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DESIGN AND DEVELOPMENT OF A DIGITAL BLOOD PRESSURE MONITOR

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ABSTRACT
This paper presents a design and development of a digital blood pressure monitor. The device was designed with the help of a microcontroller PIC 16F688A, a power supply unit, a blood pressure sensor, a signal conditioning unit and an LCD display. The constructed and tested device was found to perform satisfactorily. The developed blood pressure monitor and the Omron blood pressure monitor available in the market were used for blood pressure measurement on some persons and the results were compared. The percentage error in the reading of the newly developed equipment was approximately ± 4 %. This indicates that the developed monitor can be use for blood pressure monitoring.

Key Words: Blood pressure, hypertension, systolic level, diastolic level. Microcontroller

INTRODUCTION
Blood pressure is the pressure within the arteries. It is produced by the contraction of the heart muscle.

Justification for the Work
Hypertension and other blood diseases are on the increase in Nigeria, therefore there is need for a locally developed blood pressure monitor which can be used at home to measure blood pressure.

Blood Pressure Measurement
There are two levels of blood pressure measurements namely; the systolic level and the diastolic level. The systolic level refers to the maximum blood pressure reading at any particular time blood pressure measurement is taken while the diastolic level refers to the minimum level reading of blood pressure at any particular time.

The range normally taken for the systolic and diastolic pressure readings is within the range of (100-140/60-85)mmHg or (110-140/64-80)mmHg. Normal blood pressure readings must fall within this range, anything above or below results in abnormality in blood pressure. That is when we have a value/reading such as 172/95mmHg. This extremely high blood pressure can lead to a situation called hypertension or if we have 75/30mmHg, this is extremely low blood pressure which can lead to a situation called hypotension. Table shows the classification of blood pressure for adults (Hughes, E. 1995).

Table 1: Classification of Blood Pressure for Adults

Category	Systolic level (mmHg)	Diastolic level (mmHg)
Normal	Less than 120	Less than 80
Pre-hypertension	120-139	80-89
High blood pressure stage 1	140-159	90-99
High blood pressure stage 2	160 or higher	100 or higher

Globally, hypertension is a major chronic, non-communicable disease and a leading cause of death and disability in economically developing countries (Kanfman, M. and Seidmen, A.H. 1988; Omron, S. 2005). Hypertension is a sustained elevated blood pressure (BP). It is a dangerous medical condition that stresses the heart and promotes vascular weakness and scaring, making blood vessels more prone to rupture (Whitehead, R.J. 1988). Uncontrolled and untreated hypertension increases the risk of coronary arteries damage, heart attack, stroke, kidney disease, eye damage and is responsible for other conditions such as pre-eclampsia (Drzewiecki, G et al. 1994). Most of these problems can be found in developing countries and are a serious economic burden.

Types of Blood Pressure Monitors

Blood pressure monitors are divided into three main types which are automatic, manual and ambulatory blood pressure monitors (Geddes, L. 1991).

Automatic Blood Pressure Monitors

The majority of home blood pressure monitors are called automatic blood pressure monitor or digital blood pressure monitor. The automatic blood pressure monitors are easier to use than the manual blood pressure monitor. The technology of digital blood pressure monitors have improved rapidly and over the years. They have sensors that detect the sounds of blood in the artery in the cuff. They are generally recommended for home use. Most of the popular models are automatic and inflate the cuff. This research work concentrates on the digital blood pressure monitor.

Manual Blood Pressure Monitors

The type of blood pressure monitor that is used by most doctors is called a sphygmomanometer. This is a manual blood pressure monitor. This type of monitor has a cuff that is wrapped around the arm and then inflated with a squeeze bulb. A stethoscope is used to listen to the blood in the artery. The pressure is measured either by a column of mercury or by a circular dial. Now that there is a wide range of accurate and easy to use digital monitors available, manual monitors are generally not used as home. Training is required to operate the manual properly and to be able to hear properly they must be used in a quiet environment.

