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# Development of the Portable Blood Glucose Meter for Self-monitoring of Blood Glucose

Qi Li [1], Jingqi Yuan [1, 2]

[1]Department of Automation, Shanghai Jiao Tong University, 200030 Shanghai, China
[2]State Key Laboratory of Bioreactor Engineering, ECUST, 200237 Shanghai, China

Abstract--The work outlined in this paper is towards developing a portable, economy blood glucose meter for self-monitoring of blood glucose, which has high performance-price ratio with multifunction and is attractive to the average people. Its functions include blood glucose concentration measurement, LCD display, historical records restore, calendar/timer. It enables the patients with diabetes to detect blood glucose with a glucose oxidase electrode independently at home. This paper will outline hardware configuration in the implementation and software management. Especially, graphic trend curve on LCD allows individuals to easily see how actual blood glucose readings compare with historical records stored in the meter and show how individuals stay within their specific target range so that they can determine how well they are controlling their diabetes. Experimental results indicate that this device is easy-to-use and suitable for home blood glucose monitoring for patients.

Keywords--portable blood glucose meter, oxidase electrode, trend graphs, microcontroller, historical records

## Ⅰ. INTRODUCTION

Diabetes is a chronic and potentially disabling disease that represents a major public health and clinical concern [1]. There are an estimated 30 million people in the China who have diabetes and the number increases at 1.5% per year. Diabetics are at increased risk of developing chronic complications such as heart attacks, strokes, amputations, kidney failure and blindness [1].Early diagnosis of diabetes and subsequent good control can reduce such risk. So patients treated with diabetes need self-monitoring of their blood glucose regularly. Traditionally, blood glucose concentration is measured in the lab of the hospitals and the result can be highly accurate.. However, long period of time, large quantity of sample blood and complex operation for measurement are required by these approaches. Therefore, the traditional method isn't suitable for patients to do self-custody and self-management. The introduction of reliable methods for patients to record their own blood glucose values at home was a major breakthrough and for the first time provided raw data of sufficient accuracy to improve to the extent that maintenance of an average blood glucose in the non-diabetic range became a possibility [2]. Glucometry analytical range should include glucose concentrations from 1.11 to 33.33 mmol/l to meet glucose variation in most situations when the patient himself can decide about food intake or insulin administration. The portable home blood glucose meter is developed for this function. Nowadays blood glucose meters available in the Chinese market are mostly manufactured by foreign companies. Various glucose meters vary with respect to their glucose sensor systems and analytical performance, showing different inaccuracy and imprecision levels. With advantages in characteristics such as multifunction and high performance, these blood glucose meters are generally expensive for Chinese customers.

In this paper, a portable blood glucose meter based on a microcontroller AT89C52 and its peripheral circuit for self-monitoring of blood glucose, which has highest performance-price ratio and is economy for Chinese patients, is developed.

## Ⅱ. GLUCOSE OXIDASE ELECTRODE SENSOR

Current blood glucose sensors can be divided into two approaches: electroenzymatic and optical [3].The electro enzymatic sensors, based on polarographic principles, utilize the phenomenon of glucose oxidation with a glucose oxidase enzyme. This chemical reaction can be measured amperometrically or potentiometrically. In the primary optical approach, the attenuated total reflection and infrared absorption spectroscopy is used to measure blood glucose levels. Many sensors use an electrode/oxidation method to determine the blood glucose level [4].

The sensor uses a platinum electrode and a silver electrode to form part of an electric circuit in which hydrogen peroxide is electrolyzed. The hydrogen peroxide is produced as a result of the oxidation of glucose on a glucose oxidase membrane as shown in Eq(1), and the current through the circuit provides a measure of the hydrogen peroxide concentration, and hence the glucose concentration, in the vicinity of the sensor [4].

$$C_6H_{12}O_6 + O_2 \rightarrow C_6H_{10}O_6 + H_2O_2 \quad (1)$$

The sensor the portable blood glucose meter uses is based on glucose oxidase electrode. Glucose oxidase was immobilized at a platinized activated carbon electrode and the enzyme electrode was used for the amperometric determination of glucose in injection by the electrochemical detection of enzymically produced hydrogen peroxide.The sensor is in the form of a composite electrode comprising electrodes, a glucose oxidase membrane layer, a polyurethane film which is permeable to glucose, oxygen and hydrogen peroxide as shown in Fig.1.

