GLUCOMETER: High Level Design

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I. Introduction

The world is becoming more connected everyday. People are using technology to monitor everything from their activity to their diets. We want to design a marketable diabetes blood glucose monitor that connects to any smartphone through Bluetooth and also combines three products (glucometer, lancing device, and test strip cartridge) into a single compact device. This will bring blood glucose monitoring to the 21st century and makes the lives of diabetics easier.

II. Problem Statement and Proposed Solution

Diabetics need to monitor their blood sugar on a regular basis and deliver insulin or glucose to their body since it does not do this naturally for them. Controlling diabetes is hard and requires constant attention. Part of this difficulty stems from the fact that it can be tough to remember the last time you took a blood sugar or gave insulin. If you are a newly diagnosed diabetic, this is extremely difficult, especially for young children. However, remembering is the least of a diabetics worry. They have to remember to bring their blood glucose monitoring kit, which includes a glucose monitor, test strips, a lancing device, alcohol cleaning pads, and something to record their blood sugar. All which are easy to forget and may require maintenance or replacement, not to mention they all must be carried and are bulky. The day in the life of a diabetic is consumed with managing their disease. We want to help free up some of the worry with our blood glucose monitoring system, which will be compact, connected, easy to use, and hard to forget.

Our solution focuses on providing an all-in-one device to measure and manage blood glucose levels. Our device will include a lancing device, a glucose meter, and a test strip cartridge, all of which will attach to existing insulin pens. The result is one single device that diabetics will carry with them, as opposed to the current solution where they are responsible for three separate devices – lancing device, glucometer, and pen. This device will also enable users to upload their readings to a mobile app. This allows for easy tracking of glucose levels over time and also provides a platform for sharing reading data with doctors or, for children, parents.