Ambulatory Blood Pressure Monitors

These are monitors that are worn continually 24 hours a day. Generally, they are provided by the health care provider and worn for one or more days. This type of monitor takes blood pressure readings at regular intervals, usually every 15 or 30 minutes. Ambulatory blood pressure monitors have a cuff that is connected to a

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small controller/recording unit that is attached to a belt (William, W.B. 2006).
These monitors are often used to determine if there are major changes in blood pressure during the day or night. They are also used if fainting spells are due to sudden drops in blood pressure.

Previous Work
Arteta C, et al. (2010), (Murray, C. and Lopez, A. 1997) developed a low cost blood pressure monitor device for developing countries. In this paper a low-cost easy-to-use blood pressure monitor device for developing countries running on a mobile phone through the use of a typical and widely available cuff. The developed device in this paper is good but complicated as it involves using mobile phone. Our developed device works without the use of a mobile phone.

MATERIALS AND METHOD
The design of the circuit is in five stages which are (i) power supply stage (ii) blood pressure sensor stage (iii) signal conditioning stage (iv) microcontroller stage (v) LCD screen output stage

Power Supply Stage
The power supply unit utilizes a 9V dc battery source. An IC voltage regulator chip 9805 was used to step down the 9V dc battery to 5V.

Blood Pressure Sensor Stage
The sensor used in this work is a semi-conductor pressure sensor MPXV5050G. This sensor was chosen because it has a pressure range of 0mmHg to 300mmHg and gives an output of 0V to 3.5V.

Signal Conditioning Stage
This stage is made up of an amplifier and two stages of high pass filters.

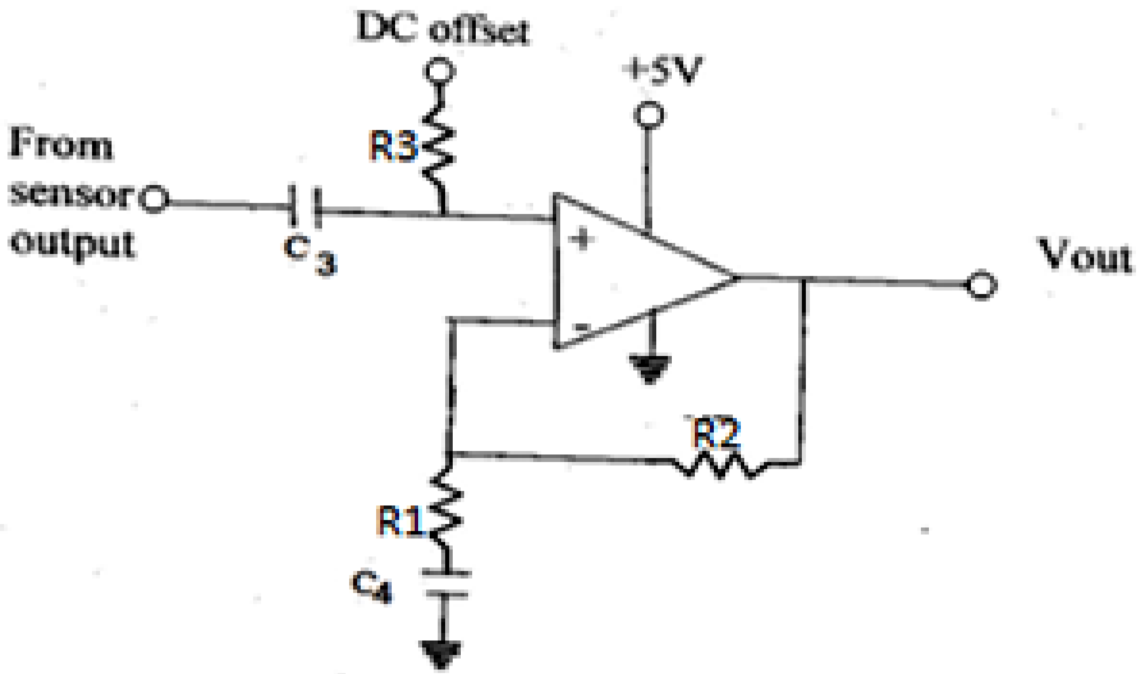

Figure 1: Signal conditioning unit

The preamp built around IC1 is expected to amplify the signal with the gain of 150 as specified in the datasheet application note AN1576. It is a non-inverting amplifier. Thus,