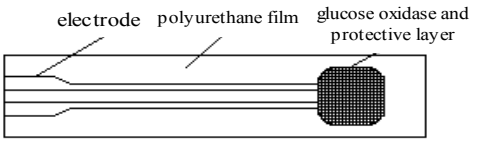


Fig.1 Structure of glucose oxidase electrode

Using amperometric determination method with constant potential, which is 0.3V used in the portable meter, the current response of the sensor is found to be linear with the glucose concentration in the range of 5 to 30mmol/ L with fast response time of about 20 seconds. Fig.2 show the relationship between oxidase electrode response current and blood glucose concentration.

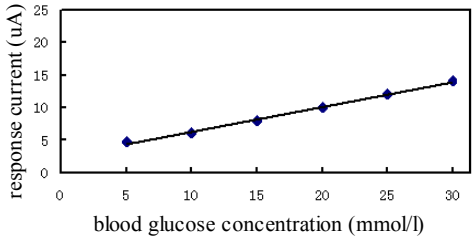


Fig.2 relationship between oxidase electrode response current and blood glucose concentration

## III. HARDWARE AND SOFTWARE OF THE METER

### A. Hardware Configuration

There are 9 basic modules in the structure of meter's hardware as shown in Fig.3: the power module, sensor signal disposal module, analog to digital convert module, button detect module, battery volume detect module, MCU module, LCD driver module, memory module and calendar/timer module.

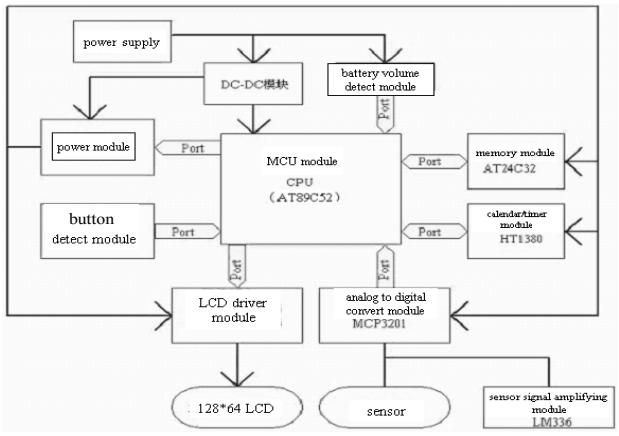


Fig.3 Hardware Structure of the portable blood glucose meter

The principle of the portable blood glucose meter is as following: The blood sample obtained from patient is applied to the reagent strip. And the strip is inserted into the port of the measuring sensor. The minute current produced after the chemical reaction shown above is transferred to signal amplifying module and analog to digital convert module step by step. The digital signal is processed by MCU module. At the same time, the current time is provided by calendar/timer module. MCU module is the core module. The information of measuring results and current time are stored in the memory by memory module. At last, the result is displayed and graphic trend curve of all the historical records is also displayed on LCD drived by LCD driver module.

Some innovative functions are emphasized here.

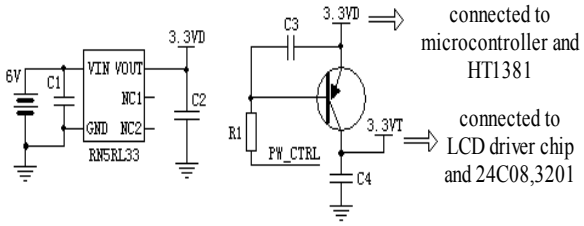


Fig.4 Low power consumption module schematics

First, low power consumption module is designed, whose schematics is illustrated in Fig.4.The output 3.3VD of RN5RL33 is power supply of the whole system, which can lower power consumption of the meter. 3.3VD is connected to an audion. Controlled by the signal PW_CTRL of singlechip, the audion generates 3.3VT.For 3.3VD is always on, it is designed to be the power supply of singlechip such as AT89C52and timer chip such as HT1380 which are working all the time. The on or off switch of 3.3VT can controlled by singlechip. It is designed to be the power supply of some singlechips such as MCP3201 which stop working when the meter is turned off. All these are designed to prolong the duration of batteries which are the power supply of the meter.

