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# DIGITAL BLOOD PRESSURE MONITOR

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## ABSTRACT

In this work we present a blood pressure monitor which measures both the high blood pressure (systolic pressure), and the low blood pressure (diastolic pressure). It is a semiautomatic meter because the inflation of the occlusive cuff is carried out in a manual way. The transducer used is a piezoresistive silicon pressure sensor integrated on chip which provides a proportional voltage to the input pressure, with a measurement range from 0 to 50 kPa (0–7.3 PSI). The oscillometric method is employed, which consists on detecting the oscillometric signal on brachial artery, being processed at each pressure step, when the cuff is gradually deflated. Signal sampling is carried out at a rate determined by the heart rate.

In order to program the digital electronics of the circuit we used Altera tools, with the compiler MAX-PLUS II, and the device selected to implement the design was an EPM7128SLC84-15 CPLD (Complex Programmable Logic Device)

## RESUMEN

El monitor digital de presión sanguínea diseñado, que se presenta en este trabajo, mide tanto la presión sanguínea alta (presión sistólica), como la presión sanguínea baja (presión diastólica). Es un medidor semiautomático, es decir, el inflado de la faja de presión para el brazo se hace en forma manual. El transductor utilizado es un sensor de presión piezoresistivo integrado en forma de chip, cuya salida es un voltaje proporcional a la presión de entrada, con un intervalo de medición entre cero y 50 kPa (0–7.3 PSI). Para realizar la medición se utiliza el principio oscilométrico, que consiste en detectar la señal oscilométrica sobre la arteria branquial, la cual es procesada para cada paso de presión, al tiempo que la faja de presión es desinflada en forma gradual. El muestreo de señal se efectúa a un valor determinado por el valor del pulso cardiaco.

Para programar la electrónica digital del circuito se usó la plataforma Altera, con el compilador MAX-PLUS II, y el dispositivo que se utilizó para implantar el diseño fue un CPLD, EPM7128SLC84-15.

**KEYWORDS:** Blood pressure monitor, Altera applications, Biomedical instrumentation

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## 1. INTRODUCTION

High blood pressure, also called hypertension, is a risk factor of health very frequently found in industrialized countries and it is one of the main reasons for which people visit doctors; this suffering could have very serious consequences, even the death.

Before it was required a trained person to be able to measure the blood pressure of another person, because a mercury sphygmomanometer and a stethoscope were required, until the automated blood pressure monitors appeared.

This type of monitors is now available for clinical use or home use; they are electronic devices that measure blood pressure in a very simple way that a person can carry out his measurement by himself. The measure is shown in a digital display, both the high blood pressure (systolic pressure), and the low blood pressure (diastolic pressure). *Unfortunately all these devices are imported.* For such reason we decided to design a device of this type.

### 1.1 Blood pressure monitors at home

High blood pressure is a sneaky ailment. This suffering has no symptoms that you can see or feel. Having your blood pressure checked regularly is the only way to know if it is high. Some studies indicate that home blood pressure monitoring has permitted to improve blood pressure control and thereby reduce the risk of cardiovascular events.

Taking blood pressure at home helps distinguish patient who genuinely suffer high blood pressure from those who have "white coat" hypertension, that is, the artificial suffering of a lot of patients that present growing blood pressure while he or she is in a unknown environment, such as a clinic or a hospital. If white-coat hypertension is suspected, home monitoring is especially important in order to avoid the unnecessary treatments with drugs.

## 2. NONINVASIVE BLOOD PRESSURE MENSUREMENT TECHNIQUES

The indirect measurement is also called noninvasive measurement because the body is not invaded in the process [1]. The most common site for indirect measurement is the upper arm where the brachial artery is located, although many other sites may be used. An occlusive cuff is placed over the upper arm of a patient the cuff is inflated at a pressure higher than the systolic blood pressure. The cuff is then gradually deflated, while a detector system determines the interest points at which the blood flow is restored. The most commonly used indirect methods are the auscultation and oscillometry, described below.

### 2.1 Auscultatory method

This method usually employs a mercury column, an occlusive cuff, and a stethoscope. The cuff is placed around the arm of the patient, when the cuff is inflated, the circulation in the artery is blocked temporarily, and when the cuff is deflated, sounds are generated because of the blood throbbing inside the artery. These sounds are monitored with a stethoscope placed on the brachial artery (Korotkoff sounds). When the first sound is listened, the blood pressure is verified in the meter: this is the systolic blood pressure, considered equal to the pumping pressure. When the sounds disappear, we have the diastolic pressure this is the pressure in the arteries when the heart relaxes between pulses. The highest number or the strongest sound is when the blood flows. Both numbers are important [1,2].

