EE 230 - Analog Lab
Wadhwani Electronics Laboratory
Electrical Engineering IIT Bombay

Lab: 11 ECG Simulation

Instructions:

- Write down all your observations in your notebook.

Objectives:

- To understand the working and design of an ECG Amplifier
- Using Simulations to support analytical analysis.

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1. **ECG Amplifier**

An ECG (Electrocardiogram) amplifier is an electronic device designed to accurately capture and amplify the electrical signals generated by the heart. The ECG signal is typically very small in amplitude, on the order of milli-volts, and may be subject to noise and interference from various sources, such as muscle activity or power line noise. The ECG waveform itself contains frequencies primarily in the range of 0.5 Hz to 150 Hz but can be contaminated with high-frequency noise. Therefore, the amplifier includes low-pass filtering to remove high-frequency noise while preserving the integrity of the ECG signal. In this homework you have to design the filtering circuit.

(a) **2nd Order Low Pass Filter**

i. **Theory**

Figure [1] shows the 2nd order Low Pass Filter. If we assume opamap as ideal then the transfer function from V_{in} to V_b is

$$\frac{V_b}{V_{in}} = \frac{-A}{1 + s\tau_1} \tag{1}$$

where **A** is the DC gain of the inverting Amplifier and τ_1 is the time constant of the transfer function from V_{in} to V_b. The Transfer function from V_{in} to V_c is

$$\frac{V_c}{V_{in}} = \frac{-A}{1 + s\tau_1} * \frac{1}{1 + s\tau_2} \tag{2}$$

There are two poles located at $\frac{1}{\tau_1}$ and $\frac{1}{\tau_2}$ Since the LPF is 2nd order hence both the pole frequency should be nearly equal.

ii. **Simulation**

A. Now you have to design a low pass filter for a DC-gain around 28 dB with 150 Hz(overall cut-off frequencies) of 3-dB cut-off frequency. For that you have to find out and report the values of R_7 and R_8 to meet the required specs. **[3 Marks]**

B. Draw the Schematic on LT-Spice and perform the AC Analysis in which select type of sweep as Decade with a frequency range of 1 to 10 KHz. Plot the output waveform V_c and tabulate the DC gain and the 3-dB cut-off frequency. **[2 Marks]**

C. Apply a sinusoidal signal with 2 KHz frequency and peak amplitude of 1 V at the input signal and plot transient response of V_{in} and V_c. **[2 Marks]**

(b) **Notch Filter**

i. **Theory**

To design a 50 Hz notch filter using a **combination of a low-pass filter (LPF) and a high-pass filter (HPF)**, we can employ a technique known as the twin-T notch filter. This involves combining the outputs of a LPF and a HPF to cancel out a specific frequency (in this case, 50 Hz). You can design a 50 Hz notch filter using a LPF and a HPF:

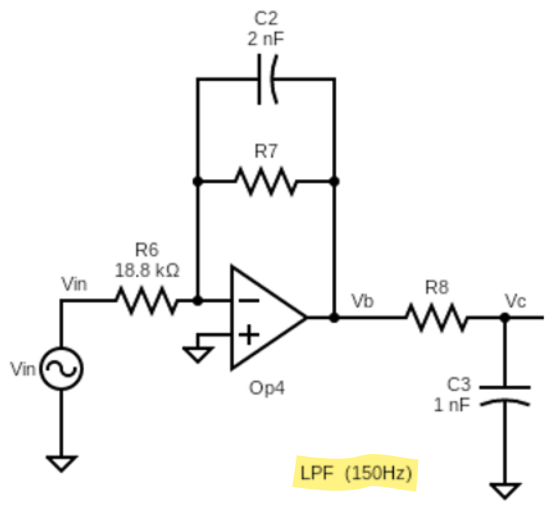

Figure 1: Low Pass Filter

Design a Low-Pass Filter (LPF): Design a LPF with a cutoff frequency lower than 50 Hz to allow frequencies below 50 Hz to pass through. The LPF should have a steep roll-off to attenuate frequencies above its cutoff effectively. In the fig. [2], the left side circuit where R_9 and C_6 are connected is a Low pass filter.
Design a High-Pass Filter (HPF): Design a HPF with a cutoff frequency higher than 50 Hz to allow frequencies above 50 Hz to pass through. Similar to the LPF, the HPF should have a steep roll-off to attenuate frequencies below its cutoff effectively. In the fig. [2], the the left side circuit where R_{10} and C_4 are connected is a High pass filter.
Combine the LPF and HPF Outputs: The outputs of the LPF and HPF can be combined in such a way that they cancel each other out at the desired notch frequency (50 Hz). The combined circuit for the notch filter by adding LPF and HPF is shown in fig. [3] By summing the output of the LPF and the inverted output of the HPF, the signals at 50 Hz will be attenuated, while frequencies outside of the notch frequency will pass through relatively unaffected.

