INDIAN INSTITUTE OF TECHNOLOGY
BHUBANESWAR

Introduction to Electronics Laboratory

School of Electrical Sciences

Name: Shorya Sharma
Roll Number: 19EE01017

Design Experiment-01

- **AIM OF THE EXPERIMENT:**

  Design and simulate in LT-SPICE a second order passive band pass and band stop filters.

  (a) Determine suitable R L and C values of Band Pass and Band Stop Filter for specifications given in section -4, Design Specifications (Table.1)

  (b) Simulate and provide frequency response plots for BPF and BSF clearly showing Pass band and Stop bands

  (c) Determine R L and C values of BPF and BSF for same centre frequency and -6 dB bandwidth of 200 KHz + 10*X KHz

  (d) Give comments on frequency response and R L and C values.

  (e) Discuss all the results with proper circuits, component values and graphs.

- **SIMULATION TOOLS:**

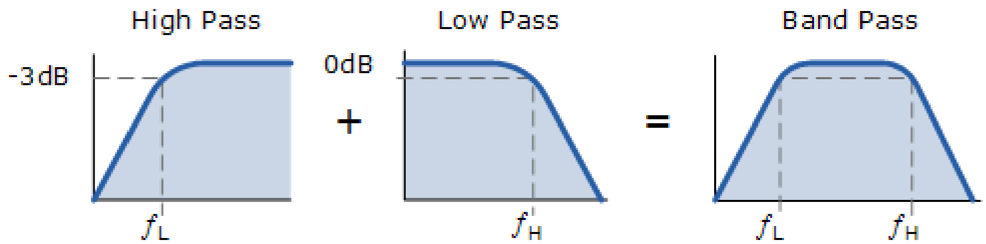
* Inductor (X4)
* Resistor (X4)
* Capacitor (X4)
* AC Voltage Source (X4)
* Connecting wires (as required)

- **LEARNING OUTCOMES**

* Able to design and simulate the passive RLC for given set of specifications.
* Able to determine the transfer function of the passive filter.
* Able to determine the component values for required specification

Theory: -

This cascading together of the individual low and high pass passive filters produces a low "Q-factor" type filter circuit which has a wide pass band. The first stage of the filter will be the high pass stage that uses the capacitor to block any DC biasing from the source. This design has the advantage of producing a relatively flat asymmetrical pass band frequency response with one half representing the low pass response and the other half representing high pass response as shown.

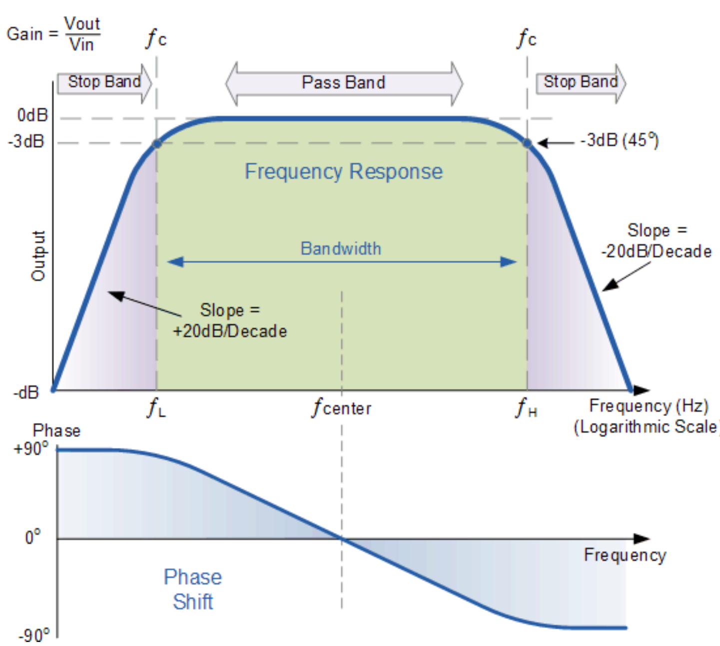


The higher corner point (f_H) as well as the lower corner frequency cut-off point (f_L) are calculated the same as before in the standard first-order low and high pass filter circuits. Obviously, a reasonable separation is required between the two cut-off points to prevent any interaction between the low pass and high pass stages. The amplifier also provides isolation between the two stages and defines the overall voltage gain of the circuit.

