ECG Lab Procedure

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Pre-Lab

Measurement with an Instrumentation Op Amp

The first stage of amplification uses an AD623 instrumentation amplifier. The gain should be between 40 and 60. To provide an additional layer of safety, resistors (Rp) will be added to limit the maximum current flowing from the circuit to the electrodes. A safety factor of 1000 will be employed; therefore, the maximum current will be limited to 10 µA with a given voltage of 5 V.

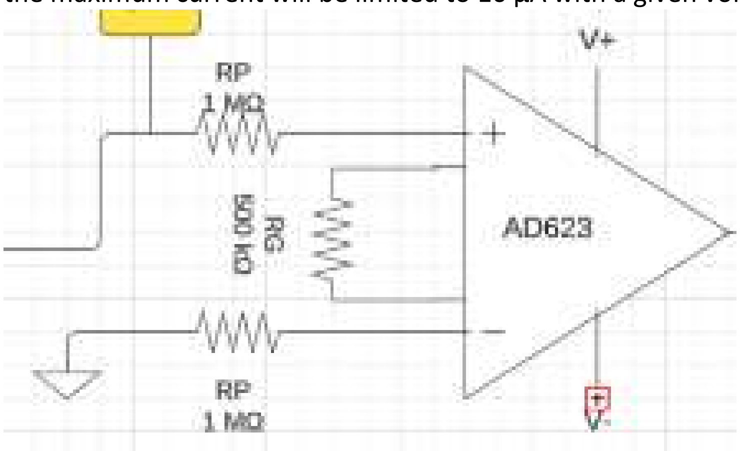

Figure 1: Circuit Schematic of AD623 instrumentation op amp with reccomended resistor values

$$\text{Gain} = 1 + \frac{100k}{Rg}$$

Stage 2: Passive Notch Filter

In the first stage or buffer amplifier, 60 Hz noise is filtered in stage 2. 60 Hz noise is a particular issue in CMU's electronics labs. This design follows the Twin-T notch topology. Since this design is particularly sensitive to tolerances in component values, measure resistances carefully and trim values.

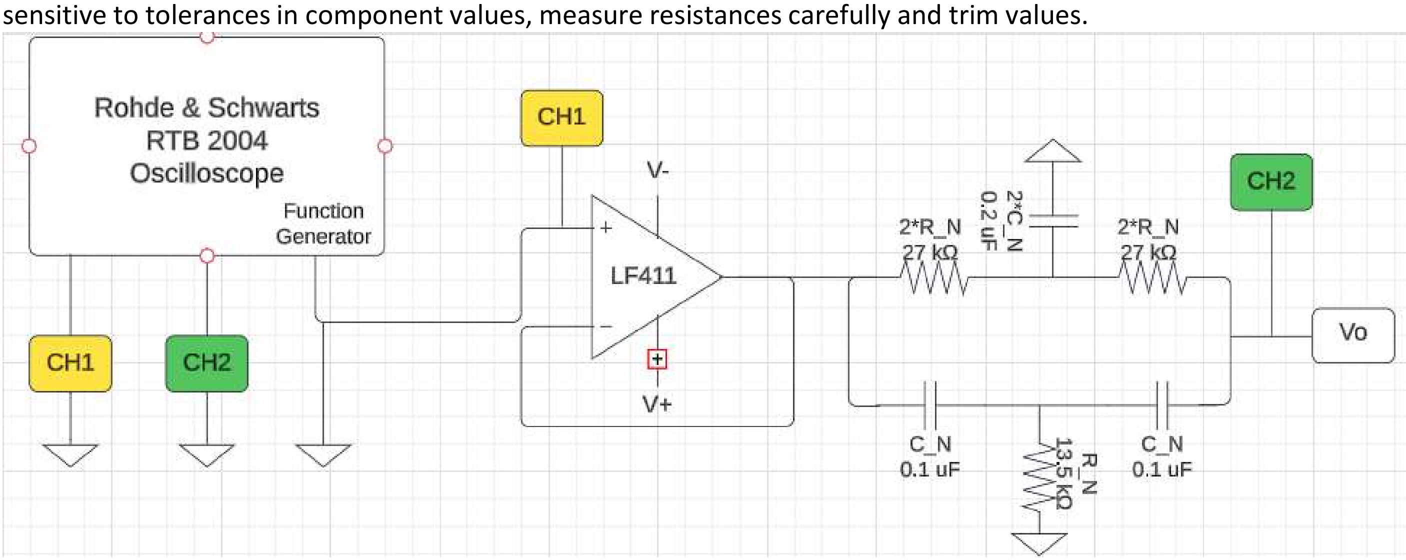

Figure 2: Circuit schematic of LF411 buffer amp and passive notch filter with recommended component values

$$f_C = \frac{1}{4\pi R_N C_N}$$

Stage 4: Active Band Pass Filter

Following another LF411 buffer amp, an active band pass filter will be used to eliminate baseline (DC) drift (e.g. low frequency noise). Generally, the heart rate is above 60 beats per minute (BPM), so a filter design with the first corner frequency below 1 Hz is ideal (One bpm is equal to 1/60 Hz). This bandpass filter will also be used to remove 60 Hz noise and does not overly affect the ECG measurement. Recall that a lower cutoff frequency will provide greater 60 Hz noise attenuation, but too aggressive of a cut-off could lead to signal distortion. The second corner frequency should be above 5 Hz.

