

Final Report

Sugar Safe: A Diabetic Alerting Device

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Abstract

The SugarSafe band is a device used to notify caregivers of blood glucose levels in children with Type 1 Diabetes (T1D). The clients have requested the device to be compatible with a Continuous Glucose Monitor (CGM) and suited for patients with T1D. Statuses of hyperglycemia (high blood sugar), hypoglycemia (low blood sugar), and healthy ranges must all be physically displayed by the wearable system. Current devices to alert caregivers of a child's blood glucose level include the *Glowco*, which lacks portability due to a required outlet power source, and *Apple Watch*, which can be distracting for children. The team elected to create a device that will display a color signal representing a blood glucose reading following the same color scheme as devices already on market: red for levels <55 mg/dL, orange for 56-65 mg/dL, yellow for 66-80 mg/dL, green for 81-139 mg/dL, blue for 140-200 mg/dL, and purple for levels >201 mg/dL. The device is intended to be worn on a child's wrist; therefore, it must be portable and not impede the activity demands of daily life. The bracelet consists of a resin watch face, silicone wristband, LED light, and XIAO Microcontroller with BLE transmission to an iOS smart phone application. The device receives blood glucose data from a compatible programmed mobile application, pulling directly from the user's Dexcom app. The alerting system displays a color intuitively corresponding to blood glucose levels, ensuring caregivers can respond confidently and appropriately. Testing was focused on the bracelet's ability to display the correct color signal, provide sufficient visibility and color differentiation, and maintain an adequate range of connections, while being secure on the wrist. These metrics are vital for device reliability.

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Introduction

Type 1 Diabetes (T1D) is an autoimmune disease affecting the production of insulin-producing beta cells in the pancreas, leading to the inability to self-regulate blood sugar levels. Currently, there are 1.2 million Americans living with T1D [1]. Studies show that a diagnosis can be equally as stressful for parents as the child themselves, with an average of 81% of parents reporting distress following a diagnosis of T1D [2]. Continuous glucose monitors (CGMs) are the most widely adopted device for active and constant observation of blood glucose. For this project, compatibility with Dexcom-branded CGMs will be prioritized, specifically the Dexcom G7 because it is the newest and most accurate model on the market [3].

There are a few third-party devices that help visually represent CGM readings, including the *Glowcose* light. The *Glowcose* works by mapping CGM data to a color-coded light source: red to yellow for hypoglycemia, green for numbers in range, and blue to purple for hyperglycemia. While this product is celebrated for its simplicity and ability to offer peace of mind, it relies on a steady Wi-Fi connection and wall plug power source [4]. Another similar product is the *Sugar Pixel*, which also relies on Wi-Fi to pull CGM data and displays blood glucose levels on a clock-like display [5]. For a portable solution, many T1Ds choose to use an *Apple Watch* or *Fitbit* to display CGM readings on their wrist for easy and frequent monitoring [6]. While using a smart watch display is convenient for the wearer, it provides no visible signal to others. Additionally, they can be distracting to children in school environments, and their high cost can be a barrier to many families. The lack of a portable device that can visibly display blood glucose statuses led to the client's request for a wearable glucose alerting system to make status updates more clearly visible, understandable, and actionable for anyone supervising a child with T1D. The device should alleviate the stress associated with interpreting blood glucose numbers by eliciting a visible signal to parents and caregivers, which will convey whether treatment is needed or not.

Background

Type 1 Diabetes is an autoimmune disorder that affects the body's ability to produce insulin. Insulin regulates the concentration of glucose in the blood, commonly referred to as blood sugar levels. A lack of naturally produced insulin can lead to chronic high blood sugar, or hyperglycemia

[7]. When untreated, hyperglycemia can result in serious long-term health complications, including coma, nerve damage, vision impairment, blindness, heart disease, and impaired wound healing that may lead to amputation [8]. Currently, most individuals with diabetes manage their condition by routinely monitoring blood glucose levels using a CGM, counting ingested carbohydrates that raise blood sugar, and calculating insulin doses based on these factors [9].

While T1D can affect individuals of all ages, the SugarSafe band focuses on pediatric patients, who make up approximately 20% of diabetes diagnoses [1]. Children are often less able to understand and independently manage their treatment plans, especially at ages when they frequently spend time in school, daycare, or sports practices under supervision of caregivers who may not be trained in diabetes management [10]. Diabetic treatment plans can vary significantly between individuals, depending on a range of factors such as exercise, gender, weight, height, and types of food consumed [11]. These variations, along with differences in how each child physically presents symptoms of dangerous blood sugar levels, make standardized training in these settings extremely difficult and often overwhelming for caregivers [12].

The clients, Dr. Beth Martin, PhD, a professor in the School of Pharmacy, along with Olive Carniglia and Callie Berg, students in the School of Pharmacy, have requested a device to help reduce this burden. The goal is to develop a wearable system that provides a universal signal that is visual, intuitive, and actionable for a wide range of caregivers.

The device uses a customizable LED interface to display a range of colors, notifying caregivers of blood glucose statuses and system failures. It is rechargeable, wireless, comfortable for prolonged wear on a child's wrist, and adjustable to accommodate growth (12.5–17.5 cm) [13]. The device is compatible with the Dexcom G7, one of the most widely used CGMs, to maximize potential usability and market reach. It aligns with FDA Class II requirements under the Integrated CGM category and meet IP54 standards for water and dust resistance [14][15]. Additionally, ISO 15197 and ISO 17511 standards were considered to ensure high accuracy relative to blood glucose measurements [16]. A comprehensive outline of product design specifications (PDS) can be found in Appendix A.

Preliminary Designs

Band and Materials

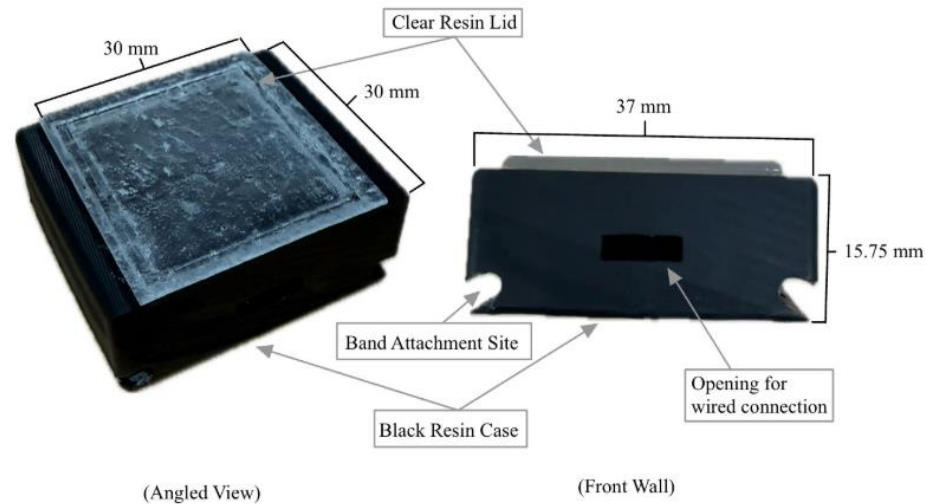


Figure 1: Resin Case and Lid

The enclosure is designed as a 3D-printed black resin box paired with a clear, snap-fit resin lid. Resin was selected for its high print resolution, durability, and overall strength. The box includes two band attachment points on opposite sides, compatible with commercially available Apple Watch bands [17]. To accommodate the geometry of these connectors, the side walls are extruded to a thickness of 5.41 mm, while the front and back walls are thinner at 1.905 mm.

A 9×3 mm opening is incorporated into the front wall to allow USB-C access for charging the internal microcontroller and battery. The internal cavity measures 26.2×26.2 mm, providing sufficient space for all electronic components. The lid measures 30×30 mm and attaches using snap-fit features along both side walls. All external edges of the case and lid are filleted with a radius of 1.27 mm for a smoother, more ergonomic finish.

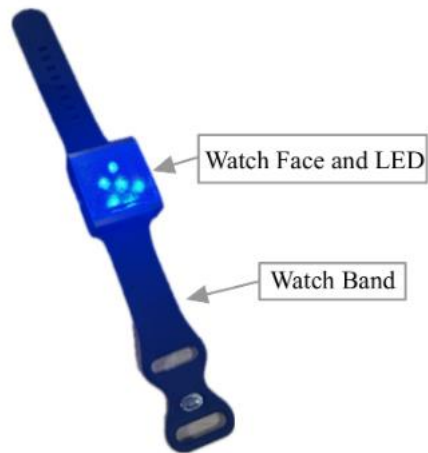


Figure 2: Previous Band and Box Design

The box is designed to be compatible with the Polyjoy Kids Apple Watch Strap, designed originally for Series 10/11 Apple Watches. It is made from silicone, which provides a waterproof, heat-resistant, hypoallergenic, and easily sanitizable surface. It features an adjustable loop with a peg-style closure and a double buckle mechanism, offering added security and making it difficult for a child to remove independently [17].

Hardware

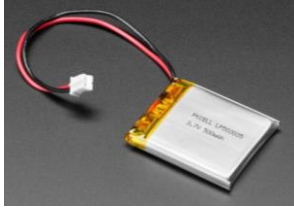


Figure 3: Battery



Figure 4: LED



Figure 5: Microcontroller

The device will use a 3.7 V, 500 mAh lithium-ion battery that is permanently soldered in place and charged directly through the microcontroller via USB-C forward charging [18]. The selected LED component is a NeoPixel 7-ring Jewel, with each LED drawing up to 18 mA at maximum brightness; this represents the primary load of the system. Based on this, the expected runtime is approximately 6 hours per charge. The XIAO ESP32-C6 microcontroller supports very low power consumption along with Wi-Fi 6 and Bluetooth Low Energy (BLE) 5.0 connectivity, while also remaining a cost-effective option within the project budget.

Data Transmission



Figure 6: BLE 5.0 Only Connection

The first transmission method considered for communication between the application and the microcontroller was BLE 5.0 only. This method uses a minimal amount of current to maintain a connection, typically under 10 mW [19]. Its connection range is approximately 50 m indoors and up to 100 m outdoors, which satisfies the PDS requirement of 50 m [20]. A BLE connection is generally straightforward to set up, involving a single pairing process similar to connecting headphones or a speaker to an application. BLE is also widely accessible both nationally and

globally, which would help expand the device’s potential market. Because it only requires a single connection, this transmission method is easily replicable and feasible for the team to implement.



Figure 7: Wi-Fi 6 Only Connection

The second transmission method considered was using Wi-Fi 6 only. Wi-Fi connections require significantly more power than BLE and generally have slightly shorter effective ranges: 41 m indoors, and 90 m outdoors [19][20]. When used with the microcontroller, a Wi-Fi connection would also require access to a specific network, along with password and router configuration, making it a much less user-friendly option.






Figure 8: Both Wi-Fi 6 and BLE Connection

The third connectivity option is to enable transmission through both BLE and Wi-Fi. The main drawback of this approach is the significantly higher overall power consumption when both systems are used simultaneously. Additionally, both Wi-Fi and BLE operate on the 2.4 GHz frequency band [18], which can lead to potential interference or crossover in data transmission. While this hybrid model would be beneficial in terms of range and accessibility, it lacks the user-friendliness and replicability of the other options.

