PASSIVE FILTERS

Topic Outcomes

- Describe different types and components of passive filters.
- Analyze the frequency response of passive filters
- Discuss methods of measuring frequency response, critical frequency, and bandwidth thru computations.

Filters

Filters

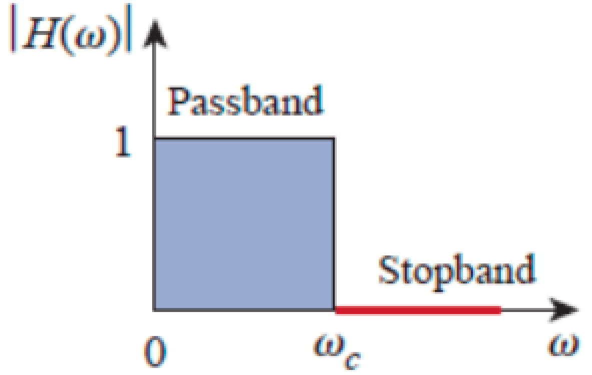
- In telecommunications and signal processing, it is very useful to separate a specific bandwidth from the total spectrum.
- A filter is a circuit that allows certain range of frequencies to pass and attenuates all the other frequencies.
- The range of frequencies allowed to pass through filter is called the passband.
- The passband should have a minimum attenuation of <-3dB.
- The end of the passband is called the critical frequency or cutoff frequency (f_c)
- The critical frequency is the point where the response drops -3dB from the passband.
- The transition region and the stopband regions are the regions after the passband.

Filters

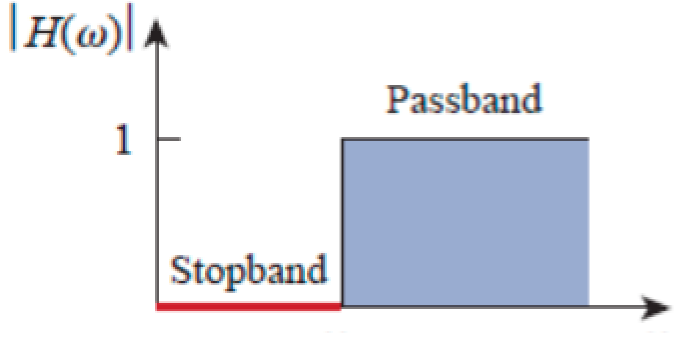
- Filters can be categorized into two types: passive and active.
- The four general categories of filter according to their response are:
  - Low-pass filter- allow frequencies below the cutoff frequency and reject all frequencies above the cutoff frequency.
  - High-pass filter – allow frequencies above the cutoff frequency and reject all frequencies below the cutoff frequency.
  - Band-pass filter – allows frequencies within a band or range of frequencies and reject all frequencies outside the band
  - Band-stop/Band-reject filter – rejects frequencies within a band or range of frequencies and allows all other outside the band

