Model of Digital Blood Pressure Meter Using FPGA

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Abstract: Hypertension is one of the most common diseases nowadays, and it is important to monitor the blood pressure in a patient's daily life. The goal of this work is to design and develop an intelligent and easy-to-use digital blood pressure meter for convenient personal use. Due to the high speed offered by Field-Programmable Gate Array (FPGA) and because FPGA overcomes the disadvantages of a single-chip microcomputer's lack of on-chip resource and high-end Advanced RISC Machine (ARM) processors' higher costs, FPGA is chosen as the processor in this work. We first use a pressure sensor to capture the blood pressure signal, out of which a pulse wave is electronically extracted through a band-pass filter to determine the systolic and diastolic points. Both the original pressure signal and the pulse wave signal are digitized and fed into the FPGA which implements an Oscillometric method to process these two digital signals to get the systolic pressure and the diastolic pressure. The Temperature and the heart rate is also obtained to get the information of the body behavioural. The readings are then shown on a display module. Experimental studies demonstrate that the digital blood pressure meter is fast and accurate in measuring blood pressure.

Keywords: *Blood Pressure, Heart Rate, Temperature, Field-Programmable Gate Array, Oscillometric Method, Digital Meter, Pressure Sensor.*

I. INTRODUCTION

As hypertension become more and more widespread, people tend to pay more attention to their health. It is important to track the blood pressure in a patient's daily life, especially who werediagnosed with hypertension. Traditional mercury blood pressure meter needs special training to get the right systolic anddiastolic pressure. Therefore, digital blood pressure meter becomes more and more necessary in our daily life.

Blood pressure commonly refers to the arterial pressure measured at a person's upper arm. Traditionally the unit of blood pressure is mmHg. A healthy adult at rest normally sees a systolic pressure reading between 90 and 140 mmHg, and a Diastolic pressure between 60 and 90 mmHg. Blood pressure is a main indicator reflecting the state of blood flow dynamics and the health condition of the cardiovascular system. At present, the blood pressure measurement technologies can be divided into two categories, that is, direct (invasive) manometry and indirect (non-invasive) manometry.

Temperature refers tothe degree or intensity of heat present in a substance or object, especially as expressed according to a comparative scale and shown by a thermometer or perceived by touch. The average normal body temperature is generally accepted as **98.6°F** (**37°C**). Some studies have shown that the "normal" body temperature can have a wide range, from **97°F** (**36.1°C**) to **99°F** (**37.2°C**). A temperature over **100.4°F** (**38°C**) most often means you have a fever caused by an infection or illness.

Heart Rate refers tothe speed at which the heart beats. The number of heartbeats per unit of time, usually per minute. The heart rate is based on the number of contractions of the ventricles (the lower chambers of the heart). The heart rate may be too fast (tachycardia) or too slow. The pulse is a bulge of an artery from waves of blood that course through the blood vessels each time the heart beats. The pulse is often taken at the wrist to estimate the heart rate. A normal resting heart rate for adults' ranges from 60 to 100 beats a minute. Generally, a lower heart rate at rest implies more efficient heart function and better cardiovascular fitness. For example, a well-trained athlete might have a normal resting heartrate closer to 40 beats a minute.

In this project, we will use the non-invasive manometry technology. There are many ways of doing non-invasive manometry, among which the Oscillometric method is the current mainstream technology used in blood pressure monitoring. Compared to other non-invasive methods, it has better anti- interference ability and can be more reliably used to achieve automatic detection of blood pressure, temperature and heart rate. Therefore we also choose the Oscillometric method to measure blood pressure, heart rate and temperature in this project.

II. PRINCIPLE OF BLOOD PRESSURE METER

Direct measurement of blood pressure is an invasiveprocedure, but it can be indirectly, thus non-invasivelymeasured by measuring the air pressure in the cuff of a blood pressure meter. Among others, one basis of blood pressure measurement is the so called Oscillometric method. Generally, the measured pressuresignal can be decomposed into a DC and an AC component. The DC component of the blood pressure mainly comes fromthe static cuff pressure, while the AC component representsthe artery pulse wave, with its amplitude changing along withthe cuff pressure change.When the cuff pressure is high enough, it will block the arteryfrom pulsating. As shown in Figure 1, for a healthy adult, when the static cuff pressure is greater than 180 mmHg, theAC component of the pressure signal is completelysuppressed. When the cuff pressure is gradually reduced, apulse wave gradually emerges, and its amplitude envelopestarts to grow. When the amplitude reaches its maximum, thecuff pressure, or the DC component in blood pressure in corresponds to the mean arterial pressure. Afterreaching the maximum, the amplitude envelope graduallydecreases.When the envelope of the AC component is on the rise, thereis an inflection point in the DC curve, which corresponds to the systolic pressure. Similarly, when the envelope of the AC component is in the decreasing phase, there is another inflection point that corresponds to the diastolic pressure. In this paper, rather than finding the inflection points manually, we choose to use the points at 50% and 80% of the maximum as the positions to calculate the systolic and diastolic pressures, respectively [2]. These two values can be fine tuned if later needed during the process of system calibration.