The bandwidth of the filter is therefore the difference between these upper and lower -3dB points. For example, suppose we have a band pass filter whose -3dB cut-off points are set at 200Hz and 600Hz. Then the bandwidth of the filter would be given as: Bandwidth (BW) = 600 – 200 = 400Hz.

The normalized frequency response and phase shift for an active band pass filter will be as follows.

Active Band Pass Frequency Response



While the above passive tuned filter circuit will work as a band pass filter, the pass band (bandwidth) can be quite wide and this may be a problem if we want to isolate a small band of frequencies. Active band pass filter can also be made using inverting operational amplifier.

So, by rearranging the positions of the resistors and capacitors within the filter we can produce a much better filter circuit as shown below. For an active band pass filter, the lower cut-off -3dB point is given by f_{C1} while the upper cut-off -3dB point is given by f_{C2}.

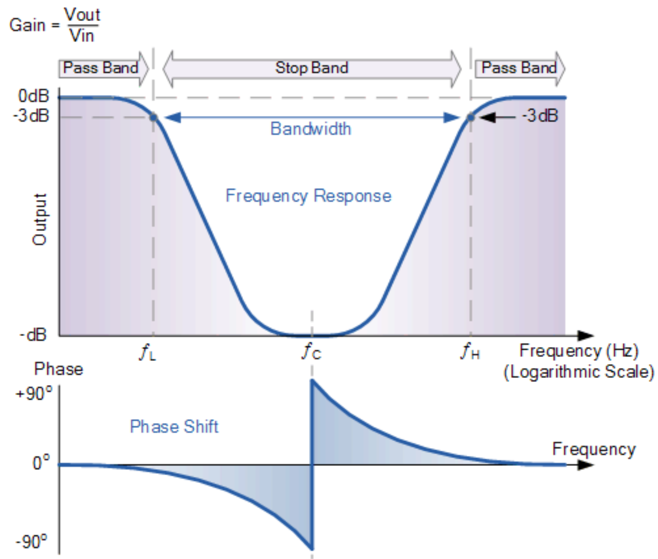
The **Band Stop Filter**, (BSF) is another type of frequency selective circuit that functions in exactly the opposite way to the Band Pass Filter we looked at before. The band stop filter, also known as a band reject filter, passes all frequencies with the exception of those within a specified stop band which are greatly attenuated.

If this stop band is very narrow and highly attenuated over a few hertz, then the band stop filter is more commonly referred to as a notch filter, as its frequency response shows that of a deep notch with high selectivity (a steep-side curve) rather than a flattened wider band.
Also, just like the band pass filter, the band stop (band reject or notch) filter is a second-order (two-pole) filter having two cut-off frequencies, commonly known as the -3dB or half-power points producing a wide stop band bandwidth between these two -3dB points.

Then the function of a band stop filter is too pass all those frequencies from zero (DC) up to its first (lower) cut-off frequency point f_L, and pass all those frequencies above its second (upper) cut-off frequency f_H, but block or reject all those frequencies in-between. Then the filters bandwidth, BW is defined as: (f_H – f_L).

So, for a wide-band band stop filter, the filters actual stop band lies between its lower and upper
-3dB points as it attenuates, or rejects any frequency between these two cut-off frequencies. The frequency response curve of an ideal band stop filter is therefore given as:

Band Stop Filter Response



We can see from the amplitude and phase curves above for the band pass circuit, that the quantities ƒL, ƒH and ƒC are the same as those used to describe the behavior of the band-pass filter. This is because the band stop filter is simply an inverted or complimented form of the standard band-pass filter. In fact, the definitions used for bandwidth, pass band, stop band and centre frequency are the same as before, and we can use the same formulas to calculate bandwidth, BW, center frequency, ƒC, and quality factor, Q.

The ideal band stop filter would have infinite attenuation in its stop band and zero attenuation in either pass band. The transition between the two pass bands and the stop band would be vertical (brick wall). There are several ways we can design a “Band Stop Filter”, and they all accomplish the same purpose.