Filters

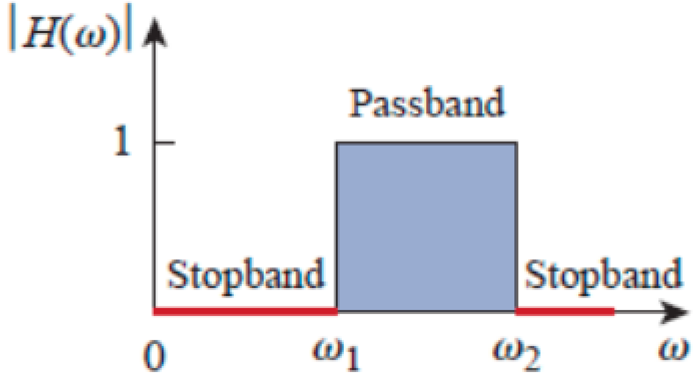
- Low-pass filter



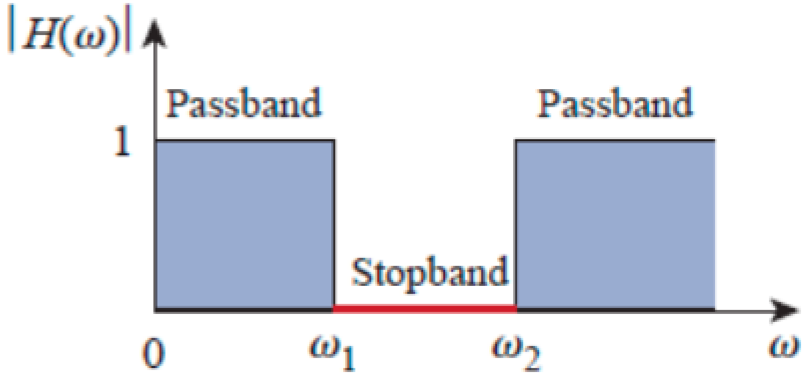
- High-pass filter



- Band-pass filter



- Band-stop/Band-reject filter



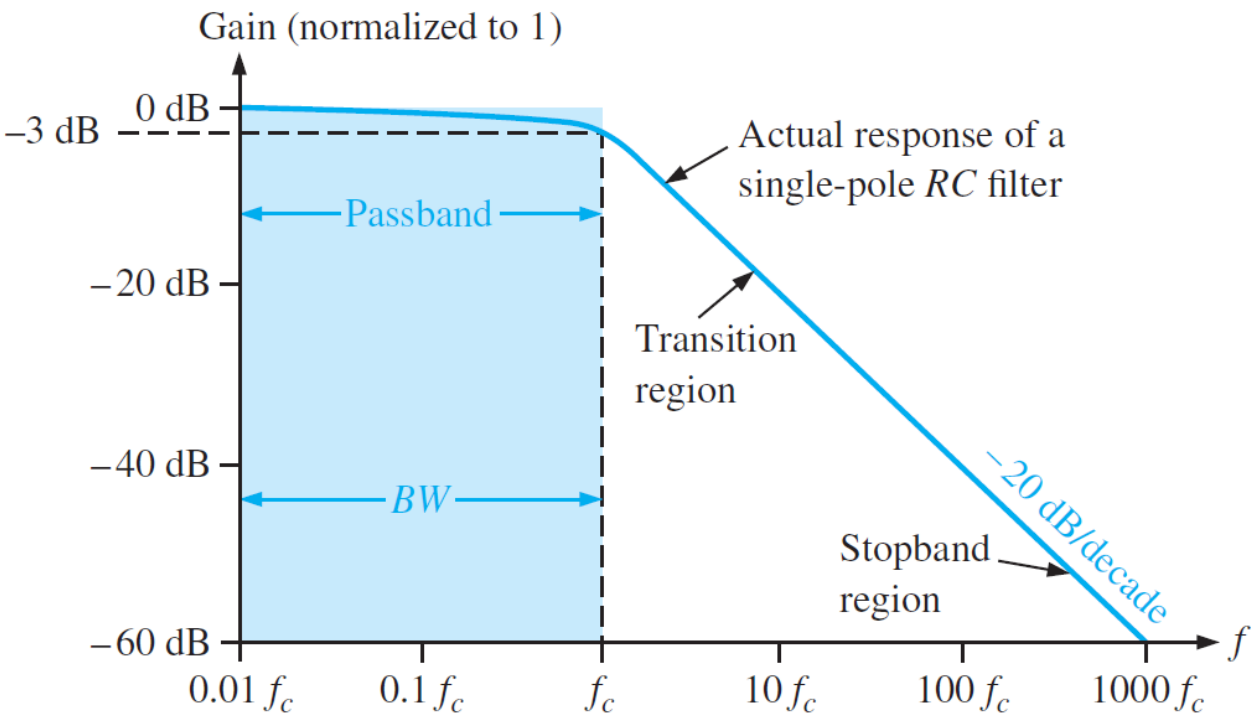
Passive filters

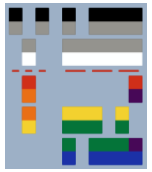
Passive filters

- Use a combination of passive components: RC, RL and RLC circuit that only passes and rejects specific range of frequencies.
- No “active” (e.g. transistor, op-amps) components

Passive Low-Pass filters

