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Development of Low Cost and User Friendly Medical Diagnostic Tools

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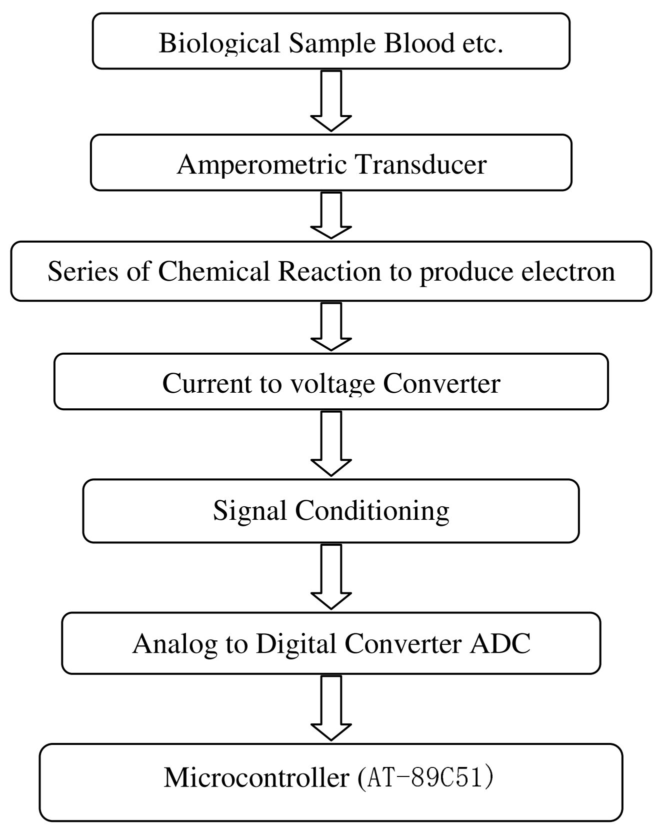
Abstract: **India being one of the largest growing economies, it lacks basic health care facility, especially medical diagnostic equipment's. While India's overall expenditure on healthcare is comparable to most developing countries, India's per capita healthcare expenditure is low due its large billion-plus population and low per capita income. This scenario is not likely to improve because of rising Healthcare costs and India's ever-growing population. According to WHO national health accounts India's health care spending as a percentage of GDP has been reduced from 4.4.in 2000 to 4.0 in 2010[1]. According to a survey conducted by Indian brand Equity Foundation, total healthcare revenues in the country hospitals account for 71 per cent and of which 9 per cent accounts for diagnostics [2]. Thus reducing the cost of diagnostic devices can contribute a lot in reducing the healthcare burden on Indian people. Use of simple microcontrollers like Arduino and accessories like Bluetooth shield and Ethernet shield can be an easy and cost effective approach. In this paper we will be discussing the techniques using voltage and current sensors and their interface with analog to digital converter. The data can be calibrated and displayed on different devices like PCs, tablets and mobile devices. Using familiar devices like mobile phone will make the device user friendly and cost effective.**

1. INTRODUCTION

Medical diagnostic tool comprises a machine or a device or something which can acquire biological data from a living being's body. Thus we need something that consist of two major components namely a biological entity that recognizes the target analyte and the transducer that translates the bio recognition event in to an electrical signal. Further these analog electrical signals are sent to analog to digital converter, from where it is transferred to microcontroller, where data is processed and further viewed on display devices [3]. The transducer used is generally amperometric and the whole system can be termed as a biosensor. In amperometric biosensors the potential at the electrode is held constant while the current is measured. The performance of the biosensor will mainly depend on, the properties of bio sensing (enzyme) membrane and to a little extent on the instrumentation system used to acquire the signal generated by biochemical reaction at the bio sensing membrane. The amperometric biosensors are known to be reliable, cheap, and highly sensitive for the analysis of bio parameters present in food ingredients and environment. The goal of the proposed work involves integration of amperometric biosensor with a simple microcontroller based data acquisition system and analysis of different biological parameters. Further, for making the system user friendly, use of wireless media like internet and Bluetooth is discussed. Using this wireless media will introduce devices like our mobile phone, personal computers, and LCD for data logging for future response. Simple microcontroller like AT-89C51 is being used. The system can be used for real time analysis of glucose concentration in the field such as, food and fermentation and clinical (In-Vitro) applications. The optimum operating parameters for the better performance were found and reported.

2. METHODOLOGY



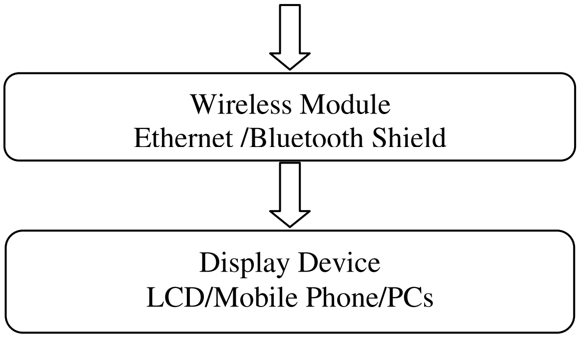


Fig. 1. Flow chart showing methodology

Figure 1 shows the flow chart explaining the methodology of simple diagnostic tool built using a simple microcontroller and analog to digital converter.

