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PULSE OXIMETRY MODULE TO IMPLEMENT IN TEAM MONITOR OF VITAL SIGNS

A. Soto Otalora[1], L. A. Guzman Trujilloy[2] and A. DiazDiaz[3]
[1]Industrial Control Engineering, Universidad Surcolombiana Neiva, Avenida Pastrana Carrera
[2]Industrial Control Engineering, Facultad de Ingeniería Electrónica y Biomédica, Universidad Antonio Nariño, Neiva, Colombia
[3]Electronic Engineering, Universidad Surcolombiana Neiva, Avenida Pastrana Carrera
E-Mail: agussoto@usco.edu.co

ABSTRACT

This article presents meticulous description of a pulse oximetry module. This module allows to measure two variables: the saturation of oxygen in the hemoglobin of the blood and heart rate. The measurement is made through a sensor which contains two LEDs that emit red and infrared light which pass through the patient's finger to a photodetector, which measures the absorbance of each wavelength caused by arterial blood. The microcontroller calculates the percentage of oxygen saturation by the ratio of the absorbance of the red and infrared light. The pulse oximeterplethysmographic sensor wave whose period corresponds to the heartbeat is also obtained. These two facts together with the other variables are shown in a GLCD screen 240x128 pixels.

Keywords: pulse oximetry, heart rate.

1. INTRODUCTION

Pulse oximetry is a noninvasive method to measure the amount of oxygen from hemoglobin in the blood, besides obtaining plethysmographic waveform and with it to calculate the heart rate. In this technique, the clamp pulse oximeter is placed in a body part that is relatively translucent and has a good blood flow, such as fingers, toes, or the earlobe. The pulse oximeter clip has two LEDs that emit lights with different wavelengths, red and infrared light which pass to a photodetector (photodiode) through the patient. The absorbance of each wavelength caused by the arterial blood (pulse component) data with which it is possible to calculate the saturation of oxygen in blood is measured.

To calculate% SPO2 is necessary to process the signal output from the photodiode. Since the signal current is given, it is necessary to convert it to a voltage signal. The power LEDs is intermittent and the output signal will be too, that is why it is necessary to have a sampler-holder circuit (sample and hold) that allows to reconstruct the signal and separate them into two red and infrared components. The two resulting signals are filtered separately with cutoff frequencies of 0.33 Hz and 5.89 Hz and obtaining two plethysmographic waves, one for red and one for infrared which are amplified and inverted for proper display on GLCD screen.

Finally, to calculate the heart rate a plethysmographicwave red component is used, and an operational amplifier as crossing detector is set, so as to generate a train of digital pulses which can be easily read by the MSP430F2416 microcontroller [1] [2].

2. METHODOLOGY

Figure-1 shows the block diagram of the implemented pulse oximeter.

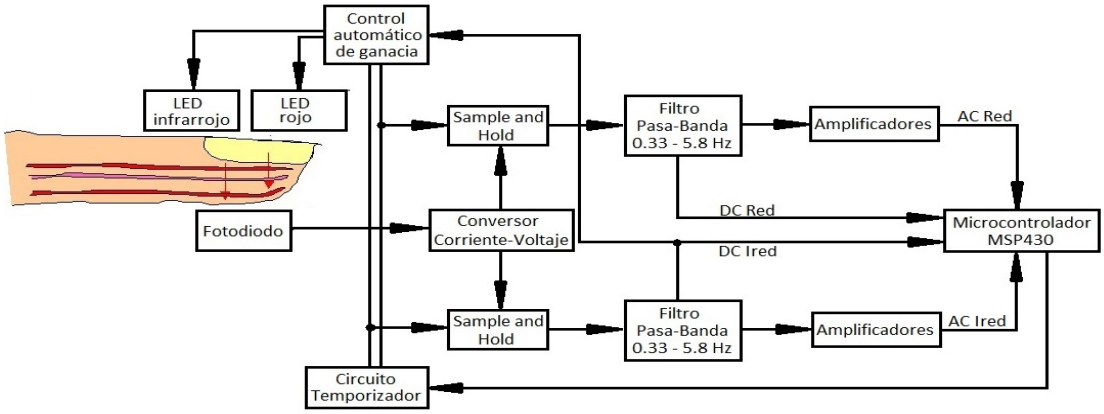

Figure-1. Block diagram of the pulse oximeter.

