Electric Circuits II

Lab Project Description

[1] Objectives

This document aims to provide the required information related to the course project. It will help understanding more about filters, their types, and discusses the required deliverables of the project. It also provides notes about your choice of values and components.

[2] Overview

Each group of students are required to choose one of the **band pass** or **band stop** filters included in this document. Each group will (1) design the chosen circuit (i.e., choose the values of components that provides a desired performance), (2) simulate the designed circuit using a suitable software (e.g., PSpice), (3) build the hardware circuit using the chosen components and check its performance, (4) write down a report including the details for the design, simulations and hardware implementation and sample of the results, and finally, (5) attend the evaluation for the project during the lab session.

[3] Requirements

- **Team formation:** each group of students (2 or 3 students) in the same tutorial/lab will form a team.
- **Circuit choice:** the team will choose one of the filter circuits included in this document.
  Teams composed of two students have to choose a circuit from a designated list and teams composed of three students have to choose a circuit from another designated list.
- **Team registration:** The students will inform their lab TA about the team members and the circuit of their choice during the lab session of Week 10 (April 27 – May 2).
- **Design and Simulation:** each team will design and simulate the chosen circuit on their own. Students can ask their TAs about the simulations during the lab session of Week 11 (May 7 – May 13). Additional office hours with the TAs can be scheduled if required.

- **Hardware implementation:** each team will implement on their own the designed circuit on a breadboard. The components should have the values used in the design and simulations. Students can ask their TAs about the hardware implementation during the lab session of Week 11 (May 7 – May 13). Additional office hours with the TAs can be scheduled if required.
- **Report preparation:** each team will prepare a report including: (1) the chosen circuit, (2) chosen values of components to achieve the required performance, (4) the circuit implementation on the chosen simulation software, (5) the simulation results, (6) the hardware implantation including pictures of the hardware and the results obtained on the oscilloscope.
- The report will be submitted to the TAs in the lab session of Week 12 (May 14 – May 20).
- **Project Evaluation:** each team will test the circuit in the lab and the TA will evaluate the understanding of all team members and examine the performance of their circuit during the lab session of Week 12 (May 14 – May 20).

[4] Theoretical Background

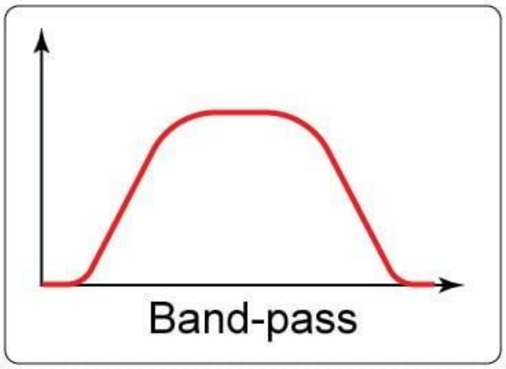
A filter is a circuit that is designed to pass signals with desired frequencies and rejects or attenuate other frequencies. As a frequency-selective device, a filter can be used to limit the frequency spectrum of a signal to some specified band of frequencies.

The concept of filters has been an integral part of the evolution of electrical engineering from the beginning. Several technological achievements would not have been possible without electrical filters. Filters are the circuits used in radio, TV receivers and other communication equipment. It allows the selection of desired signal(s) out of a multitude of broadcast signals in the environment.

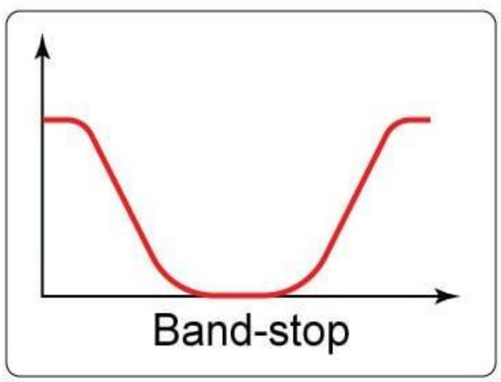
A filter is a passive filter if it consists of only passive elements R, L, and C. It is said to be an active filter if it consists of active elements (such as transistors and op-amps) in addition to passive elements R, L and C.

