

Design of Interface Circuit and Biosensor Fabrication using Inkjet Printer for the Detection of Glucose

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Abstract

Objectives: The primary objective of this paper is to demonstrate the use of non conventional methods for printing of biosensors and development of appropriate electronic circuits and embedded systems for detection of glucose.

Methods/Statistical analysis: Biosensor Fabrication requires clean room and high investment, In this paper, an attempt is made to design and fabricate biosensor using inkjet printer and the printed sensor is interfaced with signal conditioning and processing unit to detect change in the glucose concentration of the solution to be tested. **Findings:** Biosensors of various configurations have been modeled using online simulator and have been verified for their characteristics and properties based on software simulations. One of the key challenges in biosensor is fabrication process of biosensors. The serpentine and circular structures sensors are fabricated and interfaced with signal conditioning circuit and controller. The patterns are printed using silver nitrate solution and the sensor is interfaced with wheatstone bridge and signal conditioning units. The sensing is carried out using reference circuit and the Analog-to-Digital Converter (ADC) circuit. Interface circuit and ADC is configured on Programmable System-on-Chip (PSOC) which are interfaced with Liquid Crystal Display (LCD) for display for readings. **Application/Improvements:** The circular designed biosensor is reliable than the serpentine structure and has more than 40% improvement in sensitivity in glucose detection.

Keywords: Biosensor, Glucose Detection, Ink Jet Printer, Serpentine and Circular Design

1. Introduction

To produce and achieve reproducible and rapid deposition of sensing solutions within small areas, photolithography and screen printing technologies are extensively used. Screen printing technique is more advantageous for most of the biosensor production as it has high speed, high accuracy and low cost. In screen printing special inks are enforced through a mesh screen to produce an image on a surface. Biosensors are produced using enzyme containing pastes or electron conductive material and dot diameters with high resolution of 390 dpi using screen

printing technique¹. The disadvantage of screen printing is the amount of enzyme ink which is applied to the print screen with a large amount of the enzyme ink is left unused, hence is not an economical process. Inkjet printing is a non-contact digital printing method that is used for highly precise rapid deposition². Inkjet printing allows very small volume droplets deposition of ink with minimum volume (approximately 1 pl), on a compatible surfaces such as metal, plastic and glass. Ink jet printer has high precision and reproducibility higher than 1200 dpi (dots per inch) is achievable, depending

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on the extent of spreading. The main advantage of inkjet printing is the mass production of smaller and cheaper biosensors. There are two types of inkjet printing which are classified based on the drop generation mechanisms which are Continuous Inkjet printing (CIJ) and Drop-On-Demand inkjet printing (DOD)³. In CIJ, the ink is passed through a small diameter orifice resulting fluid jet breaks up into a regularly spaced droplets and these droplets are charged electrically by an electric field. In DOD, drops are generated by flow of pressure pulse in a fluid filled chamber only when a drop is needed. Drops are generated in the particular location by moving the print head in that location before drop are being generated². In piezoelectric DOD mechanism, the pulse is formed by mechanical actuation of chamber walls. Desktop inkjet printers are the most extensively used printer for thermal DOD. There are significant works in recent years in the use of inkjet printing to produce different types of biosensor structures⁴⁻⁷. Biosensor based on tin oxide and nanostructures demonstrated⁸ and in the most of the biosensor application are possibly to use piezo-electric DOD printing. CIJ method is not suitable because of contamination risk that occurs during ink re-circulation⁹.

Thermal printers with the small amount of fluid have been used to deposit enzymes and cells without damage. The thermal inkjet printing technology is used for biosensor fabrication for glucose-oxidase sensor structures and it has better feasibility¹⁰. However piezoelectric printing is conventional choice for printing biological materials¹¹. In drop on demand printing, significant shear rates occur during drop generation and there these high shear rates may damage biological material^{12,13}. The Investigation is performed in detail about the inkjet printing affected by the activity of Glucose Oxidase (GOx) and set up using fluorescent assay¹⁴. In this paper, biosensor is fabricated using conductive silver nitrate, and wheat stones bridge network is designed to interface the sensor to respond to changes in conductivity of the sensing arm of the network and to work as a sensing system in detecting glucose samples.

2. Fabrication of Sensors

Glucose sensors are of different types such as continuous and point sample. Point sample based detection is either based on finger prick or urine dipstick meth-

Table 1. Typical properties of silver nitrate

| Parameter | Property |
|-------------------|------------------------------|
| Pigment | Silver |
| Binder | Thermoplastic vinyl |
| Solid content | 70% |
| Viscosity | 150-200 KCPS |
| Self life | One year |
| Sheet resistivity | 0.02-0.03 Ohm/Sq. at one mil |
| Coverage | 100-200 cm/gm |

