UNIVERSIDAD CARLOS III DE MADRID

LABORATORY

Electronic Instrumentation

PROJECT #3

ESCUELA POLITÉCNICA SUPERIOR
DEPARTAMENTO TECNOLOGÍA ELECTRÓNICA

PROJECT #3: PULSE OXIMETER – HEART RATE MONITOR

3.1 Introduction

Optical pulsoxymetry is a non-invasive method for monitoring the heart rate and the blood oxygenation of a patient. The pulse oximeter measures by sensing the infrared and red light absorption (two wavelengths) of tissues with deoxygenated and oxygenated hemoglobin, such us monitoring the light through a finger or an earlobe. The optical sensor is comprised of two LED emitting 660 nm (red-light) and 940 nm (infrared) and a photo-detector. Since the absorption of deoxygenated and oxygenated hemoglobin is very different for these two light wavelengths, the oxygen saturation level is obtained by a ratio of both measurements.

The intensity of the detected light also changes with the heart beats because the arteries that carry the oxygenated blood are contracted and expanded. Consequently, the heart rate can be also monitored, as well as a signal related to the blood flow within the artery.

The objective of this project is to design and calibrate an optoelectronic instrumentation system to measure the heart rate of a patient (optical pulse monitor). The instrument also visualizes the heart beat signal output and activates an alarm if the beat rate drops below a predetermined level. The high-power LED emitters (single chip PDI-E833) and a photodiode (PDB-C165) are mounted in a finger clip sensor.

3.2 Description of the Set-up.

The block diagram of the sensor is shown in Figure 3.1.

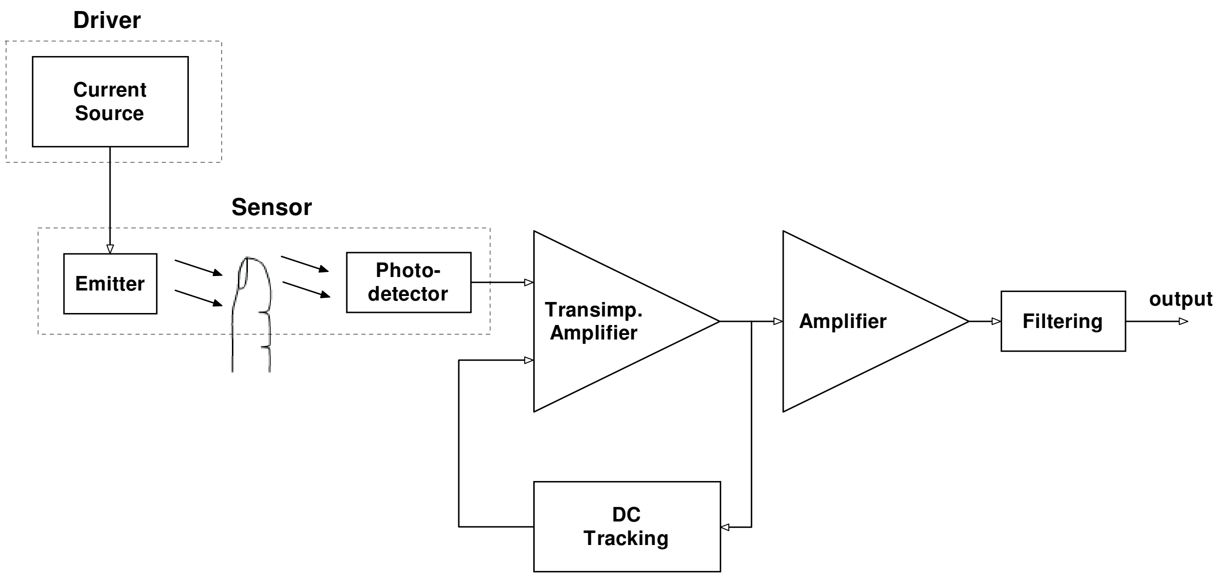

Figure 3.1: *Block diagram of the sensor system*

It is composed of the following parts:

1. Driver: Fixes the bias point for the LED to 20 mA. Pulse modulation of light intensity is possible using the enable input.
2. SpO2 Sensor: Includes the IR-LED and the red-LED (not used) mounted in front of the photo-detector. It is a finger clip sensor. Students are referred to the data sheets (PDI-E833, PDB-C165) for this component.
3. Trans-impedance amplifier: Is the front-end amplifier and current to voltage converter.
4. DC tracking: The beat signal is a little portion of the total light detected. Most of the photo-current is continuous. A drift is observed due to the sensor motion. This block compensates the DC current and drift for optimizing the signal amplification, that otherwise leads to saturation.
5. Signal conditioning of the AC component: Amplification and filtering.