However this is generic methodology and can be applied to nearly all diagnostic tool, to understand the methodology we must put a specific example. Though we have performed a series of experiments for different biological sample; we will discuss glucose detection in detail.

The amperometric biosensor is operated in cathodic amperometric configuration. After applying a potential of 750 mV (negative) to the working electrode, the current (*I*) is produced and is proportional to the oxygen concentration (that is in-turn related to the amount of analyte). The current (*I*), flows between the electrodes. This electrode compartment is separated from the biocatalyst (enzyme membrane) by a thin membrane permeable only to oxygen. The reaction involved at the Detachable Membrane Unit is shown in equations 1 and 2 respectively. The reduction of oxygen occurs at working electrode involving the acceptance of four electrons [3].

$$\text{Glucose} + O_2 \xrightarrow[-750\text{mV}]{\text{Glucose oxidase}} \text{Gluconic acid} + H_2O_2 \quad (1)$$

$$O_2 + 4H^+ + 4e \longrightarrow 2H_2O \quad (2)$$

The reduction of oxygen (consumption of oxygen by the analyte) leads to the change in current and is linear to the analyte concentration. The resulted analog signal was converted to an equivalent digital value and interfaced to microcontroller for computation.

The major components used in the design of electronic hardware system are

(a) Signal conditioning system

(b) ADC and Microcontroller.

The current generated from enzyme electrode depends on analyte concentration, area of electrode and also on the protocol used to develop bio transducer. The current was converted to voltage and amplified using signal conditioning circuit as shown in Fig 2. The output of signal conditioning circuit was given to a high accuracy instrumentation amplifier for buffering and to maintain the level of 0-5 volts required for data acquisition system [4].

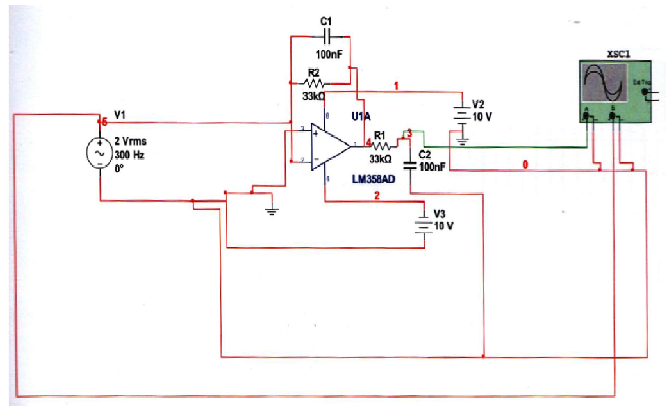


Fig. 2. Circuit for current to voltage converter with signal conditioning.

Eight bit ADC 0808 is used to convert the analog signal received from signal conditioning circuit to a digital data. It operates with +5V power supply voltage. Microcontroller AT89C51 is used for computation, which is to calculate the unknown sample concentration of glucose using the calibration factor. The circuit layout is as shown in Fig. 3. The converted data form the ADC is read from microcontroller and later it is transferred to the parallel port of PC. AT89C51 microcontroller is an 8 bit and has been operated at 11.05 MHz clock frequency. It has 128 bytes of RAM and 64K ROM, two 16 bit Timer/counter, 32 I/O lines, four parallel I/O ports of each 8 bit, one programmable serial port and six interrupt ports[5].

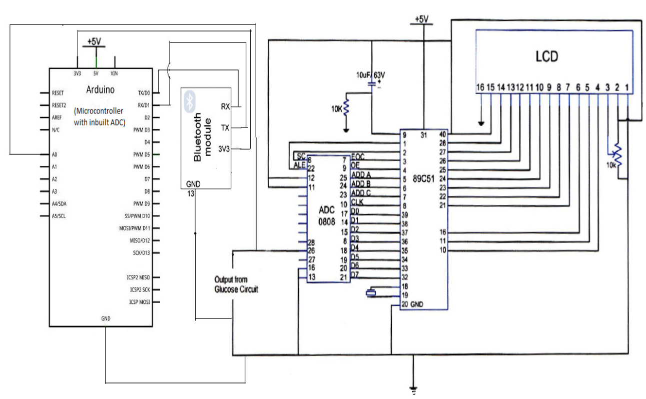


Fig. 3. Microcontroller interfacing circuit.

An Arduino microcontroller with inbuilt ADC is being used to calibrate and transfer data using Bluetooth or Ethernet (Bluetooth in this case). A different microcontroller is being used because, LCD uses parallel communication but Bluetooth shield uses serial. In real time applications, only one microcontroller can be used based on the requirement.