ods. In continuous method there are two types such as non-invasive and invasive. Factors for fabrication of sensor are stability and activity.¹⁵ Subcutaneous sensor belongs to invasive type glucose detection methods. In subcutaneous needle type sensing method glucose is sensed using enzyme electrodes.¹⁶⁻¹⁸ Micro-Electro-Mechanical Systems (MEMS) based biosensor explained for the detection of pathogens¹⁹. Electrodes are catalyzing Reduction-Oxidation (redox) reactions and hence either accept or donate electrons during this reactions.²⁰ The electrons produced due to redox changes the concentration of current or voltage which is measured by the electrode. Mediators such as GOx are considered as electron donors as they make the redox independent of local oxygen. Polymer substrate is extensively used in the fabrication of biosensor^{21,22}. In this work the electrode is fabricated and is made of silver nitrate Conductive silver preparation No. SIL. No. 050 is specifically designed for screen printing application on flexible substrate like polyester, polycarbonate, polyimide, ceramic etc,.. It is a dispersion of fine silver particles in a thermoplastics resin system. The major advantages of this material is the flexibility that it offers, adheres to both bare and Indium Tin Oxide (ITO) sputtered membrane touch key boards and thixotropics nature provides good dispersion for excellent screen printing characteristics^{23,24}. The applications where silver nitrate is used are in membrane touch key boards and switches, Printed Circuit Board (PCB) track jointer, low flexible voltage circuitry substrates, flexible PTF resistor inks and brushing ceramic substrates for electroding^{25,26}. In order to convert the biological signal to electrical signal different bio signal conditioners are

implemented^{27,28}. Typical characteristics of silver nitrate are given in Table 1.

2.1 Experimental Procedure

Silver nitrate is applied by standard screen printing techniques. SILTECH SIL No. 50 is ready to use consistency but should be mixed thoroughly with plastic spatula prior to each use. The product is mixed smoothly from the bottom of the container; need to be careful not to whip air into the product. By the use of plastic spatula, it will decrease the possibility of plastic grinding. If necessary SILTECH thinner is used for printable consistency. The SILTECH SIL solution is further mixed with adhesive; in our work we have used fevicol as the adhesive, to bind the product so as to perform printing. The solution is taken into a syringe with needle of size 1 micro diameter, and the solution is pushed into the cartridge. HP DeskJet Ink Advantage 2545 All-in-One Printer is selected for biosensor printing that has speed of 20 ppm with cartridge compatibility of 678/67. The injected solution in the cartridge is loaded on to the printer for printing. A pre-defined printer pattern is captured in word document and is printed on normal paper first and then on glassy paper. The patterns are verified for their reliability. Aluminum foils of sheet thickness less than 5 microns are pasted on white paper. The paper is loaded into the printer for printing the solution for fabrication of biosensor. Figure 1 shows the redox process with glucose oxidase and mediators. The electrode is of silver nitrate, the glucose reacts with the oxygen and the conduction property of electrode changes thus providing additional current flow in the sensing material.

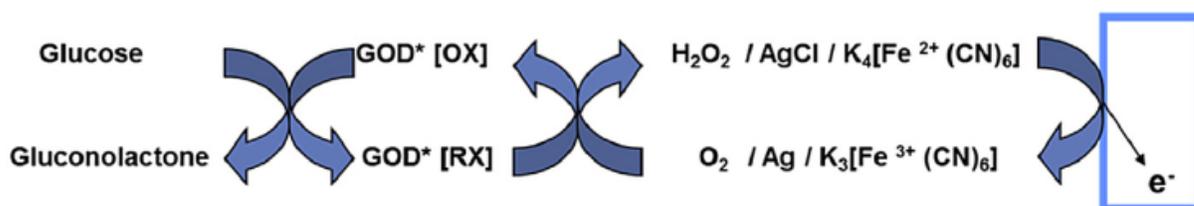


Figure 1. Reduction-oxidation in glucose with mediators.

2.2 Design of Resistor using Silver Nitrate

Design of resistor using silver nitrate is discussed in this section. The silver nitrate is a conductor and hence the structure needs to be designed such that it exhibits the property of resistor. The resistance of any structure is given by Resistance (r) = (Length(L)* resistivity(ρ)) / Area(A), which can be represented as $r = \rho / t * L/w$, if the thickness t is very small, then $r = \rho'$, for L = W. This is termed as resistance per unit area which is resistivity. To achieve higher values of resistance the number of squares need to be appended to form resistors. For silver nitrate $\rho' = 7.314 \times 10^{-5} \Omega \text{ mm}$, therefore $r = 7.314 \times 10^{-5} * N$. For SILTECH SIL solution, sheet resistance is 0.02-0.03 Ohm/Sq. mm.

3. Design of Serpentine Structure

The shape of the serpentine covers optimum area.²⁹In this design, Resistance of one square = $7.314 \times 10^{-5} \Omega$. A 5cm X 20cm is subdivided in to 100 sqcms each square cm consists of 100 sq of mm size offered a resistance of

$7.314 \times 10^{-3} \Omega$. The resistance printed in serpentine structure consists of 60 squares with each square contributing resistance of $7.314 \times 10^{-3} \Omega$. The total resistance offered by the serpentine structure $R_s = R_b * 60 = 0.43884 \Omega$. Figure 2 shows the structure of resistor designed using serpentine logic. The serpentine structure consists of 5 x 20 units, the units labeled 1 – 60 forms the resistance.

