EL 473:

Biomedical Instrumentation

Project 2:

ECG Design

R. Yağız Mungan 8288

INTRODUCTION

The aim of the lab is designing an ECG amplifier using an AD620 instrumentation amplifier and necessary number of operational amplifiers. The output data will be displayed from computer screen via an USB data acquisition board. For user safety the computer (preferably a laptop) will have no connection other than the ECG board.

- Use an Analog Devices AD620 Instrumentation Amplifier as your input stage.
- Set the system lower and upper cut-off frequencies to 0.05 Hz and 150 Hz, respectively.
- Include a right leg drive sub-circuit in your design to reduce common mode noise.
- The ADC voltage range is from 0.0 Volt to 5.0 Volt. Use a level shifter, if necessary.

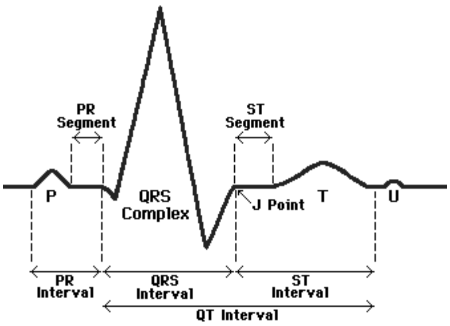


Figure 1.a: Sample ECG Waveform

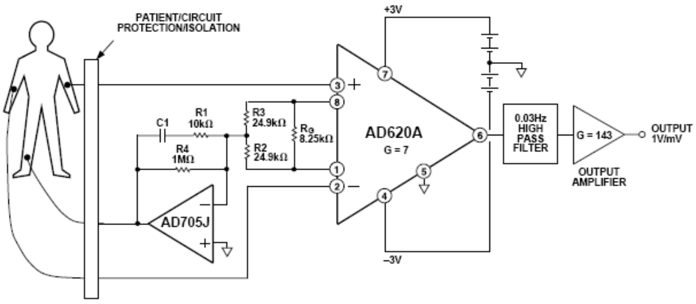


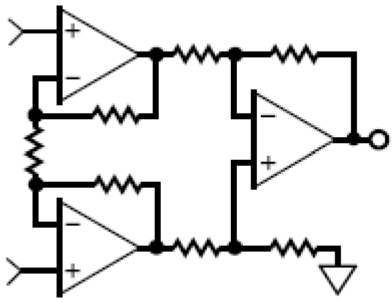
Figure 1.b: Sample ECG from AD620 Datasheet

ECG waveform is an important source for a person's hearth health, such that atrial fibrillation can be detected by the distortion in the p wave. Thus for correct evaluation of a person, a precise device is needed to make the measurement misinterpretations may prove fatal.

For this reason the gain should be enough to make the signal observable however, it should not be large enough to saturate the devices, so that no false peak should occur.

DESIGN PROSEDURE

About AD620



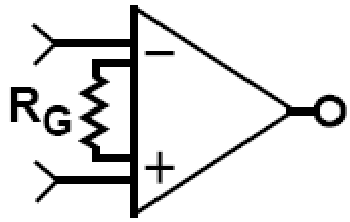


Figure 2.a. Internal Schematic of AD620   Figure 2.b. Symbol View of AD620

AD620 as seen in figure 2.a is made of three operational amplifiers. The resistances are precise thus it has great CMRR and can be used in commercial circuits. The resistance between the two inverting inputs of the input operational amplifiers is called Rg as seen from the Figure 2.b.

The resistance Rg defines the gain of the instrumentation amplifier such that for the input stage of the instrumentation amplifier the differential gain is:

$$G_D = 1 + \frac{2R_2}{R_G}$$

For the total gain of the devices one can refer to the look-up table in the datasheet:

1% Std Table Value of R_G, Ω	Calculated Gain	0.1% Std Table Value of R_G, Ω	Calculated Gain
49.9 k	1.990	49.3 k	2.002
12.4 k	4.984	12.4 k	4.984
5.49 k	9.998	5.49 k	9.998
2.61 k	19.93	2.61 k	19.93
1.00 k	50.40	1.01 k	49.91
499	100.0	499	100.0
249	199.4	249	199.4
100	495.0	98.8	501.0
49.9	991.0	49.3	1,003

