**EGR24L Project 3 – Passive Filter**

Circuit demo (80/200) due: 12/14/2023

LTspice design files (100/200) due: 12/14/2023

Report (20/200) due: 12/16/2023

Construct a band-pass filter (BPF) by using capacitors and resistors. A typical BPF consists of a low-pass filter (LPF) and a high-pass filter (HPF) arranged in a cascaded configuration.

Filters that are constructed with passive elements (usually capacitors and resistors) only are called passive filters. Throughout the frequency spectrum, the passive filters have gains of less than or equal to one (which is 0 dB). Therefore, at any given frequency, the output signal has an amplitude that is less than or equal to the input signal. In contrast, active filters use active elements (such as op amps) to achieve gains of more than one. The BPF in this project is a passive filter.

The main property of a BPF is its passband, which consists of a left-side (low-end) cutoff frequency, and a right-side (high-end) cutoff frequency.

**Cutoff frequency** is the frequency at which the output signal’s voltage amplitude is about 70% of the input signal’s voltage amplitude. This corresponds to the filter attenuating half of the input signal’s power. The cutoff frequency also called the **-3dB frequency**, because the gain at this frequency is 3dB below the maximum (unattenuated) gain of 0 dB. To view the frequency response of a circuit, a **Bode plot** is often used. The Bode plot is a semi-log plot of the gain in dB vs. the input signal’s frequency, where the frequency is plotted on a log scale. The cutoff frequency is sometimes referred to as the **corner frequency**, because on the Bode plot, this characteristic frequency is near the corner where the output signal rolls off from its maximum level at -20 dB per decade.

Your instructor will randomly generate the BPF passband low and high cutoff frequencies, and give them to you. Please record them below:

|  |  |
| --- | --- |
| Left-side (low-end) cutoff frequency |  |
| Right-side (high-end) cutoff frequency |  |

You will first use LTspice (particularly the AC analysis to obtain a Bode plot) to help you accomplish a preliminary design. Then, physically build your BPF on a breadboard with capacitors and resistors. If you need to use additional elements (such as op amps), you may do so, but please keep in mind that the simplest solution contains only two capacitors and two resistors.

Demonstrate with a function generator and an oscilloscope that your filter’s two cutoff frequencies agree with the design values.

**Deliverables:**

1) The circuit product on a breadboard. Clearly label all the input, output, and ground terminals. Demo in person to me how your circuit works, using your oscilloscope and function generator.

2) LTspice circuit file demo and upload.

3) Short report write up –

a) your basic design idea – must include why you choose the R and C values

b) the necessary calculations to support the RC values you choose

c) what you have learned in this project

**Grading rubric**

1) Circuit performance (LTspice and actual breadboard circuit)

2) Circuit economy – fewer and simpler elements is better

**Design insight**

The main task of this project is to determine the proper resistors and capacitors to use. Recall in the previous lab how the corner frequency is related to the R and C values. This is a helpful starting point.

You may reason that if you first design a LPF and a HPF separately and then assemble them in a cascade, you will produce the requisite BPF. This strategy is reasonable, but there is a potential catch. After attaching the second filter stage to the first stage, the BPF’s gain may drop significantly. This is a type of loading effect. Recall the loading effect in DC circuits – attaching a load resistor to a voltage divider circuit often destroys the original voltage division (and solutions to overcome this loading effect). The loss of gain you may see in this BPF circuit is based on the same physics. Your challenge here is to find a solution to overcome the loading effect in this AC circuit. The simplest solution is to choose the proper R and C values. This is the most challenging aspect of this project. Other solutions do exist, but the best solution here is the simplest solution, where the BPF contains only passive elements.

**LTspice resources**

Please see the circuit below for AC analysis of an RC circuit.

Diagram, schematic

Description automatically generated

The result is a Bode plot of the output signal. After successful simulation, you can use cursors in the plot plane to find the cutoff frequency.

Chart

Description automatically generated