### 2.2 Oscillometric method

Electronic pressure monitors based on oscillometry have become popular in recent years due to their simplicity of use. The principle of blood pressure measurement using this technique depends on the transmission of intra-arterial pulsations through the occluded arm. The cuff is placed around the upper arm and rapidly inflated to pressure 30 mmHg above the prospective systolic blood pressure, occluding the blood flow in the brachial artery. Then the cuff is deflated gradually while the detecting system, by means of a pressure sensor, detects the oscillometric signal step by step. The oscillations on the arterial pressure are processed to establish an oscillometric envelope or curve. The signal sampling is adjusted to a value determined by the value of the heart pulse.

## 3. DESIGN OF PROTOTYPE

### 3.1 Description of the instrument

The prototype built is a blood pressure digital monitor which measures both the high blood pressure (systolic) and the low blood pressure (diastolic). This is a semiautomatic meter, because the cuff pressure is inflated manually, by means

of a rubber pear. The first prototype designed is supplied with AC current (127Vac) and it has a luminous display (LEDs). A piezoresistive transducer is used as pressure sensor. To carry out the measure the principle of oscillometry was used. To program the digital circuit for this design the Altera platform was used, with the compiler MAX-BONUS II, and the device used to implant the design was an EPM7128SLC84-15 CPLD.

### 3.2 Instrument Block architecture

We can consider that the instrument designed is constituted by some basic blocks and they are shown in the diagram below (Figure 1) and later on a brief description is made for each one of these.

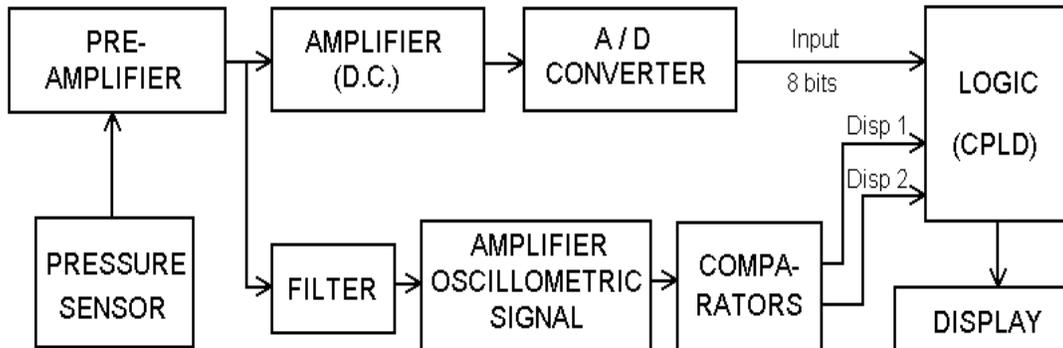


Figure 1. Blocks diagram of the device

## 4. GENERAL DESCRIPTION

### 4.1 Pressure sensor

The pressure transducer used is a piezoresistive pressure sensor integrated on-chip which generates a changing output voltage proportional to the applied pressure, with a measurement range from 0 to 50 kPa (0–7.3 PSI) with high accuracy. This sensor has temperature compensation and offset calibration. It is a monolithic silicon pressure sensor in which the “strain gauge”, the diaphragm and the resistive network are integral parts of the same chip.

Applying pressure to the diaphragm results in a resistance change in the “strain gauge”, which in turn causes a change in the output voltage in direct proportion to the applied pressure. [3]

### 4.2 Preamplifier

This stage is integrated basically by an amplifier with low gain, which can be used in different configurations. An instrumentation amplifier or conventional operational amplifiers in some amplifying configuration can be used; the output voltage is referred to ground. The preamplifier has a low noise level in the output signal and high common-mode rejection ratio (RRMC).

The output of this circuit is applied as an input for two different circuits, one is a filter and the other is an amplifier.

### 4.3 Amplifier

This amplifier receives the signal obtained from the previous stage and it is used to provide high gain, in order to adapt the signal to the later stage (A/D converter) to full scale. It also includes a zero adjustment. The signal is handled as a D.C. signal [4].

#### 4.4 Analog to Digital Converter

The A/D converter used is an 8 bit converter that provides 256 possible values. The sensor used can measure up to 377 mmHg; but the pressure to measure does not exceed 256 mmHg, then the gain of the amplifier was adjusted so that 1 mmHg coincides with each one of the possible values of the converter. The value obtained from A/D converter in binary code is applied to the digital stage (logical CPLD).