- A low-pass filter is a circuit that passes the frequency range from DC (0 Hz) to f_c and attenuates all the other frequencies.
- The shaded region in the figure shows the ideal response ("brick-wall") of the low-pass filter.
- In this case **BW = f_c**



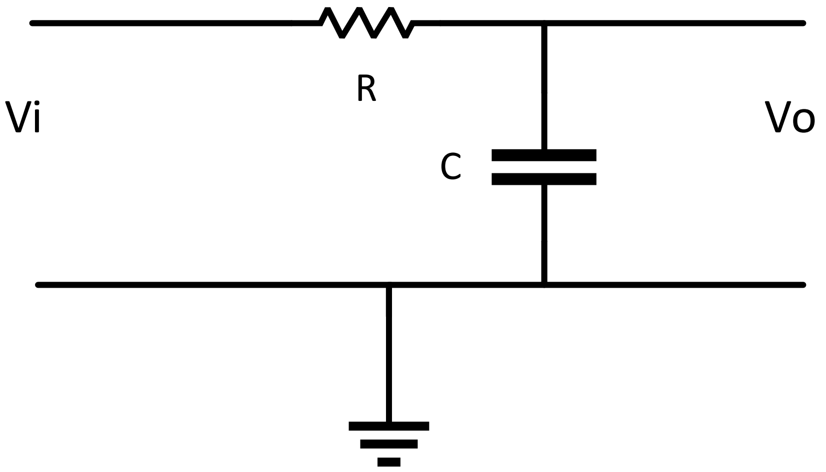


Passive Low-Pass filters

- The most basic low-pass filter is a simple RC circuit shown.
- The output is taken across the capacitor
- The circuit has a single pole and rolls off at – 20dB/decade beyond f_c