Filters have mainly four types: low pass, high pass, band pass and band stop filters. We will only be focusing on **band pass** and **band stop** filters for this project.

a. **Band pass filter:** Passes frequencies within a frequency band and stops or attenuates frequencies outside the band.



b. **Band stop filter:** Passes frequencies outside a frequency band and stops or attenuates frequencies within the band. If the band width of the filter is very narrow, the filter is called a **Notch filter** which has a specific cut-off frequency.



[5] Project Report:

- The project report is expected to include the following sections:
  - ✓ **Theoretical background:** which provides an explanation about the chosen filter and the related equations for the gain, and half-power frequencies (or cut-off frequency).
  - ✓ **Filter design:** which provides the values for the components and parameters (Resistance/Capacitance values, half power frequencies, …, etc.) to be used in the simulation and hardware implementation.
  - ✓ **Circuit simulation:** which includes the detailed steps for the circuit construction on the software, i.e. screenshots for the schematic diagram and simulation profiles.
  - ✓ **Simulation results:** which provide the screenshots for the obtained simulation results and comments on the simulation results.
    You need to run two simulation profiles:
    1. i. AC sweep simulation: to sketch the gain versus the frequency, where VAC is used as the input signal (One sketch is required).
    2. ii. Time domain simulation: to sketch voltage amplitude versus time, where Vsin is used as the input signal at three different frequencies ($f < fo$, $f = fo$ and $f > fo$) (three sketches are required).
  - ✓ **Hardware implementation:** this should include the details of the purchased components and pictures for the hardware implementation of the filter circuit.
  - ✓ **Hardware results:** pictures from the oscilloscope for the input voltage and the output voltage at three different frequencies (to show that the filter is band pass or band stop) and discussion of the results obtained from the hardware implementation.

[6] Evaluation:

- Each group should connect their circuit on their own during the evaluation, TAs WILL NOT OFFER ANY HELP. You should test the circuit in multiple cases of the input signal (e.g. with $f < fo$, $f = fo$ and $f > fo$) and display the output for each case.
- Each group will have a max of 7 mins to display their circuit output and for the individual oral questions.
- Each student in the group is asked individually oral questions to demonstrate his/her understanding and contribution to the project.

[7] Filter Circuits (Choose one):

For any of the circuits below, assume either a center frequency or an upper and lower cutoff frequencies of your choice. Then adjust the values of the resistors and capacitors to reach the chosen frequency.

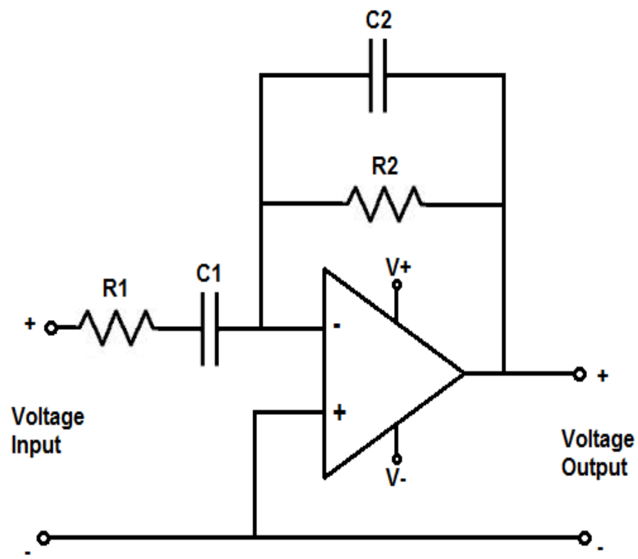
The following points should be considered for a proper circuit design:

- Range of the frequencies between 1 kHz and 100 kHz, in order to prevent the non-idealities of the op-amp.
- Values for the resistor in the kilo range for example 1KΩ, 10KΩ…etc.
- Values for capacitor in pico-farad (pF) or nano-farad (nF) range.
- LM741 or LM324 opamps check their pinout for correct pins connection.
- You will need to buy multiple of jumper wires for connection.
- One medium breadboard.
- It is recommended to buy two or more for each component in your circuit.
- The chosen values of the components in the simulations should be available in the market for hardware implementation. Please check the websites for the commercial distributors of electronic components to choose the available values.
- Addresses for electronic stores:

-El-Nekhely (Bab El-Louk) Address: 176 Tahrir Street, Bab El-Louk
-Mamoun (El-Korba) and (ElRehab)
-Allam (Nasr city) Address: 47, Mohamed Hassanen Hekl, Nasr city
-Online: https://www.maamoon.com/ , https://store.fut-electronics.com/

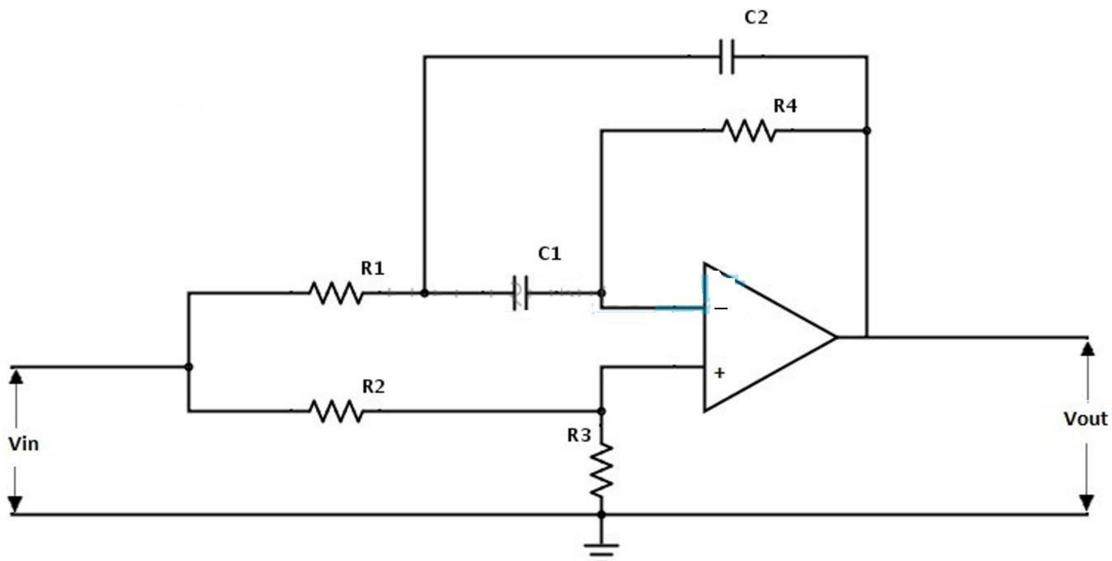
[7.1] Circuits for Teams of TWO Students

1- Band Pass Filter Circuit 1 (Inverting Band Pass Filter Circuit)



Low Cutoff Frequency	$f_L = \frac{1}{2\pi R_1 C_1}$
High Cutoff Frequency	$f_H = \frac{1}{2\pi R_2 C_2}$