Preliminary Design Evaluation

Table 1: Design Matrix of Connection Mode Options

Designs	BLE 5.0	Wi-Fi 6	Both Wi-Fi 6 and BLE 5.0
			
Power Consumption (25)	5/5 (25 pts)	3/5 (15 pts)	2/5 (10 pts)
Connectivity (25)	3/5 (15 pts)	4/5 (20 pts)	5/5 (25 pts)
Ease of Use (20)	4/5 (16 pts)	2/5 (8 pts)	3/5 (12 pts)
Accessibility (15)	3/5 (9 pts)	4/5 (12 pts)	5/5 (15 pts)
Feasibility (10)	5/5 (10 pts)	3/5 (6 pts)	2/5 (4 pts)
Replicability (5)	4/5 (4 pts)	3/5 (3 pts)	1/5 (1 pt)
Total (100)	79 pts	64 pts	67 pts

The BLE 5.0, Wi-Fi 6 (2.4 GHz), and a combination of BLE and Wi-Fi designs all have distinct tradeoffs across power consumption, connectivity, ease of use, accessibility, feasibility, and replicability. BLE 5.0 is the most efficient power option by a significant margin, typically consuming less than 0.01 W [19]. Wi-Fi however draws substantially more power, 0.5 to 2 W, and the combined BLE and Wi-Fi design utilizes additional power due to shared frequency operation [18][19]. From a connectivity standpoint, the combination offers the most reliable and consistent coverage since it can theoretically switch to the method with a stronger connection. BLE is more

susceptible to signal interference from the environment but meets the 50 m range requirement as outlined in Appendix A. Wi-Fi on its own receives less interference with a similar distance range to BLE [19][21]. Ease of use favors BLE due to its simple device pairing and minimal configuration. Wi-Fi requires network credentials and router setup and could run into issues if there is a Firewall or proxy in place, a common occurrence in schools [22]. The combination increases the complexity of user set-up since it requires both routes to be configured correctly. Wi-Fi and BLE see similar accessibility globally and domestically. The United States (US) sees about 90% access to Wi-Fi and 70% globally while BLE is available in 82% of the US and 63% worldwide [23][24]. The hybrid option naturally takes the combination of both accessibility percentages and allows for flexible pairing, hence its high scoring. In terms of feasibility, BLE is the winning option due to its standardized iOS support and lack of network requirements or a backend application programming interface (API). Wi-Fi and the combination design have additional complexity with network policies and extra logins [22][25]. Each device can operate independently with the BLE model, giving it the highest replicability score. Significant configuration and maintenance would be required to adapt to multiple devices with the Wi-Fi and combination designs [26]. The BLE option is the most straightforward, power efficient, and overall well-suited model for the final design.

Proposed Final Design

The proposed final design consists of an adjustable silicone band attached to a 3D resin box with a detachable lid. Silicone was chosen as the band material as it is hypoallergenic, waterproof, and safe in the range of temperatures outlined by the PDS. See Appendix B for material design matrix. The light will be a Neo Pixel ring LED which will display a color corresponding to the glucose status. The LED will display a pulsing white light in the event of a malfunction or dropped connection. The Lithium-ion battery will be permanently installed and charged using a USB-C cable through the microcontroller. A Lithium-ion battery was chosen due to existing prevalence in similar portable devices, see Appendix C for battery design matrix. The battery will also be soldered to the XIAO ESP32-C6 Microcontroller and LED to minimize hardware dimensions. All electronic circuitry components are to be housed inside a 3D printed box. The data retrieval system will be adapted for compatibility with an iOS application and updated to initiate a BLE transmission to the device. A user's CGM will connect to the Dexcom app, and their individual login information will be used to access the custom-created app. The app will pull the most recent blood glucose value, auto refreshing every 5 minutes, to communicate with the microcontroller via BLE. The microcontroller then categorizes the new value to a color that matches the set ranges. The LED will then be updated to display the corresponding color.

Fabrication

Software

Software was developed in two parts; a fully functioning iOS application and a programmed microcontroller. Deployment of the mobile app was implemented using Flutter, Google's open-source user interface (UI) programming platform. To use the app, the user logs in with their existing Dexcom credentials on the login page, as shown in Figure 9. The service code of the app uses Dexcom's Share feature to pull live CGM data straight from the account. Every 30 seconds, the raw data is scraped and formatted into a clean package that the app can then interpret and display. The app will display the most recent blood glucose value in mg/dL and a trend arrow inside a colored box that corresponds to the predetermined color range. In the app's settings page is an adjustable brightness slider and the Bluetooth pair/unpair buttons, allowing for a seamless setup. The microcontroller software emits a unique BLE signal visible by the app to allow for a

steady and uninterrupted connection. Every five minutes, the app sends the most recent blood glucose number to the microcontroller over this established BLE connection. Once it receives a number, the microcontroller then maps the value to the correct range and updates the led correspondingly. As an added safety measure, after 12 minutes without a new value, the band will automatically blink white to alert caregivers of a malfunction. Access to the GitHub repository containing app code and microcontroller code can be found in Appendices F and G, respectively.

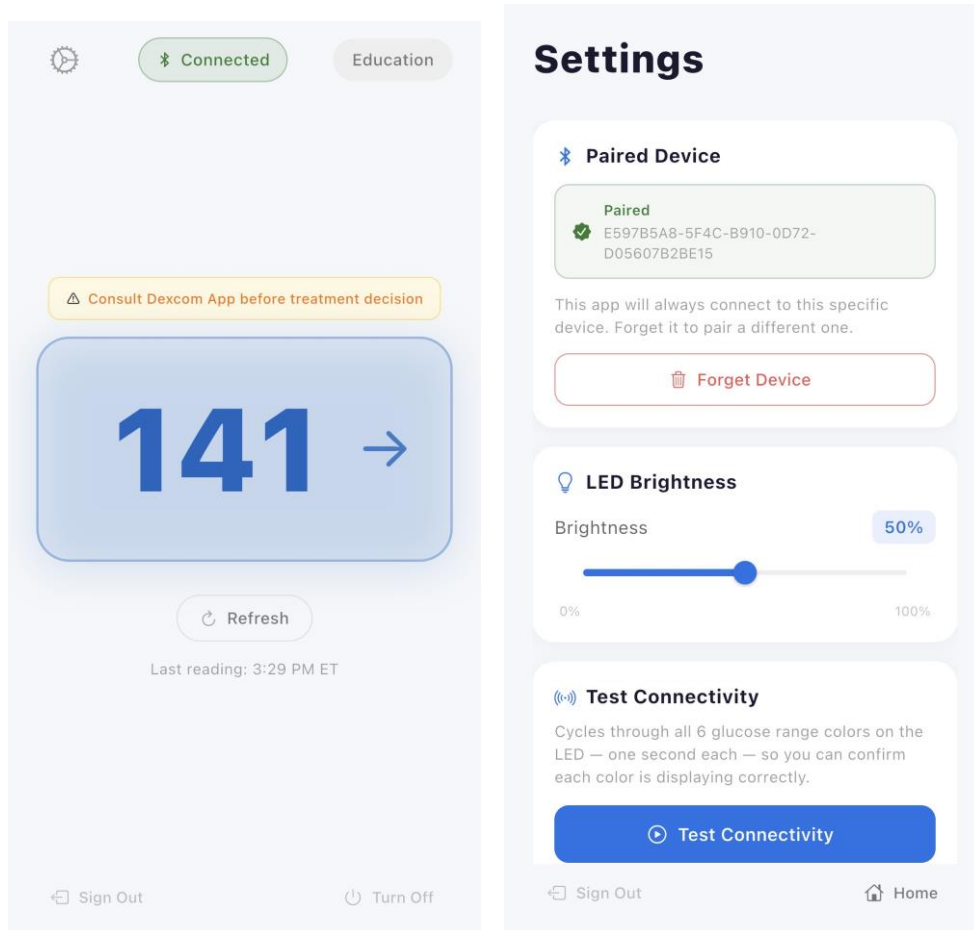


Figure 9: SugarSafe App Home and Settings Page

Hardware

The microcontroller chosen for the band is the Seeed Studio XIAO ESP32-C6 model with on-board BLE and Wi-Fi capabilities. It is connected to the LED, a NeoPixel Jewel with seven individual lights that are synchronized to provide a strong and clear signal color signal. Insulated wiring was used to connect the LED to the microcontroller via soldering. Both components are

powered through a USB-C connection to a 5000 mAh, 5V portable battery. At a maximum current load of 426 mA, this power bank provides over 12 hours of battery life to the band.

Band Design

The microcontroller and LED are housed inside a 3D printed box made of black resin filament. The box measures 26 x 30 mm in size and is 15 mm tall. The lid is made of clear resin and snaps into the box base, providing a secure fit for the components without hindering the LED's brightness. Resin was selected for both the box and lid components due to its widespread availability, existing prevalence in medical devices, and low cost at \$0.24/mL [28][29]. There is one cutout on the side of the box, measuring 6.60 mm in length, with a 3.40 mm radius for the USB-C cable insertion necessary to power the microcontroller and LED. All edges of the watch face and lid are filleted with a radius of 1.27 mm to remove any sharp edges and provide a more finished appearance. Along opposite bottom edges are two cylindrical grooves designed according to the specifications of an Apple Watch band insertion slit. This enables compatibility with third party Apple Watch bands, notably the Polyjoy children's band. See Appendix E for detailed CAD dimensions. This band is made of silicone, a material chosen due to its durable and hypoallergenic nature, meeting the client's requirement for a water resistance rate of IP 54 [30][18]. Additionally, this band features a double-slit securing system, making it more difficult for children to remove themselves. It also is adjustable to the desired wrist sizes of 12.7-17.8 cm [13].



Figure 10: SugarSafe Band

Final Prototype

The final design, as shown in Figure 11, is a fully adjustable, wrist-worn band that emits an LED signal. The power source, a 5V Vanyust portable battery, is also worn on the arm of the user inside a Yuniyan Universal Sports Armband that provides an adjustable and secure fit. The battery and band are connected through a 30 cm USB to USB-C charging cord. The user will

download the SugarSafe app on their iOS device, sign in, and pair the device using the built-in Bluetooth connection. Once connected, the device will continuously update LED color based on real-time blood glucose values from the Dexcom account.



Figure 11: SugarSafe Band and App In-Use

Testing and Results

Accuracy Testing

In order to be considered successful as an accessory alerting device, the band must be consistent with ISO 15197:2013, which focuses on the standard of a CGM device to achieve 95% accuracy compared to the glucose test strip reading [13]. To maintain this degree of accuracy, the band cannot introduce any additional source of variance from the user's Dexcom-recorded blood glucose value as displayed in their Dexcom app. Accuracy testing was performed by recording values from both the Dexcom and SugarSafe apps as well as the color of the SugarSafe band over the course of 5, non-consecutive hours, measuring at intervals of 5 minutes. Testing was performed across different dates to ensure test values encompassed the spectrum of ranges, both low and high. Results demonstrated that the SugarSafe app and band displayed the correct expect values and

colors, respectively, with 100% accuracy. Plotting expected values against observed shows a perfect linear slope with an R^2 of 1, as demonstrated in Figure 12. This test meets the PDS requirements of maintaining at least 95% accuracy with transmitted test results as well as the client requirement stating delay time should not exceed 5 minutes, as data is updated continuously. See Appendix H for full data report.

Blood Glucose Readings Actual vs Observed

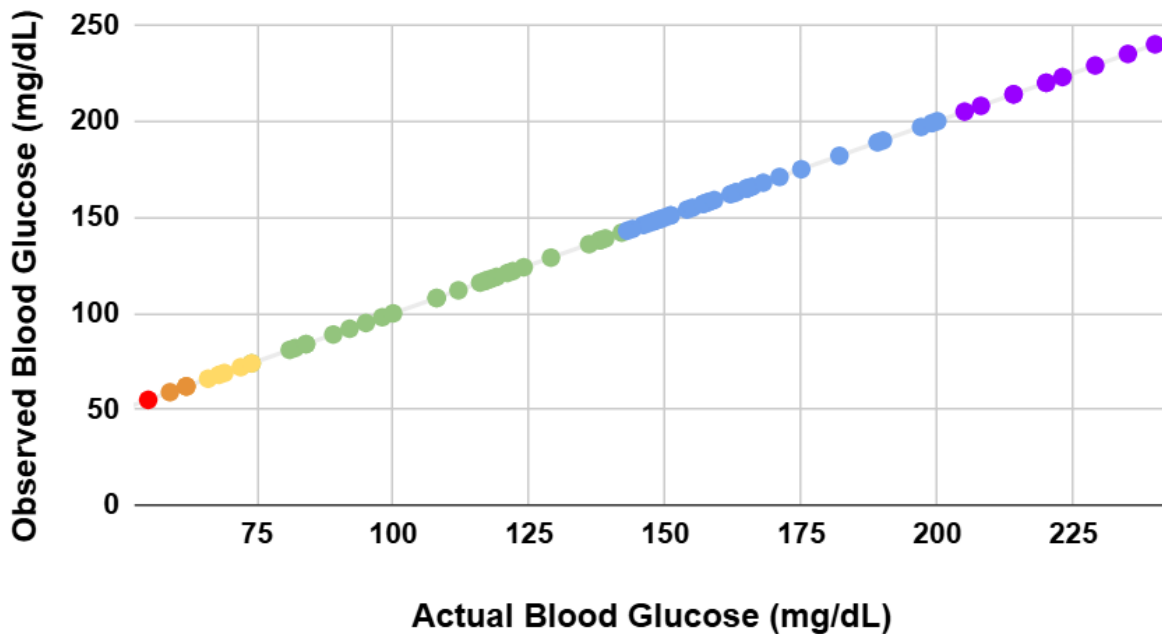


Figure [12]: Plotted Graph Showing Actual vs Programmed Blood Glucose Levels (LED Colors Denoted By Plot Points)

Connectivity Testing

To evaluate connectivity, a “Test Connectivity” program was added to both the app and the microcontroller. Upon manual initiation of this test on the SugarSafe app, a BLE signal tells the microcontroller to cycle through each of the six colors, red to purple, pausing at each color for one second. This program is intended to rapidly simulate band color changes that could occur throughout a day of use while providing an instantly detectable confirmation of BLE connection. For the test to run, the iPhone running the app must be in range of the microcontroller, meaning that the LED can only cycle through the test program if a successful connection is actively established. The range of sustained BLE connectivity was tested from 0 to 150 m at intervals of

10 m. At each distance, the test was initiated in the SugarSafe app and the observance of the test cycle on the band was recorded as a pass or a failure. The presence of a delay between calling the test and observing the light changes was also recorded. Testing was repeated 3 times at each distance, and the overall percent of passed tests was calculated. Per PDS requirements, the band must maintain connectivity in a range of 50 m with 95% accuracy, which is consistent with the average size of a school playground. As outlined in Figure 13, results demonstrated that BLE connectivity is maintained with a 100% success rate though the entire range of tested distances up to 150 m. This surpasses the client requirements by 200%. Additionally, no delay time was observed during any of the 48 trials, proving the establishment of a strong and reliable BLE signal. See Appendix I for full data report.