Second, the meter employs the EEPROM AT24C32 to record all kinds of parameters necessary and historical results of glucose concentration.. It helps people with diabetes to get all of the information that they need - so that they can take better care of themselves. It eliminates the need to write down the results in a record book. 90 historical records, which is necessary for patients to review their glucose concentration trend, can be stored in the meter. Many meters available in the market has no such function.

Third, graphic trend curve of historical records of blood glucose concentration will be displayed on LCD as illustrated in Fig.5 which allows individuals to easily see

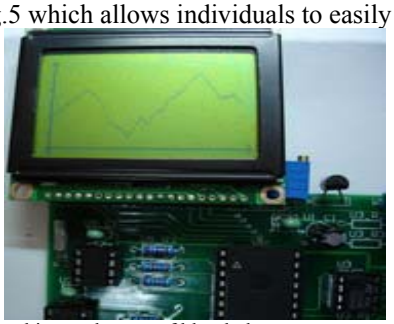

Fig.5 Graphic trend curve of blood glucose concentration

how actual blood glucose readings compare with a desired target range and historical records and show how individuals stay within non-diabetic range so that they can determine how well they are controlling their diabetes. It is

an innovative function compared with the most meters available in the markets.

Some other traits highlight this portable meter. First of all, for all the modules of the meter are composed by cheap singlechips, the cost of the meter developed in this paper is low, which is economy compared with the meters manufactured by other companies for the Chinese patients.

Secondly, there have been many reports on the analytical and overall performance of home blood glucose meters, but their overall accuracy depends not only on the analytical performance of the instrument, but also on the proficiency of the operator. So maximum simplicity of the operation of blood glucose meter should be guaranteed due to patients' lack of analytical skill in order to diminish this effect on the glucose assay. Thus there is only one button on the meter for the patients to do the measurement. The meter functions differently according to the time intervals that button is pushed. The button detection circuit is shown in Fig.6.