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

- The output at the critical frequency is 70.7% of the input which is equivalent to an attenuation of -3dB



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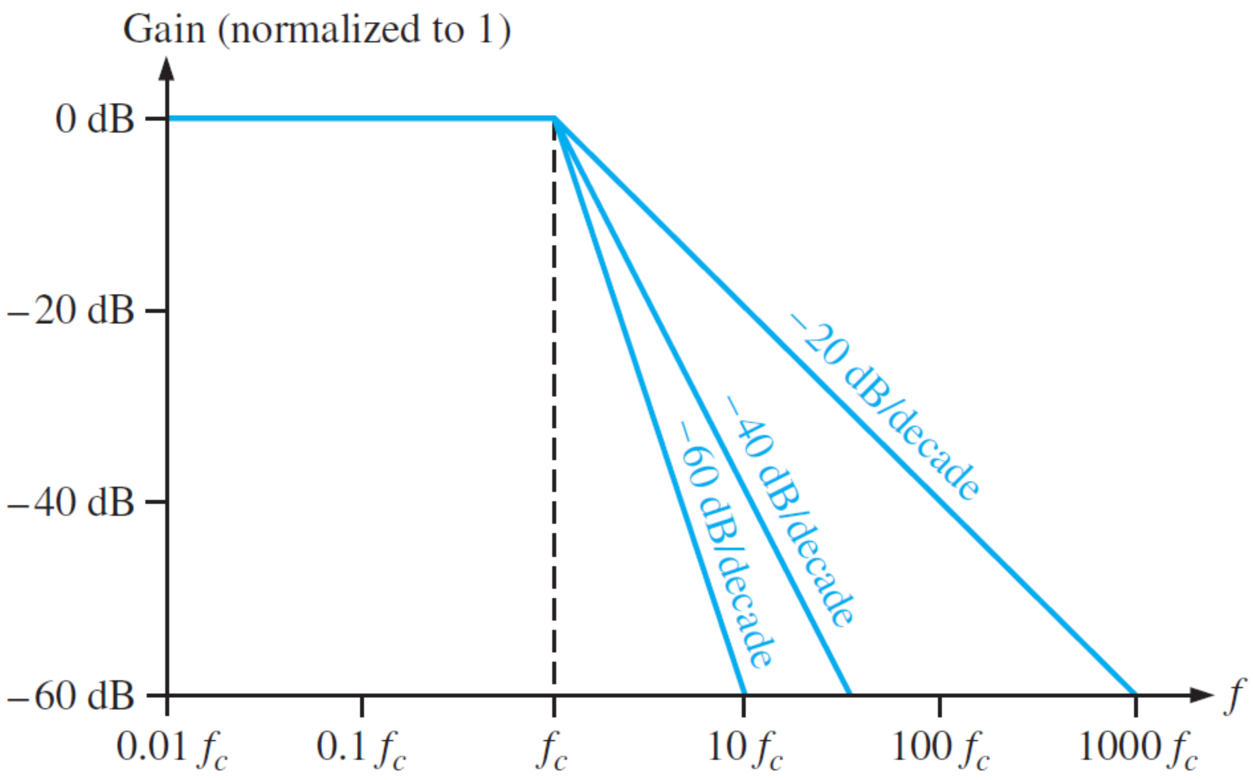
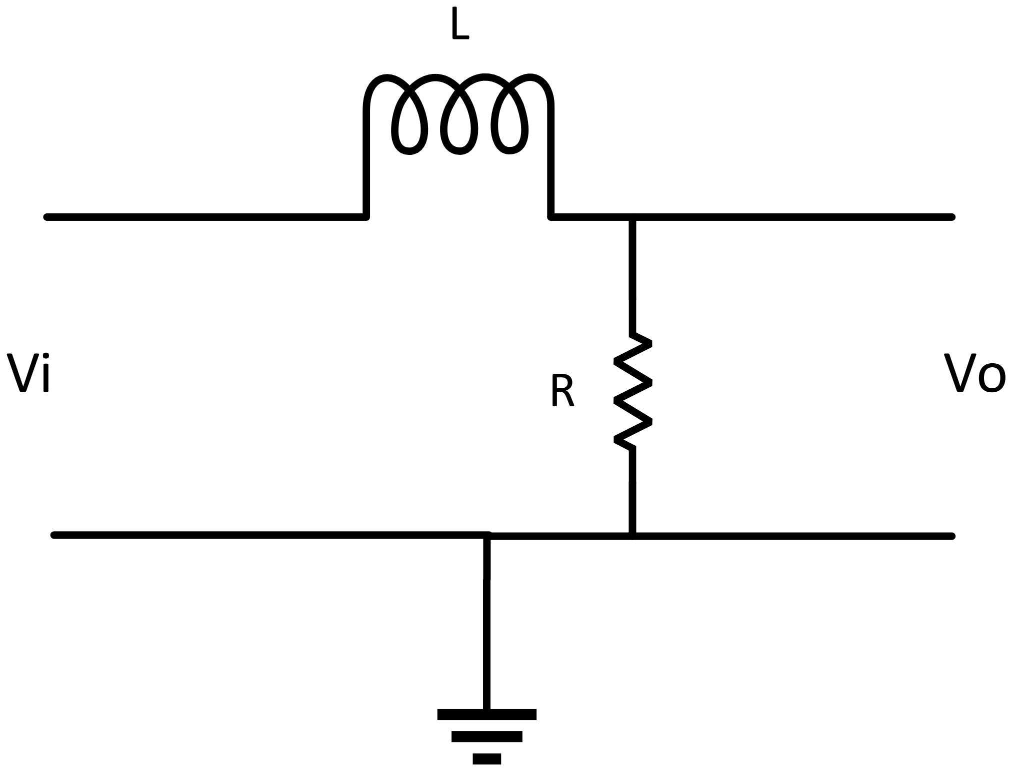
Passive Low-Pass filters