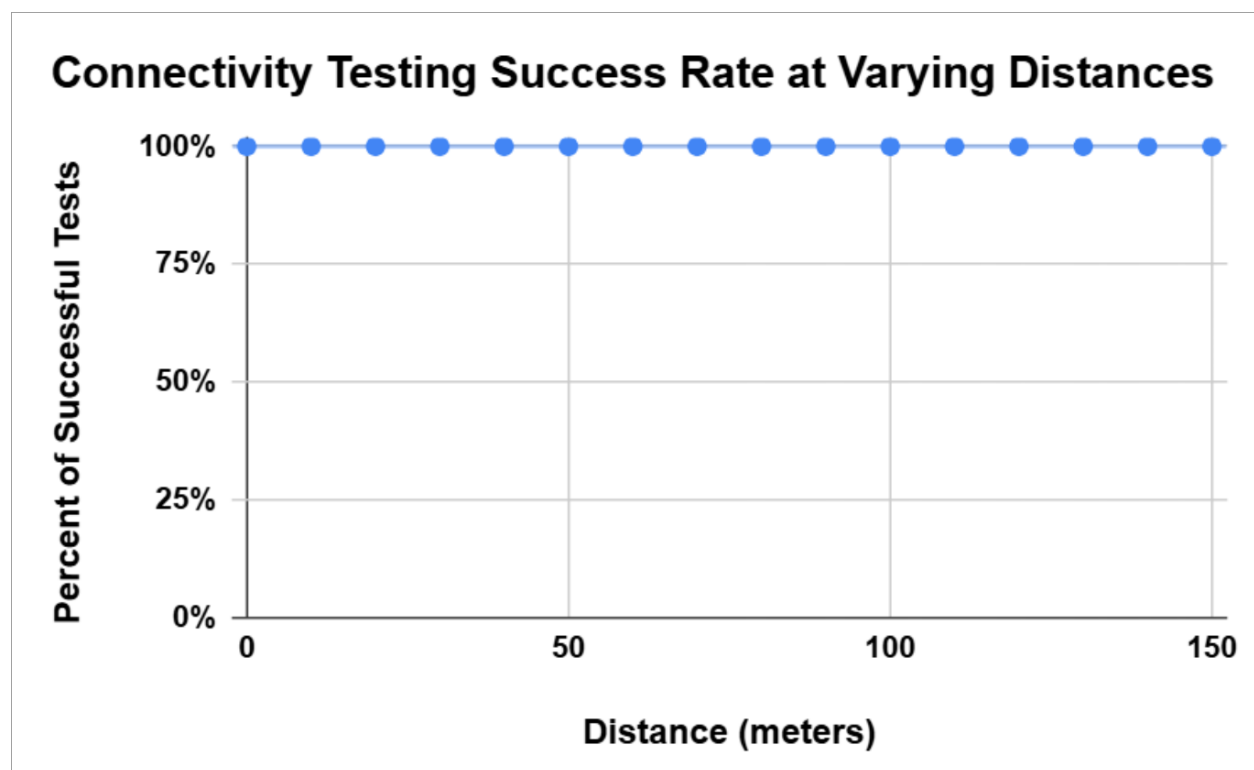


Figure [13]: Plotted Graph Showing Percentage of Successful Connection Tests at Varying Distances, Results Averaged Over 3 Trials

Visibility Testing

Visibility testing was conducted to ensure the LED color was clearly visible and distinguishable from 50 m. The LED was manually programmed randomly through each of the six possible display colors and a total of 8 participants at 50 m away were asked to state the observed color of the LED. All testing was performed with LED brightness set at 80%. Results found that

participants were able to correctly identify the programmed color 100% of the time. This confirms that at the client-determined operating range of 50 m, the color signal is both easily visible and differentiable from other programmed colors, ensuring caregivers can rely on a clear and visible signal from the band.

Failure Alert System Testing

One of the programmed safety features of the SugarSafe band is the implementation of a program that will override the LED to display a pulsing white light at 100% brightness if no updated value is sent to the microcontroller after 12 minutes. To test the responsiveness of the malfunction alert, the connection was established and then intentionally dropped to simulate a connectivity error between the SugarSafe app and band. A successful test was denoted by the observance of the pulsing white alert light after exactly 12 minutes from the time of the dropped connection. The test was performed 5 times, and results demonstrated 100% accuracy by initiating the alert light feature.

Activity Testing

Per client requirements, the band must fit securely around the wrist without impeding the lifestyle of an active child. This means that the need to adjust the band must be kept to an absolute minimum. To test its security, the team measured how much the band shifted after different types of activity. The subject secured the band on their wrist and performed one minute each of walking, running, stationary jumping, and jumping jacks. The distance of rotation around the wrist was recorded and calculated as a percentage of the circumference of the wrist. Each exercise was performed three times. Results found that band shift was minimal for all types of movement, with walking and running observing almost no shift and jumping jacks observing about a 10% shift due to the additionally extraneous arm movement. A full outline of test data can be found in Appendix J.

Average Percent Rotation of Band Around the Wrist

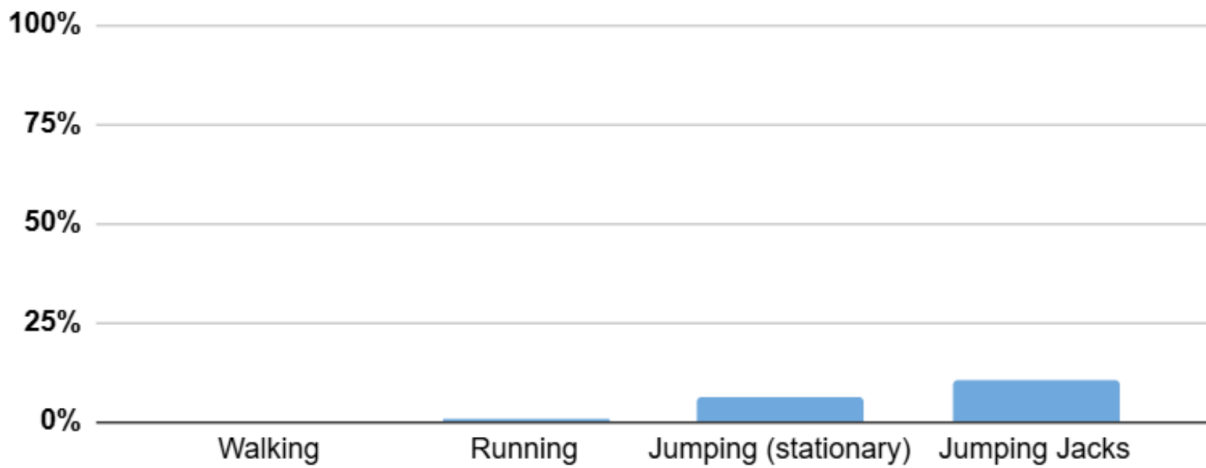


Figure [14]: Bar Graph of Rotation Around Wrist After Activities Were Performed for 60 Seconds, Results Averaged Over 3 Trials

Material Strength Testing of the Device Container/Box

Compression testing was conducted using a Material Test System (MTS) testing machine to evaluate the structural performance of the resin and PETG watch face. All watch faces were 3D printed with identical wall thicknesses and infill to ensure direct comparison between materials.

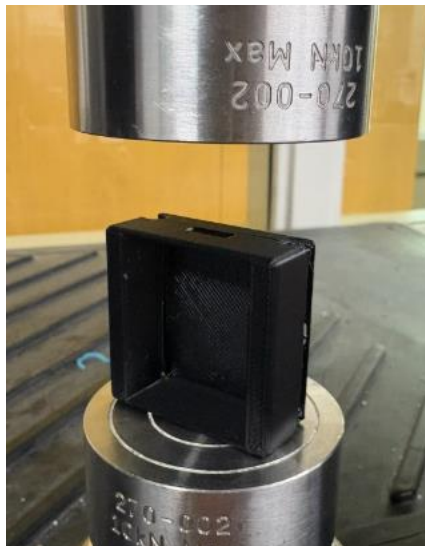


Figure [15]: MTS Testing Orientation of Device Watch Face with PETG Material



Figure [16]: MTS Testing Orientation of Device Watch Face with Resin Material

Each watch face was tested at the same orientation to maintain uniformity, aligning the axis of compression with the thicker side of the box. See Figures 15 and 16 for face orientation. Theoretical compressive capacity for each material was estimated using published average compressive strengths of 68 MPa for resin and 35.03 MPa for PETG for comparison and for verifying compliance with PDS requirements [21][22]. Calculated compressive stresses based on experimental failure loads and areas of each were 20.3 MPa for the resin samples and 9.1 MPa for the PETG samples. Although these values are lower than the theoretical material strengths, this outcome is expected because the test watch faces were hollow, rather than solid blocks. Both materials exceeded the minimum load and compressive stress required by the PDS.

The MTS testing showed clear differences between the materials. The resin watch face reached a maximum load of 6.380 kN, while the PETG watch face failed at 2.850 kN. Resin therefore carried higher loads in both orientations. PETG exhibited earlier deformation, while resin-maintained load capacity until higher forces were applied. Figures 17 and 18 present the corresponding load vs extension curves for each material.

