can successfully manage blood glucose is a complex task and involves a large number of variables. The pancreas has a very complex biological role that has to be mimicked by a combination of electronics, chemistry, and biology. This project explores some of the complexities engineers and scientists face as they develop artificial pancreas technologies.The body uses a simple sugar, called glucose, as its primary fuel. We get glucose from the food we eat. Both table sugar (sucrose) and other types of carbohydrates, such as starch (found in large quantities in pasta and other grain-rich foods), are broken down by our bodies to make glucose. Because food can be broken down to make glucose, the level of glucose in a person's blood which is commonly referred to as the blood glucose level usually goes up after he or she eats. Note that blood glucose is typically measured in milligrams per deciliter (mg/dL) .The amount of sugar in your blood is carefully controlled by the body. After eating, the sugar level in the blood rises. To manage this, the pancreas releases insulin, which helps parts of the body like the liver, muscles, and fat tissues absorb the extra sugar from the blood and store it for future energy needs in the form of glycogen. When the sugar level in the blood starts to drop, the pancreas reduces the release of insulin, allowing the stored sugar to be used for energy. If the sugar level gets too low, the pancreas releases glucagon, which helps release the stored sugar back into the blood. This process keeps the sugar level in the blood balanced. and impact echoing across the globe. The goal of the 'Hydro Pancreas' project is to design and implement a circuit model that mimics the functionality of an artificial pancreas. This system uses a conductivity sensor, a control circuit, and a water delivery mechanism to simulate the regulation of blood glucose levels write the system overview for the given data embarks on the exploration of artificial intelligence.

II. Literature Review

The development of artificial pancreas systems has significantly advanced diabetes management by integrating sophisticated technologies to automate insulin delivery .1) Yu,Liu, and Nemati (2020) provide a comprehensive survey on the application of reinforcement learning (RL) in healthcare, highlighting its potential to enhance decision- making processes in chronic disease management. Their work underscores how RL algorithms can be utilized to personalize insulin delivery, thereby optimizing blood glucose control in real-time. This approach is particularly relevant for artificial pancreas systems, where adaptive learning can continuously improve the precision and Physiological conditions. 2) Complementing the advancements in machine learning, Åström and Murray (2006) offerfoundational insights into feedback systems, which are crucial for the stability and reliability of closed-loop control mechanisms in artificial pancreas devices. Effective feedback systems ensure that insulin delivery is accurately adjusted in response to fluctuating glucose levels, minimizing the risks of hypoglycemia and hyperglycemia. 3) Theevolution of insulin delivery devices, as detailed by Kesavadev et al. (2020), illustrates the transition from traditional methods such as syringes and pens to advanced insulin pumps and DIY artificial pancreas systems. This progression highlights the importance of integrating robust feedback control with user-friendly interfaces to enhance patient adherence and system efficacy. 4) Furthermore, Massoud et al. (2020) demonstrate the practical implementation of a closed-loop artificial pancreas, showcasing the design, implementation, and evaluation processes that ensure the system's effectiveness inmanaging Type 1 diabetes. Their study emphasizes the interdisciplinary efforts required to combine biomedical engineering, control theory, and clinical practices to create reliable and efficient artificial pancreas solutions. 5) The development of artificial pancreas systems has been greatly supported by foundational and technological insights into diabetes management and its underlying mechanisms. The U.S. Food and Drug Administration (2018) provides a detailed overview of the pancreas's role in regulating blood glucose levels and introduces the artificial pancreas device system. This includes components such as continuous glucose monitoring and automated insulin delivery, which are integral to simulating the natural function of the pancreas. These insights establish a baseline understanding necessary for developing simplified circuit-based artificial pancreas models. 6) Similarly, the National Institute of Diabetes and Digestive and Kidney Diseases (2021) highlights advancements in artificial pancreas technologies aimed at improving glucose regulation and overall quality of life for individuals with diabetes. This resource emphasizes the variety of approaches in artificial pancreas systems, offering valuable context for comparing current innovations with experimental models. Such comparisons can guide the refinement of simplified designs that mimic the physiological functions of the pancreas.7) In addition to these medical perspectives, Taylor (n.d.) provides essential knowledge onelectrical principles, including voltage, current, resistance, and Ohm's Law, which are critical for designing and implementing electrical circuits in artificial pancreas prototypes. The concepts outlined in this resource directly contribute to the accurate measurement of voltage and current in conductivity sensors, ensuring the reliable functioning of components that simulate insulin delivery mechanisms. Together, these resources underscore the interdisciplinary nature of artificial pancreas development, combining medical, technological, and electrical engineering insights to improve diabetes management