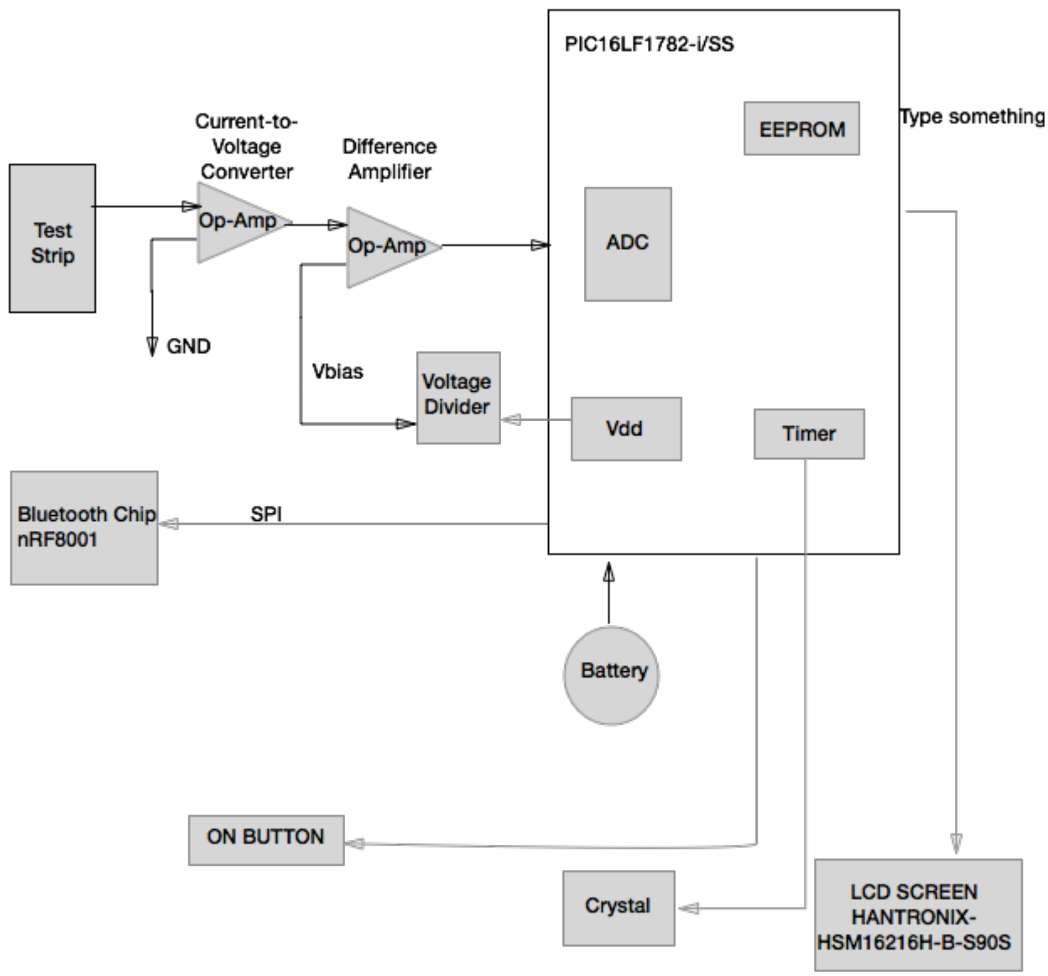
III. System Requirements

- Provide a lancing device that will prick the user's finger to draw blood. This lancing device will contain a small needle that will be cocked back manually.
- A slot to insert the test strip into the glucometer.
- A microcontroller with analog to digital converter to generate a blood sugar reading.
- A microcontroller that can calibrate to multiple test strips
- A small screen LCD display to show the blood sugar reading, as well as give a basic user interface to show battery life, Bluetooth connectivity, etc.
- A Bluetooth chip to send to the user's smartphone.
- A smartphone app that will store user's data, help interpret blood sugar readings, provide literature on diabetes, allow communication with their physician, and send reminders to check blood sugar.

- Cross platform mobile app downloaded from various app stores: Apple App Store, Google Play Store, Windows App Store
- Either replaceable watch button batteries or micro-USB rechargeable battery
- The system should be able to run on one charge for one week or on a button battery for about 3 months
- Packaged in a sleek design that will comfortably attach to the user's insulin pen.
- Casing must be light and compact
- Attachable to the majority of insulin pens on the market

IV. System Block Diagram

1. Overall System:



2. Subsystem and Interface Requirements:

Glucometer

- Measure current from testing strip
- Convert current to voltage
- Amplify voltage
- Analog to Digital Conversion interface on the microcontroller
- Convert digital voltage to associated glucose level
- Save last 20 glucose readings and associated timestamps using an EEPROM
- 3.3 V power line
- PIC microcontroller (PIC16LF1782-I/SS)
- On/Off button
- Crystal Oscillator for Timing

LCD Display
- Display glucose level from glucometer
- Serial connection to microcontroller

Bluetooth
- Transfer glucose readings and associated timestamps to smartphone app
- SPI interface to microcontroller

Smartphone Application
- Allow users to record and track glucose readings
- Provide reminders to test glucose if record has not been submitted for a specified time period

Online Database
- Store historical glucose readings for each user in order to be accessed from the mobile application.

3. Future Enhancement Requirements

Improved LCD Display
- Display additional information beyond current reading.
  - Scroll through previous readings/times
  - Battery level