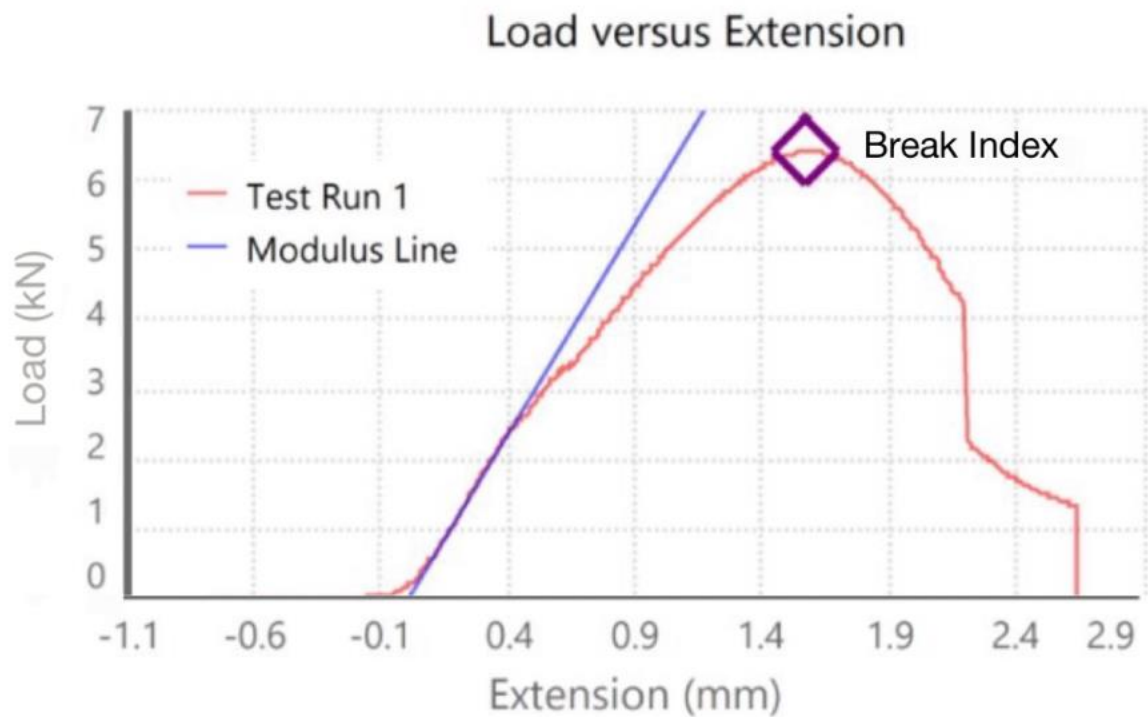


Figure [17]: Curve Showing Load (kN) vs Extension (mm) of Resin Material

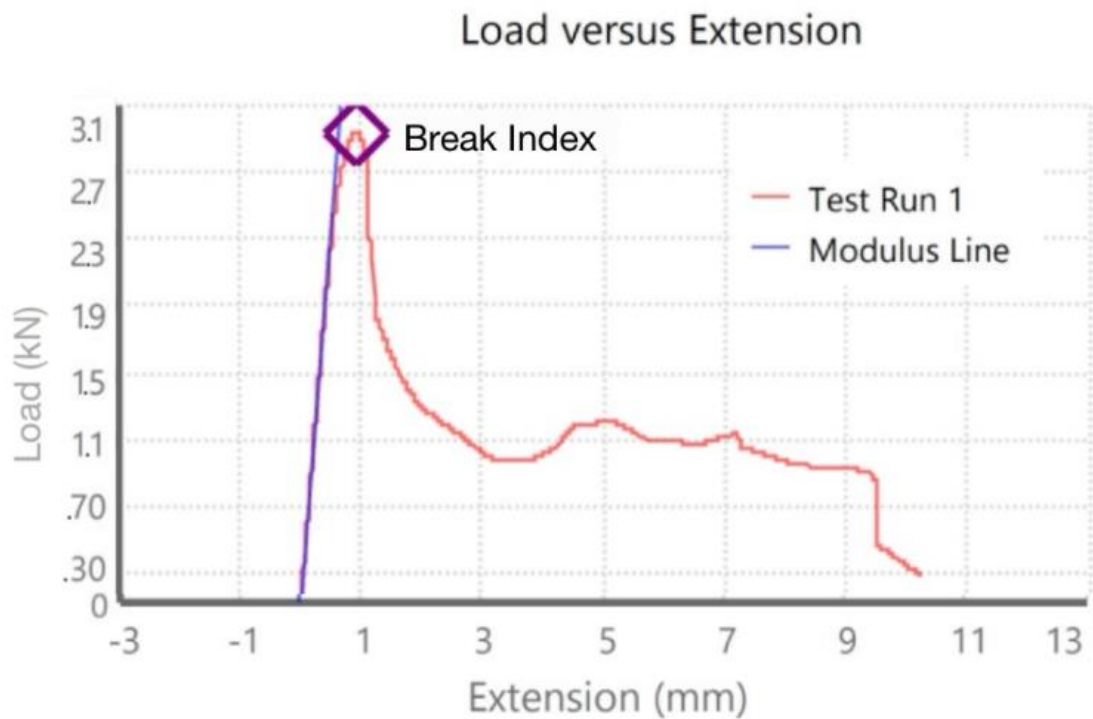


Figure [18]: Curve Showing Load (kN) vs Extension (mm) of PETG Material

In addition to compression testing, a drop test from 2.5 meters was performed, as specified in the PDS based on the average height of a playground. Both the resin and PETG watch faces passed this requirement with no breakage and no visible damage.

All experiments confirmed that both resin and PETG exceeded the minimum load requirements specified in the PDS. However, resin provided a significantly larger compression margin, outperforming PETG across all test conditions, and demonstrating better compressive strength and deformation resistance. These results indicate that resin was the material of choice for the device.

Discussion

The SugarSafe Band attempts to correct the communication barrier between parents of T1D children and any approved supervisor without access to the Dexcom users' current levels. Testing from earlier prototypes focusing on the band's accuracy, visibility, and ability to withstand drops all yielded successful results in accordance with the outlined client specifications [Appendix A]. The accuracy test was reprised with the updated device and still produced a linear slope of blood sugar as presented by the Dexcom app vs received by the microcontroller, proving the functionality of the color-updating system. Visibility was tested from over 160 m, surpassing the client requirement of 50 m, a distance comparable to the average length of a playground, by over 300%. The final design resin watch face was able to withstand an MTS max compression load of 6380 N and passed the drop height test from 2.5 m, and the band is adjustable 12.5-17.5 cm [Appendix A]. The connectivity test had to be deferred last semester due to the inability to establish a Bluetooth connection between the microcontroller and mobile device. After significant breakthrough, the BLE to iOS connection was made, and connectivity testing went smoothly, being performed at the same time as visibility to produce a range of 161 m with no notable obstructions in the path. Activity and malfunction testing were added as additional tests this semester to prove physical device security and responsiveness, respectively. Jumping jacks caused the largest movement in band shift at 10% with all others, stationary jumping, running, and walking resulting in negligible changes to support adequate band security. Malfunction testing resulted in 100% accuracy as every

12-minute time increment signaled the white malfunction light to turn on. All tests combined achieved each specification given to the team by the clients at the beginning of the project.

In previous fabrication and testing of this device, each section had varying sources of error. Due to setbacks with last semester's proposed circuit configuration, the resin watch face was unable to house all electrical components for the December 2025 Poster Presentation. In the Spring semester, changes were made to begin shrinking down the size of the circuitry. As the hardware was powered via the USB-C microcontroller port previously, once the 3.7 V, 500 mAh lithium-ion battery was connected to the XIAO battery pads; unexpected compatibility issues also arose. The LED ring requires a voltage supply between 3.5-5V to function [Appendix K]. By the time the 3.7 V battery had powered the XIAO, there was not a constant 3.5 V supply reaching the LED through the 5VBUS pin. Under the conditions the device needed to withstand, even with the maximum capacity 3.7 V battery soldered to the microcontroller battery pads, the LED would never be able to light. After extensive research into alternative LED and battery options, the team pivoted to using a 5000 mAh, 5V portable battery that connects to the microcontroller through the USB-C port, surpassing the 3.7 V battery pad maximum. The portable charger was placed in an arm sleeve to stay secure on a user's body while powering the device.

On the band side, the tight-fitting slide in slots on the sides of the box used for the watch band connection were abrasive and caused mild band shredding with repeated use. After removing the enclosed battery, the box dimensions were decreased by a significant margin which alleviated the wear on the band.

The previous primary problem, the BLE connection between the microcontroller and the Flutter app has been established using the XIAO C6, BLE 5.0 and a fully functioning iOS app. Appendices F and G outline the software used to create the SugarSafe app that has now been replicated on a total of five devices. All soldering issues encountered in the first prototype have been addressed in subsequent models. The previous Soldered Electronics LED that had issues maintaining complete functionality because of cheap manufacturing was replaced with the NeoPixel Jewel Ring LED which offers increased durability and simplifies soldering. The original circuit included a 330 k Ω resistor and a 1000 F capacitor, both of which were removed from the final design due to redundancy. The implemented changes have accommodated remaining client specifications, streamlined process flow, and improved appearance and useability of the device.

Ethical considerations in the ultimate use of this device will be regulated under FDA Class II Medical Devices, as the necessary market specifications address safety concerns for a wearable data-using device [14]. ISO 15197:2013 outlines the required test strip accuracy needed for user safety, and IP54 enforces water and dust resistance to prevent electronic short-circuiting [31][32]. The main device implications are data transfer accuracy between the bracelet and user CGM data, malfunction detection, visibility of the LED from specified distances, and the connectivity range of the operating phone receiving Dexcom data with the bracelet [Appendix A]. These key sources of error have been examined and addressed by the testing protocols explained above.

Beyond these mechanical and regulatory requirements, the device also raises several ethical considerations centered on safety, privacy, and user well-being. Since the bracelet handles sensitive health information, strong data protection and clear control over who can access glucose readings are essential to safeguard patient privacy. Ensuring device accuracy is equally critical, as false alerts or missed warnings could result in inappropriate treatment decisions and potential medical harm. Additionally, since this device is intended for children, both informed consent from caregivers and age-appropriate assent from users must be prioritized [33]. Finally, considerations of accessibility and cost are important to prevent technology from widening health disparities, ensuring that the benefits of safer, more visible glucose monitoring are available to all families who need them.

During fabrication of the device, environmental concerns such as waste of materials, frequent malfunction and replacement, or incompatibility of parts were avoided to the best of the team's ability. Overall, many changes based on last semester's progress and further prototyping were made to finally achieve a fully functional device. The team competed at the ShaRx presentation on April 9th, 2026, and were awarded 1st place and a cash prize! In terms of real-world development to meet technical, clinical, and ethical standards, the primary challenge would be finding a battery with capabilities to run the LED while matching the standards of the microcontroller, receiving Dexcom collaborator access to simplify app updating, and increasing to IP 67 to cover full waterproofing.

Conclusion

The SugarSafe Band aims to improve how caregivers monitor the blood glucose status of young children with T1D by providing a clear, intuitive, and actionable visual indicator. Research and preliminary prototyping efforts identified a wrist-worn device as the most effective solution. The resulting design integrates a resin watch face, a silicone wristband, an LED-based alert mechanism, and a Seeed Studio XIAO microcontroller with Bluetooth Low Energy (BLE) capabilities. This microcontroller interfaces with a custom-developed mobile application to display and communicate real-time blood glucose values.

Component selection was guided by performance, durability, and user-centered considerations. The resin casing provides suitable protection for internal electronics; the silicone band ensures comfort and secure placement, and the ring LED offers a highly visible method for conveying glucose status efficiently.

Despite demonstrating functionality in initial fabrication and testing, several challenges came to light. Achieving a stable and reliable BLE connection between the Flutter-based mobile application and the microcontroller halted prototyping progress but was eventually overcome, leading to seamless communication and dependable alerts. The battery originally intended to power the hardware had compatibility issues due to the microcontroller pulling more voltage than expected. Extensive testing proved the visibility, malfunctioning, activity, accuracy, and connectivity to be more than sufficient in achieving the client specifications for the project, denoting a successful final device. Minor alterations will need to be made before the SugarSafe band can be placed on the market. Dexcom collaborator access would allow direct retrieval of user data, streamlining the service code within the app. Currently, the device has an IP 54 rating, covering small range splashes, but should be increased to IP 67 to achieve full waterproofing similar to the Apple Watch. Most importantly, the portable charger will be replaced with an enclosable battery to optimize capacity specifications and voltage.

References

- [1] American Diabetes Association, “Statistics about diabetes,” diabetes.org, 2023. <https://diabetes.org/about-diabetes/statistics/about-diabetes>
- [2] R. Whittemore, S. Jaser, A. Chao, M. Jang, and M. Grey, “Psychological Experience of Parents of Children With Type 1 Diabetes,” *The Diabetes Educator*, vol. 38, no. 4, pp. 562–579, May 2012, doi: <https://doi.org/10.1177/0145721712445216>.
- [3] G. Freckmann, “Basics and use of continuous glucose monitoring (CGM) in diabetes therapy,” *Journal of Laboratory Medicine*, vol. 0, no. 0, Feb. 2020, doi: <https://doi.org/10.1515/labmed-2019-0189>.
- [4] “Glowcose,” *Glowcose*, 2024. <https://glowcose.com/> [Accessed: Sep. 17, 2025].
- [5] “SugarPixel blood glucose pixel clock Review - Integrated Diabetes Services,” *Integrateddiabetes.com*, 2022. <https://integrateddiabetes.com/sugarpixel-blood-glucose-pixel-clock-review/?print=print> (accessed Oct. 01, 2025).
- [6] S. G. James, M. Elaine, Z. S. Abdallah, H. Emerson, and Aisling Ann O’Kane, “Integrating Technology into Self-Management Ecosystems: Young Adults with Type 1 Diabetes in the UK using Smartwatches,” pp. 1–20, Apr. 2025, doi: <https://doi.org/10.1145/3706598.3713247>.
- [7] M. Campbell-Thompson, T. Rodriguez-Calvo, and M. Battaglia, “Abnormalities of the Exocrine Pancreas in Type 1 Diabetes,” *Current Diabetes Reports*, vol. 15, no. 10, Aug. 2015, doi: <https://doi.org/10.1007/s11892-015-0653-y>.
- [8] D. Tomic, J. E. Shaw, and D. J. Magliano, “The burden and risks of emerging complications of diabetes mellitus,” *Nature Reviews Endocrinology*, vol. 18, no. 9, pp. 525–539, Sep. 2022, doi: [10.1038/s41574-022-00690-7](https://doi.org/10.1038/s41574-022-00690-7).

