Glucose Level Detection in Blood using Non-Invasive Techniques

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Introduction:

One of the diseases that affects a huge population worldwide is diabetes. Since diabetes has no well-established cure, control of elevated glucose levels is critical for avoiding severe secondary health complications in multiple organs including the retina, kidney and vasculature.

While finger-stick testing continues to be the mainstay of blood glucose detection, we have begun building a non-invasive solution for glucose level detection using the concept of absorption spectroscopy.

In the further sections we give the circuit diagrams and details about how we plan to take the measurements and analyze the same.

Work Done:

We experimented with different SoCs such as Raspberry Pi and Arduino but finally settled on PSoC. While Arduino provided an inbuilt ADC (Analog to digital converter), its precision was only up to 12-bits, whereas Raspberry Pi needed an additional ADC shield. PSoC proved to be the most precise of them all and provided ease of implementation.

We then designed and implemented the circuit for proving our concept. We then conducted experiments using different resistors for the circuit. This would enable us to vary the current passing through the IR LED. The intensity of the LED would be proportional to the current passing through it. This was done to check the response and correctness of the circuit.

The components that we used, the circuit diagrams and the experiments that were conducted are detailed below.

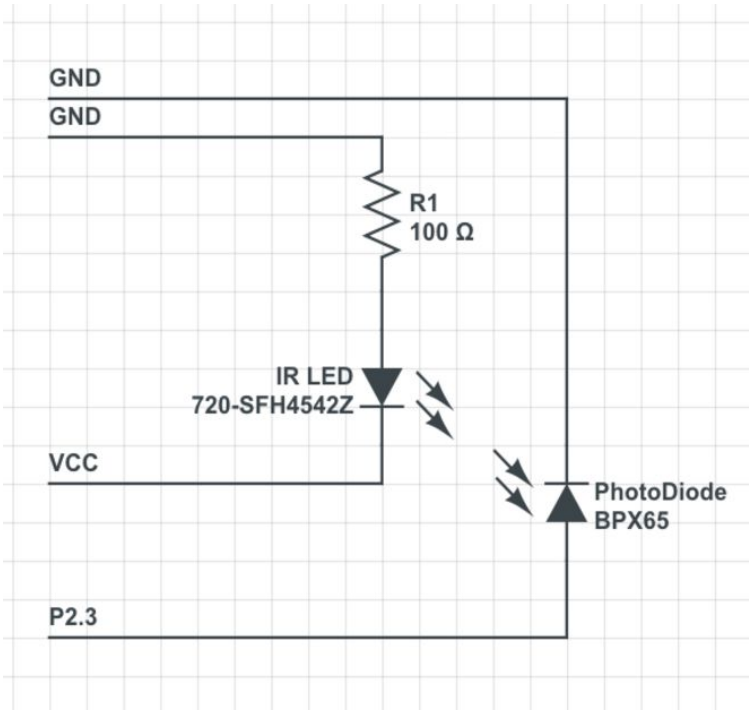
Components Used:

1. Sensor - PhotoDiode - BPX65
2. InfraRed LED - 720-SFH4542Z
3. PSoC 5LP
4. Serial Monitor- (MakerPlot)

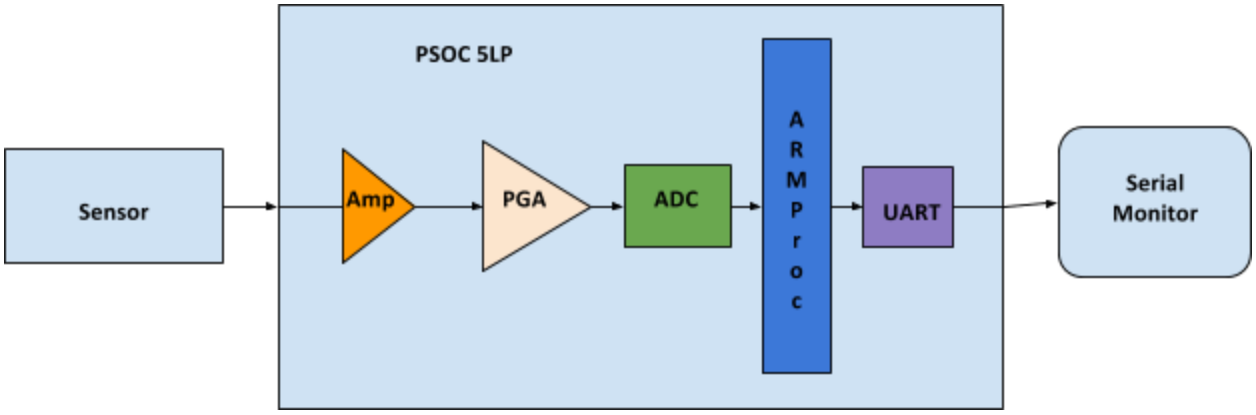
PSoC internals:

1. Amp - OpAmp
2. PGA - Programmable Gain Amplifier
5. ARM Processor - 32-bit ARM Cortex M3
6. UART - to transfer data through serial port

Circuit Diagram:



PSoC internals:

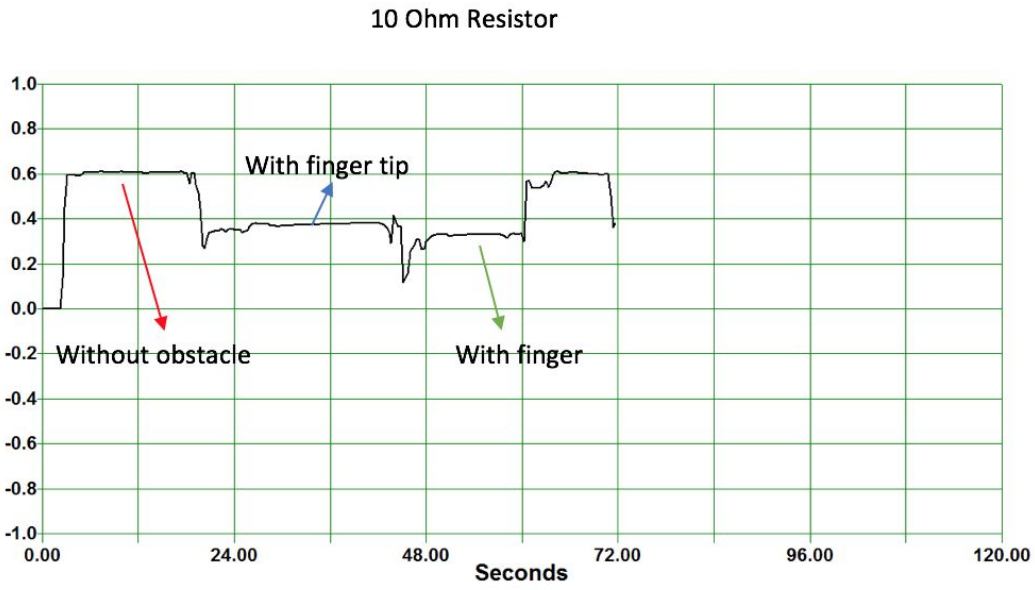


Experiments Conducted:

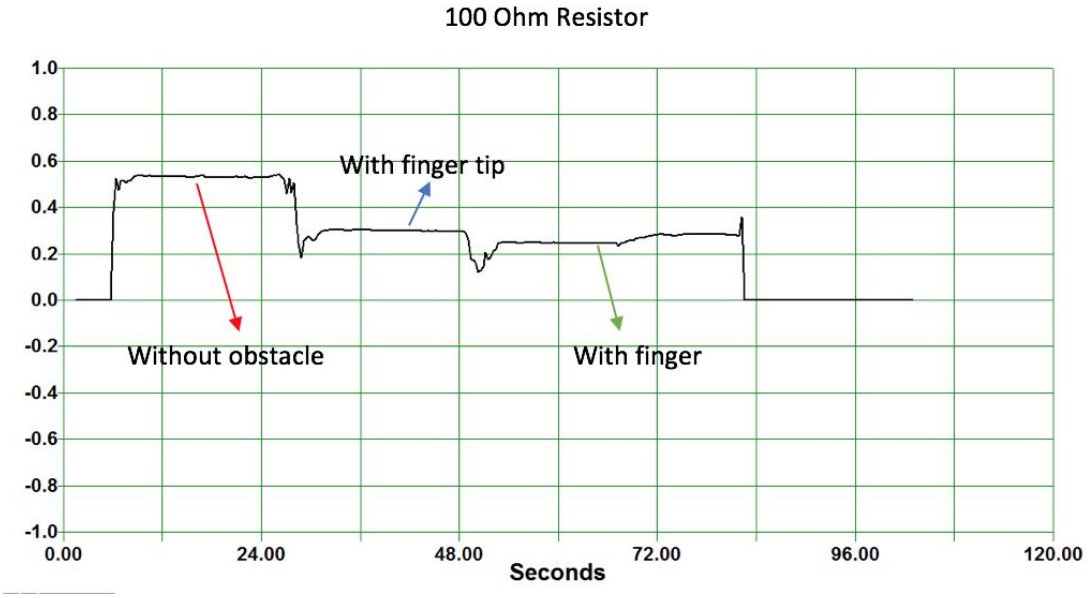
This sections provides graphs of results obtained with different resistors used which would vary the current passing through the circuit.

Our initial experiments include placing a finger between the IR LED and the photodiode and measure the voltage generated by the photodiode. The graph shows the peak voltage generated by the diode with the different resistor values as a function of time.

For example the peak voltage for the 10 ohm resistor: 0.6 V




47 Ohm Resistor
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
With finger tip
Without obstacle
With finger
0.00
24.00
48.00
72.00
96.00
120.00
Seconds


100 Ohm Resistor
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
With finger tip
Without obstacle
With finger
0.00
24.00
48.00
72.00
96.00
120.00
Seconds

Work to be done:

In order to prove our concept we plan to create a solution with glucose level that matches the blood glucose level and create a plot of the different voltages obtained for different concentrations of glucose solution.

We then would take voltage measurements by placing fingers of a set of subjects who are supposed to have a normal blood glucose level and another set of subjects who are supposed to have elevated blood glucose levels. We would then be able to obtain a correspondence between the measured voltages and the glucose levels in the blood.

We are planning build amplification circuit so that we can obtain better precision in the voltage levels and in turn the corresponding glucose levels. We use a programmable gain amplifier for this purpose.

To eliminate the effect of ambient illumination, we take the initial measurement due to the ambient light when the IR LED doesn't project any light on the photodiode. We know that this noise (ambient illumination) is additive. After taking the measurement, we subtract the initial voltage measurement to eliminate the effect of ambient noise.

For the experiments our ground truth would be 20 measurements of blood glucose levels at specific times (12 hours after their meal). Our friends would be our subjects in this case. For each of the blood glucose measurement taken, we would have a corresponding measurement taken by means of our method. We take the average of each set of measurements and as we know that voltage levels are directly proportional to the glucose levels we can then find the proportionality factor.

We then move on to similarly build a test set with another 20 measurements and verify if the proportionality factor is accurate. This would be done by working with the UW hospital pathology lab. We would be taken permission from the UW hospital and the people who show up for the tests.

The test set measurements would be taken at different times of the day and at different times after the meal so that we could determine when the model fails.

References:

1. https://eewiki.net/display/microcontroller/Utilizing+Analog+Peripherals+on+the+PSOC+5LP
2. http://ieeexplore.ieee.org/document/7782291/
3. http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2818.2000.00738.x/epdf
4. https://www.dropbox.com/s/pra1nfa3df5ptke/BPX%2065%2C%20Lead%20%28Pb%29%20Free%20Product%20-%20RoHS%20Compliant-318136.pdf?dl=0