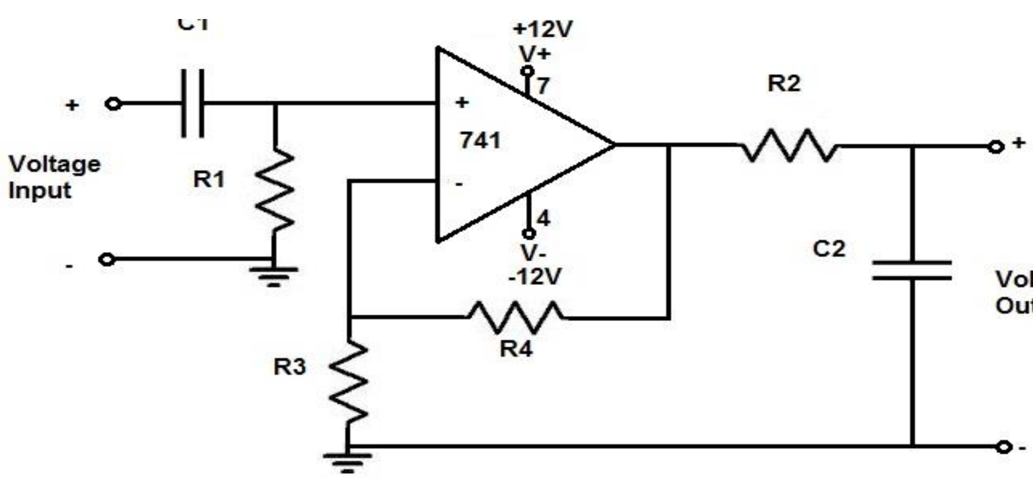
2- Band Stop Filter circuit 1 (Notch filter):



Assume that $R_1 = R_2 = R_3 = R_4 = R;\ C_1 = C_2 = C$

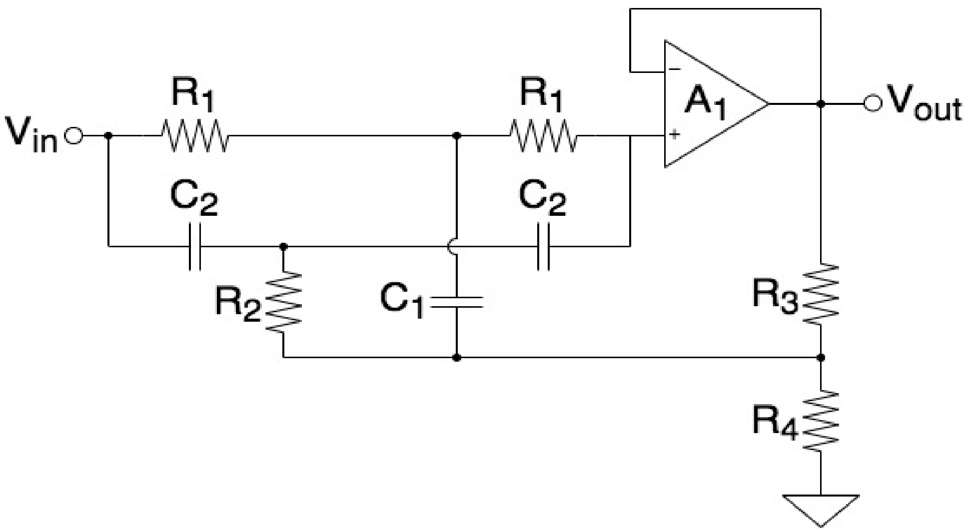
Center Frequency	$f_c = \frac{1}{2\pi RC}$

3- Band pass filter circuit 2 (Active Band Pass Filter Circuit)



Lower Cutoff Frequency	$f_L = \frac{1}{2\pi R_1 C_1}$
Higher Cutoff Frequency	$f_H = \frac{1}{2\pi R_2 C_2}$