Voltage gain $Av = 1 + R_2/R_1$ - (1)

The negative sign on the gain indicates that the output is the opposite polarity as the input.

Choosing $R_1 = 1k\Omega$, $Av = 150$; Then

$R_2 = 149\ k\Omega$

C_3 and R_3 form the first high pass filter while R_1 and C_4 form a second high pass filter. Their function is to block noise frequency approximately 0.48.Hz to 4-8Hz.

The frequency of the first high pass filter is

$F_1 = 1/2\pi R_3C_3$ - (2)

$F_1 = 0.48Hz$, R_3 chosen to be $1M\Omega$ for high input impedance, thus

$C_3 = 1/(2 \times 3.142 \times 1000000 \times 0.48)$

$C3 = 0.33\mu F$

The frequency of the second high pass filter is

$F_2 = 1/2\pi R_1C_4$ - - (3)

For $F_2 = 4.8Hz$ and $R_1 = 1k\Omega$

$C_4 = 1/(2 \times 3.142 \times 1000 \times 4.8)$

$C_4 = 33\mu F$

Microcontroller Stage

The microcontroller used in this work is the microchip PIC 16F688A. It has only 35 single word instructions. The oscillator of choice for the microcontroller is the crystal oscillator for stability and for the resolution a 10MHz crystal was used. The microcontroller sends pulses to drive the LCD screen. The microcontroller was programmed using Visual Basic (VB6) programming.

LCD Display

The Liquid Crystal Display (LCD) is the output display unit of the system and it is connected to the microcontroller at the receiver circuit. The LCD is driven by the microcontroller using ASC II information of the received byte.

The LCD used is the GM1602A model. It is a 16 x 2 character screen type and it is powered by a +5V supply.

Flow Chart

The flow chart that gives an appropriate picture of the system performance is given in Figure 2.

