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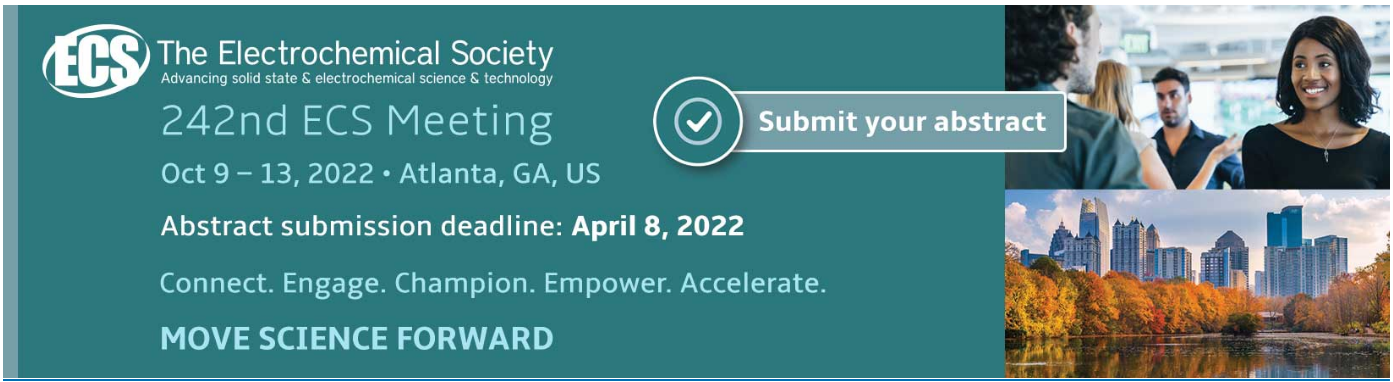

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Research Based on Non-Invasive Blood Glucose Monitoring Equipment

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Abstract. Self-monitoring of blood glucose in patients with diabetes is crucial in reducing complications. Current methods of blood glucose measurement are generally invasive. The project is to study the equipment that can help diabetics to non-invasive monitor blood glucose daily. It is made up of SPWM part, Infrared tubes, data acquisition and processing part and Screen-display part. SPWM part consists of Times of STM32; Infrared tubes are made of Infrared emission tube which can generate Near-infrared light and Infrared receiver tube; Acquisition is composed of 12-bit analog-to-digital converters embedded into STM32. This equipment is capable of identifying solutions with different glucose concentration and has the characteristics of small size and high cost performance.

1. Introduction

The diabetes mellitus is a metabolic disease characterized by chronic hyperglycemia caused by a variety of causes. Previous studies have found that diabetic patients with poor control of blood glucose are more prone to chronic vascular complications, and the risk of diabetes related death is increased. Self-Monitoring Blood Glucose (SMBG) plays an extremely important role in the management of diabetes. It can help improve blood sugar control and ensure the safety and effectiveness of hypoglycemic therapy. However, SMBG requires the patient to test blood glucose several times a day [1]. The invasive blood glucose meter has caused inconvenience and pain to the patient to a great extent. Taking blood or collecting blood from the finger make the diabetic feel pain and have the risk of infection, which limit the frequency of testing blood glucose and can't give a diabetic satisficing results of monitoring blood glucose. There is an urgent need to use non-invasive blood glucose measurement technology to make up for lack of invasive blood collection [2]. At present, the application of infrared has penetrated into the field of biomedical engineering. The technology that generates infrared rays is also becoming more and more mature, and the prices of its devices are getting cheaper and cheaper.

The ways used in equipment of measuring non-invasively blood glucose mainly are: a. The ear clip is caught in the ear lobe of the measurers, which measures the potential difference between both sides of the ear; b. The sensor is embedded a layer of skin that is gashed on the abdomen or elbow of measurer; c. optical methods. Active research areas have included dpolarimetry, Raman spectroscopy, diffuse reflection spectroscopy, absorption/transmission spectroscopy [3], thermal emission spectroscopy, fluorescence spectroscopy and photoacoustic spectroscopy. In all noninvasive glucose monitoring attempts, the optical method is the most promising. In this paper, there is the equipment which can display the waveform that reflects the near-infrared intensity transmitting the solution of glucose and

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show the value of the concentration of glucose. The equipment is portable, cost-effective and can easily different measure the concentration of glucose.

2. Hardware of System

The system structure of hardware is shown in figure 1. It consists of the generation of SPWM waveform, the circuit of Infrared transmitter and receiver, A / D acquisition, Signal Processing and LCD display.

