Active filters

Basics, theory and application

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What are these stuffs?

- As the name suggests, active filters use 'active' elements as a part of their circuit
- These may consist of either opamp, BJT or any FET
- Generally, opamps are used in designing active filters
- Why opamps !! Guess why…

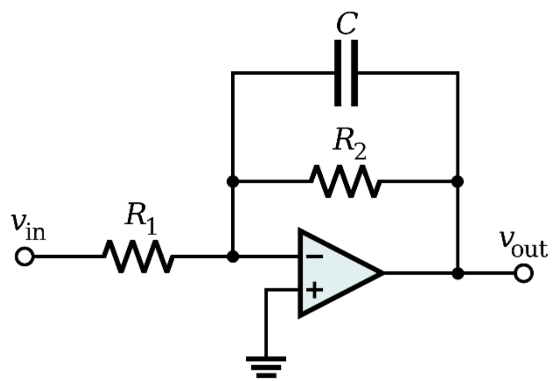
Why use an active filter

- **Less cost**: Inexpensive opamps and absence of costly inductors (especially at lower frequencies)
- **Gain and frequency adjustment flexibility**: Opamp provides gain (adjustable) -> input signal not attenuated as in case of passive filters
- **No loading problem**: Excellent isolation between stages due to high input impedance (opamps again) and low output impedance. The output can drive other circuitry without loading the source or load
- **Size**: Small in size (due to absence of bulky 'L')
- **Non-floating terminals**: Active filters generally have single ended input and output which do not float with respect to the system power supply

Disadvantages of passive filters

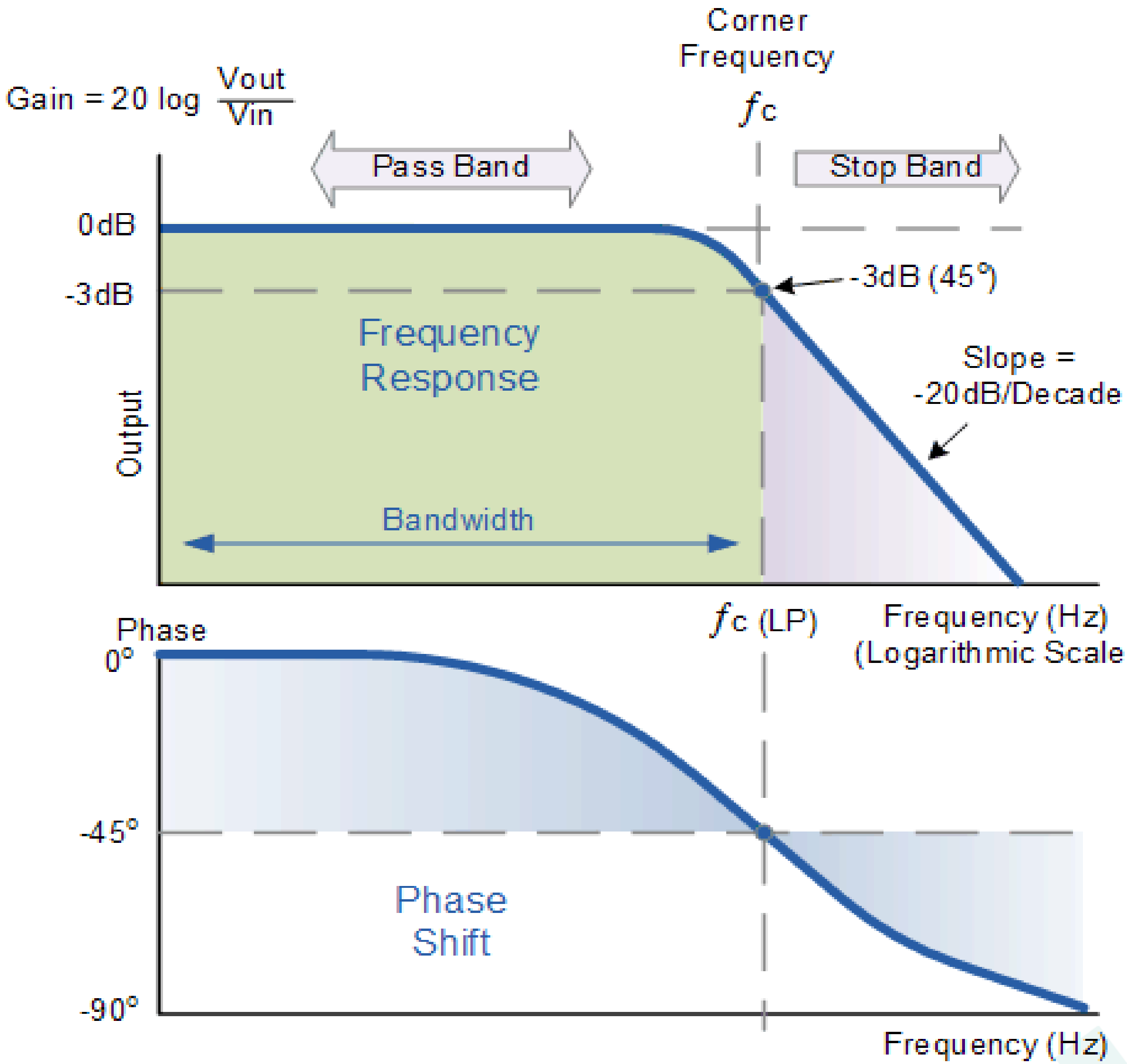
- Cannot be used to filter power as they require power to bias themselves
- **Frequency limitation**: Opamps have finite gain-bandwidth product (GBW) and hence are limited in their frequency range (> 10 MHz for example)
- At high frequencies, passive filter design for rough uses is convenient because the inductor size reduces to a nice value (EHF -> Surface Acoustic Wave filters)