3.1 Design of Wheatstone Bridge

The Wheatstone bridge is an electrical resistor circuit used to measure resistance. It consists of an input electrical current source and a galvanometer or multimeter that connects two parallel branches which containing four resistors, three of which are known and one resistance unknown. One of the parallel branches consists of one known resistance and unknown R_x . The other parallel branch contains resistors of known resistances R_1 and R_2 . In order to determine resistance of the unknown resistor, the resistance values of other three are adjusted in such a way that it balanced that is until the current passing through the multimeter reduces to zero. Due to high

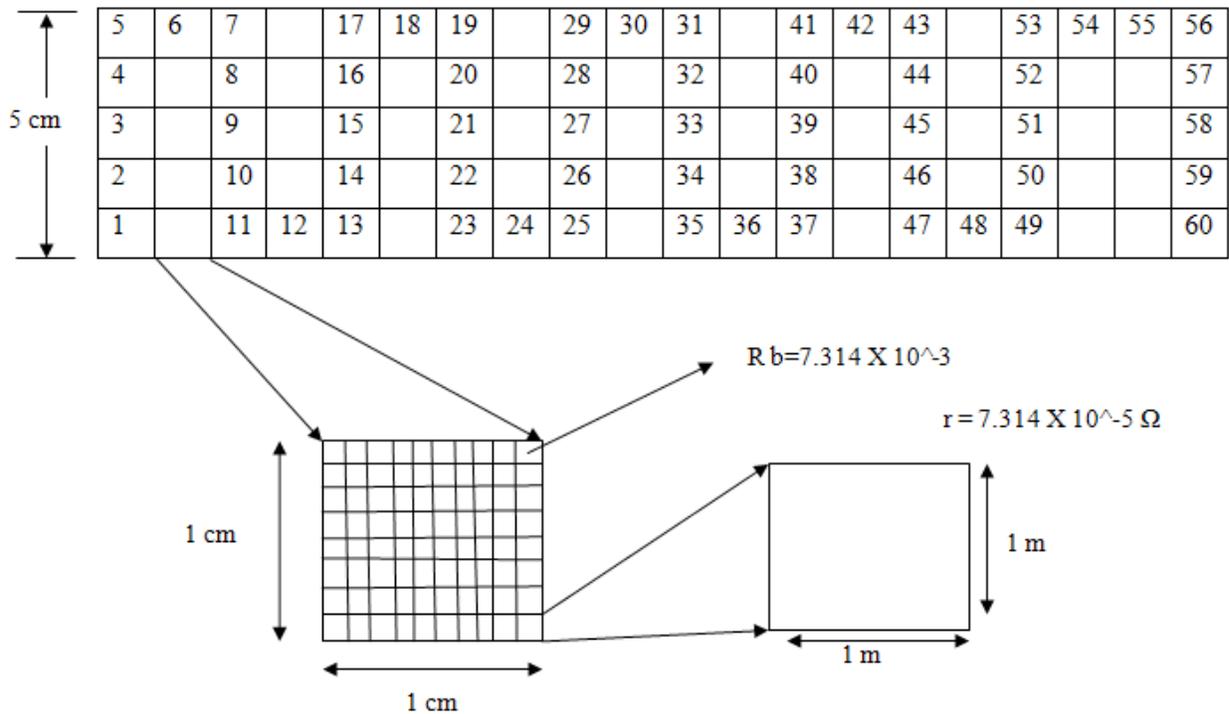


Figure 2. Design of 0.5 Ohm resistor.

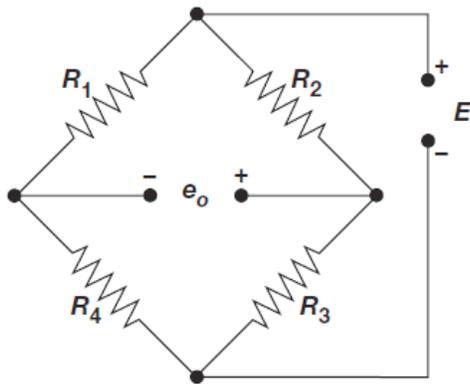


Figure 3. Wheat stones bridge.

sensitivity, Wheatstone bridge circuits are more advantageous for the measurement of inductance, capacitance and resistance. Figure 3 shows the Wheatstone bridge with four arms and when the bridge is balanced the output voltage is zero.

If $R_1/R_3 = R_2/R_4$ which is the condition for balanced bridge with $V_{out}=0$. The Structure shown in Figure 3 can also be redrawn as for simplicity as shown in Figure 4. The nodes A, B, C and D are used as identities for redrawing the wheat stones bridge network. The input voltage of V_{in} set to a constant value and the resistors are tuned to

achieve balancing of the bridge. If $R_1=R_2=R_3=R_4=1.2K\Omega$ is selected to balance the bridge.

3.2 PSOC Based Design of Sensor Interface Circuitry

Resistive arm R1 is set as sensor arm. To estimate sensitive of the bridge, the following experimental setup is developed. The input voltage is applied across two arms of the bridge at nodes A and B, the node D and C are used as output nodes. The voltage across the nodes D and C are read into PSOC Cypress Development kit³⁰. The preprocessing module processes the incoming signal and amplifies the same by a voltage gain of 100. The ADC module reads the amplified signal and converts the same to 12bit digital output, which is processed by the micro-controller and displays the reading on the LCD panel. Figure 5 shows the experimental setup for validation of the designed sensor.