2.1 Current to voltage converter

In Figure-2 are shown two operational amplifiers. The first stage consists of a high gain amplifier, being the output voltage equal to:

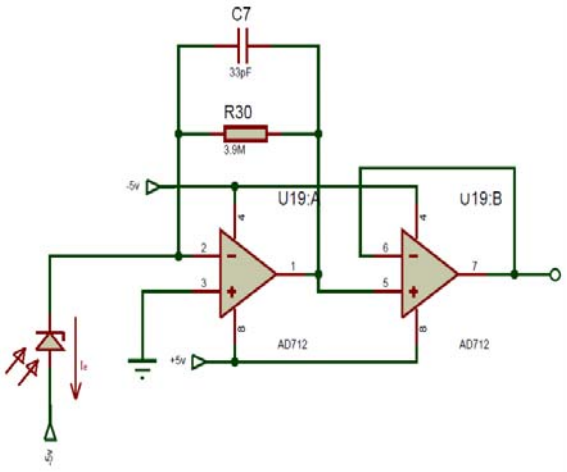

Figure-2. Current to voltage converter.

Where I_g is the current delivered by the photodiode and will range from 0 to 50 uA. Worth noting, in the resistance value (3.9MΩ) the operational amplifier is not saturated, that is, the photodiode output current does not exceed at least 1.4uA. The 47pF capacitor forms a low-pass filter which reduces errors to possible instabilities caused by unwanted signals such as ambient light filter.

The second stage of the amplifier AD712 has a voltage follower configuration, which aims to ensure no voltage drop at the moment retainers integrated circuit (sample and hold) is connected.

2.2 Sample and hold circuit

The aim of the circuit shown in Figure-3 is to reconstruct the plethysmographic signal as the red and infrared diodes are energized each with two pulse signals of 1 kHz, amplitude 12 volts, 10% duty cycle and 90 ° offset . Thus, the diodes emit light intermittently and with high current to ensure that the photodiode detects the pulsatingplethysmograph wave.

The LF398 receive the signal from current to voltage converter, the sampling times are synchronized to the timer circuit, in order to properly convert the plethysmographic signal to pulsating DC. As time signal acquisition is less than 10us, a 0.1uF capacitor will be enough to keep the signal without information loss. For impedance matching, for each LF398 output a voltage follower is connected. [3]

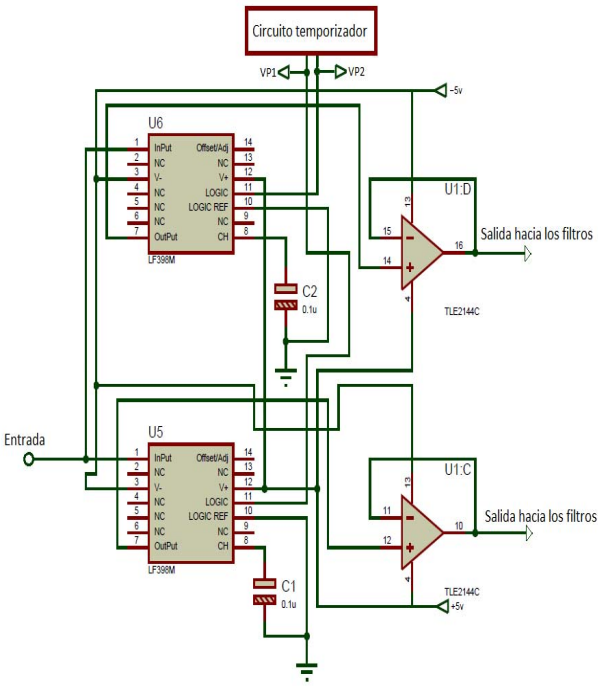

Figure-3. sampler circuit retainer.

2.3 Bandpass filter

The post-amplifier in the voltage follower configuration is a filter which is shown in Figure-4.

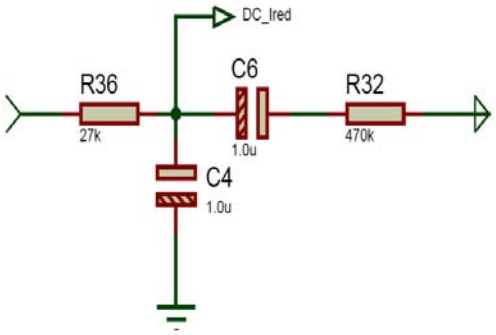

Figure-4. Band pass filter.

