Lab Exercise 3

Objectives

1. **Design first, second and third order low pass filters in LTSpice.**
2. **Plot the magnitude and phase response of the filters in a Bode plot.**
3. **Observe how the filters reduce the ripples on the pulsating DC output of the rectifier circuit.**

Reading exercise

Please read about filter circuits in https://www.tutorialspoint.com/electronic_circuits/electronic_circuits_filters.htm

Viva questions will be based on the lab and reading exercise

As we observed in the previous lab, the output of the rectifier circuits consists of a ripple factor which indicates some left over AC components. For a pure DC signal, this ripple must be removed. Therefore, we need to connect the output to a low pass filter (LPF) circuit that will allow the DC signal to pass through but block the high frequency AC signal. The order of a filter is determined by the number of storage elements (capacitors and inductors). The first order LPF filters are series inductor or shunt capacitors.

Series Inductor filter

An inductor connected in series with the rectifier output will allow the DC to pass through but provide high impedance to the AC voltage.

Lab exercise

1. Insert an AC input of 1V amplitude and a 50Ω series resistance to a 5uH series L filter circuit and sweep the frequency from 5Hz to 500MHz and plot the magnitude of the transfer function of the filter in a Bode plot. Mark the roll off rate of the filter response.
2. For the same circuit, plot the phase response of the filter circuit from 5Hz to 1MHz.
3. Plot the output voltage from Lab.2 rectifier circuit in the absence of the filter using transient simulation. Note the maximum and minimum of the voltage. The difference between the maximum and minimum provides the ripple voltage of the circuit.
4. Insert the series L filter with the output from load resistance in the rectifier circuit. Again, run the transient simulation and plot the time-domain output voltage. Compute the ripple voltage of this output. For a frequency of 50Hz, compute the impedance offered by this inductance.
5. Increase the inductance value to 500mH. Repeat previous step.

Shunt Capacitor filter

Smoothing or shunt capacitors connected in parallel with the load across the output of the rectifier circuit increase the average DC output level even higher as the capacitor acts like a storage device. In other words, it provides a low impedance path for the AC signal to the ground while passing the DC through to its output.

Lab exercise

1. Insert an AC input of 1V amplitude and a 50Ω series resistance to a 470uF shunt capacitor filter circuit and sweep the frequency from 5Hz to 1MHz and plot the magnitude of the transfer function of the filter in a Bode plot. Mark the roll off rate of the filter response.
2. For the same circuit, plot the phase response of the filter circuit from 5Hz to 1MHz.
3. Plot the output voltage from Lab.2 rectifier circuit in the absence of the filter using transient simulation. Note the maximum and minimum of the voltage. The difference between the maximum and minimum provides the ripple voltage of the circuit.

4. Insert a shunt capacitance of 50uF with the output from load resistance in the rectifier circuit. Again, run the transient simulation and plot the time-domain output voltage. Compute the ripple voltage of this output. For a frequency of 50Hz, compute the impedance offered by this capacitance.
5. Increase the smoothing capacitance value to 2200uF. Repeat previous step.

LC filter circuit

A second order LPF filter circuit can be obtained by connecting a series inductance followed by a shunt capacitor as shown below.

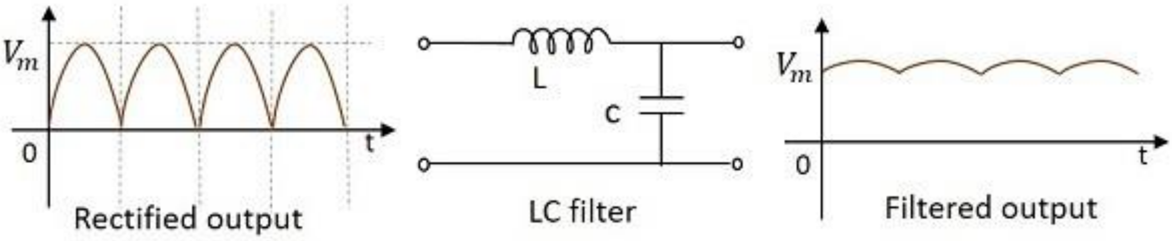

Fig.1. Rectifier output is fed to the input of an LC filter in order to obtain a filtered output (web link)

The cut-off frequency of this filter is determined by the L and C.

$$f = 1/2\Pi\sqrt{LC}$$

With the increased hardware complexity, we may obtain smoother DC output.

Lab exercise

1. Choose values of L and C to obtain a cut-off frequency of 20Hz. Use these values to design the LC filter in LT spice.
2. Insert an AC input of 1V amplitude and a 50Ω series resistance to the filter circuit and sweep the frequency from 5Hz to 500MHz and plot the magnitude of the transfer function of the filter in a Bode plot. Mark the roll off rate of the filter response.
3. For the same circuit, plot the phase response of the filter circuit from 5Hz to 500MHz.
4. Plot the output voltage from Lab.2 rectifier circuit in the absence of the filter using transient simulation. Note the maximum and minimum of the voltage. The difference between the maximum and minimum provides the ripple voltage of the circuit.
5. Insert a LC filter with the output from load resistance in the rectifier circuit. Again, run the transient simulation and plot the time-domain output voltage. Compute the ripple voltage of this output.

PI Filter

A third order circuit can be configured for obtaining an even smoother response as shown below.

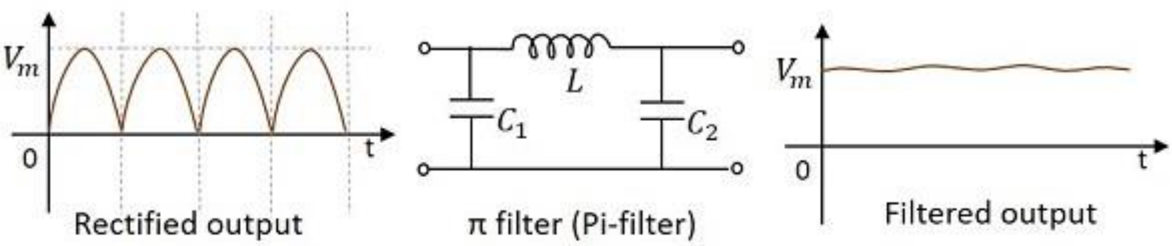

Fig.2 Rectifier output is fed to the input of a Pi filter in order to obtain a filtered output Pi Filter (web link)

Lab exercise

1. Choose C_1 and C_2 to be identical. Repeat values of L and C from the previous LC filter case and use these values to design the Pi filter in LT spice.
2. Insert an AC input of 1V amplitude and a 50Ω series resistance to the filter circuit and sweep the frequency from 5Hz to 500MHz and plot the magnitude of the transfer function of the filter in a Bode plot. Mark the roll off rate of the filter response.
3. For the same circuit, plot the phase response of the filter circuit from 5Hz to 500MHz.
4. Plot the output voltage from Lab.2 rectifier circuit in the absence of the filter using transient simulation. Note the maximum and minimum of the voltage. The difference between the maximum and minimum provides the ripple voltage of the circuit.
5. Insert a Pi filter with the output from load resistance in the rectifier circuit. Again, run the transient simulation and plot the time-domain output voltage. Compute the ripple voltage of this output.