- The figure shows the idealized response of the basic low-pass filter circuit.
- It shows a flat response up to the cut-off frequency and a constant roll-off rate after the cutoff frequency which the actual filter doesn't have.
- The addition of circuit components in a basic filter will produce a steeper region which is more effective.



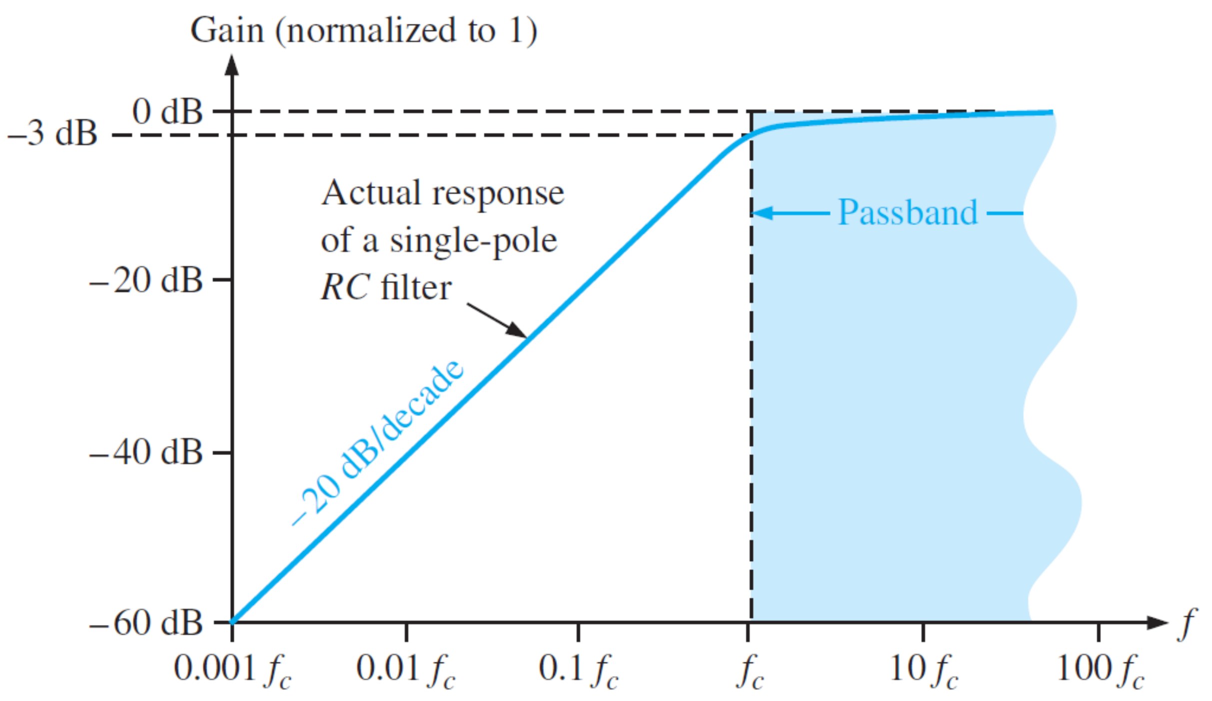
Passive Low-Pass filters

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



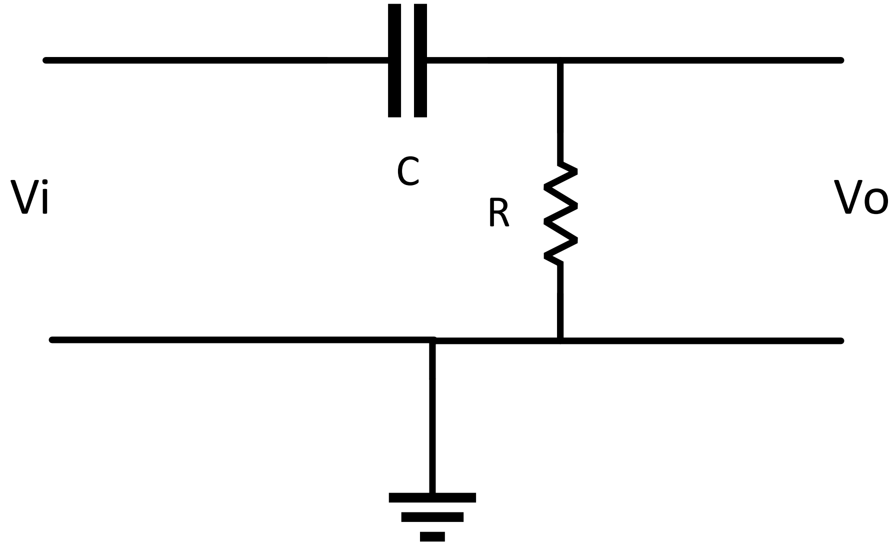
Passive High-Pass filters

- A high-pass filter rejects all frequencies below critical frequency and passes all frequencies above f_c
- At the critical frequency the output is 70.7% of the input (-3 dB attenuation).
- Ideally the passband of a high-pass filter is all frequencies above the critical frequency



Passive High-Pass filters

$$f_C = \frac{1}{2\pi RC}$$



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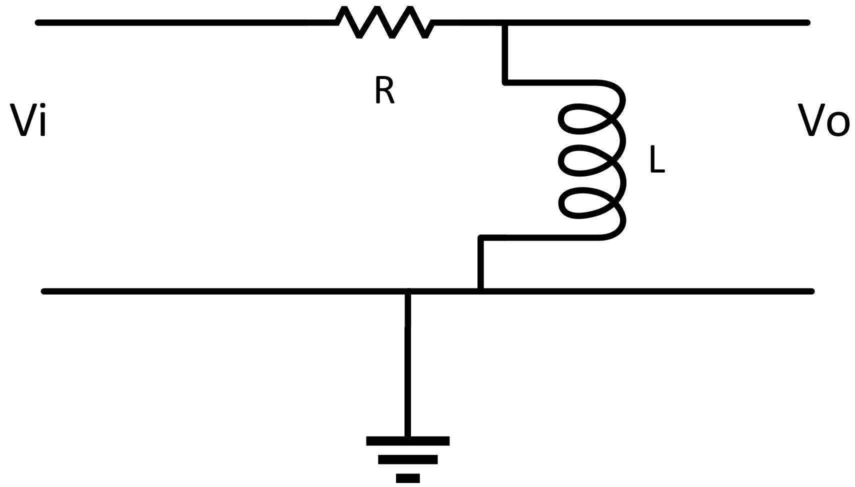