The Delta Sigma Analog to Digital Converter (ADC_DelSig) provides a low-power and low-noise front end for precision measurement applications. We can use it in a wide range of applications, depending upon sample rate, resolution, and operating mode. It produces 16-bit audio, high speed and low resolution for communications processing. It produces high-precision 20-bit low-speed conversions for sensors such as thermocouples, strain gauges, and other high precision sensors. When process-

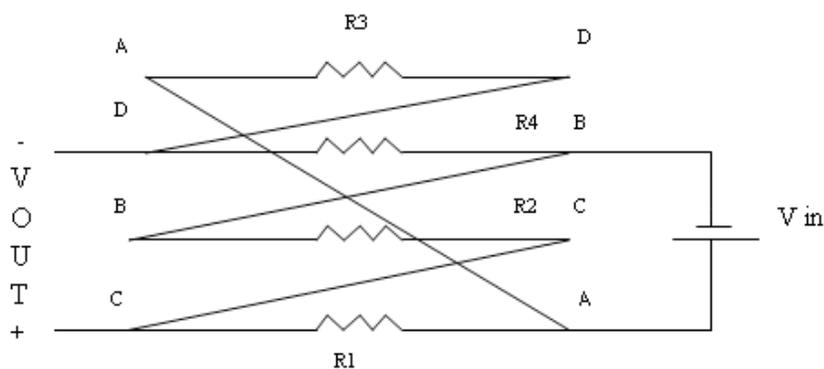


Figure 4. Simple notation of wheat stone bridge.

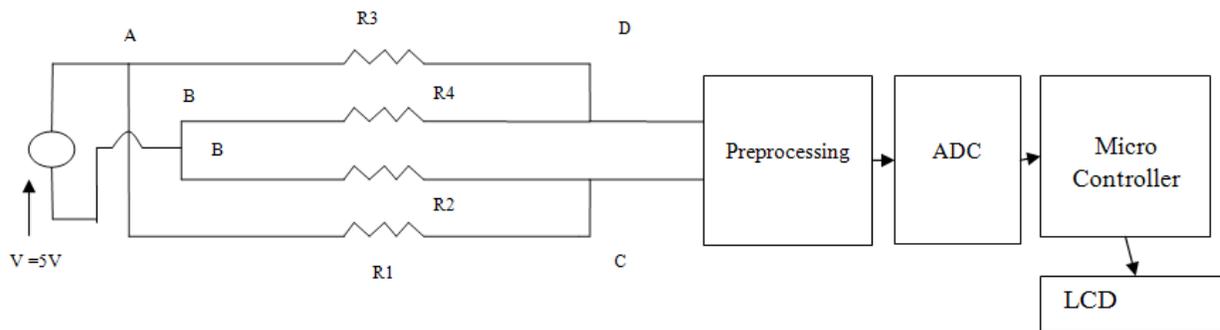


Figure 5. Experimental setup for validation of sensor.

ing the audio information, the ADC_DelSig is used in continuous operation mode. When it is used for scanning multiple sensors, the ADC_DelSig is used in one of the multi-sample modes. When it is used for high-resolution single-point measurements, the ADC_DelSig is used in single sample mode. Delta-sigma modulators use oversampling to spread the quantization noise across the wider frequency spectrum. This noise is shaped to move most of outside the input signal's bandwidth. An internal LPF (low pass filter) is used to filter out the noise outside the desired input signal bandwidth. Due to this, delta-sigma converters have well in operation for both low-speed high-resolution (16 to 20 bits) and high-speed medium-resolution (8 to 16 bits) applica-

tions. The sample rate is adjusted between 10 and 384000 samples per second, depending upon the mode and resolution. Choices of conversion modes simplify interfacing to single streaming signals such as audio, or multiplexing between multiple signal sources. Figure 6 shows the design of ADC interface using PSOC designer.

The ADC_DelSig consist of three blocks, an input amplifier, a third order delta sigma modulator, and a decimator. The input amplifier provides a high-impedance input and input gain which is a user-selectable. The decimator block consists of four-stage CIC decimation filter and a post processing unit. The CIC filter operates on the data sample directly from the modulator. The post-processing unit optionally performs offset, gain and simple

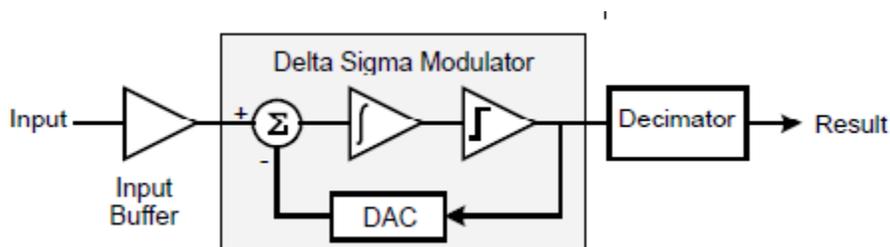


Figure 6. PSOC circuit schematic for ADC design.