Measured cuff air pressure is decomposed into DC and AC components. Systolic and diastolic pressures are determined at the 50% height position before and 80% height position after the AC envelope peak, respectively.

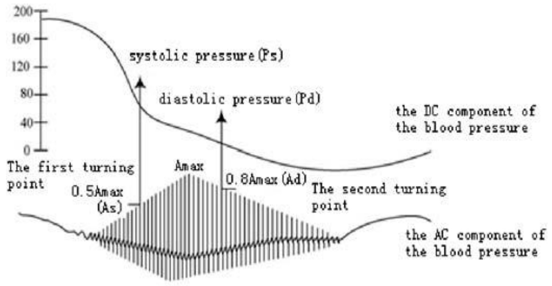


Figure 1: Diagram of the Oscillometric method.

III. LITERATURE SURVEY

Design of automated Oscillometric electric Blood Pressure Meter based on MSP430F449

It uses MSP430F449 single-chip microcomputer as the controller kernel. The serial communication and real-time clock are also included in the system. The automated electronic blood pressure meter performs satisfactorily when compared with conventional auscultation method and has realized accurate measurement of blood pressure. In the measurement process, there is some small difference between the pressure sensor output signal, the output signal of the filtering circuit and the real value, therefore there is some error.

The design of electronic Blood Pressure Meter with function of hemodynamic parameters detecting

The electronic blood pressure meter with function of hemodynamic parameters detecting is designed in this paper. It adopts the C8051F020 single-chip microcomputer as the core of calculating and processing of the device.This paper suggests the use of gasbag method which the user can handle independently. But compared to film type detection method the gasbag method in measuring radial artery pulse wave still exists shortcomings such as it will make some errors by losing some information when calculating the blood flow parameter with the pulse waves.

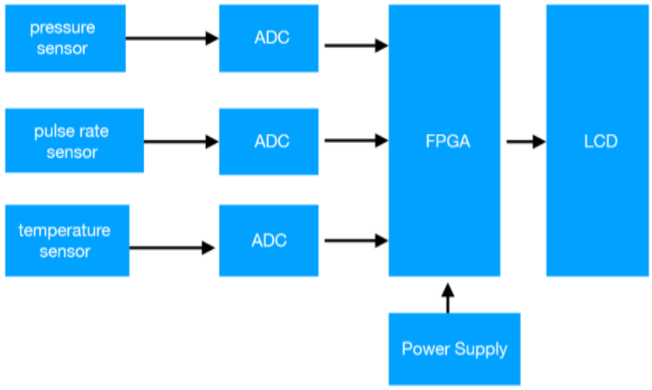
A novel digital Blood Pressure Meter using Cortex-M3 microcontroller

This issue introduced a new design of blood pressure meter which do not need complicated signal conditioning circuit. Based on digital signal processing technology, it achieved a blood pressure meter with the least spare parts needed. All signal processing procedures are accomplished by digital filters using ARM Cortex-M3 microcontroller, which were both stable and cost-saving.FIR filters are used here. FIR filters has limited cutoff characteristics. A greater order of FIR filter will have better frequency response but will cause longer delay from input to output of the filter. Parallel processing is not possible using Cortex-M3 microcontroller. Processors have a fixed hardware structure. It means that all the transistors memory, peripheral structures and the connections are constant.

IV. PROPOSEDSYSTEM

The proposed block diagram is as follows:

Here we are proposing an electronic blood pressure meter using FPGA. Due to the high speed offered by Field-Programmable Gate Array (FPGA) and because FPGA overcomes the disadvantages of a single-chip micro-computer's lack of on-chip resource and high-end Advanced RISC Machine (ARM) processors' higher costs, FPGA is chosen as the processor in this work.



In this project we use pressure sensor to calculate blood pressure (systolic and diastolic), pulse ratesensor for measuring heart rate, and temperature sensor for calculating body temperature. The analog outputs from these devices are converted to digital signals using Analog to Digital converters (ADC). These outputs from ADC's are processed parallelly by FPGA processor. The processed outputs are displayed on a LCD. Thus we design a digital blood pressure meter has its suitable for household use.

V. SYSTEM DESCRIPTION

FPGA software

The FPGA software is divided into seven modules, namely, frequency module, display module, button module, sampling as shown in Figure.