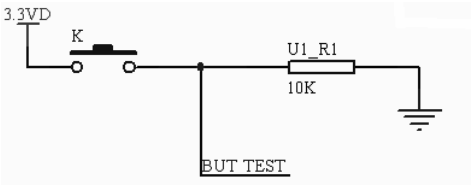


Fig.6 Keyboard detection circuit

B. Software Configuration

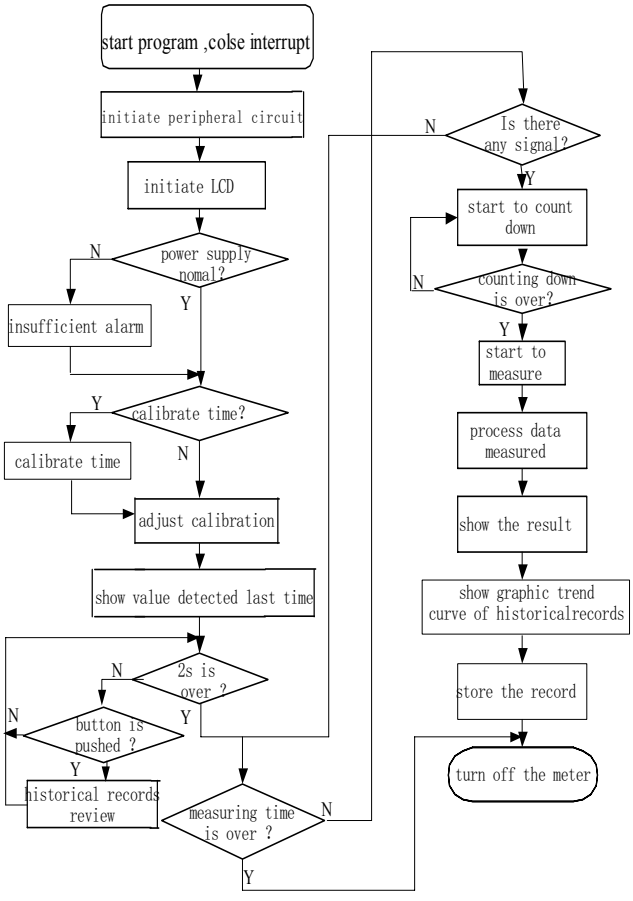


Fig.7 System software flow chart of portable blood glucose meter

The design of software for the portable blood glucose meter follows blocking principle. All the programs are developed in C language. Fig.7 presents system software flow chart of portable blood glucose meter, which consists mainly of drivers which is designed for driving hardware modules.

The glucose oxidase is subject to ambient moisture and temperature. So the oxidase electrode response current response current is different in different areas, such as northern china and southern china. To compensate for the systematic deviation brought by this characteristic of the glucose oxidase, software calibration is applied in this meter. The software calibration is carried out by the patients according to the manual. So it is a simple, easy-to-use, convenient method to reduce the measuring error.

## IV. EXPERIMENTAL RESULTS

The performance of the portable blood glucose meter is evaluated.

To evaluate the accuracy of the meter, precise resistance is employed because the meter determine the blood glucose concentration by measuring the voltage of the resistance through which the current generated by the chemical reaction illustrated above flows. The glucose oxidase electrode is provided with 0.3V power supply.

All functions are controlled by one button. The average duration required for set-up of the meter and measuring is 10 seconds and 20 seconds separately. Analytical range of glucose meter is 2.2–27.8 mmol/l, which covers normal glucose variation in most situations.

82 experimental samples were employed. The relationship between oxidase electrode response current and blood glucose concentration is shown in Fig.8. The results of experiment showed that the portable blood glucose meter achieves a total error of ±1% of entire measuring range at glucose concentrations ranging above 11.1 mmol/l and a error of ±0.1mmol/l at glucose concentrations ranging from 2.2 to 11.1 mmol/l. We also found a desired linearity of glucose meter response with actual glucose concentrations.

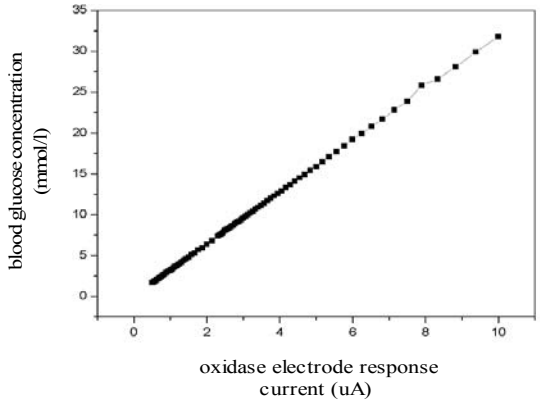


Fig.8 relationship between oxidase electrode response current and blood glucose concentration

The ISO/CD15197 have recommended that a difference of ±1.1 mmol/l below glucose levels of 5.0

mmol/l, and a difference of ±20% above glucose levels 5.0 mmol/l is acceptable[5]. The results of this study showed that the accuracy of the blood glucose meter compared to the over the entire range was acceptable.

## V. CONCLUSIONS

The portable blood glucose meter developed in this paper have shown the desired analytical range and a satisfactory precision in serial glucose concentration measurements. It is easy-to-use. .It provide innovative solutions in blood glucose monitoring ,which include reducing the size and cost of blood glucose meters to make them more convenient to use and economy for Chinese patients; making them suitable for patient self-monitoring at home, which is now considered the cornerstone of effective diabetes management.

The products based on the prototype of the portable blood glucose meter developed in this paper have been produced by Xinli Medical instrument company in Shanghai. The appearance of this kind of the portable blood glucose meter is shown in Fig.9.


Fig.9 Overview of Microsense

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