The active Low Pass Filter

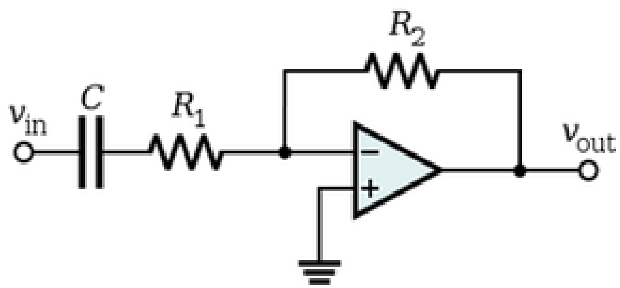


- Transfer function: $A_v = -\frac{R2}{R1}\left(\frac{1}{1+R2Cs}\right)$
- We know, s=jω (neglecting convergence factor)
- Consider two cases: at ω=0 and at ω=∞
- At ω=0, $A_v = -\frac{R2}{R1}$ and at ω=∞, $A_v = 0$
- This denotes that the circuit allows signals at low frequency to pass through and blocks signals at higher frequencies

Frequency response of the active LPF



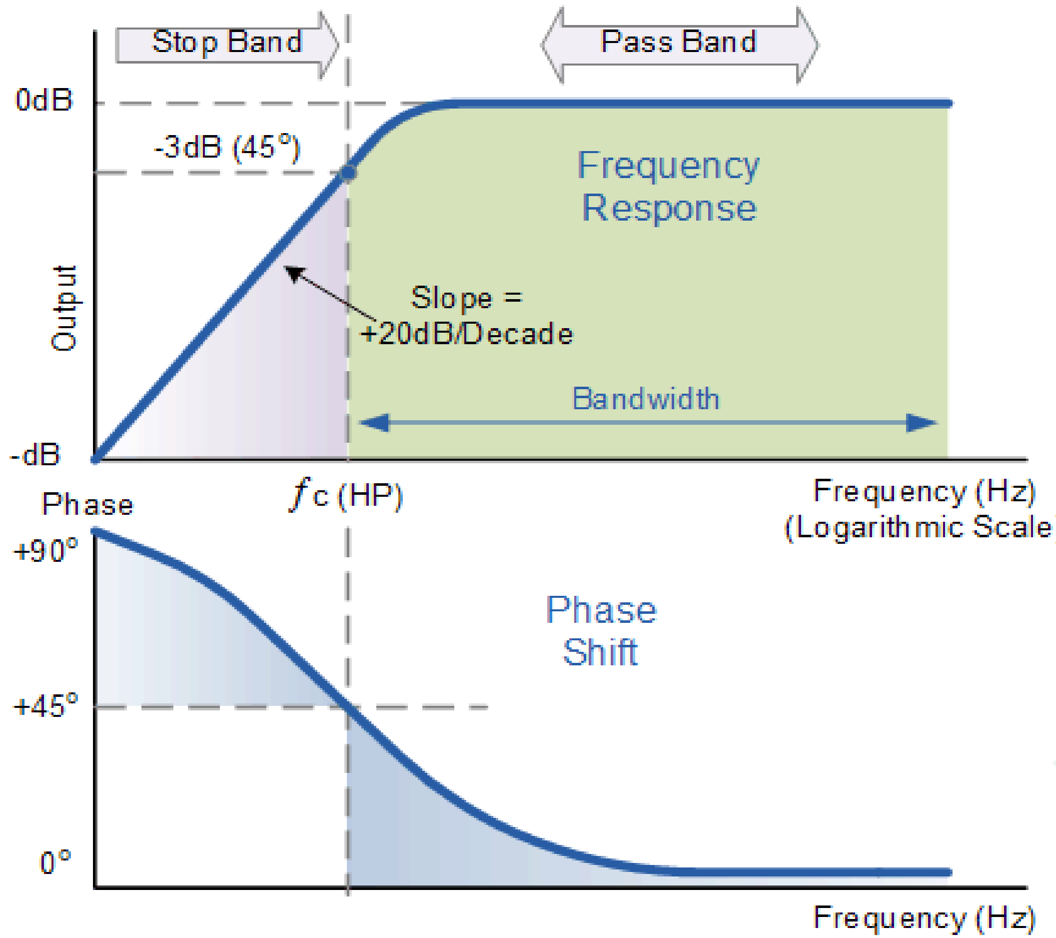
The active High Pass Filter



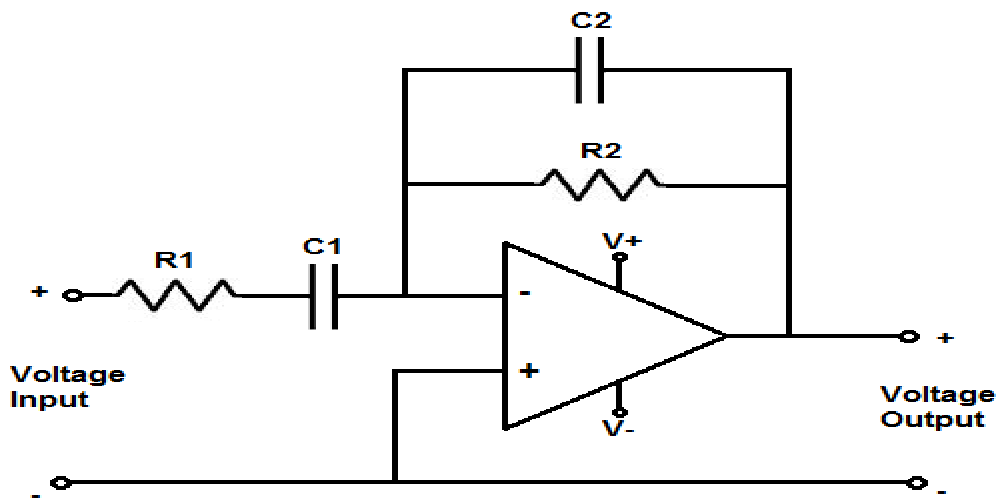
- Transfer function: **Av =** $-\left(\frac{R2}{R1}\right)\left(\frac{Cs}{\frac{1}{R1}+Cs}\right)$
- We know, s=jω (neglecting convergence factor)
- Consider two cases: at ω=0 and at ω=∞
- At ω=0, Av = $\mathbf{0}$ and at ω=∞, Av = $-\frac{R2}{R1}$
- This denotes that the circuit allows signals at high frequency to pass through and blocks signals at lower frequencies