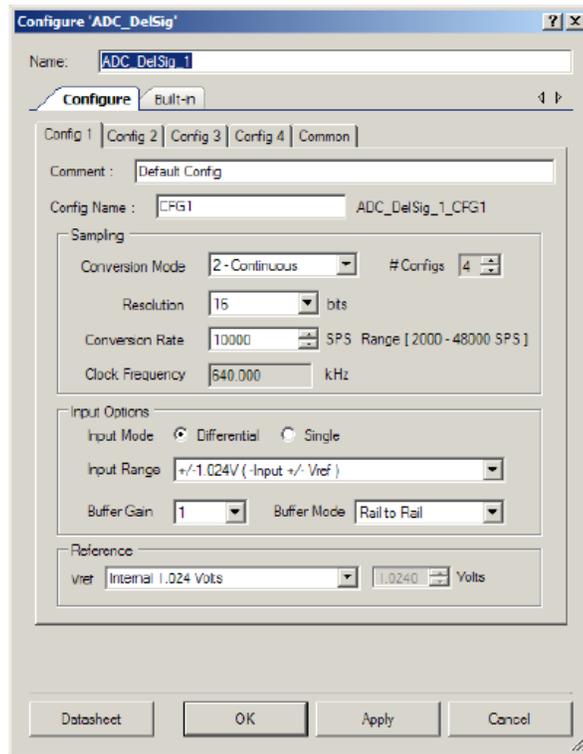


Figure 7. ADC design specifications.

filter functions on the output of the CIC decimator filter. ADC component parameters are shown in Figure 7.

The Character LCD component contains a set of library routines that enable simple use of one, two, or four-line LCD modules that follow the Hitachi 44780 standard 4-bit interface. The component provides APIs to

implement horizontal and vertical bar graphs, or you can create and display your own custom characters.

3.3 Modified Sensor Arm for Sensing

The sensor arm $R1=1.2K\Omega$ is modified by connecting two resistors as in Figure 8.

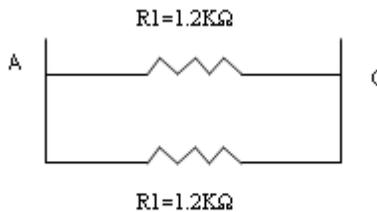


Figure 8. Modified sensor arm for glucose detection.

The Two resistors in parallel contribute a resistance of R_p , $R_p = R_1 R_2 / (R_1 + R_2) = 0.6K\Omega$. With 5V as input DC voltage and bridge being unbalanced ($R_p = 0.6K\Omega$, $R_3 = R_4 = R_2 = 1.2K\Omega$). The output at LCD is found to be 2.516 volts. Thus a change in sensor arm resistance from 1.2K Ω to 0.6K Ω unbalances the bridge by 2.516volts. thus sensitivity is $S = 2.516 / (1.2K\Omega - 0.6K\Omega) = 4.19 \times 10^{-3}$, $S \approx 0.0419V/\Omega$. The resistor printed using silver nitrate is of $R_s = 0.43884 \Omega$. Sensitivity of designed wheat stone bridge is 0.042v/ Ω , thus by connecting R_s in series with R_1 , the sensor arm resistance can change from 1.2K Ω To 1200.43884 Ω , for change of approximately 0.5 Ω resistance the V out voltage can change by a factor of approximately 0.021v (S/2). Therefore the sensitivity is 0.042 V/ Ω , if resistance changes by 0.5 Ω voltage will change by 0.021V. Since the voltage change is very less it is required to design an 8 bit ADC. If $V_{ref} = 2.5v$, the ADC equation is given by (1),

$$V_{out} = V_{REF} [b_1 2^{-1} + b_2 2^{-2} + b_3 2^{-3} + \dots + b_8 2^{-8}] \tag{1}$$

The ADC is sensitive to a small voltage change of 0.0097 V, $V_{out} = [2.5] [b_8/256] \rightarrow 1LSB$. Accordingly the ADC is designed using PSOC designer.

4. Experimental Setup of with Sensor Arm

The printed silver nitrate is connected as shown in Figure 9 to balance the bridge. The voltage across ADC out is measured and is found to be 0 Volts. The four arms of the bridge have equal resistance of 1200.43884 Ω .

In order to improve reliability of sensing a reference arm is introduced as shown in Figure 10. The reference arm is designed with fixed resistors and is always balanced. Any changes in environment will change the resistance values and thus will always keep the bridge balanced as all the resistors exhibit similar behavior for changes in environment.

The arm1 of the bridge is connected with sensing resistor and any changes in chemical reaction unbalances

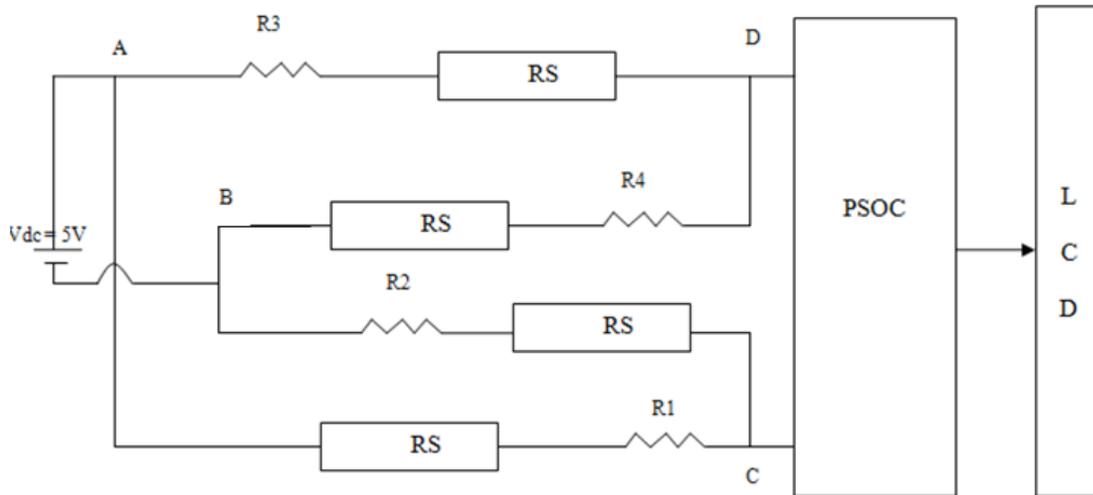


Figure 9. Four arm bridge circuit interfaced with PSOC.