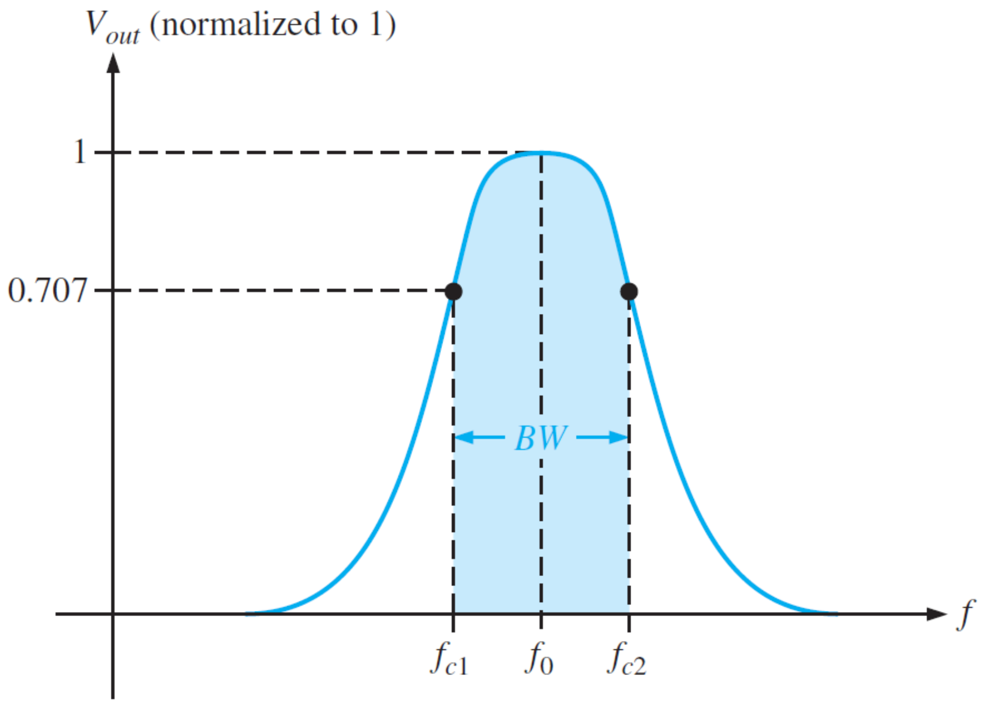
Passive Band-Pass filters

- A band-pass filter allows a certain range to pass and rejects all frequencies above and below the passband.
- The typical band-pass filter is shown in the figure.

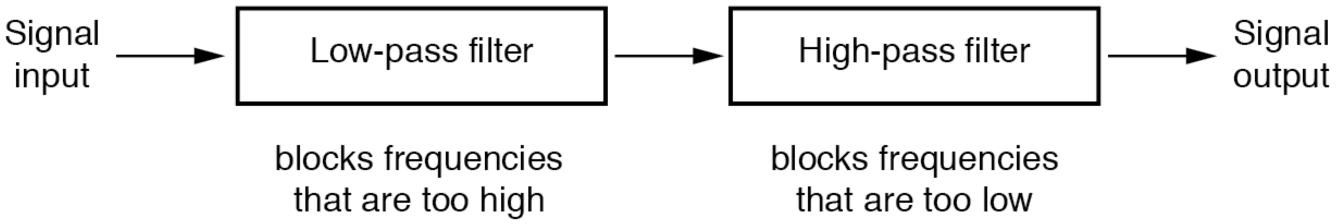
$$BW = f_{C_2} - f_{C_1}$$

- The center frequency f_o is:

$$f_o = \sqrt{f_{C_1} f_{C_2}}$$



Passive Band-Pass filters



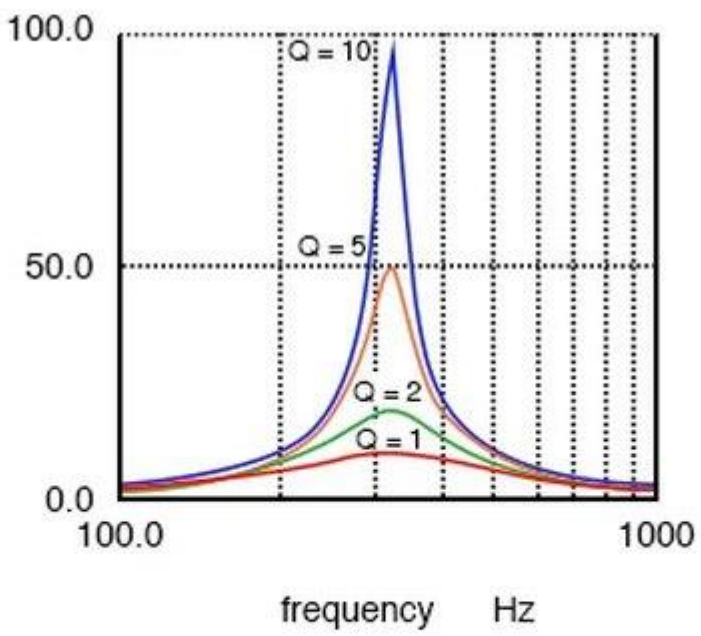
- A simple band-pass filter can be constructed by cascading a low-pass filter with a high-pass filter.
- If f_{C_1} (high-pass filter cutoff) is higher than f_{C_2} (low-pass filter cutoff), the responses may overlap and all the frequency beyond the two critical frequencies are eliminated.

Quality factor, Q

- The quality factor (Q) of a band-pass filter is the ratio of the center frequency to the bandwidth.