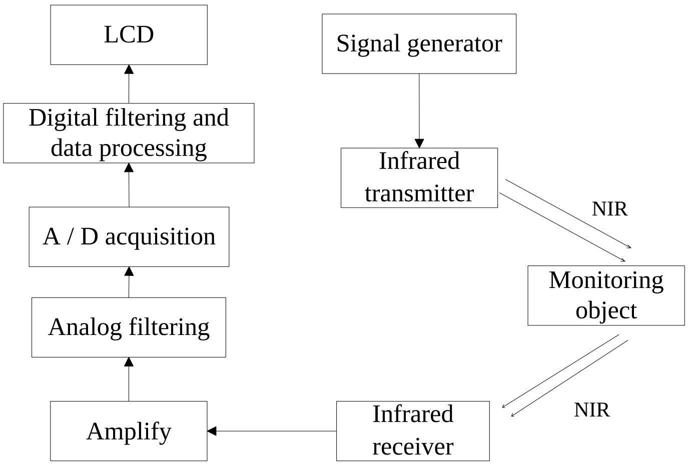

Figure 1. The structure of the system

2.1. The Circuit of Infrared Transmitter and Receiver

Near infrared ray is defined as the wavelength of 780 ~ 2526nm electromagnetic wave. The most interesting spectral range is near infrared (NIR), which allows ray to penetrate deep into the bloodstream, as result from its relatively low water absorption. Due to the absorption of glucose on the infrared ray, the paper selects infrared as a transmission signal, which has character of wavelength of 940nm. NIR spectroscopy allows glucose measurement in tissues in the range of 1– 100 mm of depths, with a decrease in penetration depth for increasing wavelength values. The light focused on the body is partially absorbed and scattered, due to its interaction with chemical components within the tissue [4].

Because the current of STM32F103's port output is not enough to make the infrared emission tube turn-on [5], the driver circuit of infrared transmitter involved in figure 2 is needed. Infrared receiver tube converts the optical signal into electrical signal. Through the Preprocessing circuit involved in figure 3, the voltage signal is used as the input signal to the positive terminal of the Operational Amplifier with 50 times, and is amplified with voltage range between 0 ~ 3V.