SPECIFICATIONS

Table 1: Specifications of required parameters

Parameter	Value
Center Frequency (f_O)	09MHz
-3 dB Bandwidth ($BW = f_H - f_L$)	210kHz

ROLL NUMBER-19EE01017

X=1; Y=7

CALCULATIONS

(A)3dB FREQUENCY BANDWIDTH

We have, center frequency f_O = 09 MHz and Bandwidth BW = 210 KHz

Let R=200Ω

$$Bandwidth = \frac{R}{2\pi L}$$

$$L = \frac{R}{2\pi(BW)} = \frac{200}{2\pi \times 210 \times 10^3}$$

$$\therefore \boldsymbol{L \approx 151.57\mu H}$$

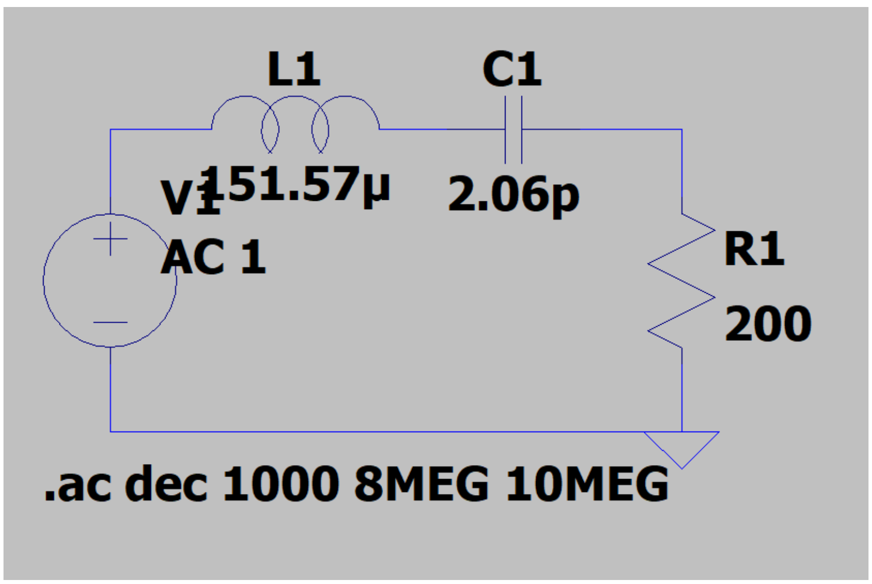
Now, From the center frequency equation, capacitor value can be found by substituting the L:

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

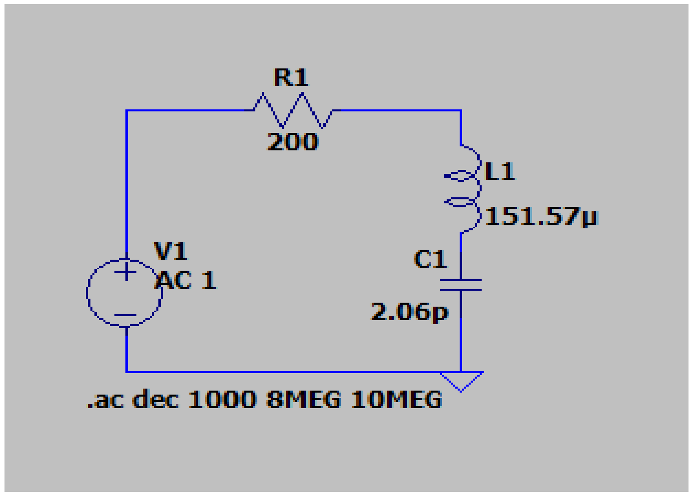
$$C = \frac{1}{(2\pi f_o)^2 L} = \frac{1}{(2\pi \times 9 \times 10^6)^2 \times 151.57 \times 10^{-6}}$$