Table 1: Gain-Rg Table for AD620

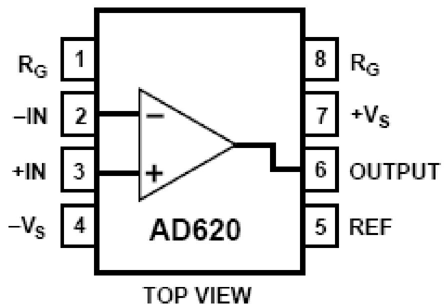


Figure 3: Pin Connections for AD620

The Rg value is taken as 8.4kΩ which is expected to provide a gain of 8.

Frequency Adjustments

The average hearth rate of a person is around 1.1Hz and the signal level is very weak thus to avoid interferences from other signals, a band pass filter is needed. The desired frequencies (between 0.05 Hz and 150 Hz) can be achieved via operational amplifier, capacitors and resistors where the values are found for the high pass and low pass respectively:

$$\frac{1}{2\pi RC} = 0.05Hz \text{ and } \frac{1}{2\pi RC} = 150Hz$$

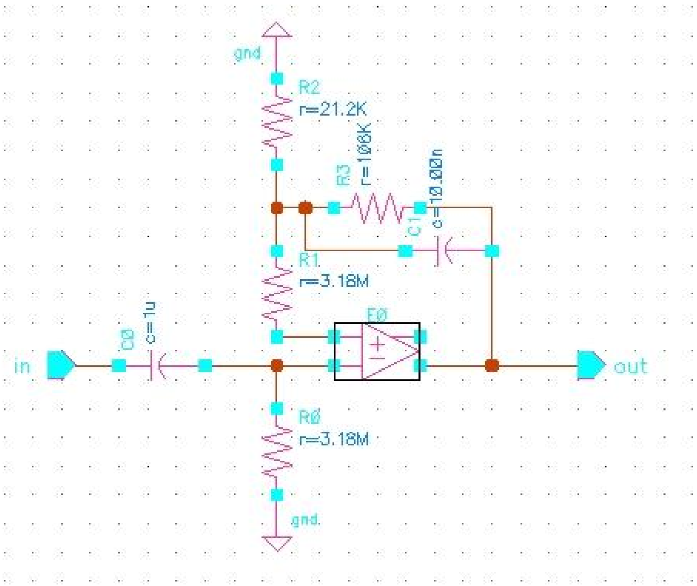


Figure 4: Band-pass Filter

For the high-pass filter: C=1µF

R=3.18MΩ

For the low-pass filter: C=0.01 µF

R=106K Ω

Thus the filter supplies a gain of 5. The 3.18MΩ connected to non-inverting input is for keeping the balance and symmetry.

Right Leg Drive Sub Circuit

The aim of right leg driven circuit is reducing the effect of noise. The common mode signal taken from the both ends of the Rg (gain resistance of AD620) is given back to body as a reference.

The values of the resistances are 25KΩ for the input resistances. Also a low pass filter with 150Hz cut-off frequency is existent with R=10KΩ and C=106.nF. The gain of the circuitry is defined by the 1MΩ resistance and can be found as:

$$G = \frac{1M\Omega}{25K\Omega//25K\Omega}$$

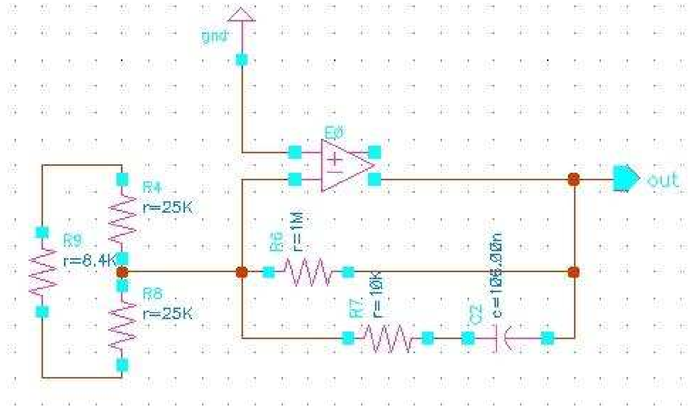


Figure 5: Right Leg Driven Circuit

Output DC Level Shifting

The last stage of the circuit is both designed to provide the necessary gain and the necessary voltage shifting to make the signal appear on the limits of ADC which is 0 to 5 volts. This stage is expected to have a gain of 25. Since the amount of voltage shifting is unknown the voltage shifting is applied after the first ECG signal is observed. Initially an inverting amplifier with R1=5KΩ and R2=125KΩ is used.