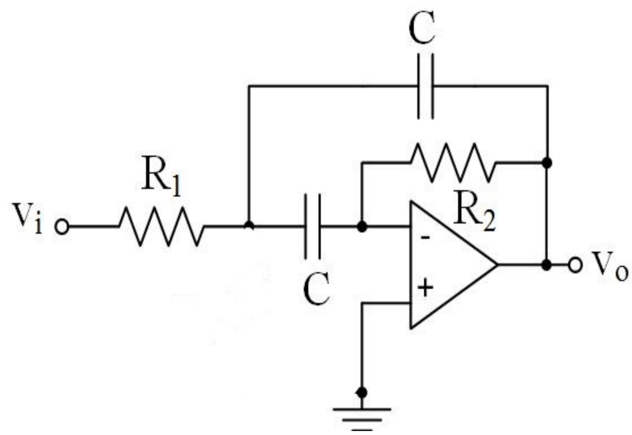
4- Band stop filter circuit 2 (Single Op-amp Twin-T Notch Filter with feedback):



Assume that $R_1 = 2\,R_2, C_1 = 2\,C_2$

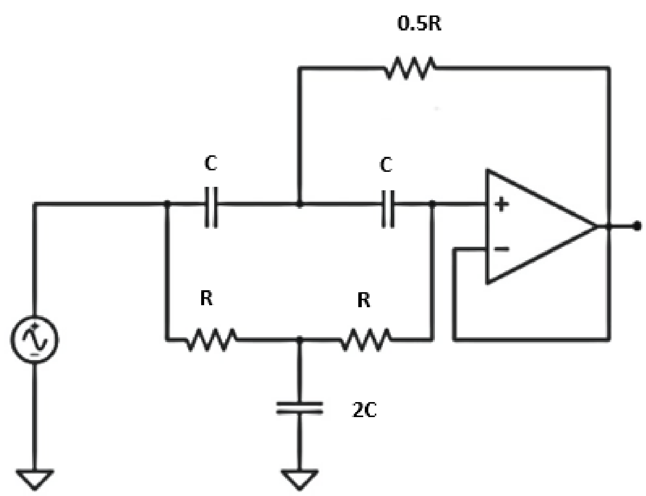
Center Frequency	$f_c = \frac{1}{4\pi R_2 C_2}$

5- Band Pass circuit 4 (Infinite Gain Multiple Feedback Active Filter):



Center Frequency	$f_c = \frac{1}{2\pi\sqrt{R_1R_2C^2}}$

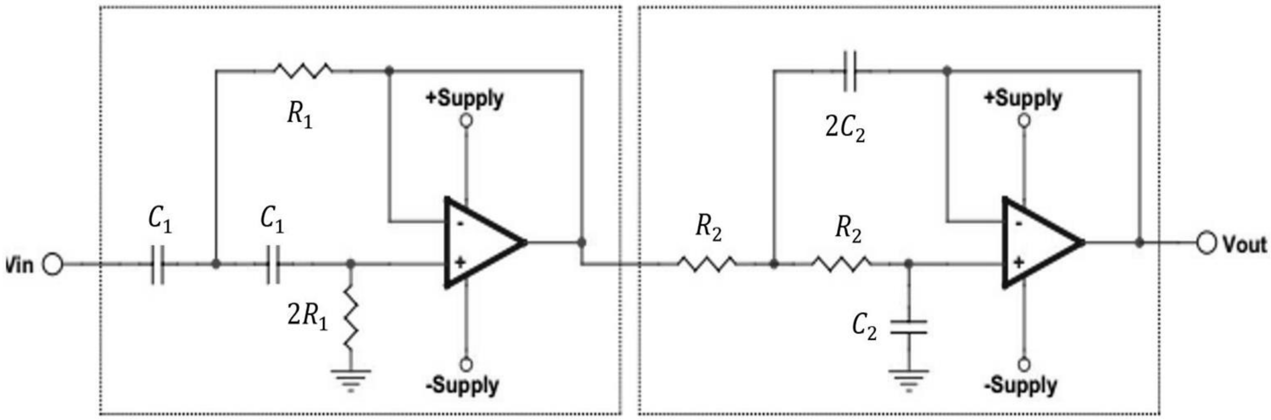
6- Band Stop filter circuit 3 (Single Op-amp Twin-T Notch Filter without feedback):



