Wearable Glucose Alerting System

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Motivation and Problem Statement

Motivation

Caring for a child with Type 1 Diabetes (T1D) demands constant vigilance, yet caregivers often lack a simple, immediate way to understand when blood sugar levels require action.

Problem Statement

Parents and caregivers of children with T1D often struggle to quickly see and interpret glucose readings, leading to stress and delayed decisions. The Wearable Glucose Alerting System aims to solve this problem by providing a clear, visible signal that instantly shows when a child's blood sugar needs attention.

Background and Impact

Background

- T1D is an autoimmune disease where the body's immune system mistakenly attacks and destroys the insulin-producing beta cells in the pancreas [1]
- T1D affects **1.2 million children** in the United States [2]
- Currently, T1Ds use Continuous Glucose Monitors (CGM)s to keep track of their blood glucose levels

Competing Designs

- **Glowcose**
  - Connects to 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
  - Flaws: requires a wall connection and isn't portable or wearable
- **Sugar Pixel**
  - Receives data from CGM to show real-time glucose readings and trends via a clock-like display
  - Flaws: not fully portable and requires strong WIFI connection for use

Figure 1: Glowcose

Figure 2: Sugar Pixel

Design Criteria

- Display a color signal consistent with active glucose readings
- Maintain an accuracy of a mean absolute relative difference (MARD) of under 8.5% to measured blood glucose readings [3]
- Time delay of 5 minutes
- Compatible with a modern CGM device, Dexcom G7
- Rechargeable battery system with 12+ hours of charge
- Withstand a range of environmental conditions encountered by an active child:
  - Temperatures of –20 °C to 43°C [4]
  - Water-resistant with an IP rating of 54
  - Accidental drops from 2.5 meters [5]
- Comfortably fit around a child's wrist (Wrist sizes from 12.5-17.5 cm) [6]

Table 1: Blood glucose levels and their corresponding colors

Dangerously Low	<55
Very Low	56-65
Low	66-80
In Range	81-139
High	140-200
Dangerously High	>201

Final Design and Prototype

Software

- **Backend API:** PyDexcom hosted on BME SharedLab
  - Fetches most recent glucose reading via Dexcom's Share service
  - Data returned inside an HTML webpage
- **Flutter Application:** Frontend running on user's computer
  - Flutter logs into backend, downloads HTML, and extracts glucose value
  - Every 5 minutes, Flutter automatically sends latest glucose value to microcontroller via USB serial connection
- **Microcontroller Firmware:** Receives blood glucose value, updates LED to corresponding color

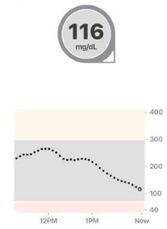

Figure 3: Dexcom Reading

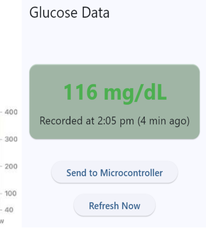

Figure 4: Flutter App Interface

Hardware

- Seeed Studio XIAO nRF52840 BLE Microcontroller operating at a 5 V max, driving LED load
- Level Shifter used to bring 5.5 V from computer to the allowable 5 V
- Soldered Electronics 4-Pin Rainbow LED in series with 220 Ω resistor on data line for signal protection
- Powered via USB-C through the 5VUSB microcontroller pin

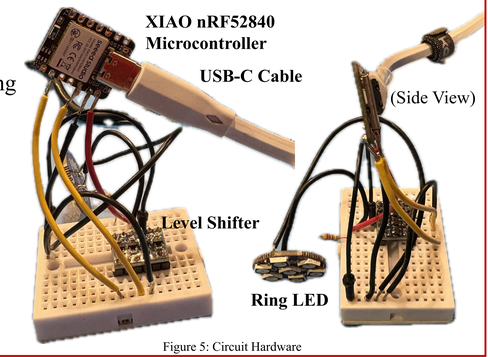

Figure 5: Circuit Hardware

Watch Face

- 3-D printed Resin case with a 26.2 x 37.7 mm interior
- Clear Resin snap-fit lid and USB-C charging opening
- Bilateral band connection sites compatible with on market smart watch bands

Figure 6: Watch Face and Band

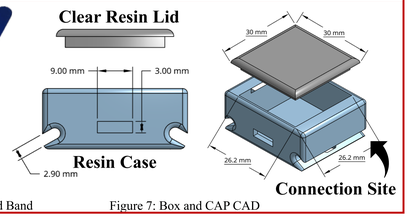

Figure 7: Box and CAP CAD

Circuit Testing

Method and Results

- Accuracy evaluated every 5 minutes over 2 hours
- Blood glucose levels from Dexcom were compared to the CGM values received by the microcontroller.
- Results confirm 100% accuracy with microcontroller updates and corresponding LED display color

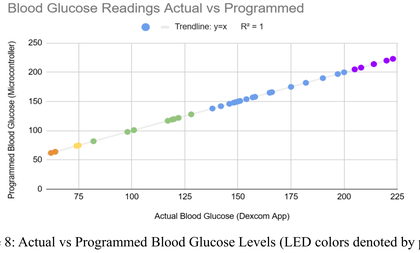

Figure 8: Actual vs Programmed Blood Glucose Levels (LED colors denoted by plot points)

- Pass/Fail Test for brightness level from 150ft was conducted and passed

Figure 9: Brightness

Box Testing

Methods and Results

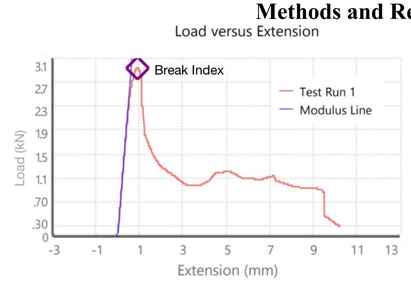

Figure 10: PETG Material

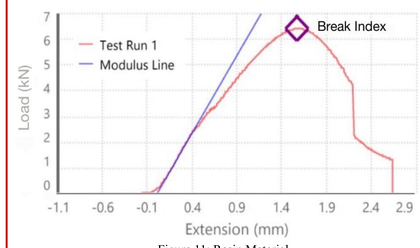

Figure 11: Resin Material

- MTS testing was used to test the final Resin box and lid, in addition to PETG boxes
- The Resin performed much better, almost doubling the compression max load capacity of PETG
- Both Resin and PETG exceeded our PDS standard for strength capacity
- Typical Max Load values were calculated using the area and compressive strengths for Resin (68 MPa) and PETG (35.03MPa) [7] [8].

Table 2: Stress and Force Results of MTS Testing

Material	Resin	PETG
Compressive Stress (MPa)	20.3	9.1
MTS Max Load (kN)	6.380	2.850
Typical Max Load (kN)	6.1	3.05

Discussion and Future Work

After fabrication and testing, many strengths and weaknesses of the device were evaluated. These changes will be made in the following semester prior to the April SharX presentation:

- Implement microcontroller with charging capabilities
- Revamp the circuit schematic
- Create and order a custom PCB
- Downsize both box and circuit components
- Make the app mobile for IOS and Android
- Replace the resin lid of the box with a screen to increase visibility of the LED
- Add visual indication for device malfunctions

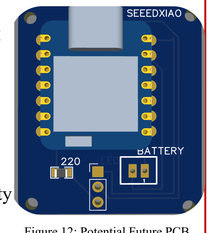

Figure 12: Potential Future PCB

Acknowledgements

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References

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