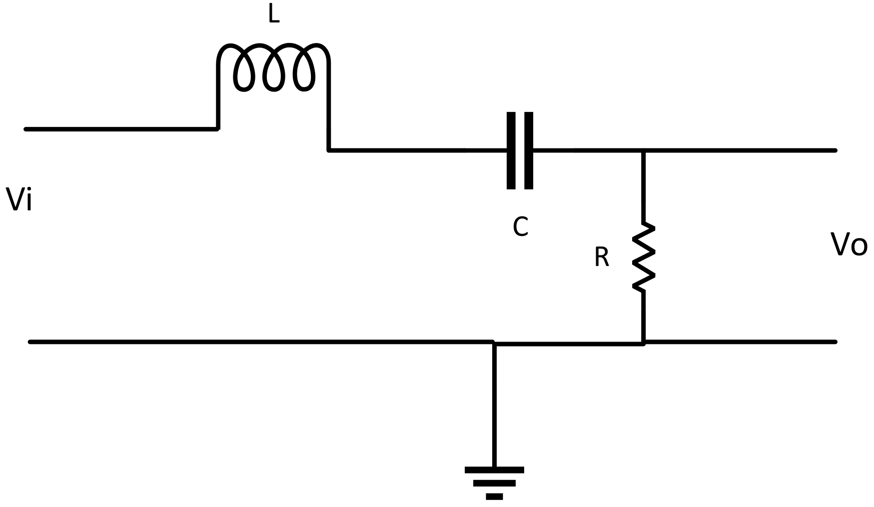
$$Q = \frac{f_o}{BW}$$

- Higher Q means narrower bandwidth for the filter.
- This also results to better selectivity for a certain value of center frequency.
- Band-pass filters are also classified as narrow-band (Q>10) or wide-band (Q<10)



Passive Band-Pass Filter

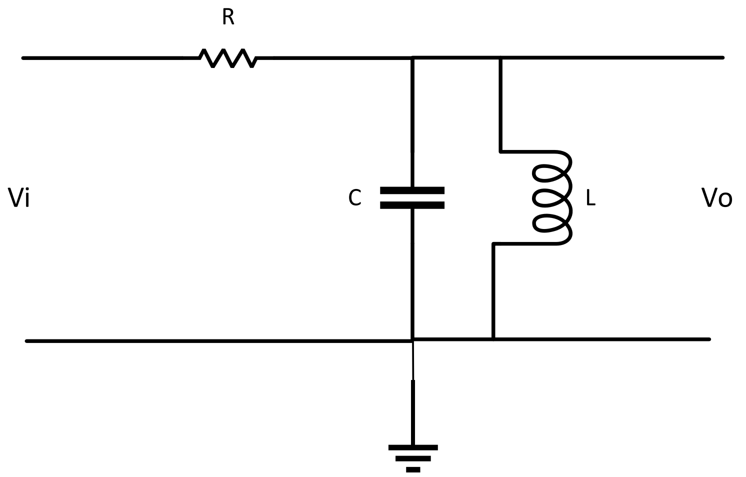
- Series Resonant Band-Pass Filter Circuit



$$Q = \frac{X_L}{R}, BW = \frac{f_o}{Q}, f_o = \frac{1}{2\pi\sqrt{LC}}$$

Passive Band-Pass Filter

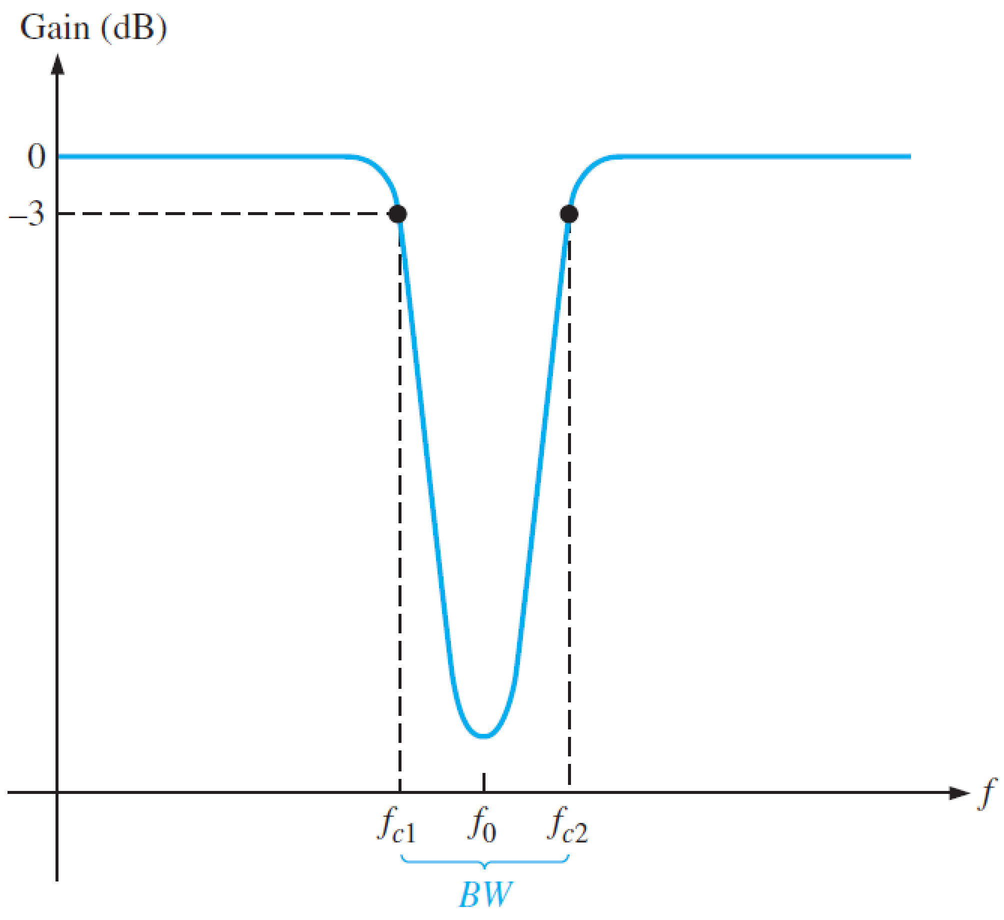
- Parallel Resonant Band-Pass Filter Circuit