REALIZATION OF THE CIRCUIT

The circuit is first realized on breadboard. Some of the values have changed due to the availability of the resistors and capacitors. For the operational amplifier ST TL081 is used in all stages. While the circuitry is being built each stage is checked by a given signal which would not cause clipping.

Changes With Realization

AD620

Installing Rg as 8.4KΩ gave unwanted gain so the value had to be increased to decrease the gain. Inserting a 27KΩ resulted with a gain of 10, even though it was unexpected, in order to not using a larger resistance, the 27KΩ is accepted and the extra gain is corrected by changing the last stage.

Band Pass Stage

For the high-pass filter a resistance of 3.18MΩ is used. The resistance is in fact labelled as 3MΩ, however its exact value was 3.18MΩ. For the low-pass filter the 106KΩ is realized as an 112KΩ and the 21.2KΩ is realized as a 21.8KΩ (series combination of 3.8KΩ and 18KΩ)

Output DC Level Shifting

The amount of shifting is done by supplying the signal from the inverting input and supplying the shifting dc voltage from the non-inverting input, thus the amount of dc input can be found by dividing the desired DC voltage level by the non-inverting gain of the stage. However due to non-idealities of the TL081 the non-inverting input lowered the gain. With an iterative method the correct values are found. The input dc voltage is supplied from Vdc by a voltage divider.

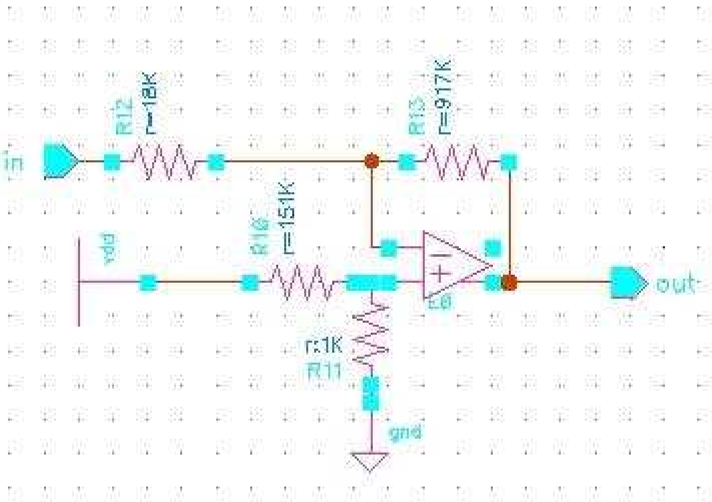


Figure 6: Gain Stage & DC Level Shifter

MEASUREMENTS

First the circuit is tested while it is on the breadboard, and the supply voltages are taken from the power supply. The output measured via oscilloscope is as:

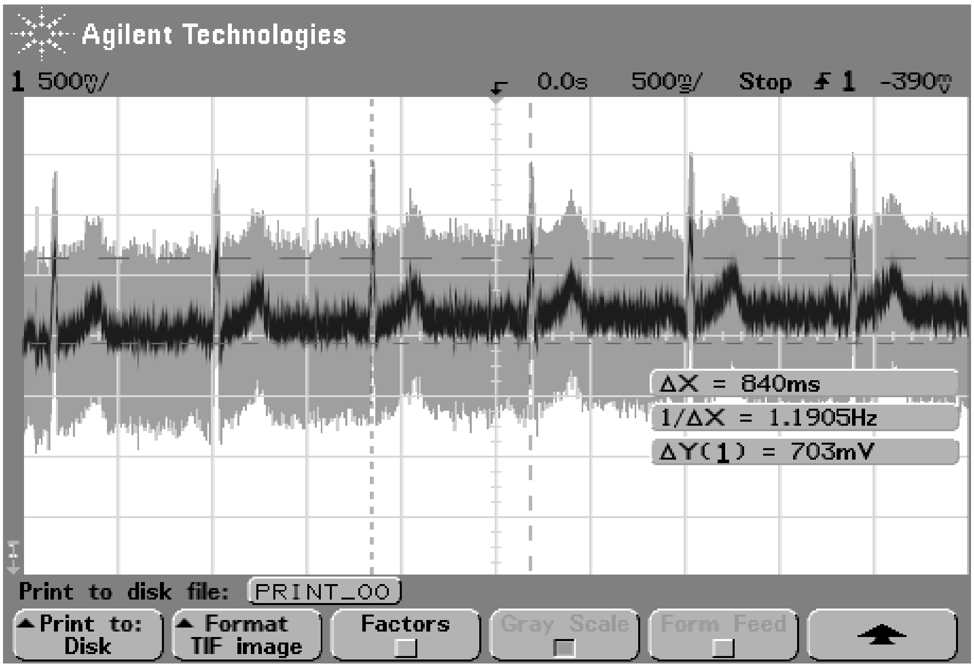


Figure 7: ECG Output Waveform

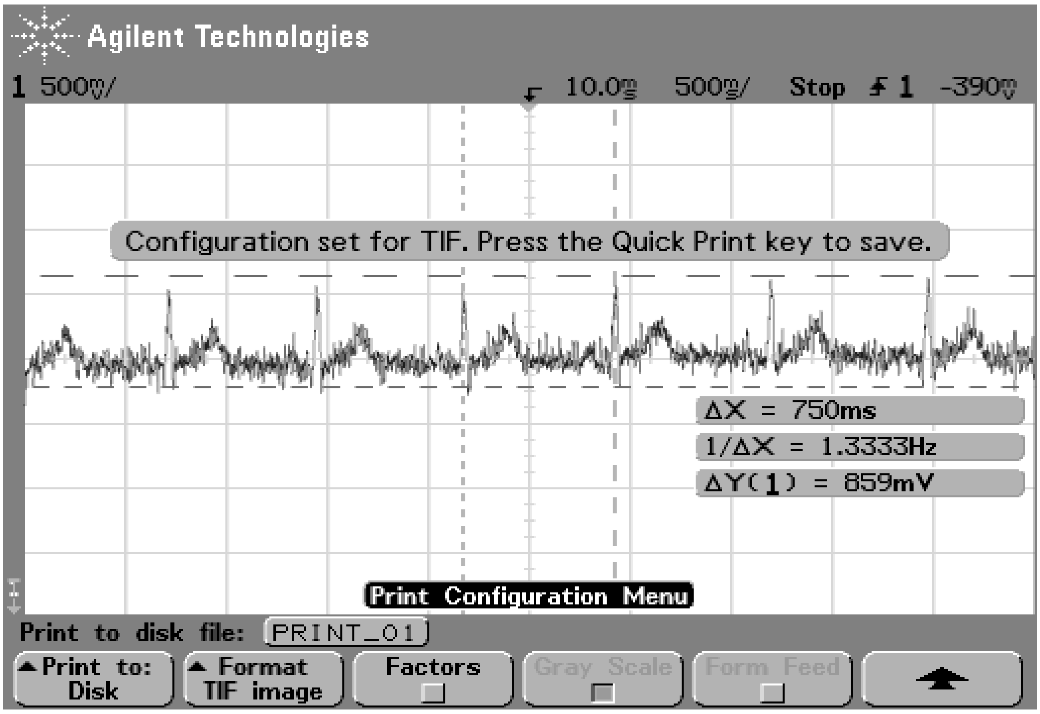


Figure 8: ECG Output Waveform with Averaging

After the circuit is implemented on board and soldered. Then the ECG waveform is measured with the USB data acquisition board. Due to noise the output is meaningless. Reasons for noise:

- Bad soldering. Causes bad connections.
- Long carrier cables to merge the same signals such as gnd, +Vcc, -Vcc. Causes antenna effect
- Low quality of the USB power source.

MODIFICATIONS

To prevent the signal being lost in the 50Hz interference, a 50Hz notch filter is designed and implemented.