[9] Centers for Disease Control and Prevention, “Type 1 Diabetes,” *CDC*, May 15, 2024. <https://www.cdc.gov/diabetes/about/about-type-1-diabetes.html>

[10] Diabetes Research Connection, “42 Factors That Affect Blood Glucose,” Dec. 19, 2023. [Online]. Available: <https://diabetesresearchconnection.org/42-factors-affect-blood-glucose/>. Accessed: Feb. 23, 2026.

[11] Children’s Minnesota, “Age-Related Guidelines for Diabetes Responsibilities,” 2023.

[12] American Diabetes Association, “Safe at School State Laws,” [Online]. Available: <https://diabetes.org/advocacy/safe-at-school-state-laws>. Accessed: Feb. 23, 2026.

[13] The Jewelry Vine, “Child bracelet size Chart by Age & length| Bangle Size Chart,” The Jewelry Vine, Oct. 27, 2024. <https://www.thejewelryvine.com/bracelet-size-chart/>

[14] S. K. Garg and H. K. Akturk, “A New Era in Continuous Glucose Monitoring: Food and Drug Administration Creates a New Category of Factory-Calibrated Nonadjunctive, Interoperable Class II Medical Devices,” *Diabetes Technology & Therapeutics*, vol. 20, no. 6, pp. 391–394, Jun. 2018, doi: <https://doi.org/10.1089/dia.2018.0142>.

[15] D. Greaney, “Exploring Waterproof Ratings: IP54, IP64, IP65, and IP67,” *Ledlightexpert.com*, Jun. 20, 2023. <https://www.ledlightexpert.com/waterproof-ip-rating?srsltid=AfmBOoqlF9uPNfmQMAFAKaD1VpC3POvxIHfOfQorsXY1-xBURPGT08Cm> (accessed Oct. 02, 2025).

[16] Guido Freckmann, A. Baumstark, and S. Pleus, “Do the New FDA Guidance Documents Help Improving Performance of Blood Glucose Monitoring Systems Compared With ISO 15197?,” *Journal of Diabetes Science and Technology*, vol. 11, no. 6, pp. 1240–1246, Jun. 2017, doi: <https://doi.org/10.1177/1932296817713220>.

[17] “Polyjoy Silicone Replacement Watch Band,” Amazon, accessed Oct. 8, 2025. [Online]. Available: <https://www.amazon.com/Polyjoy-Silicone-Replacement-Compatible-Suitable/dp/B0B28PBHY9>

[18] Seeed studio Xiao esp32 comparison: ESP32-S3, ESP32-C3, and esp32-C6 explained, <https://www.seeedstudio.com/blog/2026/01/14/xiao-esp32-s3-c3-c6-comparison/> (accessed Jan. 29, 2026).

[19] Noman, “WiFi vs Bluetooth: Understanding Power and Bandwidth Use,” Archer IT Solutions, Jan. 11, 2026. [Online]. Available: <https://www.archer-its.com/wifi-vs-bluetooth-which-uses-more-power-and-bandwidth/>. [Accessed: Feb. 9, 2026].

[20] BlueIOT (Beijing) Technology Co., Ltd., “How Far Can BLE Really Transmit? Indoor vs Outdoor Range,” 2025. [Online]. Available: <https://www.blueiot.com/blog/how-far-can-ble-transmit.html>. [Accessed: Feb. 9, 2026].

[21] Micro Center, “Wi-Fi 5 vs Wi-Fi 6,” 2025. [Online]. Available: <https://www.microcenter.com/site/mc-news/article/wifi-5-vs-wifi-6.aspx>. [Accessed: Feb. 9, 2026].

[22] K. Oliynyk, “Bluetooth vs WiFi for IoT Projects: Which is Better?,” WebbyLab, Mar. 25, 2025. [Online]. Available: <https://webbylab.com/blog/bluetooth-vs-wifi-for-iot-project/>. [Accessed: Feb. 9, 2026].

[23] World Population Review, “Internet Users by Country 2026,” 2026. [Online]. Available: <https://worldpopulationreview.com/country-rankings/internet-users-by-country>. [Accessed: Feb. 9, 2026].

[24] J. Howarth, “How Many People Own Smartphones? (2025–2029),” Exploding Topics, Jan. 12, 2026. [Online]. Available: (website URL). [Accessed: Feb. 9, 2026].

[25] M. Afaneh, “Bluetooth LE for Wi-Fi Onboarding and IoT Provisioning,” Novel Bits, Feb. 11, 2026. [Online]. Available: <https://novelbits.io/ble-wifi-onboarding-provisioning/>. [Accessed: Feb. 9, 2026].

[26] B. Marnat, “BLE or Wi-Fi: What You Need to Know,” ELA Innovation, Sep. 8, 2025. [Online]. Available: <https://elainnovation.com/en/ble-vs-wi-fi-what-you-need-to-know/>. [Accessed: Feb. 9, 2026].

[27] “Pydexcom: Python API to Interact with Dexcom Share API” PyPI, Oct. 28, 2024. <https://pypi.org/project/pydexcom/>

[28] T. Hotes, “Polymers in Medical Devices: Resins shaping modern healthcare,” Polymer Resins, Feb. 26, 2025. <https://prlresins.com/polymer-resins-in-medical-devices/>

[29] “3D printer cost calculator,” Grainger Engineering Design Innovation Lab. <https://making.engr.wisc.edu/3dprint-cost/>

[30] “Why Silicone is Safe for Skin,” Revive, Nov. 27, 2019. https://userevive.com/blogs/blog/why-silicone-is-safe-for-skin?srsltid=AfmBOoqeD_XP7hVuk5bVjoiwm7TzMmk_iu61xJmnXDcqYIa7MdMTP4H

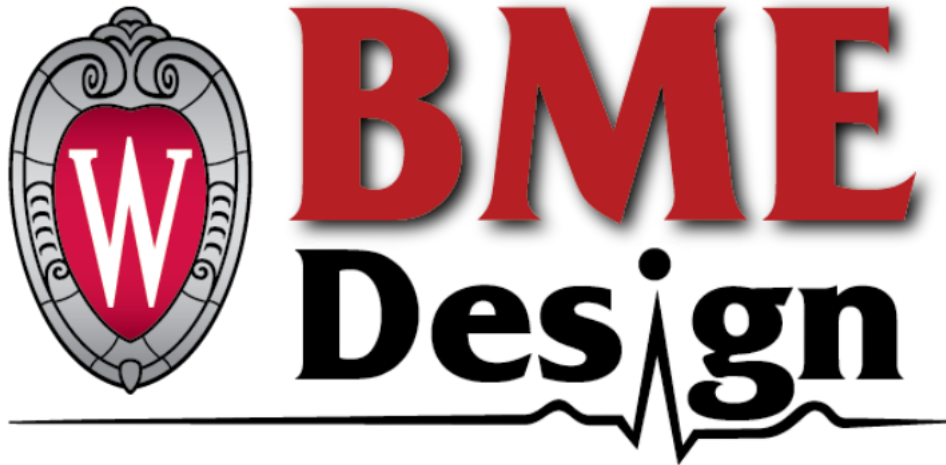
[31] D. Greaney, “Exploring Waterproof Ratings: IP54, IP64, IP65, and IP67,” Ledlightexpert.com, Jun. 20, 2023. <https://www.ledlightexpert.com/waterproof-ip-rating?srsltid=AfmBOoqlF9uPNfmQMAFAKaD1VpC3POvxIHfOfQorsXY1-xBURPGT08Cm> (accessed Oct. 02, 2025).

[32] Guido Freckmann, A. Baumstark, and S. Pleus, “Do the New FDA Guidance Documents Help Improving Performance of Blood Glucose Monitoring Systems Compared With ISO 15197?,” Journal of Diabetes Science and Technology, vol. 11, no. 6, pp. 1240–1246, Jun. 2017, doi: <https://doi.org/10.1177/1932296817713220>.

[33] L. Hanna, K. Ridsen, and K. J. Alexander, "Guidelines for usability testing with children," *interactions*, vol. 4, no. 5, pp. 9–14, Sept.–Oct. 1997.

Appendix

Appendix A: Product Design Specifications



Product Design Specifications

Wearable Glucose Alerting System

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February 5, 2026

BME 301

Function:

Understanding the needs of a child with Type 1 Diabetes (T1D) can be stressful and confusing for caregivers. The goal of the Wearable Glucose Alerting System is to provide a visible, actionable, and intuitive signal to help streamline the process of maintaining a healthy blood glucose level in a child with T1D. Pulling from the child's existing Dexcom-brand Continuous Glucose Monitor (CGM), the device will display a unique range of colors to indicate statuses of hyperglycemia (high blood sugar), hypoglycemia (low blood sugar), or normal levels [1]. The alerting system must be unambiguous, ensuring caregivers can respond confidently and appropriately. Additionally, the device will be worn on the child's wrist and must not impede the activity demands of daily life.

Client Requirements:

- Develop a device capable of displaying the status of blood glucose to anyone supervising a child with diabetes.
- Device should display up-to-date readings with a time delay no greater than 5 minutes.
- The signal must be clearly visible and distinguishable from 50 m.
- The device should be designed for a secure and comfortable fit around a child's wrist, encouraging consistent use while minimizing interference with daily activities.
- A visual indicator must be included on the device to signal when glucose readings are unavailable or when a malfunction is detected.

- The bracelet should be adjustable to accommodate wrist sizes from 12.5-17.5 cm [2].
- The alerting system must be compatible with a Dexcom CGM device.
- A rechargeable or replaceable battery system must power the device.
- Wireless connection to the device will be controlled through an associated mobile app.
- The device must maintain a Wi-Fi connection within 50 m of a connected cellular device.

Design Requirements:

1. Physical and Operational Characteristics:

a. Performance requirements:

The prototype will display a visible color signal corresponding to predetermined blood glucose ranges received from the child's Dexcom CGM. While specific ranges are adjustable, default settings are programmed as follows:

- <55: Red
- 56-65: Orange
- 66-80: Yellow
- 81-139: Green
- 140-200: Blue
- >201: Purple

The light will be powered by an internal rechargeable battery, allowing for continuous use over the course of 10 hours.

b. Safety:

The device must maintain a continuous visual signal at all times during operation. In the event of a system failure or loss of connectivity, the device will emit a distinct signal, preventing the display of outdated information. The internal circuitry will be encased in a water-resistant, durable enclosure to protect components from external elements. This layer will also make the device easy to sanitize, promoting better hygiene for regular daily use.

c. Accuracy and Reliability:

The bracelet's live color signals should mirror readings from the child's CGM with a delay of no longer than 5 minutes. Received data as shown by the app must not differ from industry expectations of a CGM, having a mean absolute relative difference (MARD) of approximately 8.5% between blood glucose readings and CGM measurements [3]. The bracelet must also contain a visual indication in the event of a connectivity error.

d. Life in Service:

The final product should last between 3 to 5 years of regular use. This is consistent with the lifespan of marketed commercial fitness watches [4]. Operability will be determined by the device's ability to accurately display CGM readings for the duration of at least 10 hours of device use.

e. Shelf Life:

When not in use or during charging, the device should be stored in a cool, dry environment. This will mitigate opportunity for internal condensation, battery corrosion, or circuitry component malfunction due to elemental factors. Wear and tear from daily use must be minimal and not impede with the device's function.

f. Operating Environment:

The device should be designed to operate across a range of environmental conditions, including outdoor temperatures from $-20\text{ }^{\circ}\text{C}$ to $43\text{ }^{\circ}\text{C}$ [5]. It should feature an IP54 water-resistance rating and be sufficiently durable to withstand routine wear by an active child, including accidental drops from heights of up to 2.5 meters, comparable to typical playground equipment height [6][7].

g. Ergonomics:

The device must be designed to ensure user safety and comfort during prolonged use. All materials in contact with the skin should be biocompatible and suitable for continuous wear, with no risk of irritation or adverse skin reactions. Electronic components and the battery must be fully enclosed to prevent exposure

to chemical or physical hazards. Additionally, the device should maintain a safe operating temperature, not exceeding 35 °C, to prevent discomfort or potential skin injury [8].

h. Size:

The device should fit comfortably around a child's wrist and be easily adjustable to accommodate growth over time. The device should be suitable for children aged 5 to 17, with wrist circumferences ranging from 12.5 to 17.5 cm [2][9]. The watch face should measure less than 35 mm in both length and width and less than 20 mm in height to ensure a comfortable fit on a child's wrist [2][9]. Additionally, the device should sit as flush to the skin as possible to minimize snagging on clothing or other materials and to avoid interfering with daily activities.

i. Weight:

The weight of the device should not interfere with normal use of the wearer's hand or arm. The device should weigh less than 58 g, in line with commercially available fitness watches, with consideration given to the fact that many watches designed for women and children weigh approximately 32 g [10].

j. Materials:

The device should be comfortable for extended wear. The wristband should be constructed from a durable, flexible, and water-resistant material that avoids common skin allergens. Many commercially available fitness watch bands use materials such as silicone, polyester, or nylon [4]. The enclosure for the alerting system should be made from material that protects internal electronic components from human exposure while providing water resistance. All materials should be easy to clean and sanitize after prolonged usage by a child.

k. Aesthetics, Appearance, and Finish:

The device should use light-based color cues to indicate different blood glucose states, including hypoglycemia, hyperglycemia, and anticipated rapid

changes in blood glucose levels [1]. The device should have a smooth, finished surface with no sharp edges that could pose a safety risk.