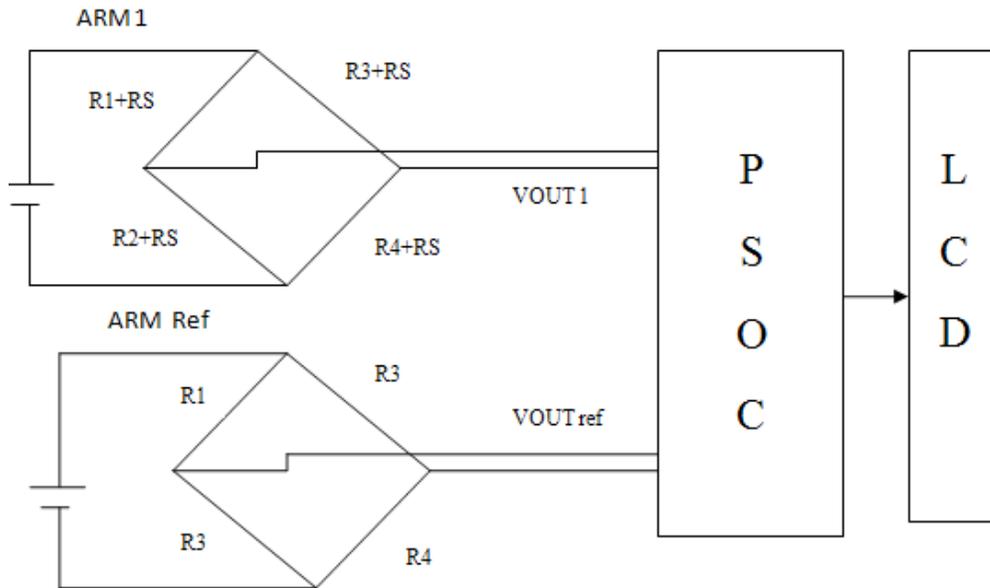


Figure 10. Sensing network with reference circuit.

the bridge and thus is used to detect the concentration of glucose levels. ARM is the sensing arm with printed resistors ARM ref in the reference arm without printed resistors. the bridge when balanced, V_{out1} and $V_{out\ ref}$ will be 0 V. The difference of $V_{out\ ref} - V_{out1}$ is computed by the PsoC for indicating changes in input. As the ADC

designed has a resolution of 0.0097V, a minimum difference of $(V_{out\ ref} - V_{out1})$ 0.0097 V can be detected by the designed experiment setup. The PSOC platform supports to use of one ADC at any time, as there are two analog inputs that need to be processed by ADC on analog mux is used, and time interleaving is carried out as shown in Figure 11.

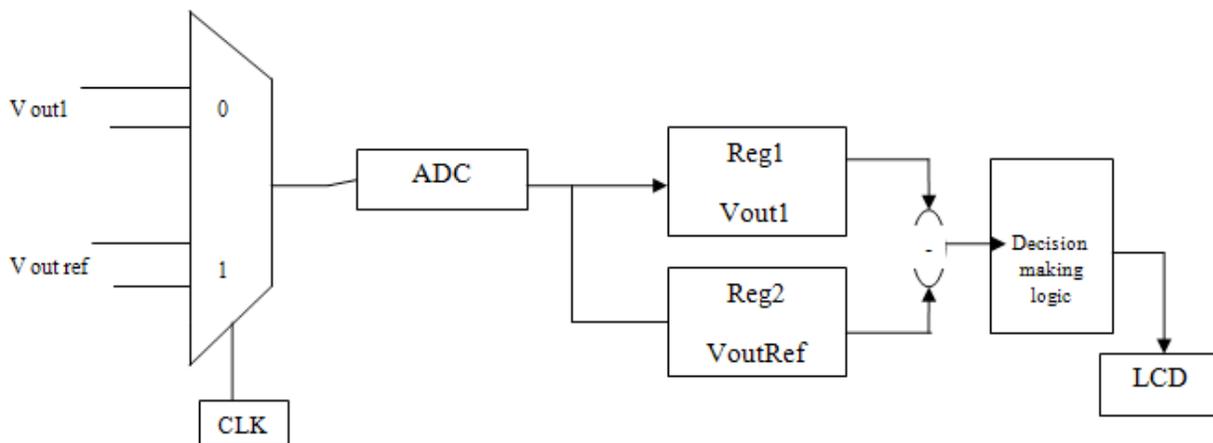


Figure 11. Multiplexed reference circuit for sensing glucose.