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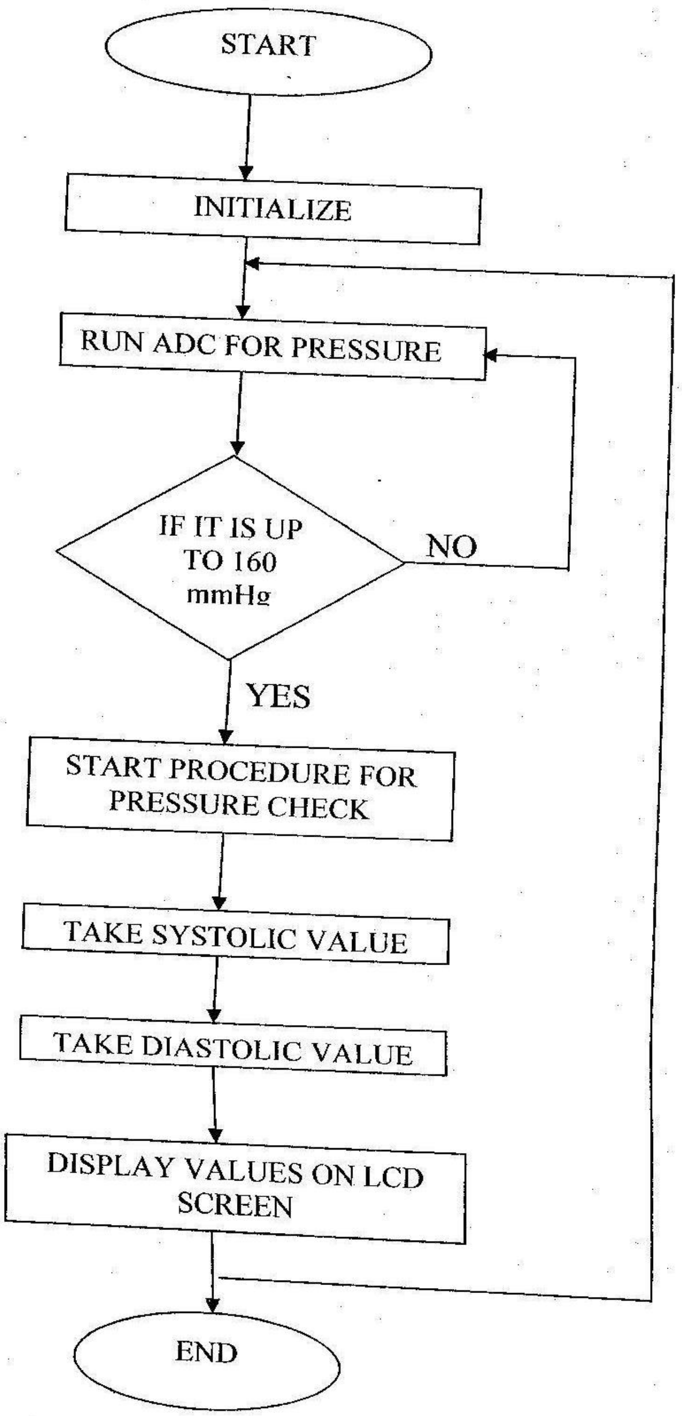

Figure 2: Flow chart for a digital blood pressure monitor

COMPLETE CIRCUIT DIAGRAM OF THE DIGITAL BLOOD PRESSURE MONITOR

The complete circuit diagram of the digital blood pressure monitor is shown in Figure 3.