2. Production Characteristics:

a. Quantity:

Only one functioning device is necessary per diabetic child. The team will produce one product for presentation at the ShaRx tank competition.

b. Target Product Cost:

The target product cost for the device and all necessary materials should stay under a total of \$400 per the client's budget. Currently, \$100.11 has been used from the budget in the first semester. Market prices for the device will be determined by the pharmacy representatives upon presentation in the spring of 2026. This price should be comparable to competing glucose alerting systems like *Glowcose* at \$60 [11].

3. Miscellaneous:

a. Standards and Specifications:

As a form of a self-monitoring blood-glucose device, the CGM bracelet falls into the Food and Drug Administration Class II integrated CGM (iCGM) category [12]. This class of medical devices must abide by the necessary guidelines to achieve 510(k) approval [12]. A mandatory shutoff is a requirement for these devices after the approved time-in-range (TIR) [12]. If devices in Class II do not achieve 510(k) approval, they will be forced to go through a longer process through pre-market approval submissions for Class III medical devices [13].

An IP water rating also must be enforced to cover the water-resistant aspect required by the client. IP54 will meet the needs of this product as this indicates any electrical exposure must be protected from water and dust [6].

Blood-glucose monitoring systems also have their own International Standard (ISO) that sets performance and quality criteria for the self-testing used by those with diabetes [13]. The current version is ISO 15197:2013 and contains requirements directed

at both health care professionals and patient users [13]. The standard specifies glucose concentration categories and percentages to be used in testing for an accurate distribution of high to low values. ISO 15197:2013 references four standards that cover measurement procedure, stemming from ISO 175119 [13]. According to 15197, each glucose test strip must achieve 95% accuracy when tested by the user without prior training or assistance [14]. The 2013 version added extensive testing procedures for user performance evaluation, still in specifications of the previously stated accuracy percentage.

b. Customer:

The device will be worn by a child for prolonged periods of time and should not cause any discomfort. The light should be visible to a caregiver from 50 meters in clear conditions to reflect typical playground environments [15].

c. Patient-Related Concerns:

The Wearable Glucose Alerting System should provide visual alerts with an accuracy of MARD of 8.5% to measured blood glucose readings [3]. The device aims to reduce stress and should not be a burden to wear or adjust. The team must ensure that the data taken from the CGM is safeguarded and maintains the same levels of confidentiality provided by CGM companies.

d. Competition:

An existing device that uses CGM data mapped to a color-coded light source is the Glowcose light. This device connects to a CGM and displays a color associated with blood glucose readings: red to yellow for hypoglycemia, green for numbers in range, and blue to purple for hyperglycemia. It requires a wall connection and is not portable or wearable, decreasing patient ease of use [10]. Another similar product that exists is the Apple Watch, which can be used by diabetics to display their blood glucose directly to their wrists via CGM readings [16]. However, it does not provide a signal visible to others and is more expensive than many alternatives. A third product, the Sugar Pixel, receives data from a CGM to show real-time glucose readings and trends using a clock-like display. It also provides alerting systems that are useful for nighttime alerts. This device is also not fully portable and requires a strong Wi-Fi connection for use [17].

References:

[1] Mayo Clinic, “Type 1 diabetes in children - Diagnosis and treatment - Mayo Clinic,” *Mayoclinic.org*, 2023. <https://www.mayoclinic.org/diseases-conditions/type-1-diabetes-in-children/diagnosis-treatment/drc-20355312>

[2] The Jewelry Vine, “Child bracelet size Chart by Age & length| Bangle Size Chart,” *The Jewelry Vine*, Oct. 27, 2024. <https://www.thejewelryvine.com/bracelet-size-chart/>

[3] “Most accurate glucose monitor for diabetes,” Dexcom, <https://www.dexcom.com/accuracy> (accessed Sep. 14, 2025).

[4] “Apple Watch Lifespan: How Many Years Will Your Device Last? - SimplyMac,” *SimplyMac*, Jul. 10, 2024. [Online]. Available: <https://www.simplymac.com/apple-watch/apple-watch-lifespan>. [Accessed: Sep. 17, 2025].

[5] “United States Climate, Weather By Month, Average Temperature - Weather Spark,” *Weather Spark*. [Online]. Available: https://weatherspark.com/countries/US#google_vignette. [Accessed: Sep. 15, 2025].

[6] D. Greaney, “Exploring Waterproof Ratings: IP54, IP64, IP65, and IP67,” *Ledlightexpert.com*, Jun. 20, 2023. <https://www.ledlightexpert.com/waterproof-ip-rating?srsltid=AfmBOoqlF9uPNfmQMAFAKaD1VpC3POvxIHfOfQorsXY1-xBURPGT08Cm> (accessed Oct. 02, 2025).

[7] “What Is Critical Fall Height? - Zeager,” *Zeager*, Jun. 21, 2021. <https://zeager.com/what-is-critical-fall-height/> (accessed Sep. 18, 2025).

[8] “Keep Apple Watch within acceptable operating temperatures - Apple Support,” *Apple Support*, Mar. 18, 2025. <https://support.apple.com/en-us/108766>

[9] A. Öztürk, B. Çiçek, M. M. Mazıcıoğlu, G. Zararsız, and S. Kurtoğlu, “Wrist Circumference and Frame Size Percentiles in 6-17-Year-Old Turkish Children and Adolescents in Kayseri,” *Journal of Clinical Research in Pediatric Endocrinology*, pp. 329–336, Dec. 2017, doi: <https://doi.org/10.4274/jcrpe.4265>

[10] H. Zhu, M. Zhou, and B. Wu, “Comfort of smartwatch wearing: A comparative study of different hand types,” *Wearable Technology*, vol. 5, no. 1, p. 2963, Dec. 2024, doi: <https://doi.org/10.54517/wt2963>.

[11] “Glowcose,” *Glowcose*, 2024. <https://glowcose.com/> [Accessed: Sep. 17, 2025].

[12] S. K. Garg and H. K. Akturk, “A New Era in Continuous Glucose Monitoring: Food and Drug Administration Creates a New Category of Factory-Calibrated Nonadjunctive, Interoperable Class II Medical Devices,” *Diabetes Technology & Therapeutics*, vol. 20, no. 6, pp. 391–394, Jun. 2018, doi: <https://doi.org/10.1089/dia.2018.0142>.

[13] Guido Freckmann, A. Baumstark, and S. Pleus, “Do the New FDA Guidance Documents Help Improving Performance of Blood Glucose Monitoring Systems Compared With ISO 15197?,” *Journal of Diabetes Science and Technology*, vol. 11, no. 6, pp. 1240–1246, Jun. 2017, doi: <https://doi.org/10.1177/1932296817713220>.

[14] G. Freckmann, C. Schmid, A. Baumstark, M. Rutschmann, C. Haug, and L. Heinemann, “Analytical Performance Requirements for Systems for Self-Monitoring of Blood Glucose With Focus on System Accuracy,” *Journal of Diabetes Science and Technology*, vol. 9, no. 4, pp. 885–894, Apr. 2015, doi: <https://doi.org/10.1177/1932296815580160>.

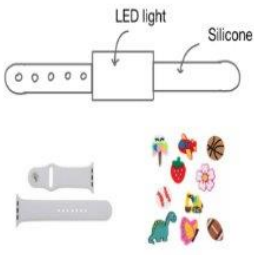
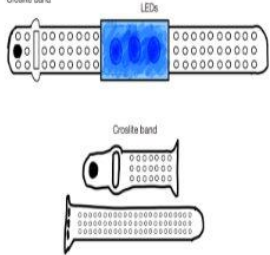
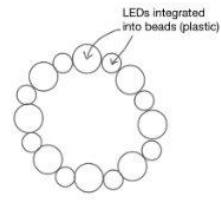
[15] KOMPAN, “Playground Sizes and Dimensions,” *KOMPAN*, 2025. [Online]. Available: <https://www.kompan.com/en/us/planning/playground-sizes-and-dimensions>. [Accessed: Sep. 17, 2025].

[15] S. G. James, M. Elaine, Z. S. Abdallah, H. Emerson, and Aisling Ann O'Kane, “Integrating Technology into Self-Management Ecosystems: Young Adults with Type 1 Diabetes in the UK using Smartwatches,” pp. 1–20, Apr. 2025, doi: <https://doi.org/10.1145/3706598.3713247>.

[16] “SugarPixel blood glucose pixel clock Review - Integrated Diabetes Services,” *Integrateddiabetes.com*, 2022. <https://integrateddiabetes.com/sugarpixel-blood-glucose-pixel-clock-review/?print=print> (accessed Oct. 01, 2025).

Appendix B: Material Design Considerations and Matrix

Table 1: Design Matrix of Band Materials

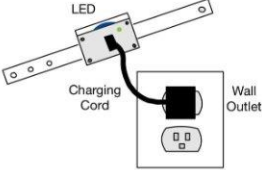
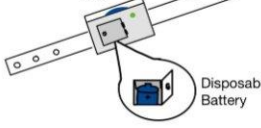
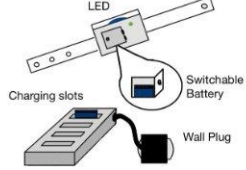
Designs	Design 1: Silicone band with LED light		Design 2: Croslite band with LEDs		Design 3: LED light with plastic beaded bracelet	
Criteria						
Safety & Ergonomics (25)	5/5	25	4/5	20	3/5	15
Adjustability (20)	5/5	20	4/5	16	3/5	12
Durability (20)	5/5	20	3/5	12	2/5	8
Accuracy (15)	5/5	15	4/5	12	3/5	9
Water Resistant (10)	4/5	8	3/5	6	2/5	4
Cost (10)	4/5	8	5/5	10	2/5	4
Total (100)	96		76		52	

For band of the device of silicone, Croslite, and plastic were considered as material options. Silicone is a highly stable synthetic polymer that is both flexible and durable. This design would include a silicone band and casing of the watch face. Croslite is a lightweight polymer material known for its use in Croc shoes, similar to silicone. This design would be a Croslite band and watch face casing. The plastic design has a bracelet made of light-up beads each in their own spherical clear plastic casing.

The silicone band significantly outperformed the other materials as it is flexible and chemically stable, durable against sweat, water, and UV damage, able to be translucent to light, and relatively cheap to buy and mold/fabricate.