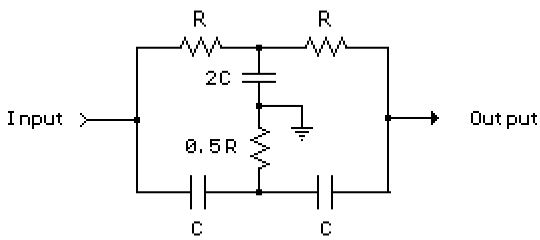


Figure 9: Notch Filter Schematic

$$\frac{1}{2\pi RC} = 50Hz$$

Using the formula, available values in the laboratory and measurements the filter is realized with C=18nF and R=200KΩ.

Thus the final circuitry can be observed by the given schematic.

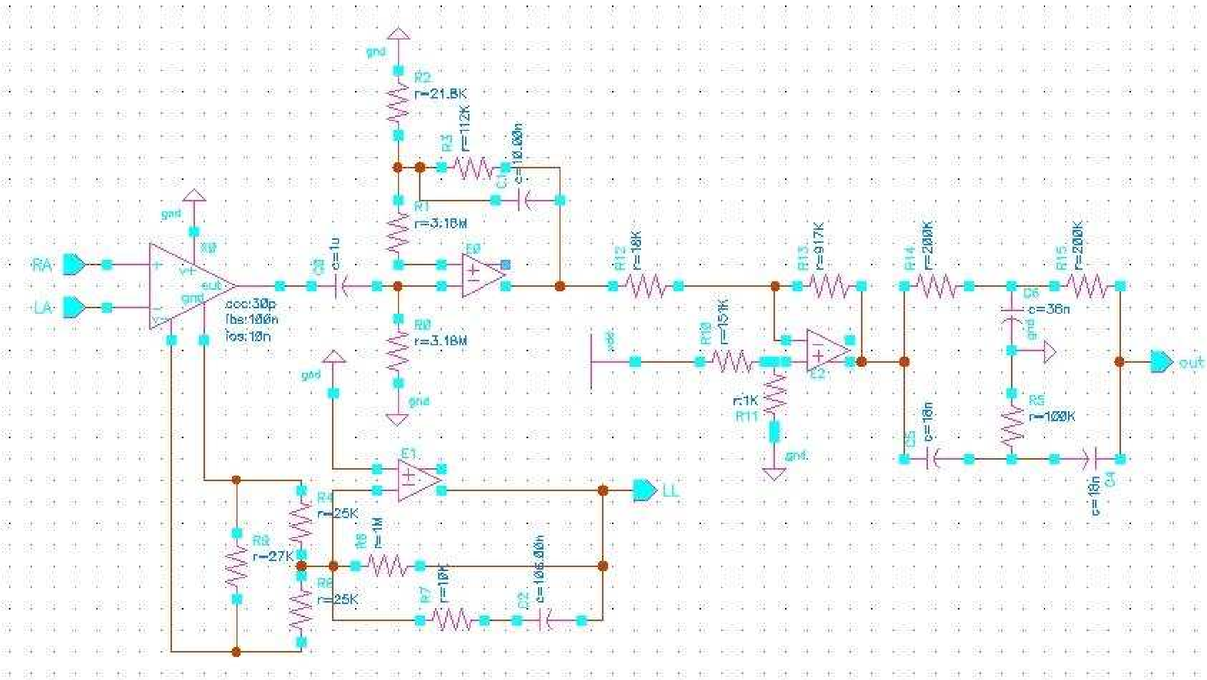


Figure 10: Overall Schematic of theECG Design

Later decoupling capacitances are added between ground to+Vcc and between ground to –Vcc. This modification removed some amount of the noise however the real problem which is assumed to be an oscillation at around 90KHz remained. When person is connected to the circuitry at the output of the AD620 one can observe the weak cardiac signal of a person but at the output of other stages only the oscillations were observable.