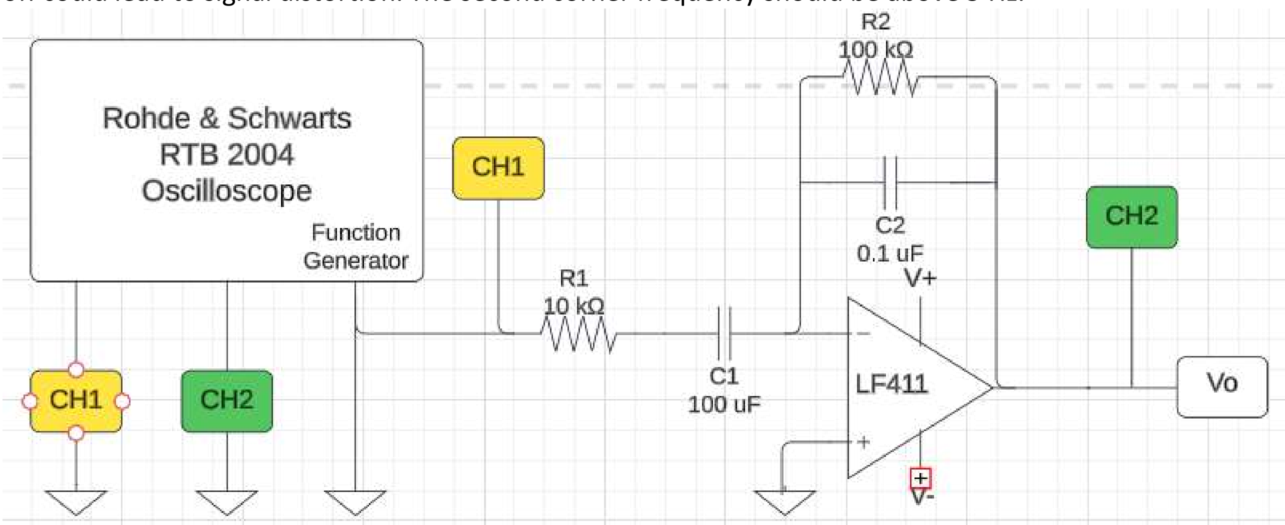

Figure 3: Circuit schematic of active band pass filter with an LF411 with recommended component values

$$f_{c_1} = \frac{1}{2\pi R_1 C_1} \qquad f_{c_2} = \frac{1}{2\pi R_2 C_2}$$

$$Gain = \frac{-R_2}{R_1}$$

Stage 5: Active Low Pass Filter

Following an active bandpass filter will be an active low pass filter to increase the maximum gain as well as providing a greater attenuation of 60 Hz noise. Recall that a lower cutoff frequency will provide greater 60 Hz noise attenuation, but too aggressive of a cut-off could lead to signal distortion. The second corner frequency should be above 5 Hz.

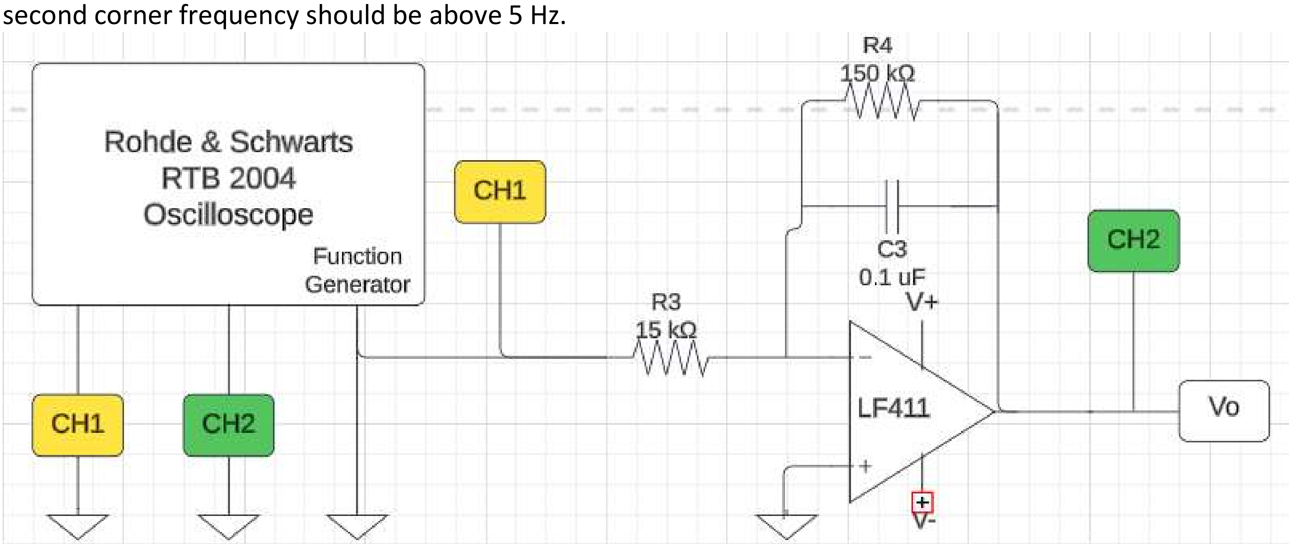

Figure 4: Circuit schematic of active low pass filter with an LF411 and recommended component values