Figure 3.2 shows the captured heart beat signal. This signal is output with continuous light illumination (left) and with pulsed light by gating the driver (right), respectively.

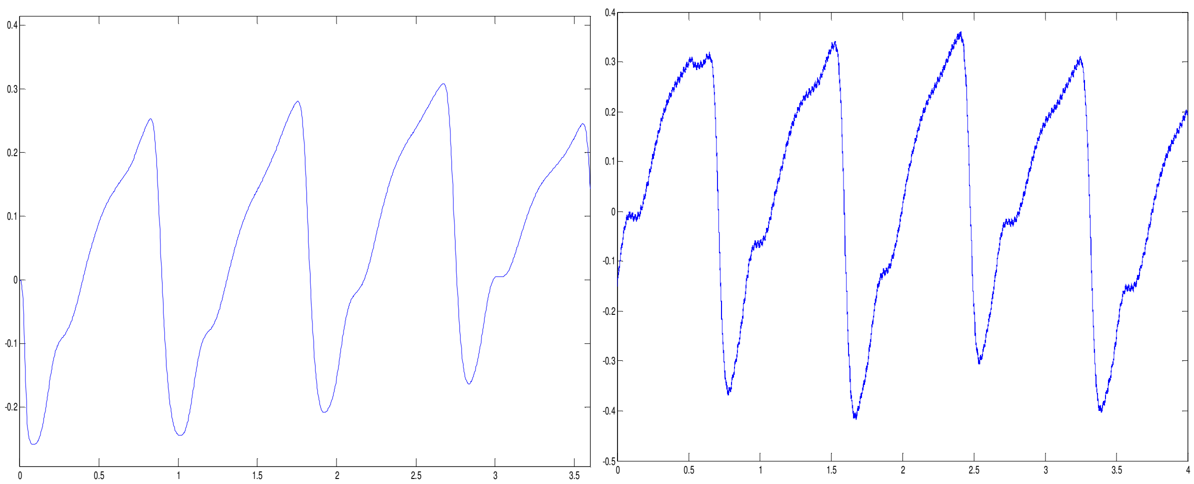

Figure 3.2: *Heart beat signal output*

3.3 Sensor System Design.

A scheme of the signal conditioning circuit is proposed in Figure 3.3. The different blocks are to be designed by the student and should match the following specifications:

1. Driver (current source): Able to supply continuous current (20mA) to the LED or pulsed current for time multiplexing (500 Hz, 50% Duty Cycle).
2. Front-end amplifier: Photocurrent signal amplitude is up to 100 nA. Design it to deliver 10 mV.
3. DC tracking: Design it using the integrator (C1, R4) to compensate at the input of the front-end the mean voltage. Consider that a typical heart beat rate is between 60 and 80 beat/minute.
4. Signal conditioning of the AC component: Design an adequate amplifier and the low pass filtering in a single stage. The final amplification is to be designed to deliver heart

beat signal amplitude of 500mV. A final adjustment should be considered. A low-pass filter is proposed for both power-line frequency (-20 dB) and light pulse modulation frequencies, but, in addition other filters can help (Notch filter).