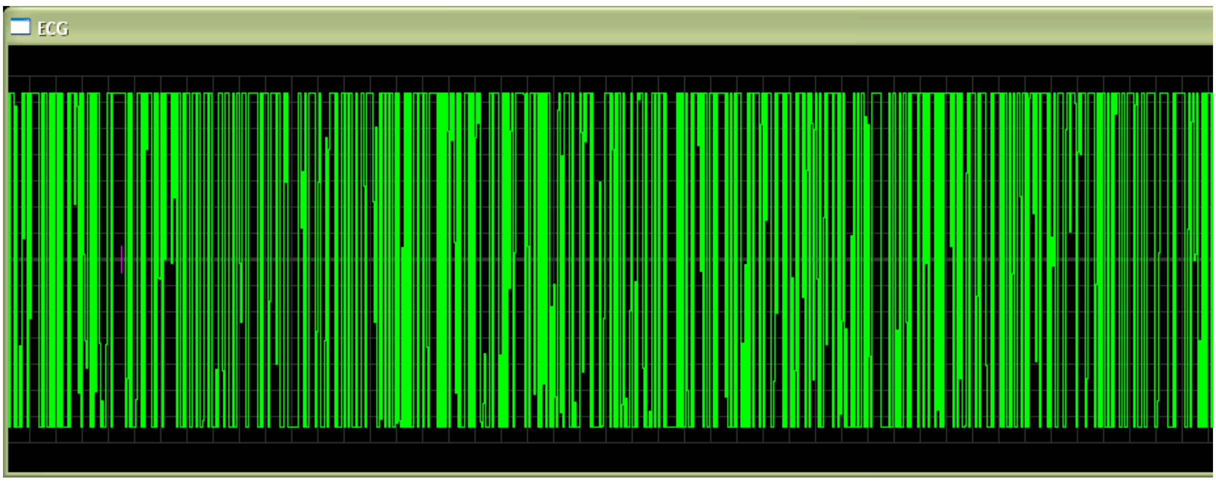


Figure 11: Output Signal Composed of Oscillations at 90 KHz

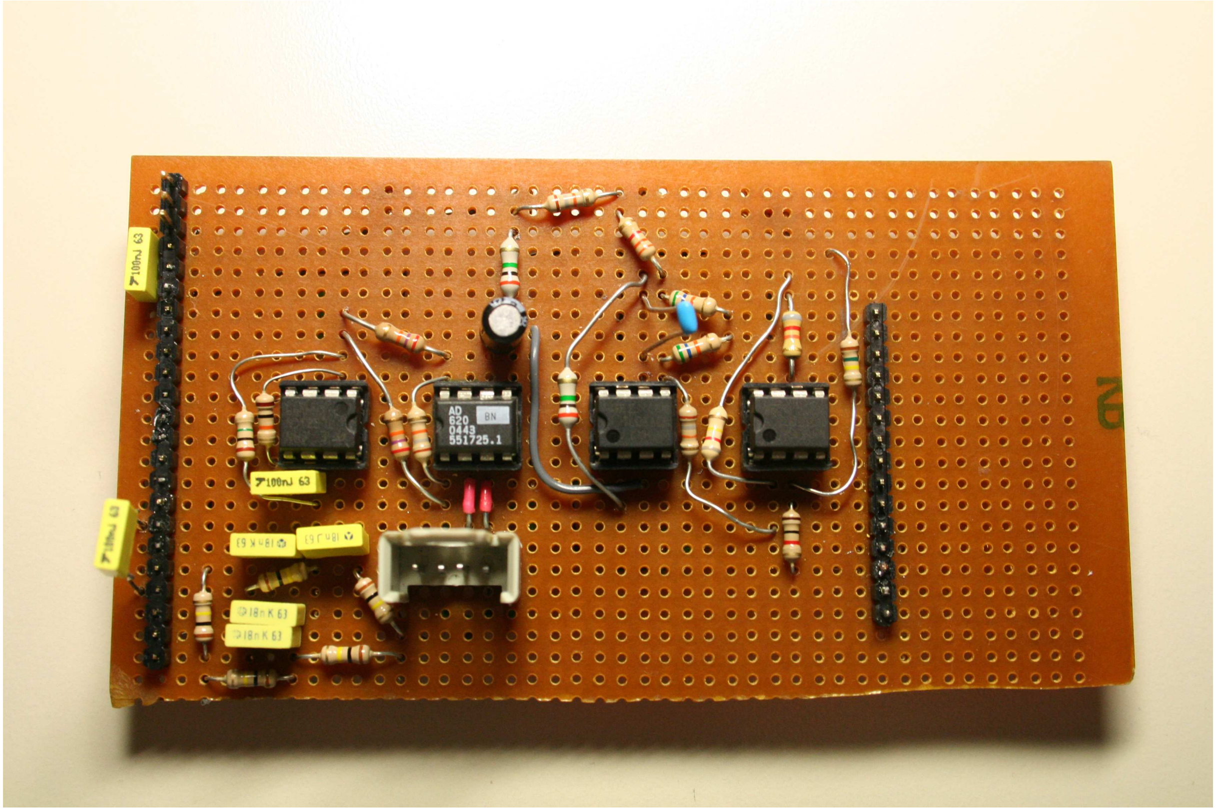