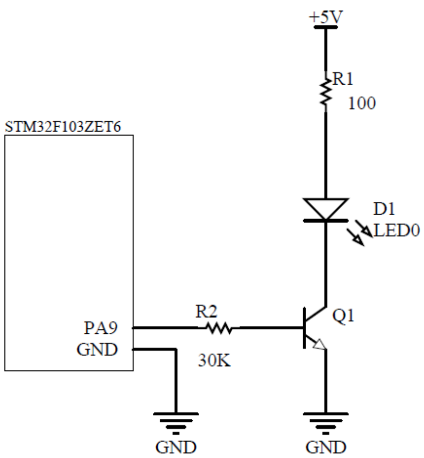

Figure 2. The circuit of Infrared transmitter

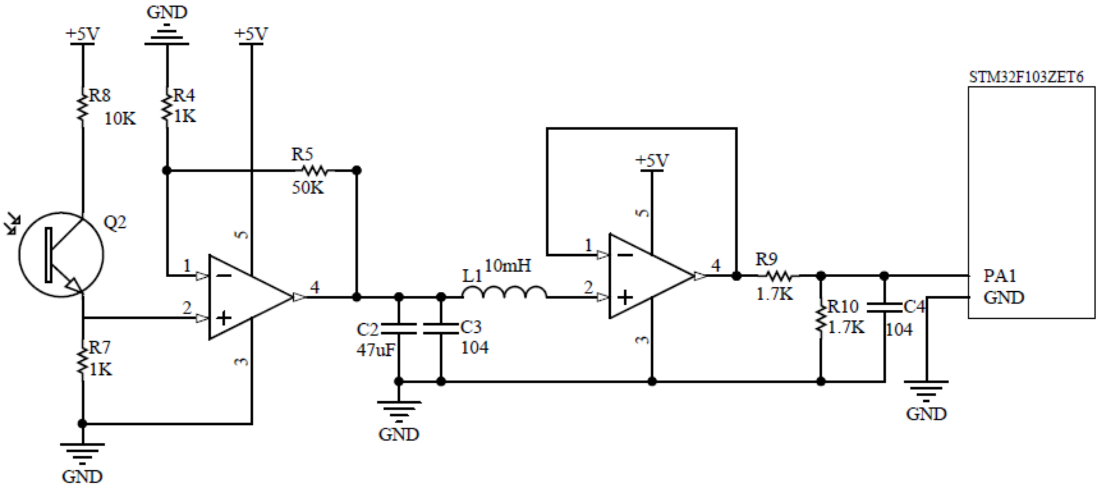

Figure 3. The circuit of Infrared receiver and analog filter

3. Software of System

3.1. Generation of Excitation Signal

Pulse Width Modulation (PWM) is a very effective technique for controlling analog circuits using digital outputs from microprocessors. When a certain frequency signal is generated, the period of the sampling pulse is kept unchanged. Meanwhile, the duty cycle is changed accordingly. The pulse duty cycle is larger as the value of sine table get larger. On the contrary, the pulse duty cycle is smaller when taking the corresponding sine table smaller value. So that the output waveform is a series of different duty cycle and the pulse width changes according to the law of sinusoidal pulse, which is SPWM that is the excitation signal [6]. One advantage of SPWM is that the signals from the processor to the controlled system are in digital form and minimizes Noise effects in digital-to-analog conversion. The pulse width of SPWM is variable with the sinusoidal disciplinarian so as to restrain the lower-order harmonics [7].

The PWM wave can be acquired by advanced timer1 of STM32F103. Clock and automatic reload cycle value of Advanced-control timer1 is 1MHz and 9999. The general timer 2 configuration is same as advanced timer1. The STM32F103 executives interrupt program per 0.01s. The resulting SPWM wave shown in figure 4 serves as the signal source of infrared emission.

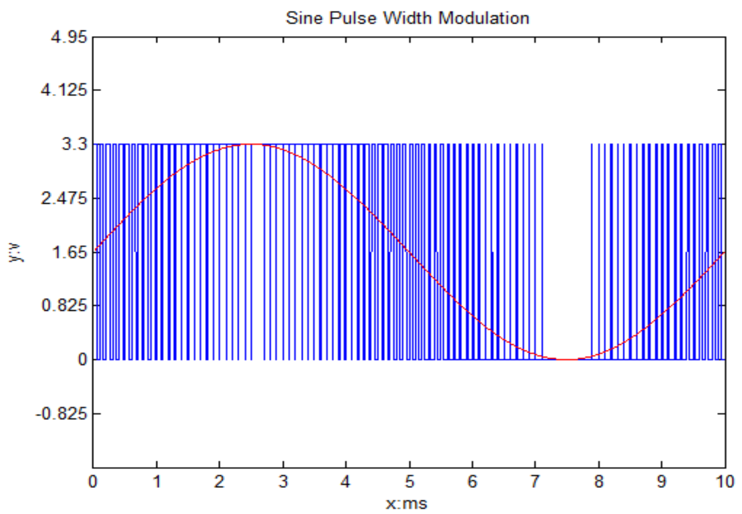

Figure 4. SPWM waveform

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3.2. A / D Acquisition

The analog filtered signal has the characters of a voltage range of 0-3.3 V and a frequency of 100 Hz, so the sampling frequency should not be less than 200 Hz. STM32F103ZET6's built-in 12-bit ADC has a reference voltage of 3.3V and a conversion time of 21.208us. Because these features meet the required acquisition accuracy and sampling rate, the STM32F103ZET6 built-in 12-bit analog-to-digital converter was chosen. Due to high rate of the conversion rate of that, in order to avoid the oversampling, we need to use the timer to meet the actual sampling frequency, which can be got from the initialization of A/D and the timer interrupt service program. Through the initialization of A/D in figure 5, the frequency of 12 MHZ that is the A/D's conversing time can be got. The time of timer update interrupt is 78.791us, and A/D acquisition is performed in the interrupt service program. Through the process of the interrupt service program in figure 6, the acquisition frequency of 100 HZ can be obtained.