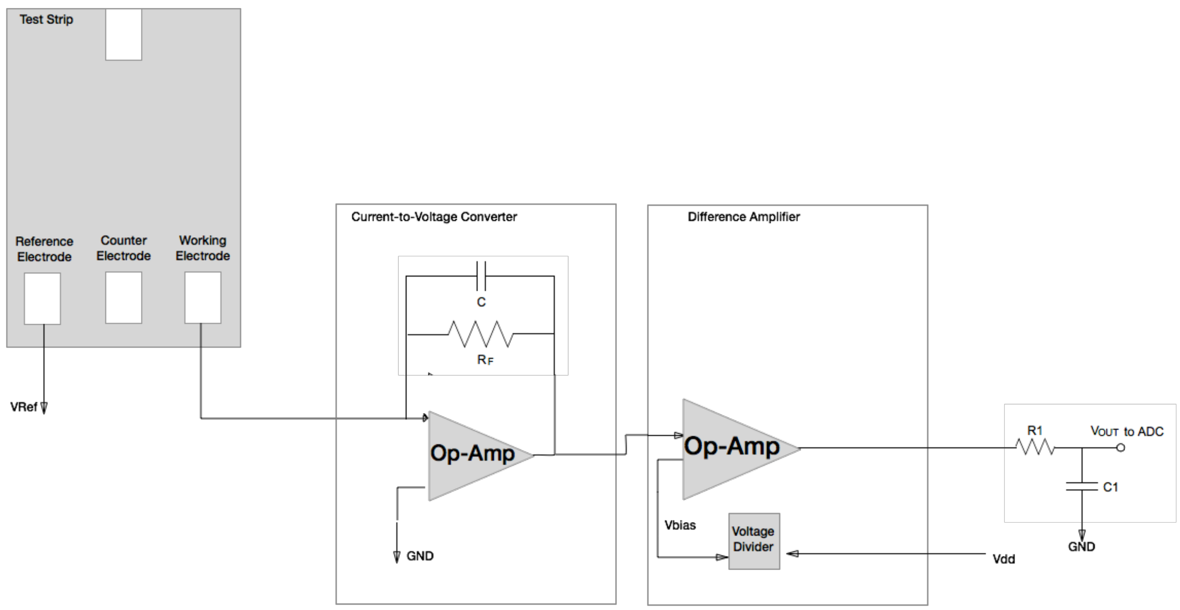
Application Functionality
- Allow doctors to access patients glucose reading history
- Provide weekly analysis of glucose readings
- Help diabetics improve their blood sugar readings through analytics and habit training through the mobile app

V. High Level Design Decisions

Glucometer
- Convert current from test strip to voltage

- Amplify voltage and digitize
  - Use A/D on IC for digitization

- Discretized voltage corresponds to a certain glucose level



LCD Display and buttons

- LCD screen is a 84x48 screen found in a Nokia 5110 phone.
- It has a 45mmx45mm dimensions and a PCD8544 controller, a low-power CMOS LCD controller/driver
- SPI interface
- 3.6V max operating range, but will run at 3.3 V, which we will supply to it
- All necessary functions for the display are provided in a single chip
- We have chosen to go with this screen because of its larger number of pixels in a compact size. This will allow us to have a dynamic user experience while still fitting within our device size requirement.

- There will be three button on our device:
  - ON/OFF button
  - Toggle – allow the user to see previous blood readings
  - Bluetooth – activate Bluetooth sync

Opening Phase

- Once the ON/OFF button is pushed, the LCD display will light up and display "Insert Test Strip"

- A dot on the LCD screen will indicate whether the device is connected to a smartphone via Bluetooth.
- If the toggle button is pressed, it will go to the Past Readings Phase.
- If the Bluetooth button is pushed, it will move to the Bluetooth Sync phase
- The device will wait for a test strip to be inserted. If no test strip is received within a minute, the glucometer will shut off to conserve the battery.

Reading Phase

- When a test strip is inserted, the screen will display "Ready", and wait until a current is produced across the test strip. If no current is read after two minutes, the glucometer will shut off. To reawaken, the user just needs to tap the On button.
- Once a current is produced by the test strip, the screen will display "Reading…"
- After it has taken a reading, it will move to the Review Phase
- Note: Bluetooth and toggle button will not work in this phase.

Review Phase

- Once the microcontroller produces a blood glucose reading, the value will be shown on screen for 15 seconds.
- After 15 seconds, it will display whether or not the info was sent to your smartphone, saying either "info saved" or "info saved and sent."
- If no button is pressed in the next 10 seconds, the glucometer will shutoff
- If the toggle button is pushed at any time, it will go to the Past Reading Phase.