$$Q = \frac{X_L}{R}, BW = \frac{f_o}{Q}, f_o = \frac{1}{2\pi\sqrt{LC}}$$

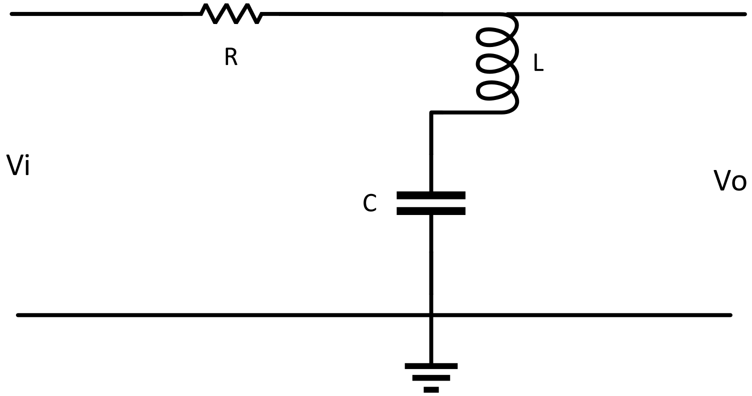
Passive Band-Stop Filter

- A band-stop filter is an opposite of a band-pass filter when it comes to responses.
- This type of filter allows all the frequencies to pass except those lying in a certain range of frequencies.



Passive Band-Stop Filter

- Series Resonant Band-Stop Filter Circuit



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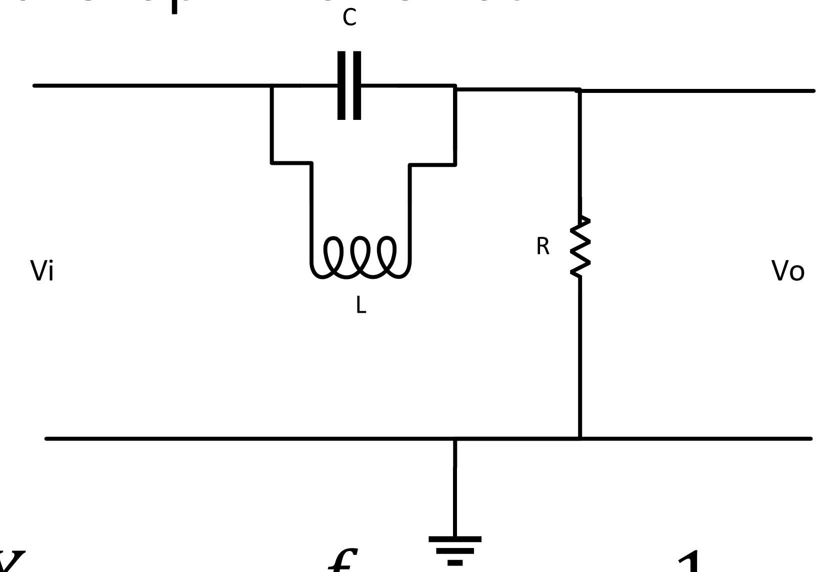
Passive Band-Stop Filter

- Parallel Resonant Band-Stop Filter Circuit



$$Q = \frac{X_L}{R}, BW = \frac{f_o}{Q}, f_o = \frac{1}{2\pi\sqrt{LC}}$$

End