As the plethysmographic signal is of very low frequency, as its maximum value is taken when the patient is a newborn baby, in which case the upper limit of the heart rate is 190 beats per minute (3.16Hz), becomes necessary implement a band-pass filter whose cutoff frequencies are:

$$f_{c_{lp}} = \frac{1}{2\pi RC} = \frac{1}{2\pi(27K\Omega)(1\mu F)} \approx 5.89Hz$$

$$f_{c_{hp}} = \frac{1}{2\pi RC} = \frac{1}{2\pi(470K\Omega)(1\mu F)} \approx 0.33Hz$$

Moreover, this noise present in the electrical network and the switching of the LED is eliminated.

2.4 Adequacy of the plethysmographic signal

For the plethysmographic waveform to be displayed on the GLCD screen appropriately, the circuit of Figure-5 is presented for adecuation.

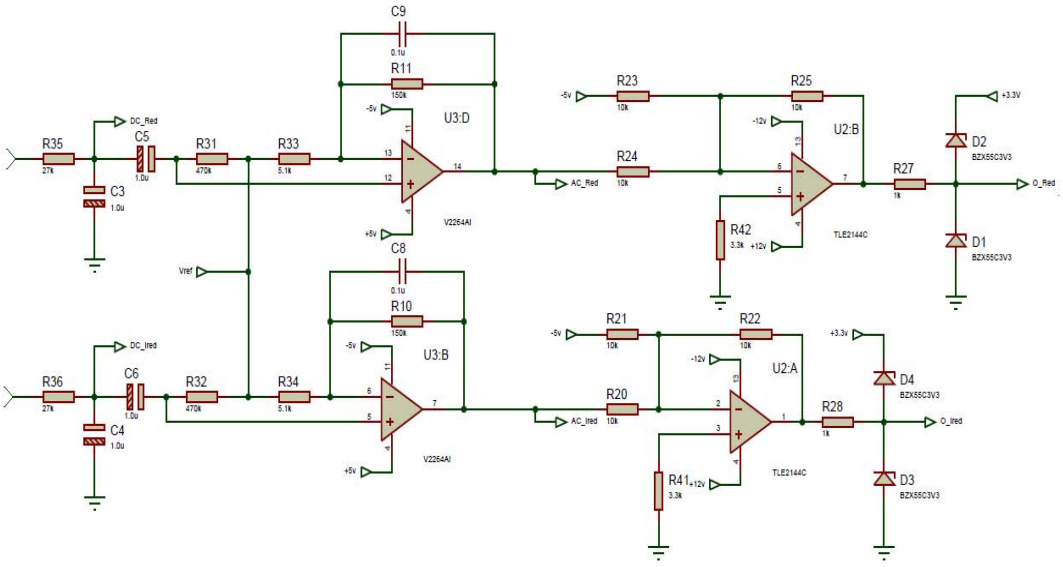

Figure-5. Adaptation of the plethysmographic waveform.

In the circuit in the above figure can be seen exiting the DC component of the low-pass filter (DC_red and DC_ired). This parameter is used to calculate the percentage of oxygen saturation (% SpO_2) below.

Since the microcontroller cannot receive negative signals, a voltage divider is implemented which is the reference voltage (Vref = 3.3V) and will upload the DC level of the signal, ensuring that no negative voltages are present at the ADC inputs of the microcontroller.

The zener diodes at the bottom of Figure-5 delimit the pulseoximetry signal from 0 to 3.6 volts. This is done in order to eliminate any positive or negative peak voltage that may damage the ADC of the microcontroller to the time to put your finger on the pulseoximeter clip.

Due to the pulsed nature of the signal, the sensor will register a large DC signal representing the residual arterial blood, venous blood and tissue. On the other hand only a small portion of the detected signal (~ 1%), will be AC signal representing the arterial pulse and is calculated using the RMS value.

The following expressions to calculate the percentage of oxygen saturation in the blood, by means of an algorithm designed in MSP430f2416 is displayed on the GLCD:

$$R = \frac{AC_{rms-roja} * DC_{infrarroja}}{DC_{roja} * AC_{rms-infrarroja}} \quad (1)$$

$$\%SPO_2 = 110 - 25R \quad (2)$$

Equation (2) is a linear calibration curve approximation which at values less than 70% are not accurate, however, no clinically values are below this value.

2.5 Timer circuit

To avoid overloading the microcontroller interrupt, a single pin of this where the signal that switches the light emitting diode will be used. In Figure-6 you can see the signal coming from the microcontroller to be VP. This signal is 2 KHz and has a 10% duty cycle.

