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CONN'COR WP3 Home Compatible Labwork
Lab#1: Design of an Electrocardiogram (ECG) circuit

Labwork duration: 3h00
Number of students: 2
Prerequisite: Opamp based circuits
List of materials:

- Analog Discovery Card (AD2)
- A breadboard
- ECG Electrodes (for example Tiga-Med Electrodes)
- A computer with the Software "Waveform" and "LtSpice"
- Opamps (for example OP482 and LF356)
- Resistors and capacitors

Introduction

During this first labwork session, we will be interested in the design of a complete acquisition circuit to observe the bioelectric activity of the heart. You will use electronic components (Opamp, resistors, capacitors) and a breadboard to create a « homemade » ECG device. You will be able to observe the different segments of your cardiac activity (PQRSTU) as presented in Figure 1.

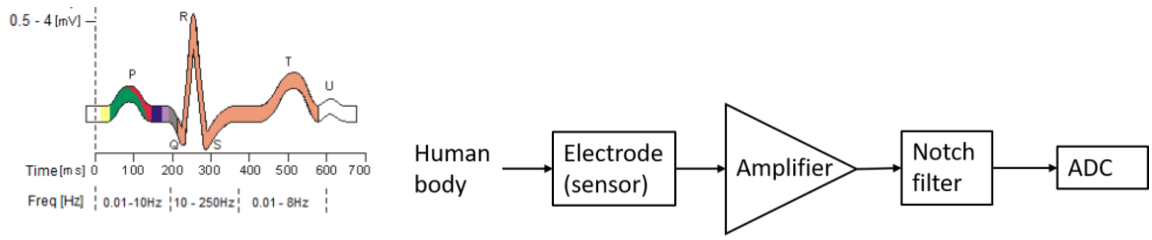

Figure 1

Experimental ECG

An ECG signal has a voltage amplitude between 0.5 mV up to 4 mV [1]. The heartbeat is comprised into the range [60bpm – 120bpm]. Useful frequency range is [0.01 – 250*Hz*]. A 50 Hz signal coming from the surrounding electrical network will be present in the ECG signal and need to be removed.

A baseline wander (see figure 2 below) due to physiological reason also appears in ECG signal and can be compensated by many techniques, in this labwork it will be removed by a high-pass filter.

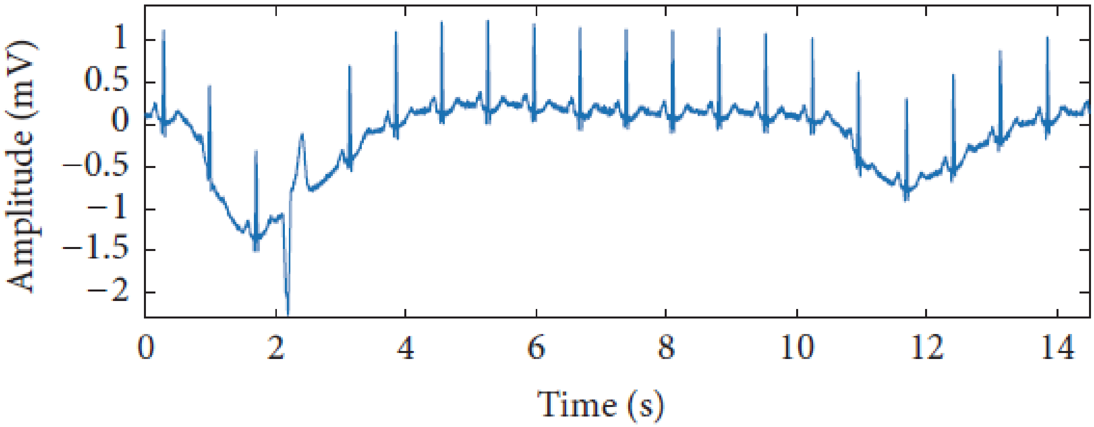

Figure 2: example of baseline wander

1. First order high-pass filter

We want to avoid amplifying this small frequency or DC difference to avoid saturation of the following amplifier. The simplest solution is to add after the electrodes a first-order high-pass filter. Dimension and implement a first order high-pass filter with a cut-off frequency of maximum 0.1 Hz with the available values of R and C in the labroom:

R= C=

2. Instrumentation amplifier

The first stage of the acquisition chain of the ECG is an instrumentation amplifier. It is presented in Figure 3.

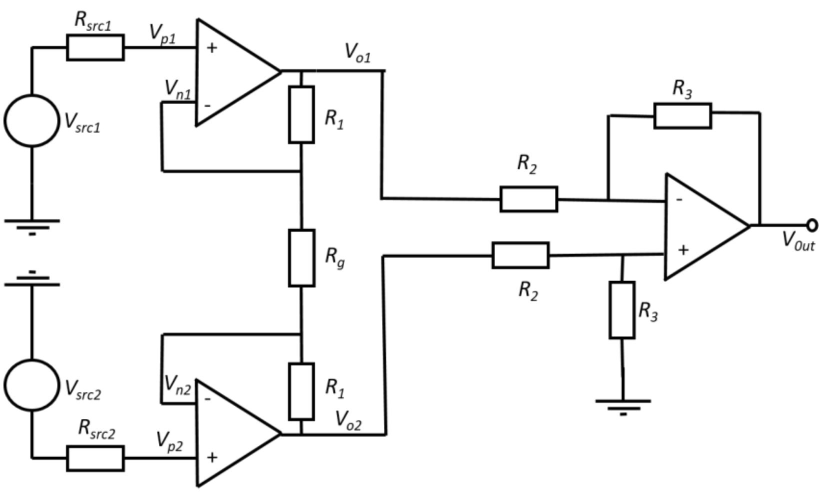

Figure 3: instrumentation amplifier

2.1 What is the advantage of the instrumentation amplifier for a sensor which can be assimilated to a voltage source?

2.2 Calculate the expression of the output signal V_{out} and dimension the resistors of this circuit for a gain in the range [7-100]

$$\frac{V_{out}}{V_{src1} - V_{src1}} =$$

R_1=

R_g=

R_2=

R_3=

2.3 Cable the circuit on the breadboard with the component OP482 and observe the output with waveforms delivered by the Analog Discovery Card. **Call the supervisor to show this result.**