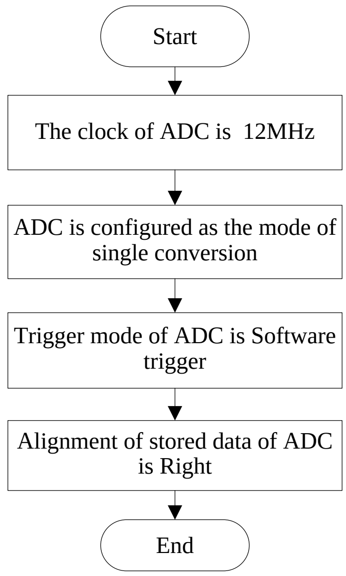

Figure 5. The configuration of initialization

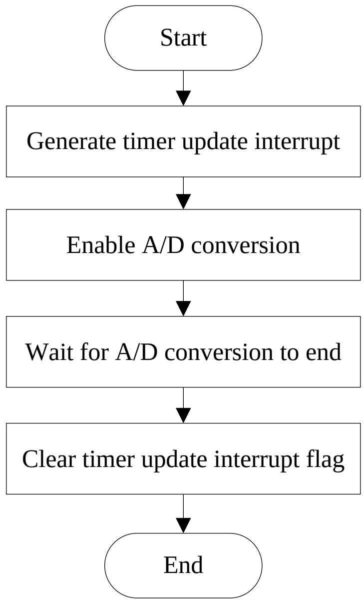

Figure 6. The process of timer interrupt service program

3.3. Signal Processing

Digital filter is important class of Linear time invariant DSP systems designed to modify the frequency characteristics of the input signal x (n) to meet certain specific design requirements. Digital filters have the potential to attain much better signal to noise ratios than Analog filters, and emerged as a strong option for removing noise, shaping spectrum and minimizing intersymbol interference (ISI) in communication architectures [8]. It is classified either as finite duration unit pulse response (FIR) filters or infinite duration unit pulse response (IIR) filters, depending on the form of the unit pulse response of the system. FIR filters have the following advantages over IIR filters [9]: a. They can have an exact linear phase; b. They are always stable; c. The design methods are generally linear; d. They can be realized efficiently in hardware; e. The filter start-up transients have finite duration.

The windowing method requires minimum amount of computational effort, so window method is simple to implement. For the given window, the maximum amplitude of ripple in the filter response is fixed. Thus the stop band attenuation is fixed in the given window [10]. The Nuttall window has the widest main lobe and lowest maximum side lobe level among the Blackman, Exact Blackman, and the BlackmanHarris windows. The equation for the Nuttall window is formula (3).

$$\omega_1 = a_0 - a_1\cos\left(2\pi \frac{n}{N-1}\right) \tag{1}$$

$$\omega_2 = a_2\cos\left(4\pi \frac{n}{N-1}\right) - a_3\cos\left(6\pi \frac{n}{N-1}\right) \tag{2}$$

$$\omega(n) = \omega_1 + \omega_2 \tag{3}$$

After passing the circuit of the infrared emission and receive and A / D conversion, signal is inevitably mixed with noise which is similar to Gaussian white noise, therefore a digital filter using easy-to-design FIR filter which uses window function design, choosing the Nuttall window, Fs = 10 kHz and Fc = 100Hz, is needed for filtering. The magnitude Response of the FIR used is shown in figure 7.

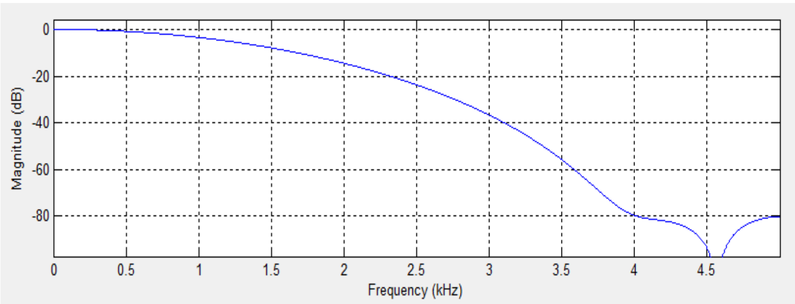

Figure 7. The magnitude Response

The result is displayed on the LCD screen as shown in figure. 8[11].The FIR filter's coefficients are obtained by MATLAB. A noise-containing signal through the FIR filter and removes the phase delay effect diagram [12], which is obtained by placing the c language program which is written in the Keil and shown in figure 9. The signal recognition part simply uses the threshold decision method.