III. System Overview

The "Hydro Pancreas" project aims to design and implement a circuit model that mimics the functionality of an artificial pancreas. The system utilizes a conductivity sensor, control circuit, and water delivery mechanism to simulate the regulation of blood glucose levels. The conductivity sensor monitors the glucose levels, and the control circuit adjusts the insulin delivery accordingly.

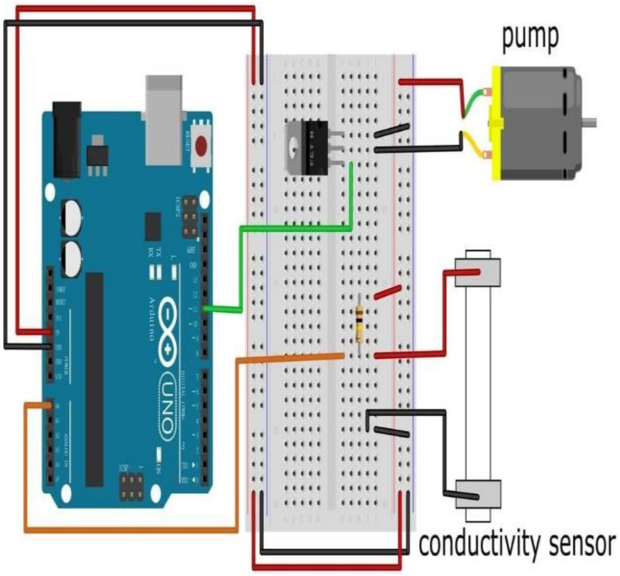


Fig.2: System design for hydro pancreas model

The water delivery mechanism simulates the insulin release, maintaining a balanced blood glucose level. This closed-loop system automates the maintenance and monitoring of blood glucose, reducing the burden of diabetes management and improving overall control.

IMPLEMENTATION OF MODEL DEVELOPED

Human body	**Hydro pancreas model**
Blood	**Distilled water**
Insulin	**Tap water**
Blood glucose level	**Voltage**
Eating carbohydrates causes blood glucose level to increase	**Voltage is decreased due to lower conductivity of distilled water**
Adding insulin to blood with High glucose causes glucose level to Decrease	**Adding tap water with comparatively higher conductivity to distilled water causes voltage to increase**

Fig 3 . Comparison between the elements of artificial pancreas and hydro pancreas

IV. METHODOLOGY

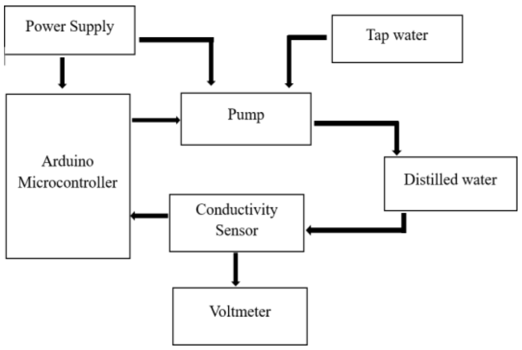


Fig 4. Block diagram of Hydro pancreas model

The block diagram of the artificial pancreas shown in fig 1 shows how different parts of the system work together. It starts with a sensor that measures the conductivity of water in a container, which simulates blood glucose levels. This sensor sends the data to an Arduino microcontroller, which acts as the system's brain. The microcontroller processes the input and checks if the glucose level is higher than a set threshold. If the glucose level is high (indicating low conductivity), the microcontroller sends a signal to activate a pump. This pump then transfers tap water, which represents insulin, into the container of distilled water, which represents blood. The water mixes to change the conductivity level and simulate the effect of insulin on blood sugar. The entire system is powered by a reliable power supply, ensuring all components work smoothly. This block diagram highlights how sensing, processing, and control mechanisms come together to simulate blood glucose regulation. The microcontroller processes the input and checks if the glucose level is higher than a set threshold. If the glucose level is high (indicating low conductivity), the microcontroller sends a signal to activate a pump. This pump then transfers tap water, which represents insulin, into the container of distilled water, which represents blood. The water mixes to change the conductivity level and simulate the effect of insulin on blood sugar.