$$Gain = -R_2/R_1$$

$$f_C = \frac{1}{2\pi R_2 C_1}$$

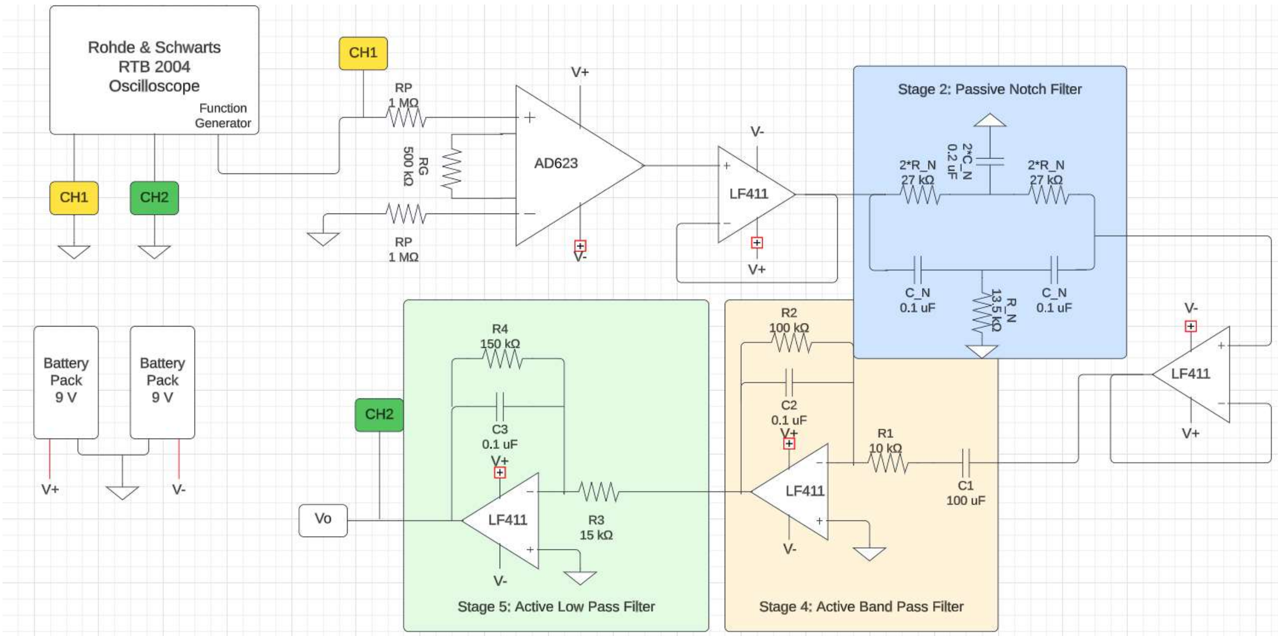

Figure 5: Circuit schematic of ECG circuit with recommended component values as well as power supply set up and measurement set up

Procedure

Part 1:

1. Build the circuit of the passive notch filter in Figure 2. Two battery packs will be used to supply the positive and negative 9 V to the operational amplifier and should be wire accordingly as shown in Figure 2. (If any values need to be altered, refer to Figure 2 for the formulas of gain and components)
2. Verify the gain at the center frequency with CH1 (yellow) and CH2 (green) placed as shown in Figure 2.
3. Repeat step 1-2 for the active bandpass filter in Figure 3.
4. Repeat steps 1-2 for the active low pass filter in Figure 4.
5. Once all stages are verified separately, cascade the stages together as shown in Figure_ with CH1 (yellow) and CH2 (green) placed as shown in Figure 5.
6. Perform a frequency sweep of the cascaded stages. Include an image in your report.
7. Perform a manual sweep of the circuit. This should be used to verify the gain and output behavior of the circuit
8. Collect at least 10 data points from the manual sweep to document the behavior of the circuit (some recommended data points to collect are the corner or center frequencies from each stage, pass band, maximum or minimum gain values, etc.). Include at least 5 images in your report.

Part 2 (optional):

9. Replace the resistor RG that is connected to the AD623 op amp with a large potentiometer. Tune the potentiometer to the far left as well as the far right.
10. Collect at least 5 data points from the manipulation of the potentiometer to document the behavior of the circuit. Include at least 2 images in your report