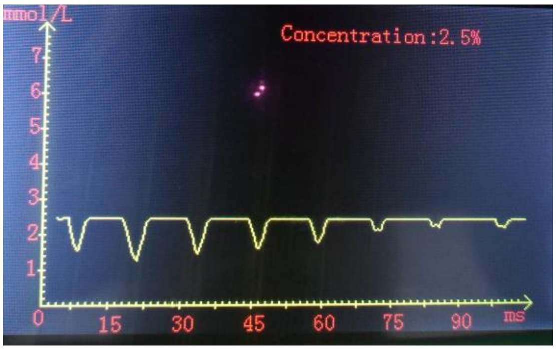

Figure 8. The result on the LCD

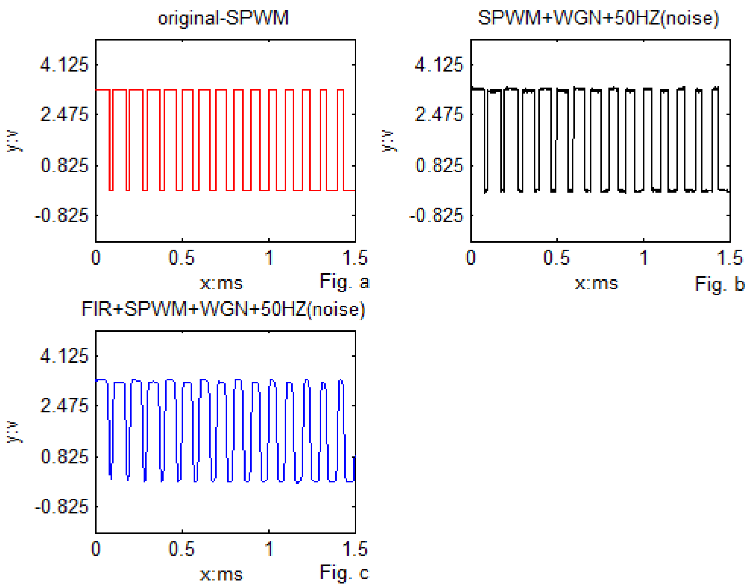

Figure 9. The effect of using c language written in Keil

4. Conclusion

The four experimental subjects were: Air, Solution of concentration of 0.9% NaCl, and Solution of concentration of 0.45% NaCl, and Solution of concentration of 5% glucose. Take the peak value after signal processing, the result is shown in figure 12. The y1 represents the average value of Air; y2 represents the average value of Concentration of 0.9% NaCl solution; y3 represents the average value of Concentration of 0.45% NaCl and 2.5% glucose solution; y4 represents the average value of Concentration of 2.5% glucose solution.

The conclusion can be drawn from the figure 10. when the object is air, the infrared ray transmittance is the largest, hence the peak value after sampling is larger than that of the other three objects; when the object is Solution of concentration of 0.9% NaCl, the common factors of water and NaCl lead to the decline of the degree of transmission of infrared ray ;When the object is solution of 0.45% NaCl and 2.5% glucose, because the absorption of infrared ray by glucose is larger than that of NaCl ,the degree of transmission of infrared ray decreases again; When the medium is Solution of concentration of 5% glucose, there is little difference between the peak value of the signal and the mixed solution of 0.45% NaCl and 2.5% glucose. They factors leading to the result are as follows: a. the degree of absorption of glucose to the infrared ray wavelength of 940 nm isn't big enough [13]; b. With the increase of concentration of NaCl, the concentration of water molecules in the third category decreases and the hydrogen bonds are destroyed, and the combination of sodium ions and some water molecules forms hydrate compounds, which leads to the relatively higher concentration and absorption of the first category of water molecules [14]; c. The ability of aqueous glucose solution to absorb infrared rays is greater than that of the same solution of NaCl.

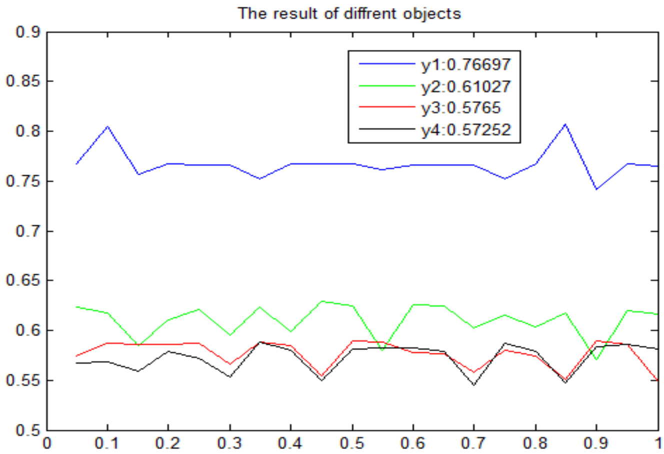

Figure 10. The result of four subjects

The four peak values of the infrared signal passing through four different media show a downward trend. This equipment is can be used as an auxiliary blood glucose monitor meter for diabetic patients. In addition, there are many improvements to the system. Due to the use of an analog-to-digital converter built into the MCU, the A/D acquisition accuracy is limited. For analog and digitally filtered data, the program does not use specific algorithm to process the data, but simply zooms in. These problems will lead to a decrease in the accuracy of the tested glucose concentration.

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