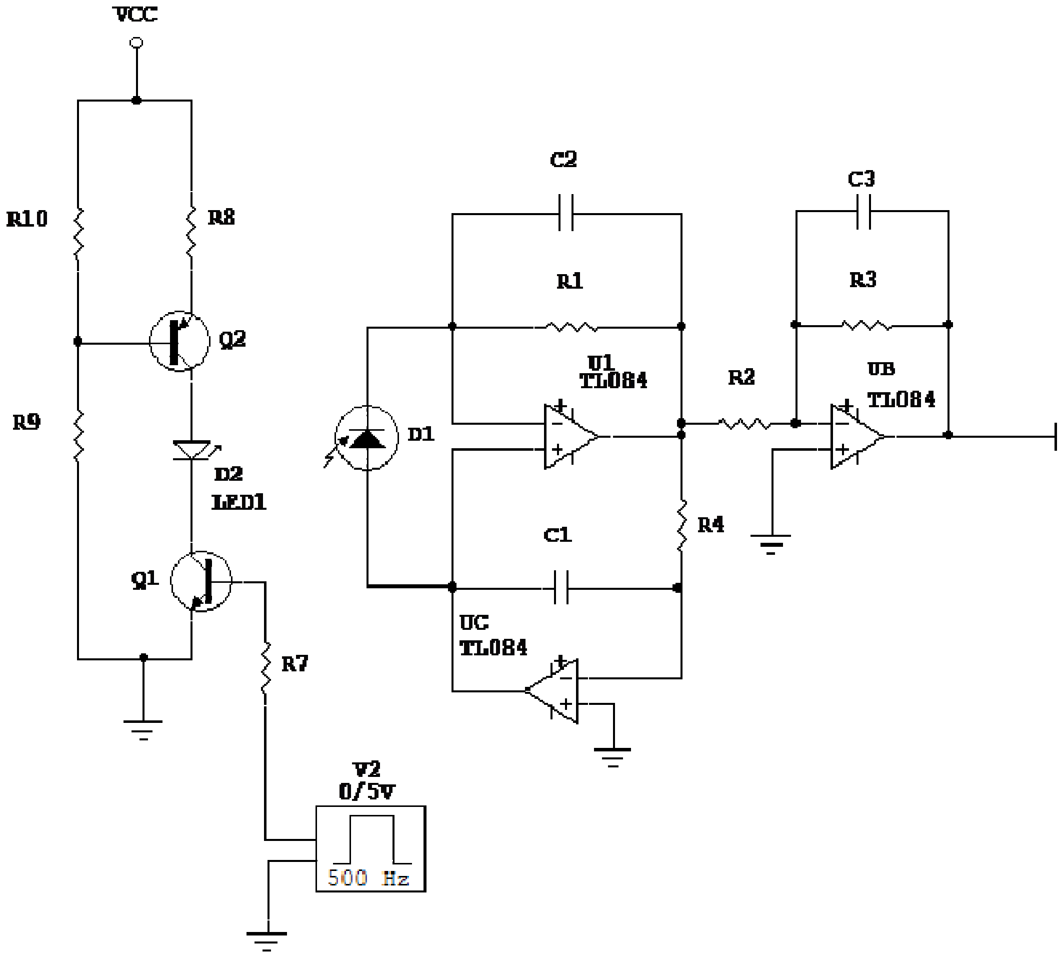

Figure 3.3. *Scheme of the proposed conditioning circuit*

In addition propose a design for the following blocks:

5. Monostable: Obtain a single pulse of 500 ms for each heart beat.
6. Alarm: Turn on a LED if the heart beat rate is below 40 beat/minute.

3.4 System Adjustment and Calibration.

a) Continuous light intensity:

Supply continuous current to the LED. C2 integrator disconnected.

- Adjustments to the circuit:

Don't monitor the finger with the sensor head, replace C1 with a short-circuit and obtain the maximum continuous voltage you have to compensate with the DC tracking.

Monitor the finger in static position and obtain the continuous voltage you have to compensate with the DC tracking in this case.

Connect the DC tracking and observe the AC signal. Estimate the ratio between AC signal and DC signal.

Adjust the gain so as to obtain a heart beat signal voltage of 500mV. Represent the front-end output and the total output.

- Calibration:

Use the time-base of the oscilloscope and measure the heart rate/minute. Complete 10 – 20 measurements in different conditions of the finger position. Note at least amplitude (mVpp), amplitude above and below zero (mV) and frequency of the heart beat signal for each measurement. Represent in an oscillogram each one of the signals which you have measured.

Adjust the hysteresis of a smith-trigger comparator in order to obtain at the monostable output a single pulse for each heart beat. Repeat the measure of the heart rate/minute (10 – 20 measurements) with a frequency-meter.

b) Pulsed light intensity:

Modulate the LED (500 Hz, square, 50%). Make sure that the adjustments made in the previous part have not been altered.

- Adjustments to the circuit:

Don't monitor the finger with the sensor head. Connect and adjust the C2 integrator so as to detect the envelope of the pulsed photo-current.

Monitor the finger in static position and obtain the drift voltage you have to compensate with the DC tracking in this case. Connect the DC tracking to compensate the drift.

- Calibration:

Repeat the calibration based on the heart beat signal frequency. Complete 10 – 20 measurements.

Adjust the hysteresis of a smith-trigger comparator in order to obtain at the monostable output a single pulse for each heart beat. Measure the heart rate/minute (10 – 20 measurements) with a frequency-meter.