Center Frequency	$f_c = \frac{1}{2\pi RC}$

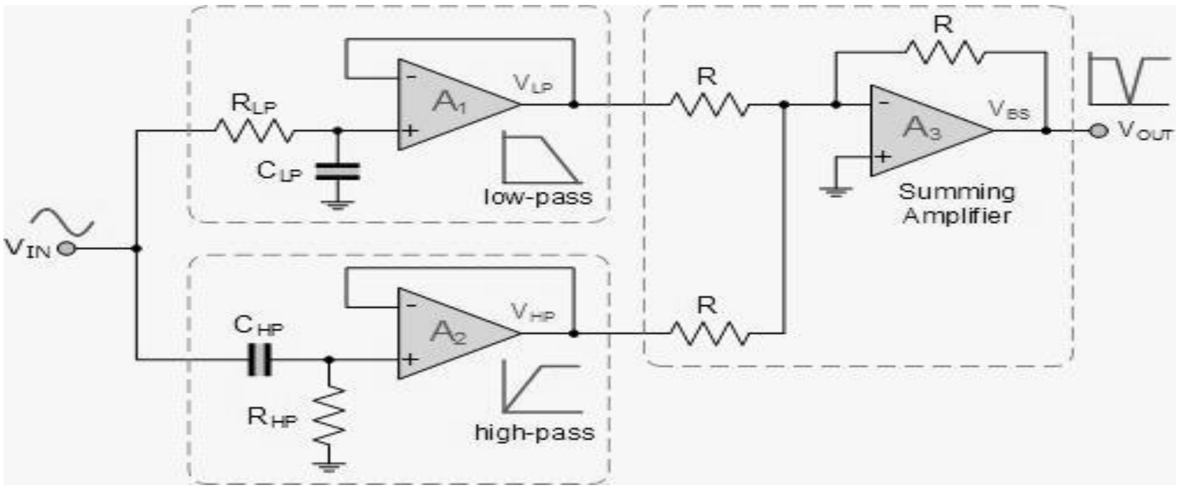
[7.2] Circuits for Teams of THREE Students

1- Band Pass filter circuit 5 (Sallen Key / Cascaded band pass filter):



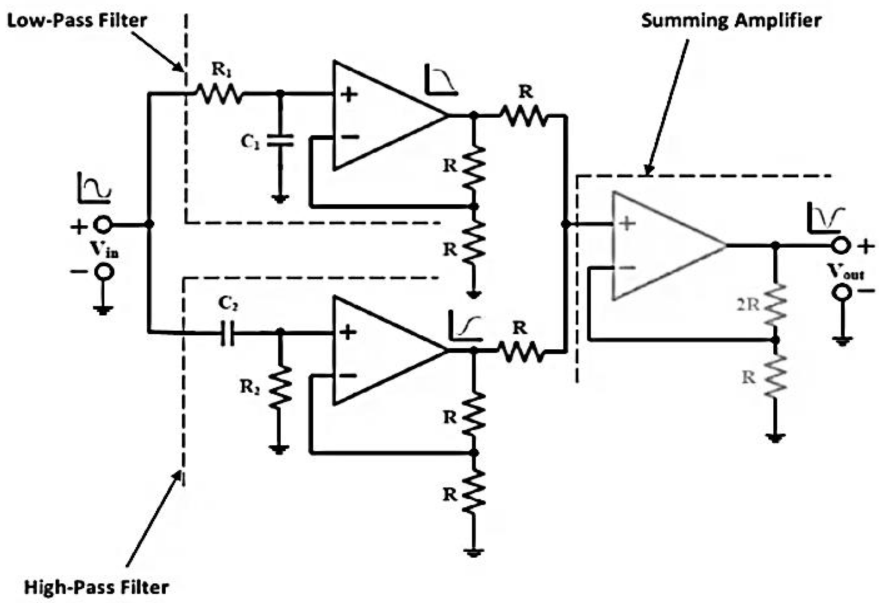
Lower cutoff Frequency	$f_L = \dfrac{1}{2\pi\sqrt{2}\,R_1 C_1}$
Higher Cutoff Frequency	$f_H = \dfrac{1}{2\pi\sqrt{2}\,R_2 C_2}$
Center Frequency	$f_0 = \sqrt{\omega_L \omega_H}$