#### 4.5 Filter

Low-pass filters: The objective of this filter is to eliminate the noise due to high frequencies contained in the signal coming from the preamplifier. The cutoff frequency for this filter is 100 Hz and is composed by two second order stages connected in cascade.

#### 4.6 Amplifier for oscillometric signal

Since the signal from the preamplifier is very small, first the D.C. component of the signal is removed and then it is amplified with a high gain ( $A \sim 1000$ ) circuit, and then used as input for two comparators in the following stage.

#### 4.7 Comparator

This stage is composed by two different comparators. The first comparator detects when the oscillometric signal appears at its maximum (bigger than a preset value); the second comparador detects when the oscillometric signal is smaller than a preset value. In both cases the comparator changes its output voltage and this change is used to trigger the control logic, located in the block called "logic CPLD" [5, 6].

#### 4.8 Logic CPLD

This block (figure 2) constitutes the digital part of the instrument it is implanted in a Complex Programmable Logic Device EPM7128SLC84-15 of Altera family [7-10]. At the same time this is composed of several blocks, below a description of the operation of the CPLD.

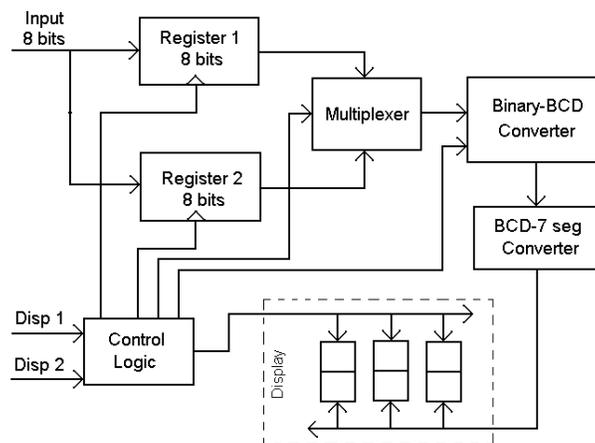


Figure 2. Blocks Diagram of the logic CPLD

The control logic receives the trigger signals Disp1 and Disp2 which indicate if the Register1 or the Register2 will be updated with the 8 bits input digitized data coming from the analog to digital converter. The 8 bits signals from registers are received by a multiplexer (controlled by control logic) that decide which of the two 8 bits data is sent to the binary-BCD converter. The binary converter converts 8 bits data to BCD format and it stores them in three internal registers of four bits each one, located in this block. The control logic indicates by means of a multiplexer located at the output of the binary-BCD converter which register will be present to the output. The BCD to 7 segments decoder

transforms the output of the previous block to 7 segments display; this decoder is shared using a multiplexer, controlled by control logic [5, 6].

#### 4.9 Display

The output of the BCD to 7 segments decoder is sent to a luminous display to show the data of systolic blood pressure and diastolic blood pressure, in alternative way controlled by the control logic.

#### 5. RESULTS

We have built a first prototype of a digital blood pressure monitor, for measuring the systolic blood pressure, and the diastolic blood pressure. This is a semiautomatic meter; the pressure cuff for the arm is inflated manually, by means of a rubber pear. The prototype is supplied with AC current (127Vac) and it has a luminous display (LEDs). The transducer used is a piezoresistive pressure sensor. The measure is carried out based on the oscillometric method. The digital part of the design was implanted in a CPLD device (EPM7128SLC84-15), this is why the instrument is less expensive than if we use conventional TTL circuits.

Although good results were obtained, further improvements to the prototype will include a microprocessor to have greater versatility of functions and storage.

#### 6. CONCLUSIONS

This kind of apparatus is of great help, it has been observed that thanks to the use of this kind of devices, doctors can obtain a better pressure control for people who suffer some cardiovascular dysfunction, diminishing in this way the risks involved.

Although in Mexico we can obtain a great variety of models of digital blood pressure monitors, there is no one made in the Country. As well as this apparatus, there are many others that could be designed and manufactured in our country; it is time that we begin to think on manufacturing our own designs.

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## Authors Biography



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Was born in Mexico City, Mexico, in 1966. He received both, the BSEE and M.Sc., degrees from the National Autonomous University of Mexico, in 1993 and 1997, respectively. From 1990 to 1993 he was with the Department of Electronics of the Engineering Faculty of the National Autonomous University of Mexico, where he was involved in microprocessor systems development. In 1994, he joined the Center of Applied Sciences and Technologic Development, where he has been the head of the Laboratory of Electronics since 1999. His current research interest are microcontroller based systems, programmable logic, control systems and computer based instrumentation.