3. Notch filter

As it has been highlighted previously, the 50 Hz component in the signal is strong and must be attenuated. Figure 4 presents two notch filter: the passive twin-T notch filter (left) and the active twin-T notch filter (right).

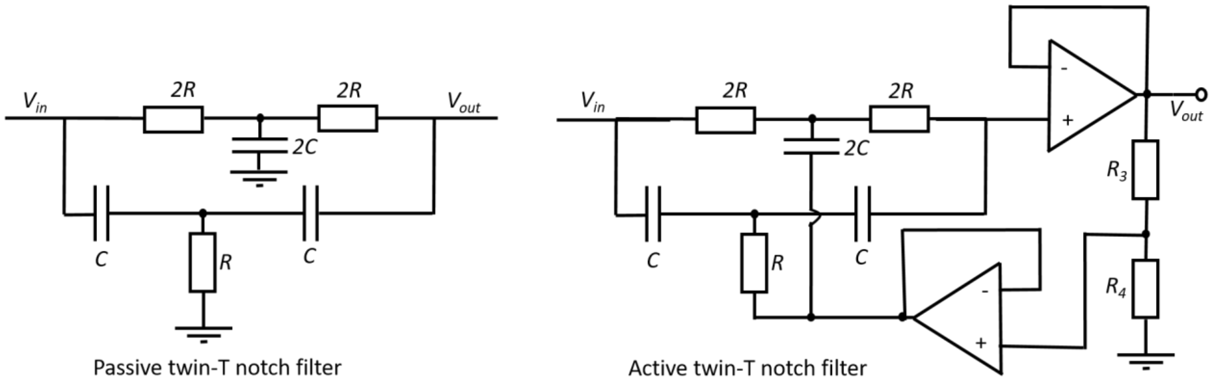

Figure 4

For both the filters, the notch frequency is:

$$f_N = \frac{1}{4\pi RC}$$

3.1 Dimension R and C to obtain a notch frequency at 50 Hz with available components in the lab (combinations of components may be necessary).

R= C=

3.2 Simulate the two circuits with LtSpice (download Passive_vs_active_notch_freq_student.asc from Edunao. You can fix R3 = 1kΩ and make a parametric simulation on the value of R4. Based on your simulation results, what are the advantages/drawbacks of the two filters?

3.3 Cable the passive notch filter after the instrumentation amplifier and verify its performance with the Analog Discovery. **Call the supervisor to show this result.**

4 Observe your ECG

To test the system, you will have to place the three electrodes on yourself or on a colleague. To do so, the ECG electrodes must be first inserted in the dedicated plugs of the sensor cable. The electrode in black is a ground electrode and must be placed on the right leg as indicated in Figure 5. The ground electrode must also be connected to the ground of the circuit. If not, the signal will be so noisy that no electrical activity could be observed. Red and blue electrodes are placed on the chest as presented in Figure 5.

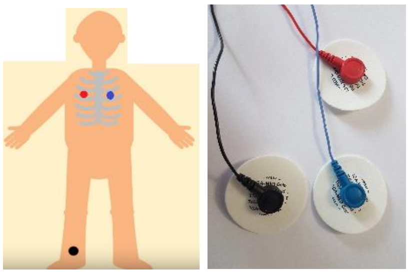

Figure 5

Test the same circuit with the ECG electrodes on yourself (or your neighbor).

Highlight the 50 Hz parasitic signal present in the ECG signal before the notch filter and the cleaned signal after the notch filter:

5 Low-pass filter

Before digitization any kind of biomedical signal, we need an anti-aliasing filter. Design a Sallen and Key low pass filter having a cut-off frequency of 250Hz. **Call the supervisor to show this result.**

References

[1] José Guerreiro “A Biosignal Embedded System for Physiological Computing », INSTITUTO SUPERIOR DE ENGENHARIA DE LISBOA, 2013.

[2] Gustavo Lenis, Nicolas Pilia, Axel Loewe, Walther H. W. Schulze, Olaf Dössel, "Comparison of Baseline Wander Removal Techniques considering the Preservation of ST Changes in the Ischemic ECG: A Simulation Study", *Computational and Mathematical Methods in Medicine*, vol. 2017, Article ID 9295029, 13 pages, 2017. https://doi.org/10.1155/2017/9295029

Appendix

This labwork will be done with a multifunction card,
a breadboard and electronic components form the lab (Opamp OP482, LF356, resistors, capacitors).

The voltage supply and scope are provided by a multifunction card. The multifunction card is an Agilent card “Analog Discovery 2” (see picture below). It is a complete kit for mini-lab which can provide:

- A voltage supply (up to +/- 5V)
- Different kind of programmable waveforms
- A scope