Figure 12: Photograph of the Final ECG Design (front view)

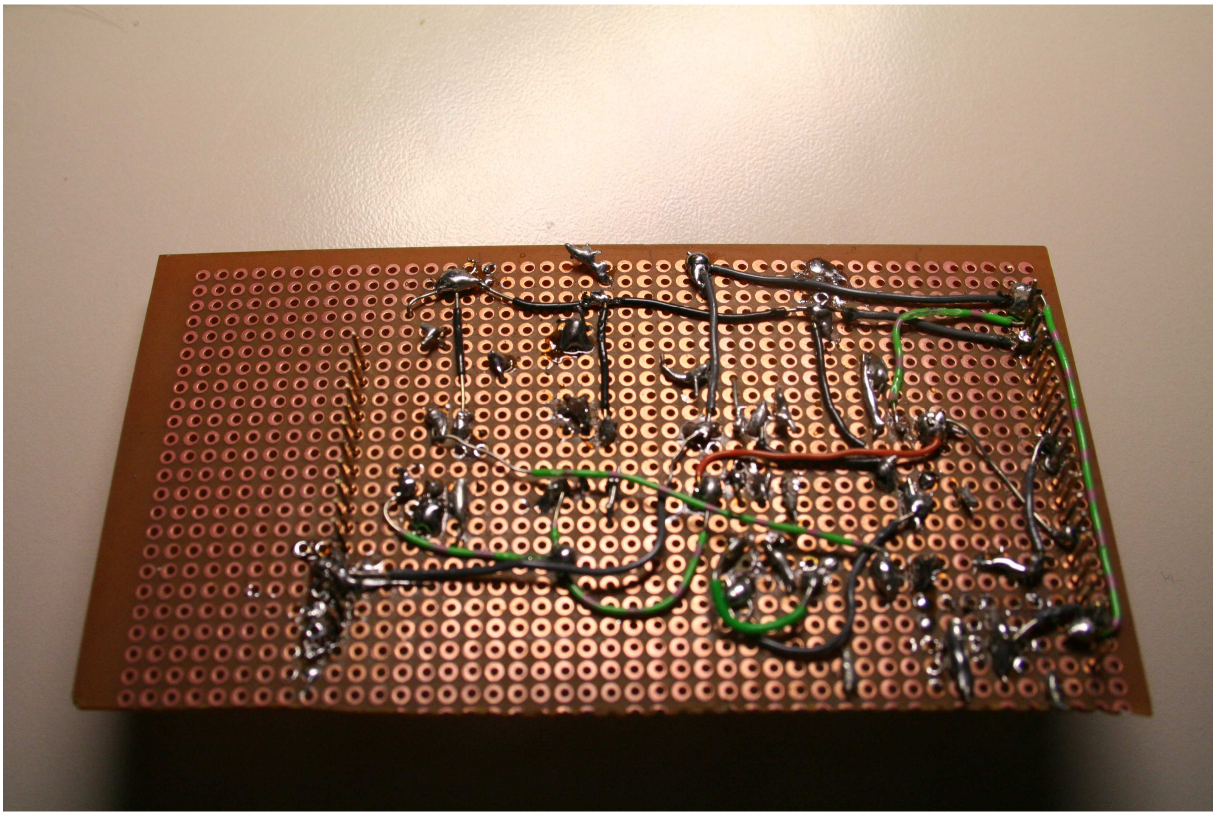


Figure 12: Photograph of the Final ECG Design (back view)