Past Readings Phase

- When entering the Past Readings Phase, the screen will display the most recent blood reading and date.
- Each additional push of the toggle button will display the previous blood reading, until the final reading is shown.
- If the toggle button is pushed again after the final reading is shown, it will return to the phase from which it came.
- If no button is pushed after one minute, the glucometer will shut off

Bluetooth Sync Phase

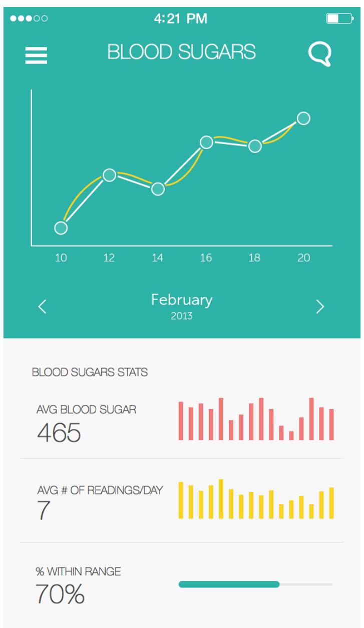
- If the Bluetooth connection is not established, a Bluetooth button will activate the sync function on the Bluetooth chip so that a connection can be established. When the button is pressed, the device will display "syncing." If a connection is made, the screen will display "device [name] found." If a connection is not made within 30 seconds, the screen will display "sync failed." After the Bluetooth protocol is finished, the screen will return to displaying "Insert Test Strip." The Bluetooth button will only work during this opening phase. It will not work once a test strip has been inserted.

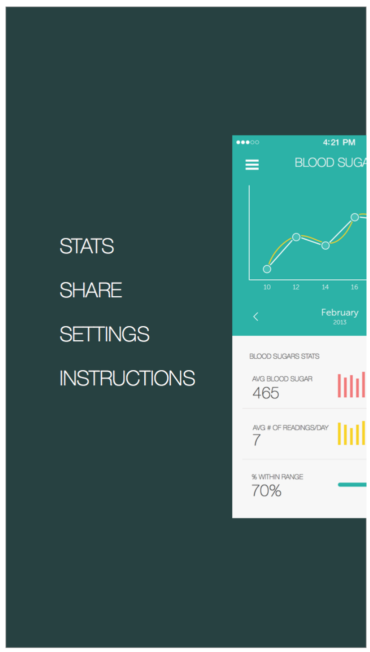
Bluetooth

- nRF8001 Bluettoth low energy Connectivity IC
- SPI interface

- Transfer glucose readings and timestamp to smartphone
  - After syncing with the smartphone, data transfer will begin from the glucometer
  - Data will be read from the EEPROM
  - Previous glucose readings that have not been transferred will be sent, along with timestamps so that the time of testing can be recorded and tracked in the database
- nRF8001 offers best-in-class power consumption which is ideal for our use. The chip will also only be turned on when the Bluetooth button is pressed to enable syncing, which will further improve battery life.