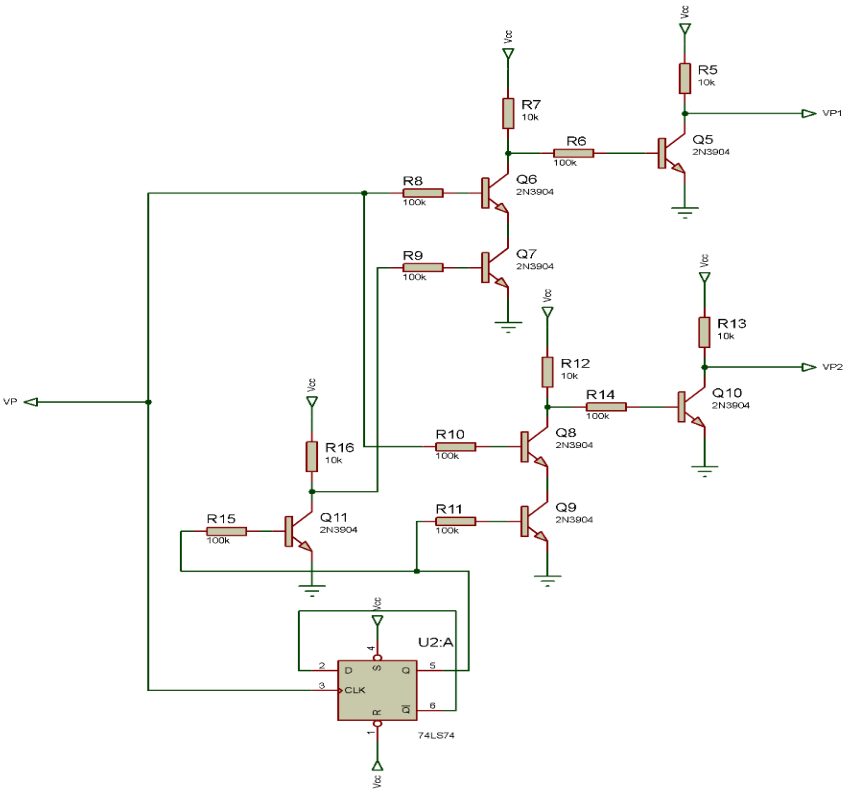

Figure-6. Timer circuit.

The flip-flop is in Figure-6, is set to toggle mode, that is, changes state when a rising transition at the CLK arrives. With this you can 'remove' the signal coming from the microcontroller into two signals with 90 degrees out of phase with the help of transistors that simulate logic gates AND and NOT, and are no more than a de-multiplexer two channels [4].

2.6 Automatic gain control

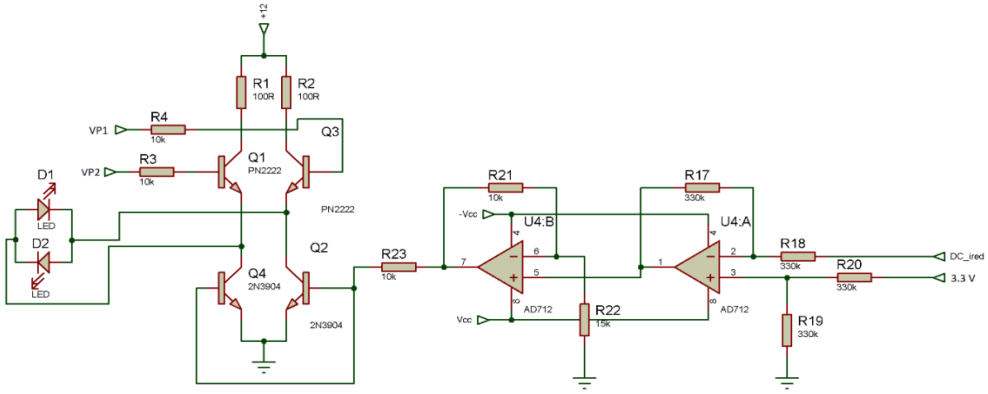

Figure-7. Automatic gain control.

Figure-7 shows a circuit which allows automatic control of brightness of the LED diodes. It consists of a proportional error control. The DC_ired signal is subtracted with a DC signal of 3.3 volts fixed and operates as follows:

When the clamp pulseoximeter is exposed to ambient light and do not have the finger placed, DC_iredrisesup to 3 volts, which makes the difference small enough that when amplifying it doesn't activate Q4 and Q2 transistors and therefore there is no current to D1 and D2 [5].