The system runs on a power supply, making sure all the parts work reliably. This diagram shows how sensors, processing units, and controls come together to mimic the regulation of blood glucose levels.

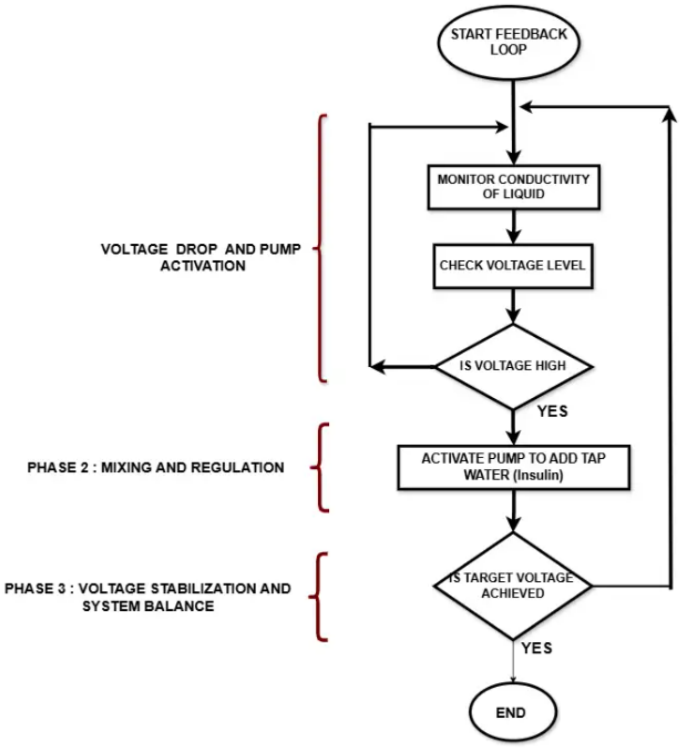
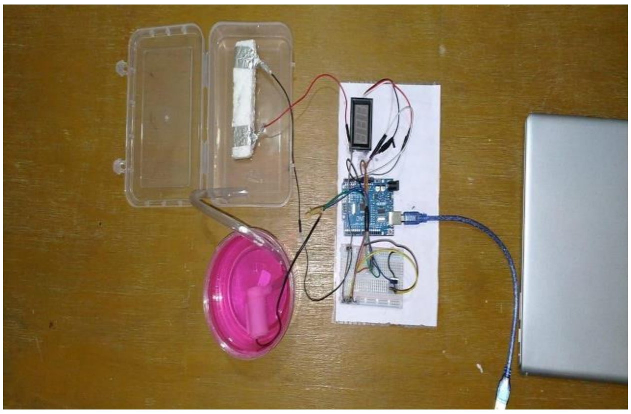


Fig 5. Flowchart explaining the working of Hydro pancreas model

V .RESULT ANALYSIS

The below image showcases the initial setup of the Hydro pancreas model. wThe setup includes a conductivity sensor, Arduino board, pump, and essential circuitry. Power is supplied through a laptop connection. The system is configured to detect voltage changes caused by the conductivity variations in the solution. A reference voltage of 5V is maintained, and any drop below 4.8V or 4.7V triggers the system to add distilled water to restore balance. This setup demonstrates the model's core functionality, mimicking the process of regulating blood glucose levels.