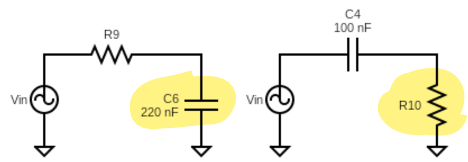

Figure 2: LPF & HPF for Notch filter

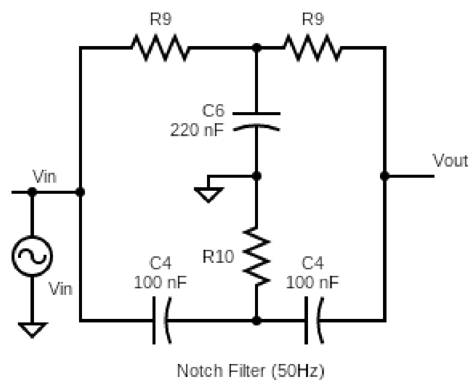

Figure 3: 50 Hz Notch Filter

ii. **Simulation**

A. Draw the schematic of the low pass filter shown in the left in fig. [2]. Find out the value of the resistor R_9 such that the cut-off frequency should lie in the range of 20-30 Hz. Perform AC analysis in which select type of sweep as Decade with a frequency range of 1 to 1 KHz. Plot voltage across capacitor. **[2 Marks]**

B. Draw the schematic of the high pass filter shown in the right in fig. [2]. Find out the value of the resistor R_{10} such that the cut-off frequency should lie in the range of 80-90 Hz. Perform AC analysis in which select type of sweep as Decade with a frequency range of 0.1 to 1 KHz. Plot voltage across resistor. **[2 Marks]**

C. Draw the Schematic of the Notch filter as shown in fig [3]. Use the values of R_9 and R_{10} that you got from A and B respectively. Perform AC analysis in which select type of sweep as Decade with a frequency range of 0.1 to 1 KHz then plot V_{out} and tabulate the cut-off frequencies of Notch filter. **[3 Marks]**

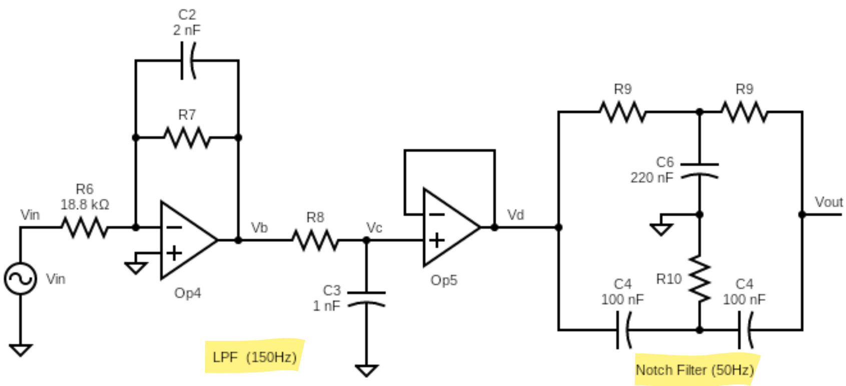

Figure 4: Combined Circuit

(c) Combined 2nd Order Low Pass Filter and Notch Filter Response

i. Simulation

A. Draw the combined circuit shown in fig.[4]. Perform the AC analysis from a frequency range of 0.1 to 1 kHz and then plot the V_{out}. Tabulate the DC gain and 3-dB cut-off frequency.**[2 Marks]**

B. Apply a sinusoidal signal with 20 Hz frequency and peak amplitude of 0.1 V at the input signal and plot transient response of V_{in} and V_{out}. **[0.5 Marks]**

C. Apply a sinusoidal signal with 50 KHz frequency and peak amplitude of 0.1 V at the input signal and plot transient response of V_{in} and V_{out}. **[0.5 Marks]**

D. Apply a sinusoidal signal with 100 Hz frequency and peak amplitude of 0.1 V at the input signal and plot transient response of V_{in} and V_{out}. **[0.5 Marks]**

E. Apply a sinusoidal signal with 2 KHz frequency and peak amplitude of 0.1 V at the input signal and plot transient response of V_{in} and V_{out}. **[0.5 Marks]**