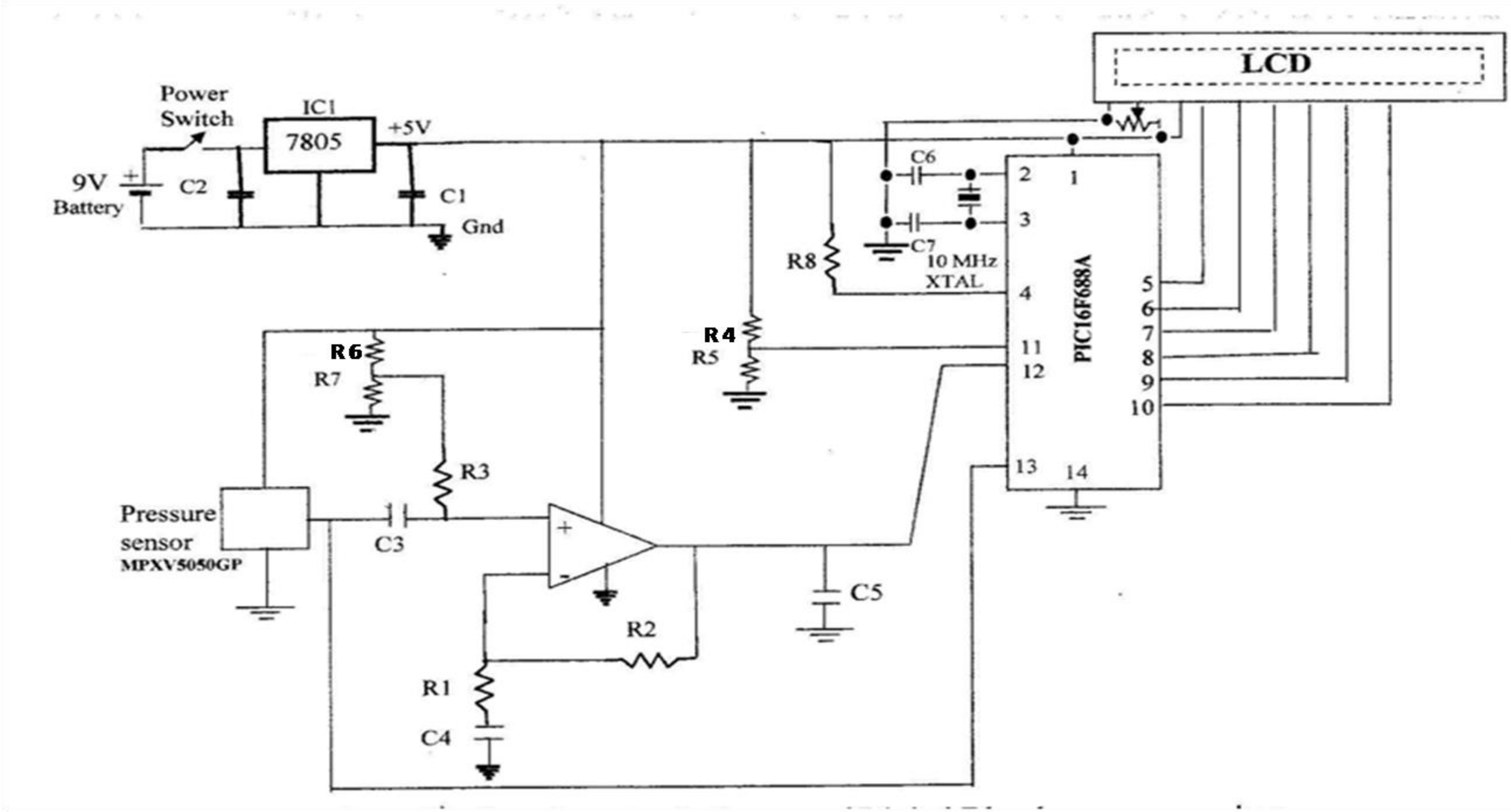

Figure 3: Complete circuit diagram of Digital Blood pressure monitor

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Operational Principle of the Digital Blood Pressure Monitor

The complete circuit diagram is presented in Figure 3. The circuit is powered by a 9V battery supply. The IC1 chip 7805 is the voltage regulator which steps down the 9V battery to 5V for use by the circuit because most components in the circuit use 5V. Capacitors C_1 and C_2 serves as the filter capacitors. The ground serves as protection for the circuit. It is also known as earthing. The sensor for the work is the MPXV5050G unit and its function is to convert the blood pressure from the cuff to analogue voltage.

The pass filter for noise signal filtration. R_3 and C_3 filters cut off at 0.48Hz while R_1 and C_4 cut off at 4.8Hz. Resistors R_1 and R_2 determine the gain of the amplifier. R_6 and R_7 form a voltage divider to give mV offset voltage to bias the op-amp. IC_2 is the signal conditioning unit stage and it consists of an amplifier and filter circuit for filtering off unwanted frequency. C_5 function is to remove noise voltage from the output of the amplifier. R_4 and R_5 are for voltage reference setting for the microcontroller internal ADC.

The microcontroller use in the circuit is the PIC16F688A. It controls the measurement process and displays the results on the LCD screen. It is the heart of the system as it controls all aspect of the measurement processes. It monitors the voltage at the AD input to know the level to take readings for the systolic and that for the diastolic points. Pin 2 and Pin 3 are for oscillator. The oscillator of choice for the microcontroller is the crystal oscillator. The oscillator of choice for the microcontroller is the crystal oscillator for stability and for the resolution needed a 10MHZ crystal was used. The microcontroller sends control pulses to drive the LCD screen. C6 and C7 are for stabilizing the crystal oscillator of 10MHz. pin 5 is the output of the signal conditioning stage which tells the microcontroller when to take reading and Pin 11 is that point where the systolic and the diastolic values are been taking. The LCD is the Liquid Crystal Display unit which displays the results of the diastolic and systolic readings as the output. It is connected to the microcontroller at the receiver circuit. The LCD used is the GM1602A model, it is a 16 x 2 character screen type and it is powered by a +5V supply.