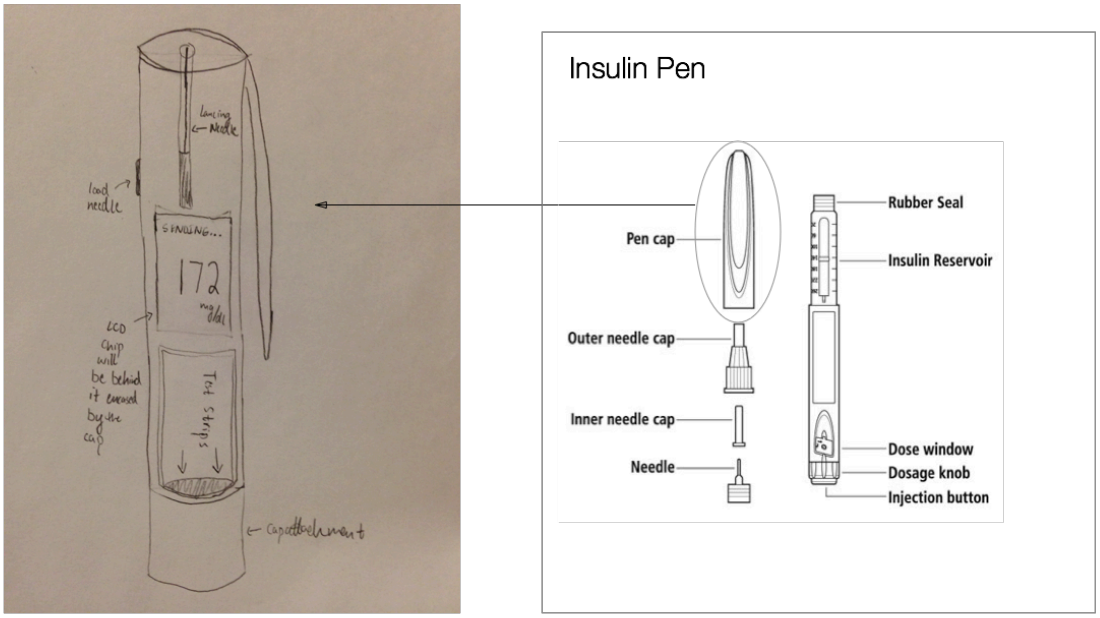
Smartphone Application





Casing Requirements: Rough Estimates since work will be done next semester

- Lancing device
- Glucometer Casing
- Test Strip Cartridge



VI. Open Questions

Moving forward, the two most pertinent questions concern size and the test strips.

Size is an important consideration due to our goals for this device – sleek, small, and lightweight – and through the board design process we will seek to minimize the size of the PCB. We plan to budget as best as possible for a second PCB in case our initial PCB fails to best meet our size requirements and we seek to improve the size through potential PCB redesign or through reconsidering the design of certain subsystems.

A few important decisions also revolve around the type of test strip we decide to use in our device. Different test strips have different circuit complexity and, due to the propriety nature of test strip circuit design, we have to reverse engineer the specific methods a test strip uses to pass the initial current to the glucometer for amplification. There is also a variable cost past on the user associated with the test strips. As such, the brand of test strip we decide to use is an important consideration. In order to show that our glucometer subsystem will work prior to the actual purchasing of material, we will measure the changing resistance across another liquid substance. This gives us a good representation of how test strips will work in our broader circuit. Understanding the lower level design of test strips is the next step.

In terms of casing, we have learned that there are many different geometries for insulin pens, thus we will need to choose the most common geometry and design for that. A large part of this decision will be based on researching what is the most common insulin pen being used right now in our target market of Asia.

VII. Major Component Costs

nRF8001: ~$4.25
PIC microcontroller: $1.70
Nokia LCD: $9.95
PCB: ~$50
Test Strips: $20-$50
Retail Glucometer: $18
Online database solution: $10/month

At this point we do not anticipate trouble in staying under budget. Test strips cost is variable because the strips can only be used once, so the cost will vary depending on how many tests we perform. The retail glucometer will be used to verify the readings from our circuit.

An additional area where we might cut costs is the online database solution. While a paid service is ideal, we are considering using a free service for the time being as we move forward with development. In the end, we plan to transition to a paid service, however.

VIII. Conclusions

We are in a good position regarding our goals and expectations for this project. As this semester concludes, we will finalize the majority of our glucometer circuit, less using actual test strips and we have a clear grasp of the subsystems and design considerations still needed. Additionally, we anticipate our project development to be well under budget. Although some open questions do remain at this point, the ultimate decisions stemming from these questions will not abruptly alter device development.

Our next team task is to set a preliminary schedule over winter break for our spring semester. Since we need to partly size our casing based on the board we design, our next task will be to build out the first iteration of our board design for rough estimates on the size for our overall product.

As development continues, we look forward to the opportunity to incorporate the other subsystems and technologies, as well as integrate the work between different engineering disciplines. By the end of next semester we are excited at the prospect of having fully functional device that will be able to alleviate many concerns for diabetics by bringing blood glucose monitoring into the 21st century.