2- Band Stop filter circuit 4 (Basic wideband Band stop filter):



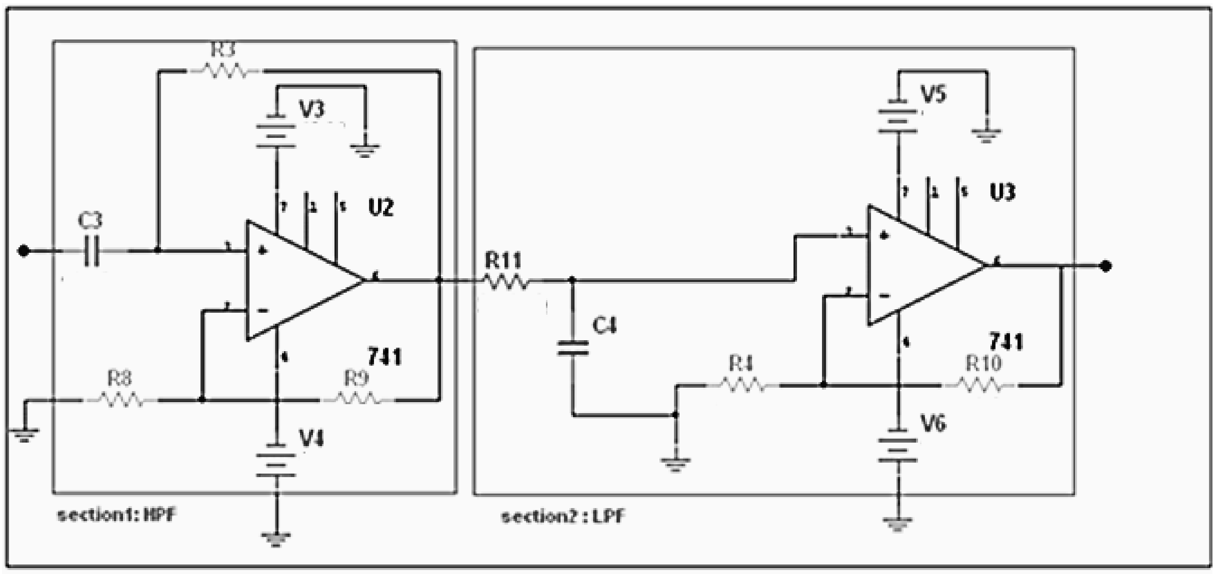
Lower Cutoff Frequency	$f_L = \dfrac{1}{2\pi R_{LP} C_{LP}}$
Higher Cutoff Frequency	$f_H = \dfrac{1}{2\pi R_{HP} C_{HP}}$

3- Band Stop filter circuit 5 (Basic wideband Band stop filter with feedback gain):



Lower Cutoff Frequency	$f_L = \dfrac{1}{2\pi R_1 C_1}$
Higher Cutoff Frequency	$f_H = \dfrac{1}{2\pi R_2 C_2}$

4- Band Pass filter circuit 6 (Wide Band pass Filter):



Lower Cutoff Frequency	$f_L = \dfrac{1}{2\pi R_3 C_3}$
Higher Cutoff Frequency	$f_H = \dfrac{1}{2\pi R_{11} C_4}$

For simplicity let $R_8 = R_9 = R_4 = R_{10}$

[7] Grading Scheme:

Report	15%
Simulations	30%
Hardware implementation	40%
Oral assessment	15%