Appendix C: Battery and Charging Design Considerations and Matrix

Table 1: Design Matrix of Battery and Charging

Designs	Design 1: Lithium-Ion with Recharging Cord		Design 2: Disposable Battery		Design 3: Switching Battery with Wall Charger	
Criteria						
Compatibility (20)	5/5	20	3/5	12	4/5	16
Safety (15)	3/5	9	4/5	12	5/5	15
Security (25)	5/5	25	2/5	10	3/5	15
Lifespan (20)	5/5	20	3/5	12	4/5	16
Cost (10)	3/5	6	1/5	2	4/5	8
Size & Weight (10)	4/5	8	2/5	4	3/5	6
Total (100)	88		52		76	

The battery and associated charging system varied by both battery type and internal vs external charging. The first design is a Lithium-ion battery permanently installed within the device and a charging cord inserted directly into the watch. Lithium-ion batteries are known for their long lifespan and high voltage per cell ratio. They do, however, have strict regulations for charging systems and require both constant current and constant voltage regulations during the charging process [1]. The second design is a removable disposable alkaline battery that would be replaced with a new battery periodically. This design includes a panel secured by a screw and no changing system. Alkaline batteries are ideal for slow-drain devices such as watches and have a high charge density, they are not rechargeable [2]. The final battery and charging system is a removable lithium-ion battery with a removable charging system. This allows batteries to be easily swapped out with a panel secured by a screw. The battery would be bulkier to allow it to be externally table.

The permanently installed lithium-ion battery was the clear best option for the battery and charging system. Since the battery is permanently installed it is easily integrated with other internal

electrical components and preventing children from having access to small parts and harmful chemicals that can cause harm [3]. Lithium-ion batteries also have a strong battery life, and the battery would be smaller than the alternatives as it does not need to be easily removable and externally stable. While this battery system risks overheating and can be more expensive to replace these effects can be mitigated with proper usage [1][4].

References:

[1] “Elevate Your Wearables With Advanced Wearable Device Battery,” *Ufine Battery [Official]*, 2025. <https://www.ufinebattery.com/applications/wearable-device-battery/> (accessed Oct. 06, 2025).

[2] A. Kiran, “A Study on the Application of Alkaline Batteries,” *Journal Of Applied Physics (IOSR-JAP) e*, vol. 14, no. 6, pp. 45–51, 2022, doi: <https://doi.org/10.9790/4861-1406014551>.

[3] “What to Do If Your Child Swallows or Ingests a Button Battery,” *Connecticut Children’s*, Dec. 15, 2023. <https://www.connecticutchildrens.org/growing-healthy/what-to-do-if-your-child-swallows-or-ingests-a-button-battery>

[4] D. Parsons, “The environmental impact of disposable versus re-chargeable batteries for consumer use,” *The International Journal of Life Cycle Assessment*, vol. 12, no. 3, pp. 197–203, Aug. 2006, doi: <https://doi.org/10.1065/lca2006.08.270>.

Appendix D: Proposed Final Design Drawings

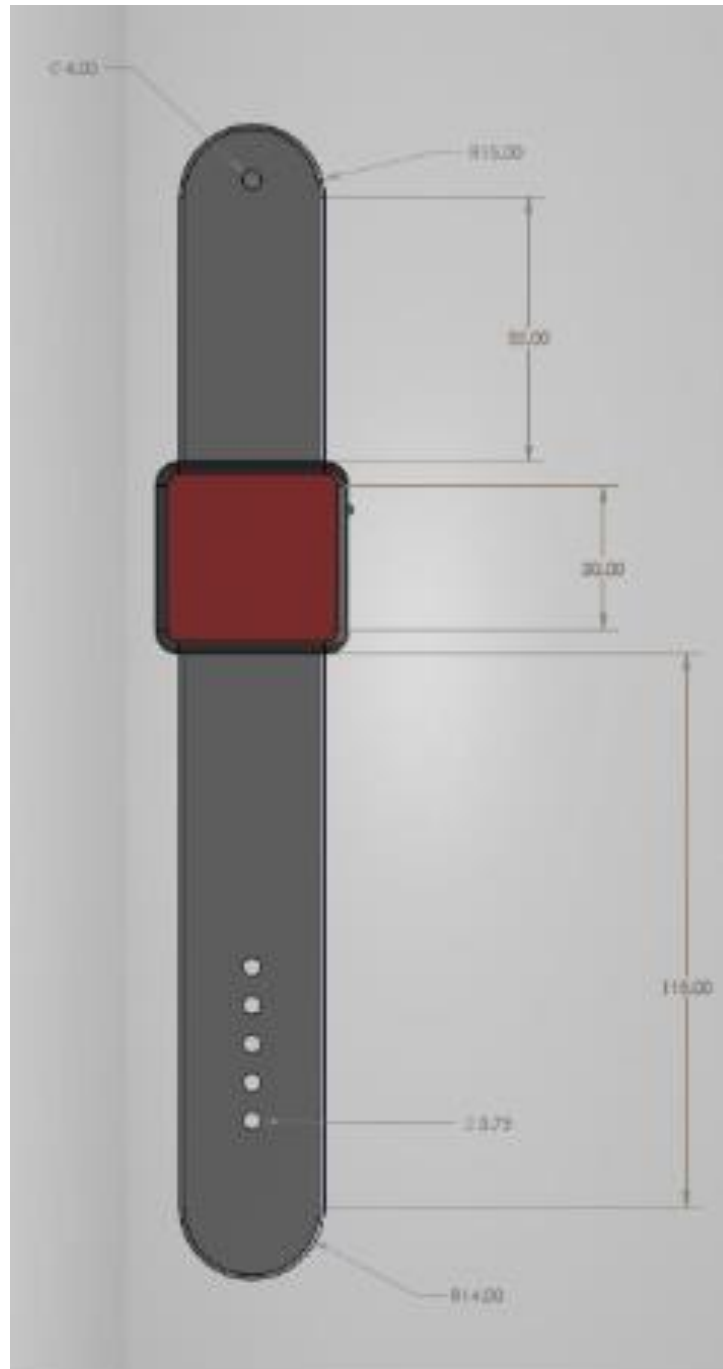


Figure 1: Top View of Proposed Final Design Drawings (All measurements in mm)

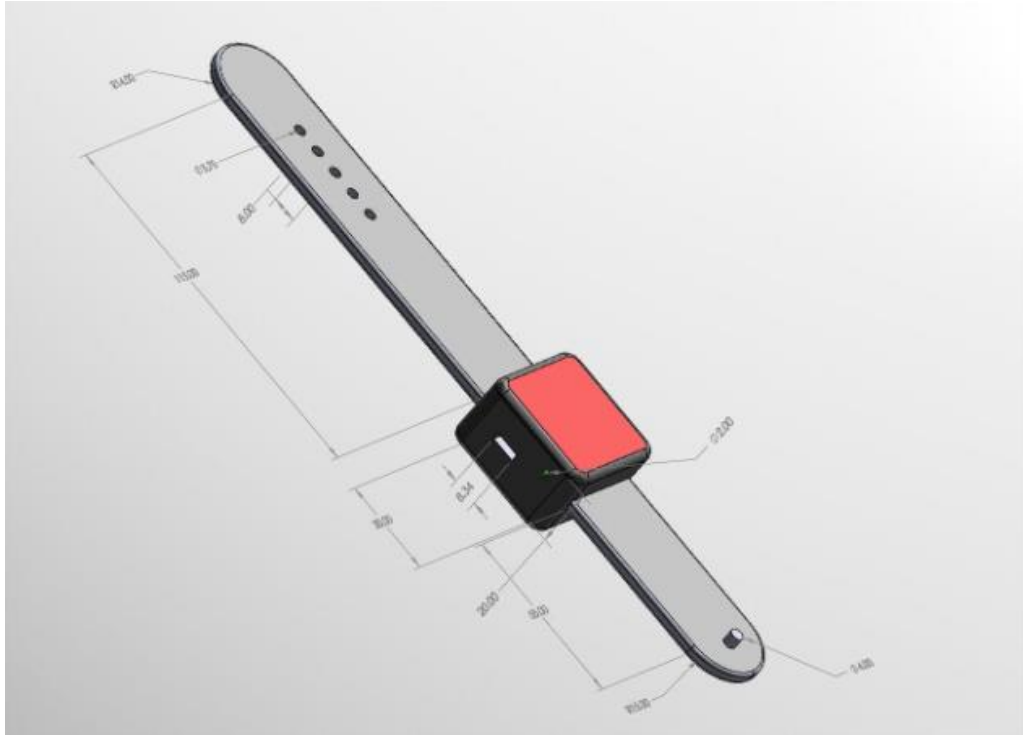


Figure 2: Isometric View of Proposed Final Design Drawing (all measurements in mm)

Appendix E: Final Design Drawings

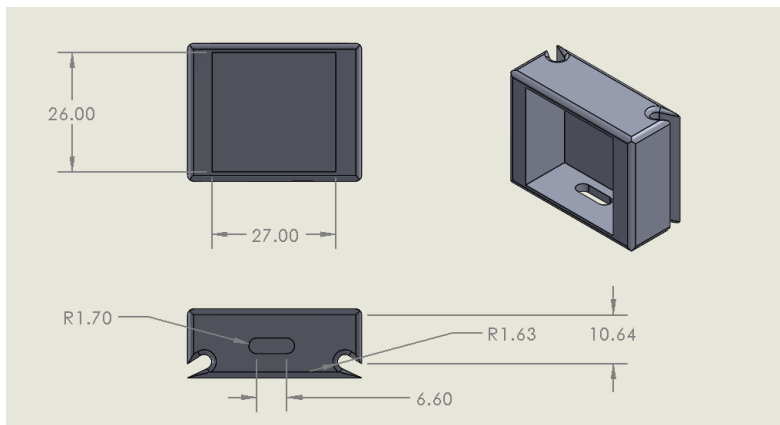


Figure 1: Black resin box CAD image with dimensions (all measurements in mm)

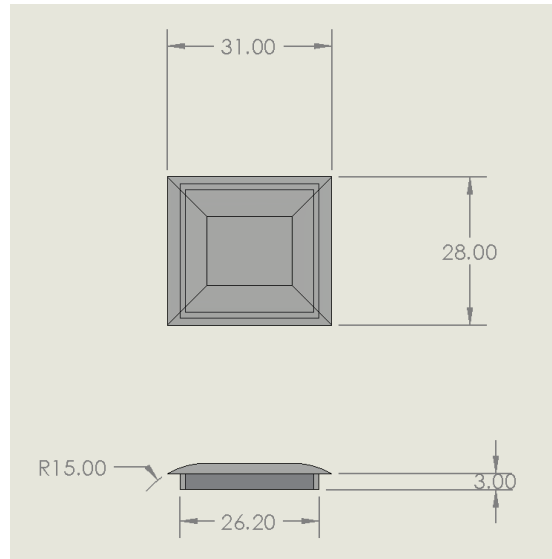


Figure 2: Clear resin lid CAD image with dimensions (all measurements in mm)

Appendix F: SugarSafe App Code GitHub Repository

GitHub Repository: https://github.com/cjbeckwith2-cyber/dexcom_project.git

Appendix G: Microcontroller Programming Code

```
#include <BLEDevice.h>
#include <BLEUtils.h>
#include <BLEServer.h>
#include <Adafruit_NeoPixel.h>

#define SERVICE_UUID "4fafc201-1fb5-459e-8fcc-c5c9c331914b"
#define CHARACTERISTIC_UUID "beb5483e-36e1-4688-b7f5-ea07361b26a8"

#define PIN D3
#define NUMPIXELS 7

#define TIMEOUT_MS 720000 // 12 minutes

Adafruit_NeoPixel jewel(NUMPIXELS, PIN, NEO_GRB + NEO_KHZ800);
BLECharacteristic *pCharacteristic;

bool deviceConnected = false;
unsigned long lastDataTime = 0;
bool timeoutActive = false;

// — Helper functions

void setAllPixels(uint32_t color) {
  for (int i = 0; i < NUMPIXELS; i++) {
```

```

jewel.setPixelColor(i, color);
}
jewel.show();
}

uint32_t getColorForValue(int val) {
if (val < 55) return jewel.Color(255, 0, 0);
else if (val < 65) return jewel.Color(255, 65, 0);
else if (val < 80) return jewel.Color(255, 255, 0);
else if (val < 139) return jewel.Color(0, 255, 0);
else if (val < 200) return jewel.Color(0, 0, 255);
else return jewel.Color(180, 0, 180);
}

// color index helper for test mode
uint32_t getColorFromIndex(int idx) {
switch (idx) {
case 0: return jewel.Color(255, 0, 0); // Red
case 1: return jewel.Color(255, 65, 0); // Orange
case 2: return jewel.Color(255, 255, 0); // Yellow
case 3: return jewel.Color(0, 255, 0); // Green
case 4: return jewel.Color(0, 0, 255); // Blue
case 5: return jewel.Color(180, 0, 180); // Purple
case 6: return jewel.Color(255, 255, 255); // White
default: return jewel.Color(0, 0, 0); // Off
}
}

// — White Pulse (error light signal)

void pulseWhite() {
static int brightness = 0;
static int fadeAmount = 5;

brightness += fadeAmount;

if (brightness <= 0 || brightness >= 230) {
fadeAmount = -fadeAmount;
}

uint32_t color = jewel.Color(brightness, brightness, brightness);
setAllPixels(color);

delay(30);
}

// — BLE Characteristic Callback

class MyCallbacks : public BLECharacteristicCallbacks {