Fig 6. Initial setup of the Hydro pancreas model



Phase 1: Voltage Drop and Pump Activation

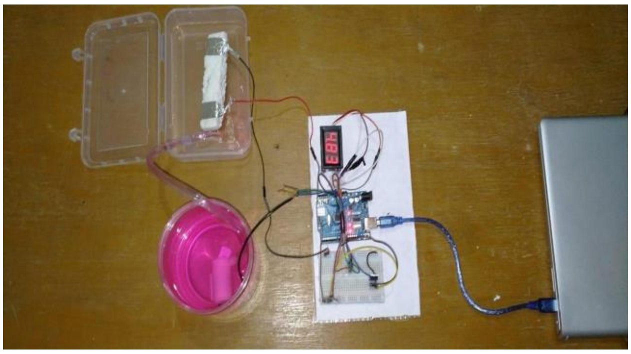
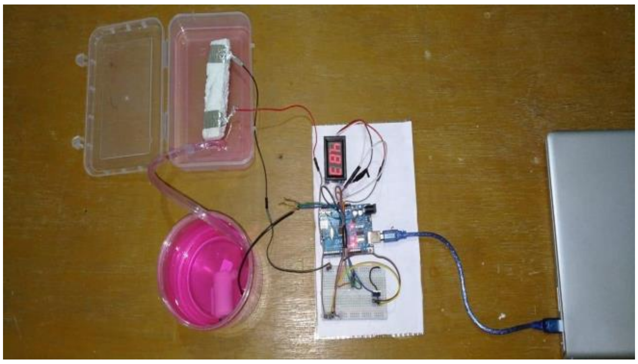


Fig 7 . Voltage Drop and Pump Activation

At a voltage drop to 4.83V, lower conductivity simulates high blood sugar levels. The Arduino detects this drop and activates the pump to add distilled water, diluting the solution. The pink tap water makes the mixing process easier to observe.

Phase 2: Mixing and Regulation



During mixing, the voltmeter briefly reads 4.83V, showing ongoing dilution. This gradual process mimics how blood distributes glucose and insulin, ensuring smooth regulation without overshooting.

Phase 3: Voltage Stabilization and System Balance

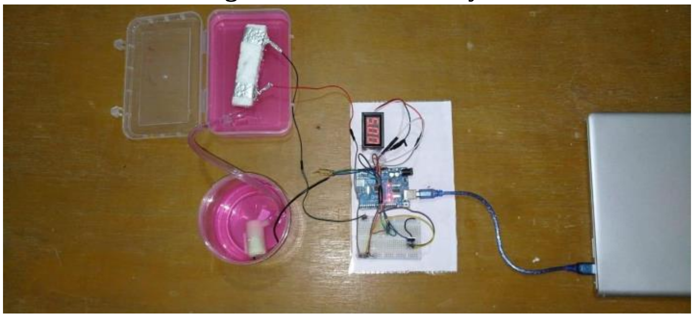


Figure 8: Voltage Stabilization and System Balance

Here, the voltmeter reading has returned to the reference value of 5V. The pump has stopped, indicating that the conductivity of the solution has been successfully adjusted to simulate normal blood sugar levels. The precise and quick response of the system, which took approximately 20–30 seconds, demonstrates the effectiveness of the artificial pancreas model in maintaining equilibrium. This phase underlines the importance of real-time feedback and controlled responses in replicating the body's natural glucose regulation mechanisms.

VI. CONCLUSION

This project demonstrates a circuit model mimicking insulin delivery regulation using water as a substitute. The system features a feedback loop mechanism, adjusting delivery based on conductivity sensor input. An Arduino microcontroller, custom circuit, and pump ensure precise monitoring and control. The model showcases the ability to maintain glucose regulation balance, replicating an artificial pancreas. This setup paves the way for advancements in closed-loop diabetes management systems. Future improvements can further bridge the gap between this prototype and practical use cases.

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PROFILE DETAILS

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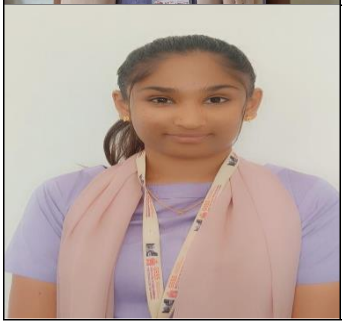	Ms. Kannika K R 4GW23EE405 GSSSIETW, Mysuru Email: kannikagowda278@gmail.com Phone No: 9036731867