Table 2. Experimental result for serpentine structure

| Glucose concentration (mmol/L) | Approximate change in resistance in Ohms | Voltage drop across the bridge (theoretical) in Volts | Voltage drop across the bridge (practical) in Volts (with amplification gain of 40dB) | Remarks |
|--------------------------------|--|---|---|-----------------|
| 2 | 1203.121 | 0.0032 | 0.16 | No significance |
| 2.5 | 1205.126 | 0.0053 | 0.265 | |
| 3 | 1207.124 | 0.00739 | 0.36 | |
| 3.5 | 1209.12 | 0.0094 | 0.47 | |
| 4 | 1211.23 | 0.011 | 0.55 | |
| 4.5 | 1214.35 | 0.014 | 0.742 | Normal |
| 5 | 1216.31 | 0.016 | 0.843 | |
| 5.5 | 1218.41 | 0.019 | 0.95 | |
| 6 | 1220.41 | 0.021 | 1.055 | |
| 6.5 | 1222.91 | 0.023 | 1.181 | Type 1 |
| 7 | 1225.27 | 0.026 | 1.3 | |
| 7.5 | 1227.46 | 0.028 | 1.414 | Type 2 |
| 8 | 1229.17 | 0.03 | 1.50 | |
| 8.5 | 1231.41 | 0.032 | 1.61 | Abnormal |
| 9 | 1232.32 | 0.0332 | 1.66 | |
| 9.5 | 1234.11 | 0.035 | 1.75 | |
| 10 | 1237.13 | 0.038 | 1.904 | |

The printed sensor has a resistance of 0.43884Ω , the solution containing glucose is dropped on the sensor arm as shown in figure above and if the solution alters the resistivity of the sensing arm by a factor of 10 the resistivity ρ changes by referred form $\rho_1=7.314 \times 10^{-5}$ to $7.314 \times 10^{-3}\Omega$. The resistance of one sq cm will change from $7.314 \times 10^{-3}\Omega$ to $7.314 \times 10^{-2}\Omega$. The solution containing glucose will alter the resistivity of approximately 50 sq out of 80 sq the total resistance is given by $RT = [7.314 \times 10^{-3} \times 10] + [7.314 \times 10^{-2} \times 50]$, $RT = 0.07314 + 3.657$, $RT = 3.73014\Omega$. Thus the presence of glucose solution dropped on the sensing arm changes the resistance of 0.58512Ω to 3.8709Ω . For the purpose of testing the working of printed biosensor, glucose solution with varied concentration is dropped on the sensing arm to detect the changes in resistance and hence the voltage. The concentration of glucose solution is expressed in Molarity (M). A mole is the amount of substance that contains as many atoms, molecules, ions, or any other entities as there are atoms in exactly 12g of carbon-12. It has been determined experimentally that the number of atoms per mole of carbon-12 is $N_A = 6.0221367 \times 10^{23}$

mol^{-1} , which is known as the Avogadro constant. Molar concentration or molarity is defined as the number of moles of solute dissolved in one liter (L) of solution; that is, $\text{molarity} = \text{number of moles of solute} / \text{L of solution}$. Thus, molarity has unit's moles per liter (mol/L). The glucose content in blood for if is between the range of 4.0 to 5.9 mmol/L, then it is normal, if it is greater than 6mmol/L then it is determined that the person has diabetics. The printed sensor is first introduced in the bridge circuit; all the four arms of the bridge are set to resistance values of 1.2K Ohms. One of the arms is connected with the sensor in series with 1.2K Ohms, thus the resistance of one arm is 1200.43884 Ohms. The corresponding voltage is measured and is found to be 0.45 mV. The glucose sample with varying concentration from 2mmol/L to 8mmol/L is dropped on the sensing arm, which will approximately alter 50 squares of area on the sensing arm which will change the resistance of the sensing arm. Table 2 shows the readings after tabulation for sensor designed using serpentine structure.

Figure 12 shows the experimental setup to determine the fabricated Biosensor response to the glucose analyze.

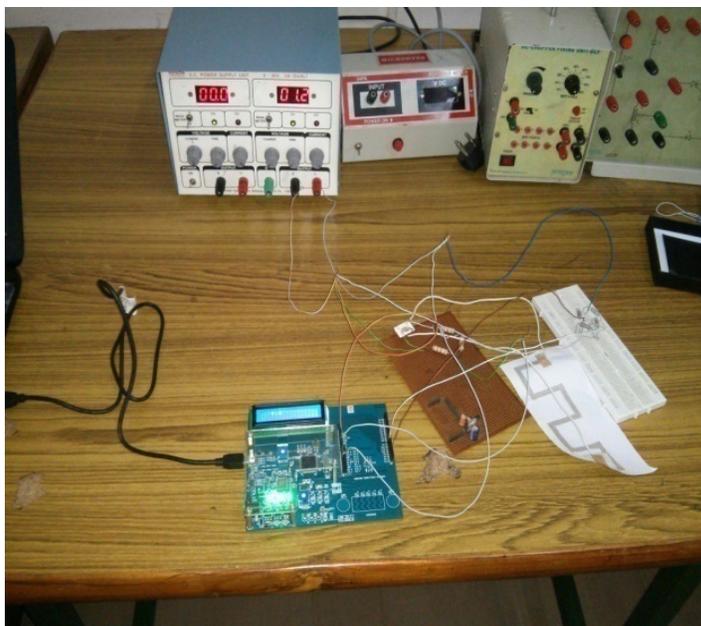


Figure 12. Experimental setup.