$$\therefore \boldsymbol{C \approx 2.06pF}$$

CIRCUIT DIAGRAMS

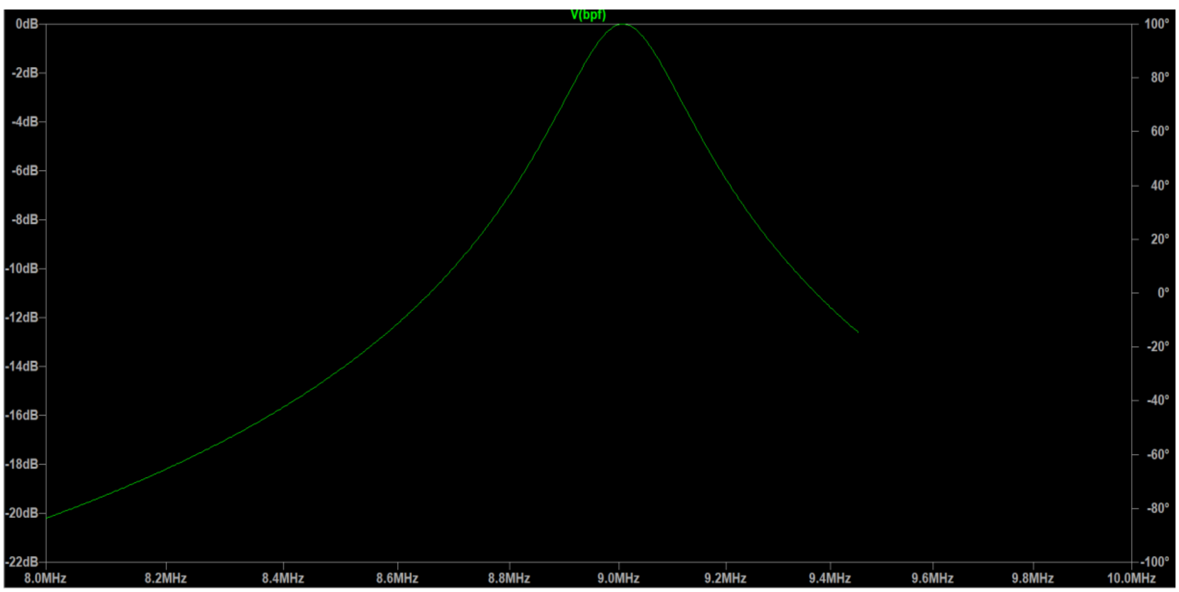


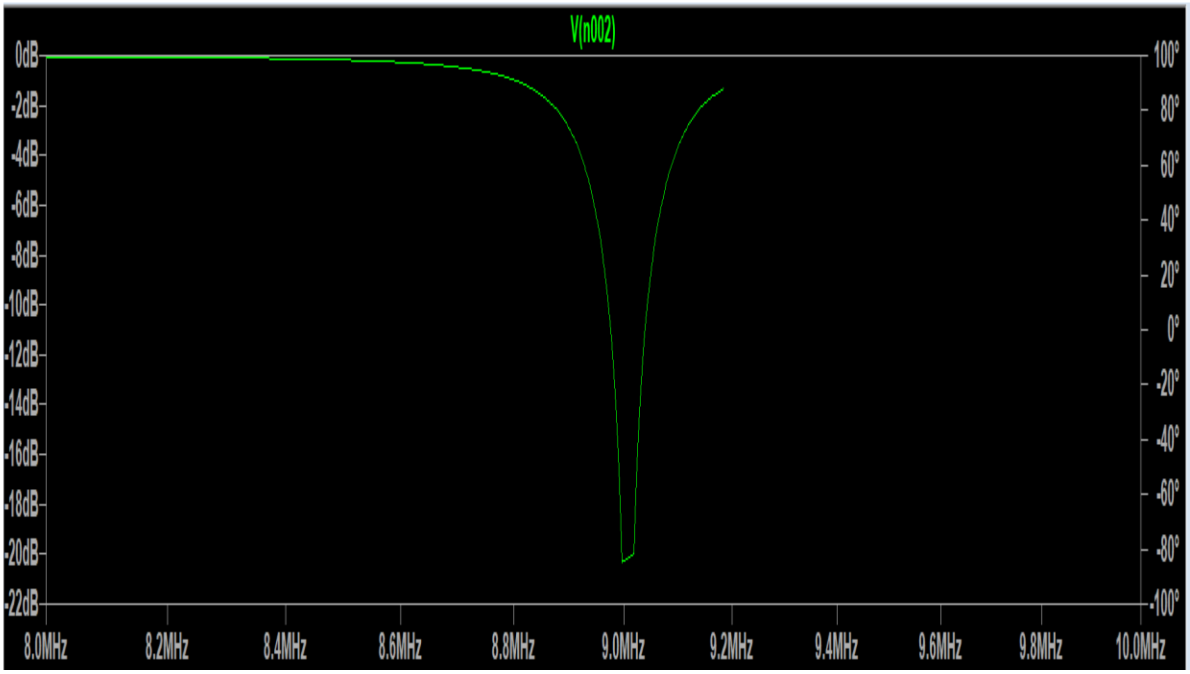
Circuit diagram for Band Pass Filter with the calculated components value.