3. PROGRAMMING MICROCONTROLLER

The program used is in the assembly language. The flowchart is as shown in Fig.4. The generated Hex code was downloaded in to the EPROM of AT89C51 using universal programmer kit. Microcontroller was programmed to generate timer delay; timer 0 in mode 2 configuration was used. AT89C51 sends start of conversion signal to ADC and later reads converted data and stores in its internal RAM in sequence. During the real time analysis of the sample, the data has been read at the end of 05 seconds. The data is then transferred to computer through the parallel port.

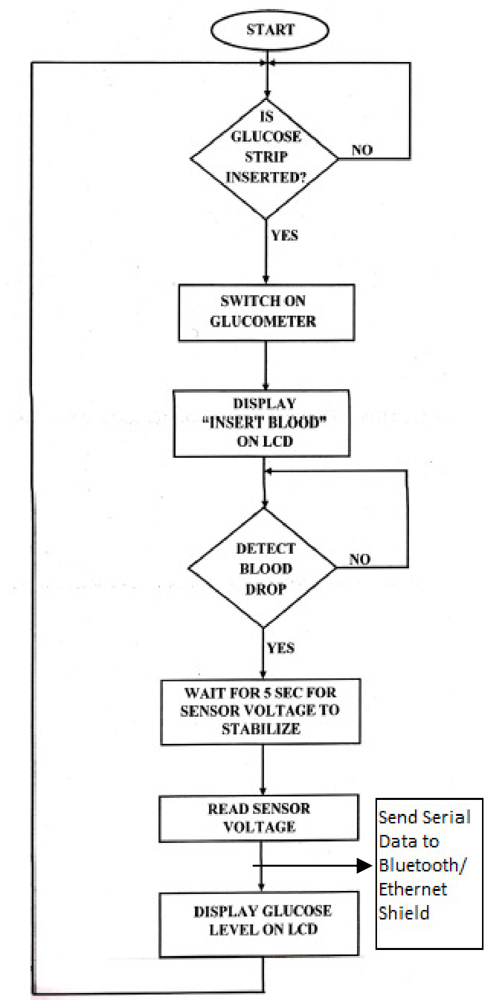


Fig. 4. Algorithm showing programming microcontroller.

4. RESULTS AND DISCUSSION

Calibration was done using standard glucose solution. The calibration results are as shown in Fig. 5. The response is almost linear with change in glucose concentration. The calibration factor obtained was used to find the concentration of glucose in the blood sample. The variation of the obtained voltage vs. time is as shown in Fig. 6.

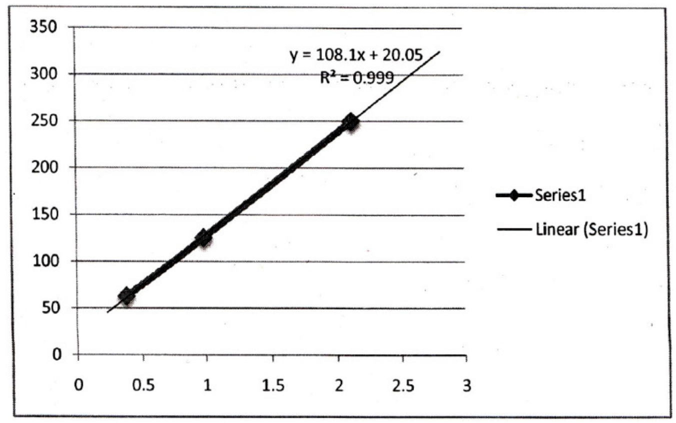


Fig. 5. Calibration Curve between glucose concentration and voltage.

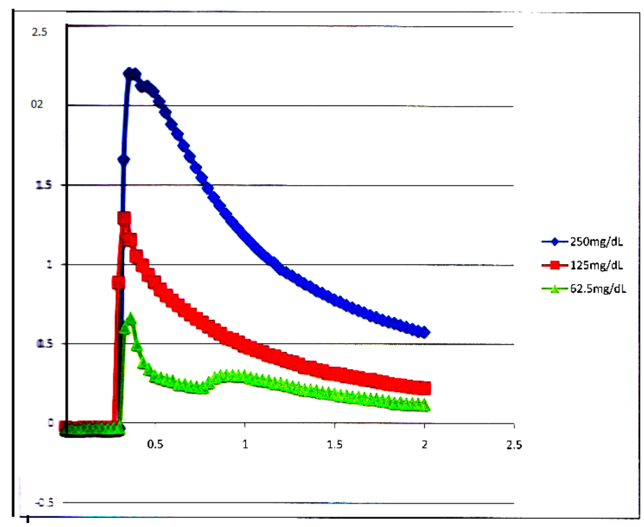


Fig. 6. Change in voltage level for different concentration of glucose

5. CONCLUSION

A low cost glucose detection technique is discussed. The blood sugar can be displayed on a LCD as well as it can be transferred to a phone or to a PC through a Bluetooth or an Ethernet shield. Data storage can be done by developing ready to use applications for different operating system like android and windows using softwares like eclipse, visual basic etc. respectively.

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