The fabricated and immobilized Biosensor as described is connected across one arm of the Wheatstone bridge. Care should be taken so that the experimental setup table and sensor surface should be free from any dust and other contamination.

- The Wheatstone bridge is energized with 1.5 V - 5.0 V DC. Before applying glucose to the sensor, the Wheatstone bridge should be balanced by using the potentiometer in one of the arm of the bridge until the LCD display 0 reading.
- Now 100 µl of research center glucose arranged with 1.4 mg/ml concentration (typical postprandial glucose level) is connected on the sensor then dried for 20-30 minutes at 36
- Due to the application glucose on the sensor there be a chemical reaction between the silver nano particle and glucose. This results change in the conductivity of the sensor element and the bridge gets imbalanced.
- Now the reading of the display is recorded.

- Experiment is repeated for various concentration of glucose as indicated in the table 1 and corresponding display reading is recorded. The readings are tabulated with respect to change in the glucose concentration.
- From the tabulated readings we found that the resistance value of the sensor increases with respect to increase in the glucose concentration and hence there will be a relative increase in the value of display reading.

5. Design of Circular Structure

If the height of cell is increased from 5 cm to 10 cm there would be 100 cells, then $R_s=0.43884\Omega$. As serpentine structure has 60 squares with resistance of 0.43884Ω , the circular structure shown in Figure 13 also has 60 squares with resistance of 0.43884Ω . When glucose is dropped on the circular structure as shown in figure 13, it is expected to alter resistivity of all squares as compared with serpentine structure that altered only 60% of the total cells.

| | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 9 | | | | | | | | | 20 |
| 8 | | 42 | 43 | 44 | 45 | 46 | 47 | | 21 |
| 7 | | 41 | | | | | 48 | | 22 |
| 6 | | 40 | | 58 | 59 | | 49 | | 23 |
| 5 | | 39 | | 57 | 60 | | 50 | | 24 |
| 4 | | 38 | | 56 | | | 51 | | 25 |
| 3 | | 37 | | 55 | 54 | 53 | 52 | | 26 |
| 2 | | 36 | | | | | | | 27 |
| | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | |

Figure 13. Design of circular structure with $RT=7.314 \times 10^{-3} \times 60 = 0.43884\Omega$.

Table 3. Results of circular structure based sensors

| Glucose concentration (mmol/L) | Approximate change in resistance in Ohms | Voltage drop across the bridge (theoretical) in Volts | Voltage drop across the bridge (practical) in Volts (with amplification gain of 40dB) | Remarks |
|--------------------------------|--|---|---|-----------------|
| 2 | 1203.8709 | 0.004025 | 0.20 | No significance |
| 2.5 | 1207.7418 | 0.008038 | 0.40 | |
| 3 | 1211.6127 | 0.012 | 0.6 | |
| 3.5 | 1215.48 | 0.016 | 0.8 | |
| 4 | 1219.35 | 0.0199 | 0.995 | |
| 4.5 | 1223.22 | 0.023 | 1.15 | Normal |
| 5 | 1227.09 | 0.027 | 1.35 | |
| 5.5 | 1230.96 | 0.0318 | 1.59 | |
| 6 | 1234.83 | 0.0357 | 1.785 | |
| 6.5 | 1238.70 | 0.0396 | 1.98 | Type 1 |
| 7 | 1242.57 | 0.0435 | 2.175 | |
| 7.5 | 1246.45 | 0.0474 | 2.37 | Type 2 |
| 8 | 1250.32 | 0.0513 | 2.56 | |
| 8.5 | 1254.19 | 0.05520 | 2.76 | Abnormal |
| 9 | 1258.06 | 0.0590 | 2.95 | |
| 9.5 | 1261.93 | 0.062 | 3.1 | |
| 10 | 1265.80 | 0.066 | 3.3 | |

The circular structure is printed using inkjet printer and the two contacts are connected in series with one arm of the bridge resistance of 1.2K Ohms. The results tabulated in Table 2 shows the variation in resistance in one arm of the bridge to which sensor is connected and the

corresponding voltage variations after amplification using the signal conditioning circuits. The theoretical voltage is also shown in the Table 3 without amplification factor.

The sensitivity of circular structure is superior compared with serpentine structure, as the glucose sample

dropped alters most of the squares in the circular structure. Also as the glucose sample is dropped it spreads slowly and uniformly in all directions and hence is more reliable in detection of glucose concentration.

6. Conclusion

In this work, a biosensor is fabricated using inkjet printer and is tested for its performance by interfacing with PSOC. The biosensor is fabricated using silver nitrate which is combined with inkjet liquid and is loaded with the printing ink. The serpentine structure and circular structure are drawn in word document and the printer is invoked to print according to the pattern. The printed pattern is connected with leads to form the resistive arm of wheat stones bridge. The signal acquired is converted to digital form by ADC and LCD interface is carried out to display the signal strength. The readings provide information on the concentration of glucose samples. The designed method and structure can be used for printing low cost sensors.

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