Circuit diagram for Band Stop Filter with the calculated components value.

Graphs: -




V(n002)
0dB
-2dB
-4dB
-6dB
-8dB
-10dB
-12dB
-14dB
-16dB
-18dB
-20dB
-22dB
100°
80°
60°
40°
20°
0°
-20°
-40°
-60°
-80°
-100°
8.0MHz
8.2MHz
8.4MHz
8.6MHz
8.8MHz
9.0MHz
9.2MHz
9.4MHz
9.6MHz
9.8MHz
10.0MHz

(B)6dB FREQUENCY BANDWIDTH

BAND PASS FILTER:

Here, by calculation, it is the point where the output power is one-fourth times the input or the output is half of input. We can infer that the 3dB frequency for a band pass filter with 6dB bandwidth given as 210kHz is given as:

$$\text{3dB bandwidth} = \frac{\text{6dB bandwidth}}{\sqrt{3}} = 121.24kHz$$

Calculating previously, we say let R=200Ω

$$Bandwidth = \frac{R}{2\pi L}$$

$$L = \frac{R}{2\pi(BW)} = \frac{200}{2\pi \times 121.24 \times 10^3}$$

$$\therefore \boldsymbol{L \approx 262.54\mu H}$$

Now, From the center frequency equation, capacitor value can be found by substituting the L:

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

$$C = \frac{1}{(2\pi f_o)^2 L} = \frac{1}{(2\pi \times 9 \times 10^6)^2 \times 262.54 \times 10^{-6}}$$

$$\therefore \boldsymbol{C \approx 1.191pF}$$

BAND STOP FILTER

Here, by calculation, it is the point where the output power is one-fourth times the input or the output is half of input. We can infer that the 3dB frequency for a band stop filter with 6dB bandwidth given as 210kHz is given as:

$$\text{3dB bandwidth} = \sqrt{3} \times \text{6dB bandwidth} = 363.73kHz$$

Calculating previously, we say let R=200Ω

$$Bandwidth = \frac{R}{2\pi L}$$

$$L = \frac{R}{2\pi(BW)} = \frac{200}{2\pi \times 363.73 \times 10^3}$$

$$\therefore \boldsymbol{L \approx 87.51\mu H}$$

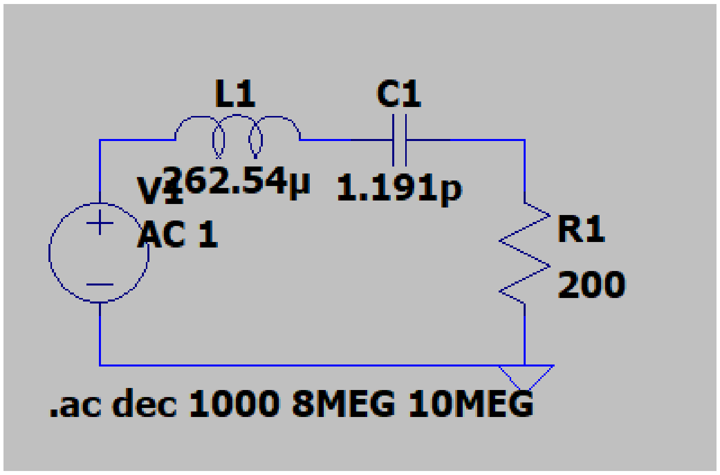
Now, From the center frequency equation, capacitor value can be found by substituting the L:

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

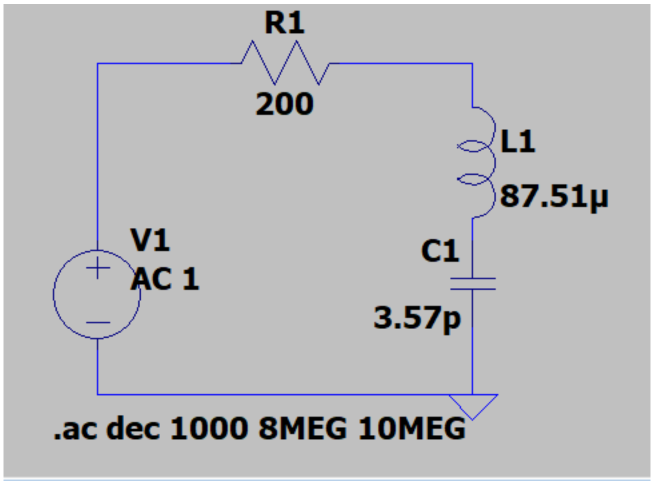
$$C = \frac{1}{(2\pi f_o)^2 L} = \frac{1}{(2\pi \times 9 \times 10^6)^2 \times 87.51 \times 10^{-6}}$$

$$\therefore \boldsymbol{C \approx 3.57pF}$$

CIRCUIT DIAGRAMS

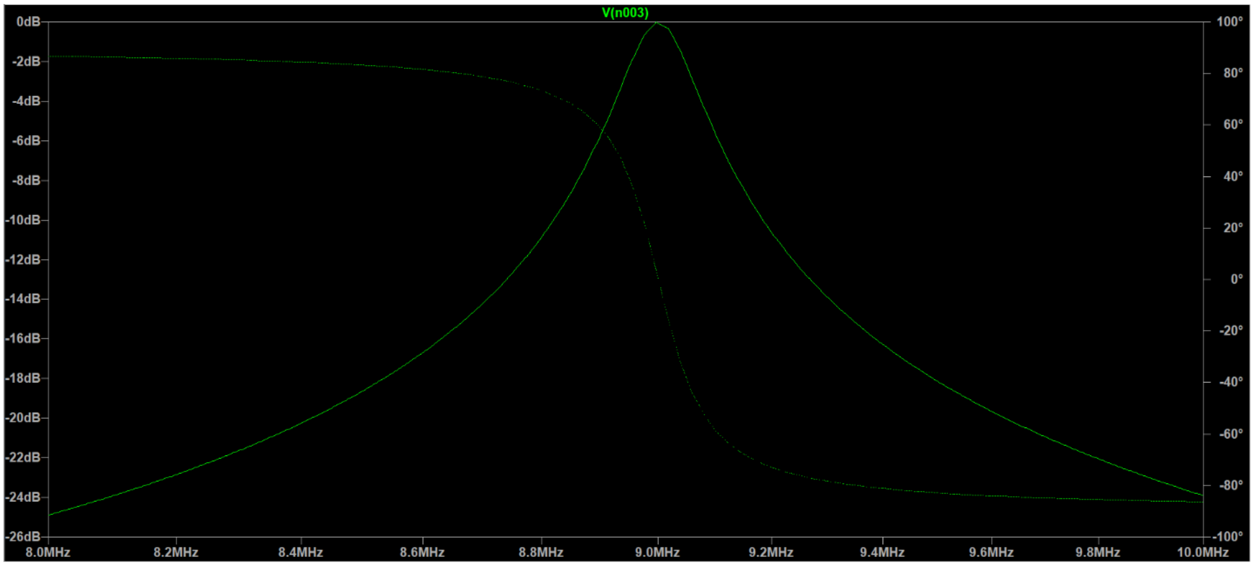


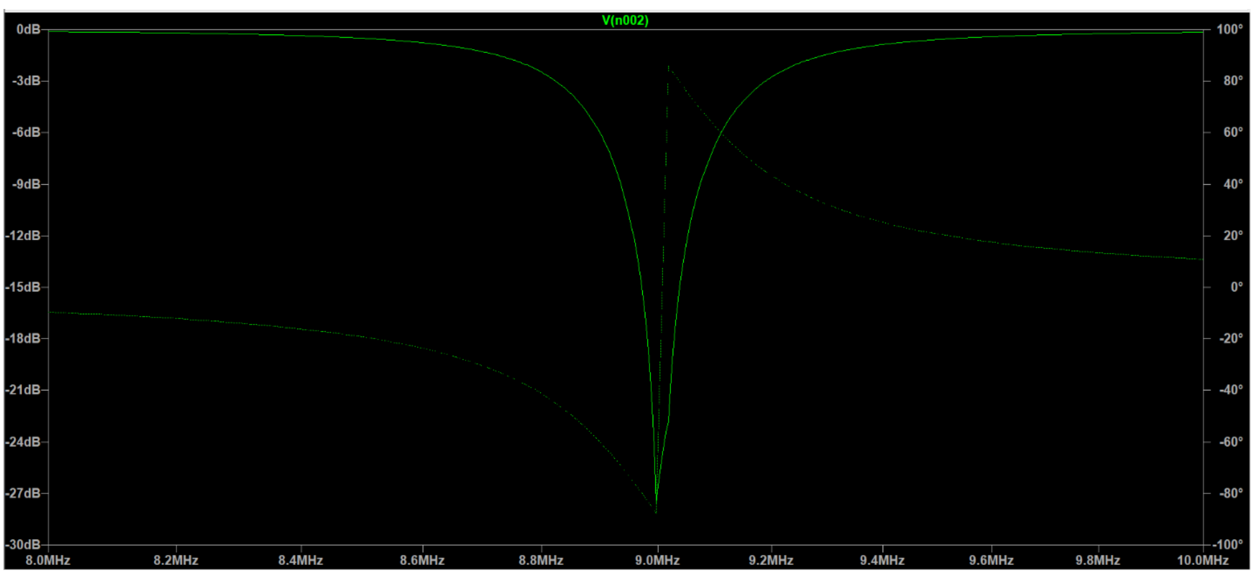
Circuit diagram for Band Pass Filter with the calculated components for 6dB bandwidth value.



Circuit diagram for Band Stop Filter with the calculated components for 6dB bandwidth value.

Graphs:


V(n003)
0dB
-2dB
-4dB
-6dB
-8dB
-10dB
-12dB
-14dB
-16dB
-18dB
-20dB
-22dB
-24dB
-26dB
100°
80°
60°
40°
20°
0°
-20°
-40°
-60°
-80°
-100°
8.0MHz
8.2MHz
8.4MHz
8.6MHz
8.8MHz
9.0MHz
9.2MHz
9.4MHz
9.6MHz
9.8MHz
10.0MHz


V(n002)
0dB
-3dB
-6dB
-9dB
-12dB
-15dB
-18dB
-21dB
-24dB
-27dB
-30dB
100°
80°
60°
40°
20°
0°
-20°
-40°
-60°
-80°
-100°
8.0MHz
8.2MHz
8.4MHz
8.6MHz
8.8MHz
9.0MHz
9.2MHz
9.4MHz
9.6MHz
9.8MHz
10.0MHz

RESULTS

Center frequency= 09 MHz

Bandwidth= 210 KHz

Table 2: Values of various components found in the experiment

Type of Filter and Bandwidth condition	R(Ω) Resistor	L(μH) Inductor	C(pF) Capacitor
BPF with 3dB frequency bandwidth	200	151.57	2.06
BSF with 3dB frequency bandwidth	200	151.57	2.06
BPF with 6dB frequency bandwidth	200	262.54	1.191
BSF with 6dB frequency bandwidth	200	87.51	3.57

DISCUSSION

The design for the 3dB frequency bandwidth was similar in both the domains of BPF and BSF as it is a point where the power of the output is half the input power.

For a Band Pass Filter, all the frequencies below the bandwidth are not allowed and other passes through it.

For a Band Stop Filter, all the frequencies above the bandwidth are allowed and other are stopped.

Bandpass filters are widely used in wireless transmitters and receivers. The main function of such a filter in a transmitter is to limit the bandwidth of the output signal to the band allocated for the transmission. This prevents the transmitter from interfering with other stations.

CONCLUSION

The circuits were appropriately designed and their values were tabulated and shown by simulation in LTSpice.

The frequency response is helpful to detect a particular band of frequencies and separate them, thus saving instruments that are sensitive to changes in frequencies.

All the graphs, calculations and tables are summarized in the report and the LTSpice files are zipped and uploaded for reference.

We witnessed the work of both BPF and BSF at random conditions and could see the difference in graphs according to difference in operational band. We also calculated the bandwidth at -6db. The calculation of peak frequency and bandwidth was same for BPF and BSF hence we didn't change values of capacitor and inductor for assumed value of resistance in both parts.