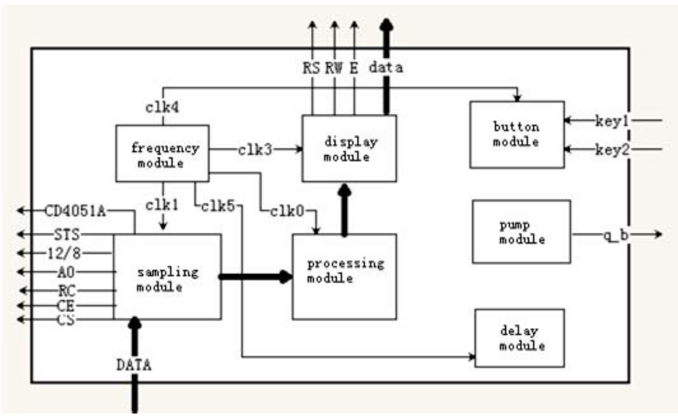


Figure 2: Diagram of the top-level modules in FPGA design

The frequency module provides clock signals to the other modules. The button module interfaces with the user and isused to identify any button pressed to control the start andstop of the blood pressure measurement process. The pump module is to control a pneumatic pump to inflate the cuffwhen the measurement starts and a valve to slowly deflate itduring the measurement. The delay module is used to add adelay of 2 seconds after the pump stops inflation, so as to avoid any invalid data being collected during the first 2speriod. The ADC sampling module is used to control theADC574 chip and the analog multiplexer, enabling the sampling of both the pulse wave signal and the static cuffpressure signal in a coordinated manner. The data processing module implements the Oscillometric processing method described in Section 2 to calculate the systolic and diastolicpressures. The display module is to display the blood pressures measured on a LCD unit.

Pulse wave extracting circuit

Since the pulse wave signal is a weak signal mixed in the DC signal, we need to design a special circuit to exact it. For this purpose, the signal obtained by the pressure sensor first goesthrough a large capacitor C3 to filter out the DC component,thus goes through a band-pass filter to filter out noise.Because the pulse wave signal is a low-frequency signal inthe order of 1Hz, we choose to set the band pass filter rangeto be 0.05 – 10 Hz. For the low pass filter, we decide to use a 2nd order filter [4] (Figure 3) with 10Hz cut-off frequency to clean up the AC signal. Referring to Figure 3, the cut-off frequency is given by:

$$Fc = 1 / (2\pi R C)$$

Where R is the resistance for R7, R8, R9, and R10, and C is the capacitance for C4 and C5. To reach a target cut-off frequency Fc of 10Hz, we empirically set C to 1uF. Then the needed resistance R is 16KΩ.

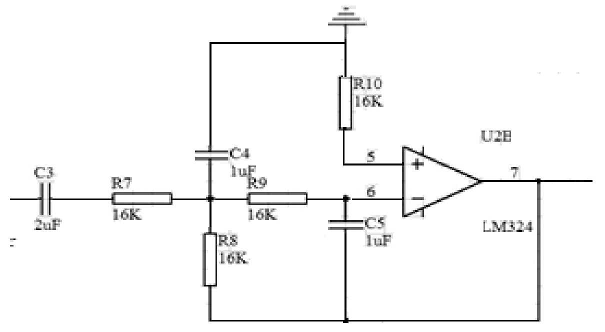


Figure 3: Diagram of the 2nd order low-pass filter circuit.

After being filtered by the low-pass filter, the signal goes through an amplifier, followed by a high-pass filter of 0.05Hzcut-off frequency. Since the high-pass filter is similar inPrinciple to the low-pass filter, it is not described in detail here.

Display and Backlighting

Blood pressure monitors use a simple LCD with 100 segments or less that can be driven by a driver integrated within the microcontroller. Backlighting can be added by using 1 or 2 white LEDs (WLEDs) or an electroluminescent (EL) source. A discrete WLED driver can easily be added to a monitor design by using a switching topology for wrist monitors and a linear topology for upper-arm monitors.

Electrostatic Discharge

All monitors must pass IEC 61000-4-2 electrostatic discharge (ESD) requirements. Using circuitry with built-in ESD protection or adding ESD line protectorsto exposed traces can help meet these requirements.

Hardware Used:

- FPGA: Spartan 6
- Heart rate measuring sensor (TCRT1000)
- Pressure sensor (MPS 2000)
- Temperature sensor: LM 35
- 12bit ADC –ADC0574
- Power Supply Device: 12V Adaptor
- LCD 16X2

Software Used:

- Xilinx
- Programming into FPGA: JTAG Interface
- Programming language: HDL (VHDL)

CONCLUSION

An electronic blood pressure meter using FPGA is designedand developed. It has shown to have accuracy comparable to Mercury blood pressure meter. There, of course, are areas forfuture improvements before it can be actually used as a Personal care device. For example, we did not design acustom power circuit in the prototype. Instead, a laboratoryDC power supply was used. Also, measurement results cannotbe stored after each use. But these problems are not critical tothe essential functionalities of the blood pressure meter and can be easily solved. In the next iteration, besides these improvements, we will also plan on adding features like aBluetooth module to link to a mobile device, and a mobileApp for data transmission, storage, and processing, so the results can be sent to the user's mobile device and be kept inmemory totrackreadings over time andfor later analysis.

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