The gain of the amplifier in noninverting mode is given by:

$$G = 1 + \frac{R_{22}}{R_{21}} = 1 + \frac{10k}{15k} = 1.667 \quad (3)$$

By placing your finger on the pulse oximetertheclip DC_ired signal falls below 3 volts, presenting a considerable difference to amplify by 1,667 is sufficient to activate the transistors Q2 and Q4 and hence the illumination of red and infrared diodes.

2.7 Cardiac pulse

Monitoring the patient's heart rate an operational amplifier is configured as crossing detector, where the input signal is the inverted red plethysmographic waveform, so that when the signal is at the lowest level, the amplifier becomes saturated and when it has passed for that level, the output signal changes state. Thus the PPM signal is a square wave whose period matches the patient's heart rhythm [4] [5].

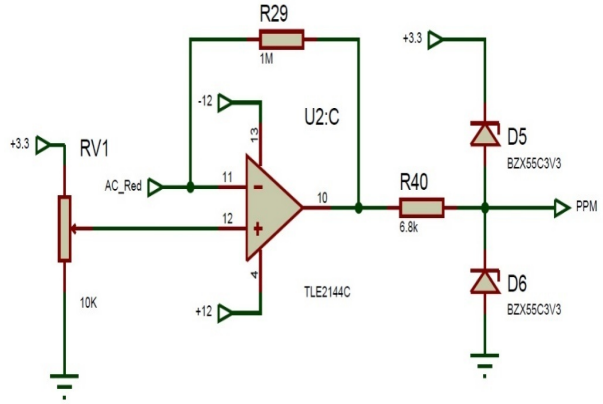

Figure-8. Heartbeat detector.

2.8 Display

To show the oxygen percentage data saturation and heart rate along with other variables, it is used a GLCD LGM240128A; this is a monochrome screen with a dimension of 240x128 pixels. The screen can be seen in Figure-9.

Figure-9. GLCD display.

3. RESULTS

Figure-10 shows the inverted plethysmographic waveform resulting from the first stage amplification shown in Figure-5, whose gains are equal and is given by equation (4):

$$G = -\frac{180k\Omega}{5.1k\Omega} = -29{,}41 \quad (4)$$

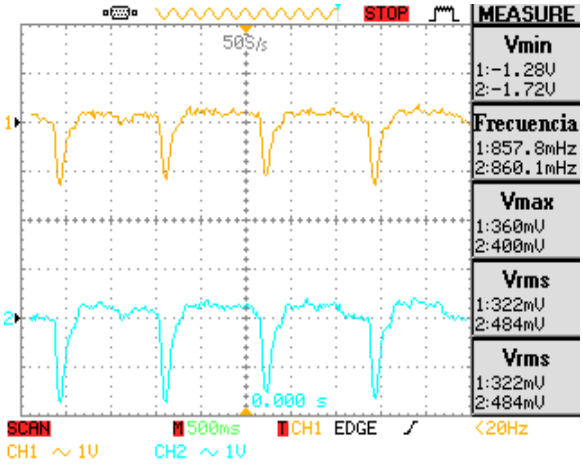

Figure-10. Plethysmographic wave inverted.

The second amplification stage of Figure-5 reverses the waveform of Figure-10 to be displayed correctly. This plethysmographic waveform is shown in Figure-11 on the GLCD display along with other variables surveyed.

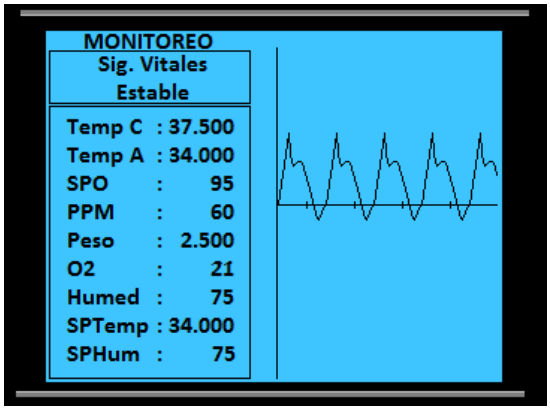

Figure-11. Viewing the plethysmographic waveform on GLCD.

4. CONCLUSIONS

A system for real-time monitoring of oxygen saturation in the blood and the patient pulses per minute were successfully prepared.

A period of adjustment and processing to calculate the patient's heart rate from pulseoximetry module is designed.

The use of low noise amplifiers, provided an accurate and reliable measure in the case of processing the pulseoximetry signal thanks to its internal features.

The implementation of a pulseoximetry module can be included in a neonatal incubator so it allows to

centralize noninvasive monitoring vital parameters for a premature neonate.

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