```

```

void onWrite(BLECharacteristic *pCharacteristic) {
String value = pCharacteristic->getValue().c_str();
if (value.length() == 0) return;

// Reset timeout timer
lastDataTime = millis();
timeoutActive = false;

// — TEST COMMAND (T0–T6) —————
if (value[0] == 'T' && value.length() > 1) {
int idx = value[1] - '0';

Serial.print("Test color index: ");
Serial.println(idx);

setAllPixels(getColorFromIndex(idx));
return; // stop here
}

// — BRIGHTNESS COMMAND —————
if (value.startsWith("B")) {
int brightness = value.substring(1).toInt();
int mapped = map(brightness, 0, 100, 0, 255);
jewel.setBrightness(mapped);
jewel.show();

Serial.print("Brightness set to: ");
Serial.print(brightness);
Serial.println("%");
return;
}

// — GLUCOSE VALUE —————
int glucose = value.toInt();
Serial.print("Glucose received: ");
Serial.println(glucose);
setAllPixels(getColorForValue(glucose));
}
};

// — BLE Server Callbacks

class MyServerCallbacks : public BLEServerCallbacks {
void onConnect(BLEServer* pServer) {
deviceConnected = true;
Serial.println("Client connected");
}

void onDisconnect(BLEServer* pServer) {

```

```

deviceConnected = false;
Serial.println("Client disconnected");

BLEDevice::startAdvertising();
Serial.println("Advertising restarted");
}
};

// — Setup code

void setup() {
Serial.begin(115200);

jewel.begin();
jewel.setBrightness(100);
jewel.show();

lastDataTime = millis();

BLEDevice::init("XIAO_ESP32C6");

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

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

pCharacteristic = pService->createCharacteristic(
CHARACTERISTIC_UUID,
BLECharacteristic::PROPERTY_READ |
BLECharacteristic::PROPERTY_WRITE
);

pCharacteristic->setCallbacks(new MyCallbacks());
pCharacteristic->setValue("Waiting...");

pService->start();

BLEAdvertising *pAdvertising = BLEDevice::getAdvertising();
pAdvertising->addServiceUUID(SERVICE_UUID);
pAdvertising->setScanResponse(true);
pAdvertising->setMinPreferred(0x06);
pAdvertising->setMinPreferred(0x12);

BLEDevice::startAdvertising();

Serial.println("BLE ready — waiting for glucose values.");
}

// — Loop

```

```

void loop() {
  unsigned long currentTime = millis();

  if ((currentTime - lastDataTime) > TIMEOUT_MS) {
    timeoutActive = true;
  }

  if (timeoutActive) {
    pulseWhite();
  } else {
    delay(100);
  }
}

```

Appendix H: Accuracy Testing Data

Table 1: Accuracy Data and Color Mapping

Time	PyDexcom Reading	Microcontroller reading	Expected color	Actual color
9:20	160	160	Blue	Blue
9:25	158	158	Blue	Blue
9:30	154	154	Blue	Blue
9:36	146	146	Blue	Blue
9:41	149	149	Blue	Blue
9:45	157	157	Blue	Blue
9:50	165	165	Blue	Blue
9:55	175	175	Blue	Blue
10:01	182	182	Blue	Blue
10:08	190	190	Blue	Blue
10:09	200	200	Purple	Purple
10:16	208	208	Purple	Purple
10:19	214	214	Purple	Purple
10:26	220	220	Purple	Purple
4:19	74	74	Yellow	Yellow
4:27	62	62	Orange	Orange
4:32	62	62	Orange	Orange
4:39	84	84	Green	Green

4:44	98	98	Green	Green
4:50	108	108	Green	Green
4:58	122	122	Green	Green
5:03	117	117	Green	Green
5:08	119	119	Green	Green
5:16	148	148	Blue	Blue
5:22	166	166	Blue	Blue
8:42	223	223	Purple	Purple
8:48	214	214	Purple	Purple
8:54	205	205	Purple	Purple
9:02	197	197	Blue	Blue
1:32	150	150	Blue	Blue
1:33	151	151	Blue	Blue
1:38	158	158	Blue	Blue
1:45	142	142	Blue	Blue
1:50	138	138	Green	Green
2:13	66	66	Yellow	Yellow
2:18	69	69	Yellow	Yellow
2:23	68	68	Yellow	Yellow
2:29	72	72	Yellow	Yellow
2:35	74	74	Yellow	Yellow
2:42	82	82	Green	Green
2:47	81	81	Green	Green
2:52	84	84	Green	Green
5:00	144	144	Blue	Blue
5:05	151	151	Blue	Blue
5:10	155	155	Blue	Blue
5:15	157	157	Blue	Blue
5:20	159	159	Blue	Blue
5:25	162	162	Blue	Blue
5:30	163	163	Blue	Blue
5:35	165	165	Blue	Blue
5:40	171	171	Blue	Blue

5:45	163	163	Blue	Blue
5:50	168	168	Blue	Blue
5:55	165	165	Blue	Blue
6:00	220	220	Purple	Purple
6:05	235	235	Purple	Purple
6:10	229	229	Purple	Purple
6:15	240	240	Purple	Purple
6:33	199	199	Blue	Blue
6:38	189	189	Blue	Blue
11:12	100	100	Green	Green
11:17	108	108	Green	Green
11:23	112	112	Green	Green
11:28	118	118	Green	Green
11:35	117	117	Green	Green
11:42	116	116	Green	Green
11:47	121	121	Green	Green
11:55	124	124	Green	Green
12:00	143	143	Blue	Blue
12:05	148	148	Blue	Blue
12:10	147	147	Blue	Blue
12:15	149	149	Blue	Blue
12:20	139	139	Green	Green
12:25	138	138	Green	Green
12:30	136	136	Green	Green
12:35	129	129	Green	Green
8:22	62	62	Orange	Orange
8:27	59	59	Orange	Orange
8:36	55	55	Red	Red
1:30	89	89	Green	Green
1:35	92	92	Green	Green
1:40	95	95	Green	Green

Appendix I: Connectivity Testing Data

Table 1: Connectivity Testing

Distance (meters)	Pass/fail trial 1	Pass/fail trial 2	Pass/fail trial 3	Delay?	Delay time (s)	Percent of Successful Tests
0	Pass	Pass	Pass	No	N/A	100%
10	Pass	Pass	Pass	No	N/A	100%
20	Pass	Pass	Pass	No	N/A	100%
30	Pass	Pass	Pass	No	N/A	100%
40	Pass	Pass	Pass	No	N/A	100%
50	Pass	Pass	Pass	No	N/A	100%
60	Pass	Pass	Pass	No	N/A	100%
70	Pass	Pass	Pass	No	N/A	100%
80	Pass	Pass	Pass	No	N/A	100%
90	Pass	Pass	Pass	No	N/A	100%
100	Pass	Pass	Pass	No	N/A	100%
110	Pass	Pass	Pass	No	N/A	100%
120	Pass	Pass	Pass	No	N/A	100%
130	Pass	Pass	Pass	No	N/A	100%
140	Pass	Pass	Pass	No	N/A	100%
150	Pass	Pass	Pass	No	N/A	100%

Appendix J: Activity Testing Data

Table 1: Activity Type and Average % of Shift

Activity	% Shift/Loosen
Walking	0%
Running	0.67%
Jumping (stationary)	6%
Jumping Jacks	10.33%

Table 2: Trial Breakdown of Each Activity Modality

Activity	Trial 1	Trial 2	Trial 3
Walking	0%	0%	0%
Running	0%	2%	0%
Jumping (stationary)	5%	6%	7%
Jumping Jacks	10%	11%	10%

Appendix K: Expense Table

Table 1: Expense Table from this Semester

Category 1 - Appearance										
Item	Description	Manufacturer	Mft Pt#	Vendor	HS Code	Date	Qty	Cost Each	Total	Link
PLA Box Prototype	Box to fit new electronic components	UW Makerspace	N/A	UW Makerspace	N/A	3/11/2026	1	0.27	0.27	N/A
Resin Box Prototype	Resized box for electrical housing	UW Makerspace	N/A	UW Makerspace	N/A	3/17/2026	1	5.07	5.07	N/A
Watch Band	Apple watch compatible silicone band	PolyJoy	D BQJBZ001Q	Amazon	N/A	3/13/2026	2	4.99	9.99	Link
PLA Box Prototype	Testing new dimensions	UW Makerspace	N/A	UW Makerspace	N/A	3/23/2026	1	0.27	0.27	N/A
Resin Box Prototype	Testing with new circuit components	UW Makerspace	N/A	UW Makerspace	N/A	3/24/2026	1	2.36	2.36	N/A
Resin Box Prototype	Updating power cord hole size	UW Makerspace	N/A	UW Makerspace	N/A	4/12/2026	1	2.36	3.57	N/A
Resin Box Prototype	Smaller size (no internal battery)	UW Makerspace	N/A	UW Makerspace	N/A	4/15/2026	1	2.36	3.30	N/A
Sports Arm Band	Holder for portable charger	Y UNYILAN	N/A	Amazon	N/A	4/19/2026	2	7.99	15.98	arm band

Resin Box Final	Final Prototype for poster presentation	UW Makerspace	N/A	UW Makerspace	N/A	4/20/2026	2	2.46	4.92	N/a
Resin Lid Final	Final Prototype for poster presentation	UW Makerspace	N/A	UW Makerspace	N/A	4/20/2026	2	1.71	3.42	N/a
Category 2 - Internal/Electronic Components										
Item	Description	Manufacturer	Mft Pt#	Vendor	HS Code	Date	QTY	Cost Each	Total	Link
SeedStudio XIAOESP 32-C6 (3PCS)	Microcontroller for internal bracelet circuitry	SeedStudio	102010574	SeedStudio	8543709990	2/4/2026	1 (3 pack)	19.98	19.98	IAO C6 microcontroller (3 pack)
1 x NeoPixel Jewel - 7 x 5050 RGB LED with Integrated Drivers [ID: 2226]	LED light for bracelet	Adafruit Industries	2226	Adafruit Industries	N/A	2/4/2026	1	20.39	20.39	NeoPixel Jewel
1 x Lithium Ion Polymer Battery - 3.7v 500mAh	Battery for bracelet	Adafruit Industries	578	Adafruit Industries	N/A	2/4/2026	1	2.50	2.50	Lithium Ion Polymer Battery
1 x Lithium Ion Polymer Battery - 3.7v 500mAh	Battery for bracelet	Adafruit Industries	1578	Adafruit Industries	N/A	3/24/2026	1	7.95	7.95	Lithium Ion Polymer Battery
Adafruit Industries LLC LIPOLY BATTERY	Battery Forward Charger	Adafruit Industries	4410	Adafruit Industries	N/A	3/24/2026	1	5.95	5.95	Battery Charger

CHARGER W/USB C											
Pin Cable Male Header	Battery connecto r cable	Adafruit Industries	3814	Adafrui t Industr eis	N/A	3/24/20 26	2	0.75	1.5	header pin	
1 x NeoPixelJewel - 7 x 5050 RGB LED with Integrated Drivers[ID: 2226] =	LED light forDr. P's ownpers onalbrac elet	Adafruit Industries	2226	Adafru it Industr ies	N/A	4/15/20 26	1	23.84	23.84	NeoPixel Jewel	
VANYUST S22 Portable Charger, 5000 mAh	Power bank for charging batteries	VANYU ST	N/A	Amazo n	N/A	4/19/20 26	2	9.99	19.98	harger link	
USB-C to USB right angle charger 1 ft	Cord to connect battery to band	SUNGU Y	N/A	Amazo n	N/A	4/19/20 26	2	7.99	5.98	harging cord link	
								TOT AL:	168.8 7		