Construction

After designing the circuit and determining components to be used and their values, the device was constructed. The construction started with mounting of the components on a breadboard. The breadboard circuit arrangement started with the power supply since the other stages needs power during testing.

After the power supply had been set up and tested, the resistors for biasing the amplifier stage was connected, followed by the resistors for reference voltage and dc offset voltage needed by the circuit. The circuit stages were all set up and tests was done on all of them accordingly. The microcontroller was connected at the completion of tests on the other stages. This was after the microcontroller had been programmed with the necessary codes to make it operational. The circuit components were connected with jumper wires. The microcontroller was connected to the LCD screen for visual display of blood pressure.

RESULTS

The device was used to read the blood pressure of ten persons, this is presented in Table 2. The test was also conducted with an Omron blood pressure monitor sold in the market in Nigeria, the result is presented in Table 3.

Table 2: Results of the Blood Pressure meter test constructed

S/N	Name of Persons	Gender	Age (Years)	Standard Pressure (mmHg)
1	A	Female	23	132/82
2	B	Male	27	132/70
3	C	Male	29	130/66
4	D	Female	31	146/61
5	E	Female	52	120/65
6	F	Female	26	134/61
7	G	Male	55	133/62
8	H	Male	51	140/79
9	I	Male	32	140/82
10	J	male	85	125/74

Table 3: Results of the Blood Pressure meter test using Omron product

S/N	Name of Persons	Gender	Age (Years)	Standard Pressure (mmHg)
1	A	Female	23	128/84
2	B	Male	27	135/68
3	C	Male	29	132/64
4	D	Female	31	144/60
5	E	Female	52	117/63
6	F	Female	26	130/60
7	G	Male	55	135/64
8	H	Male	51	141/80
9	I	Male	32	137/80
10	J	male	85	129/72

Calculation for Percentage Error between the Developed Monitor and Omron Monitor

The percentage error was calculated for the persons (A – J) as follows. Blood pressure measured with the constructed device – Omron Blood Pressure meter divided by Omron Blood Pressure meter.

For example: For A

$$\frac{132-128}{128}\ x\ 100 = 3.13\% \qquad \text{for systolic value}$$

$$\frac{82-84}{84}\ x\ 100 = -2.38\ \% \qquad \text{for diastolic value}$$

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Table 4: Percentage Error between the Developed Monitor and Omron Monitor

S/N	Name of Persons	Gender	Age (Years)	Standard Pressure (mmHg)	
				Systolic (%)	Diastolic (%)
1	A	Female	23	3.13	-2.38
2	B	Male	27	-2.22	2.94
3	C	Female	29	-1.15	3.13
4	D	Male	31	1.38	1.67
5	E	Male	52	2.22	3.18
6	F	Male	26	2.56	1.67
7	G	Male	55	-1.48	-3.13
8	H	Male	51	-0.71	-1.25
9	I	Male	32	2.19	2.50
10	J	Male	85	-3.10	2.78

DISCUSSION

The developed monitor and an Omron blood pressure purchased were used to monitor ten persons as presented in Table 2 and 3.
Figure 4 shows that there was slight variation in the values between the developed monitor and the Omron monitor but the results are sufficient to say that the developed monitor is accurate for blood pressure monitoring.

In this work, a digital blood pressure monitor was designed and developed. It can be used to measure digital blood pressure of people easily without any hindrance. The cost of the Omron monitor available in market is N13,000 while that of the developed device is N17,975 for one device. If the device is mass produce the price will come down below the price of the Omron sold in the market. A comparison of measurement of blood pressure between the developed monitor and the Omron monitor available in the market shows a percentage error of approximately 4%. This indicates that the developed monitor is reasonably accurate for blood pressure monitoring.

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