Frequency response of active HPF

$$\text{Gain (dB)} = 20 \log \frac{V_{out}}{V_{in}}$$

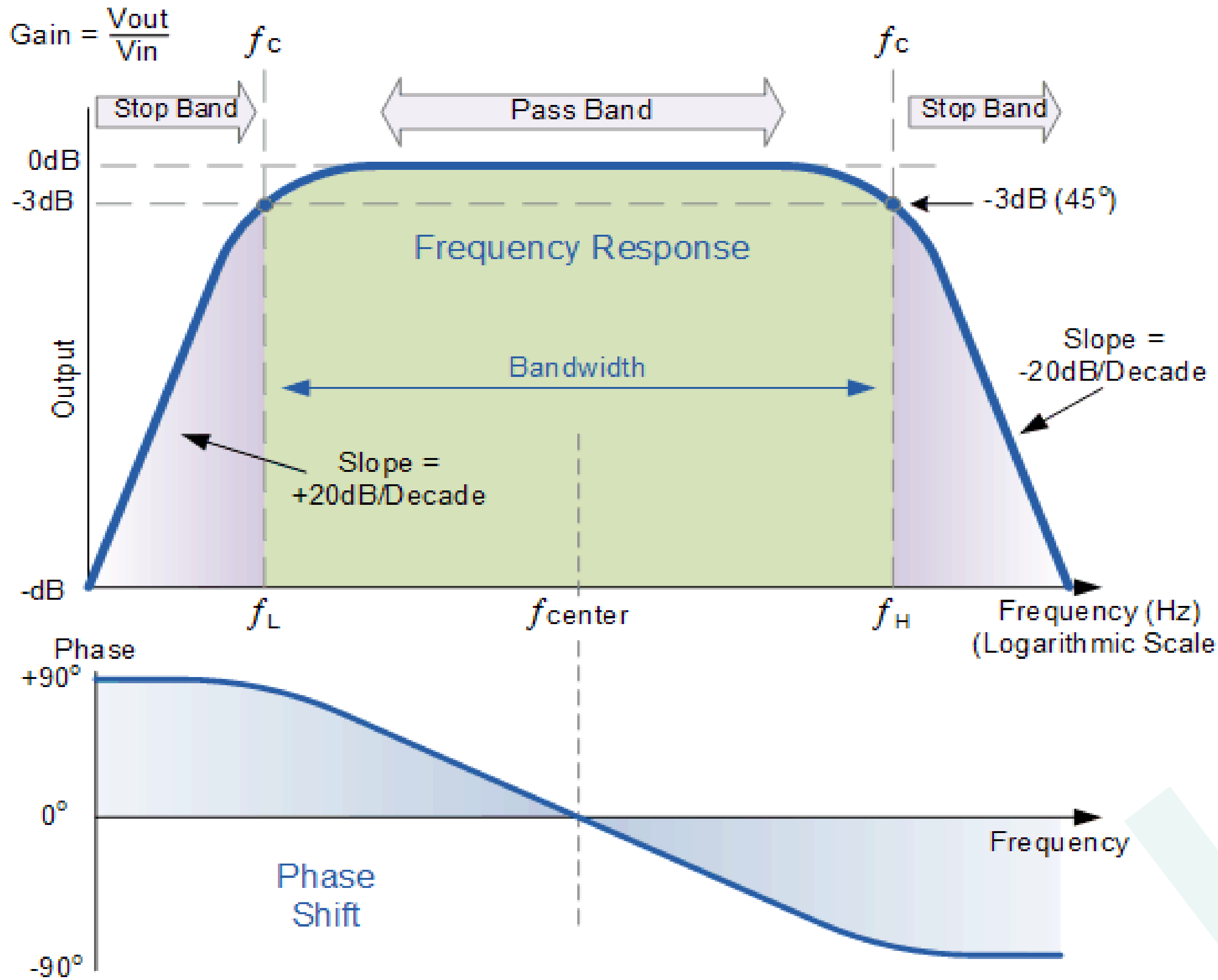


The active Band Pass Filter



- Transfer function: Av = $-\frac{R2C1s}{(1+R1C1s)(1+R2C2s)}$
- At both cases of ω=0 and ω=∞, Av turns out to be 0
- Now, if we consider an intermediate value of ω, we would see that Av has a finite value
- This signifies that the circuit blocks signals at both high and low frequencies, but passes the same at an intermediate frequency level

Frequency response of active BPF

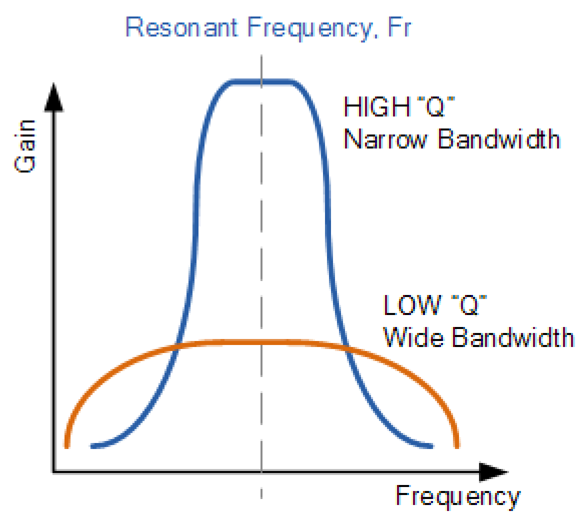


What is Bandwidth

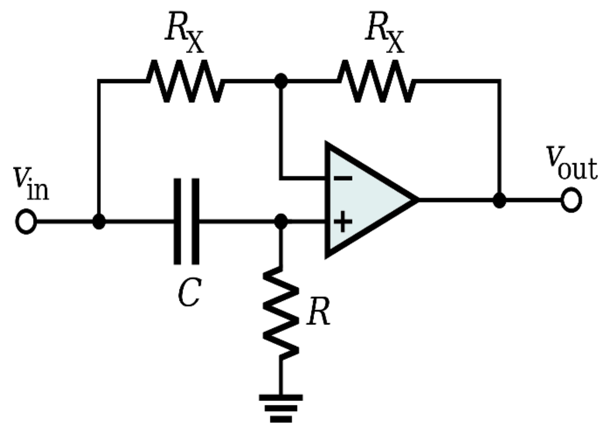
- Bandwidth means, the frequencies that are effectively passed by a circuit, i.e. the circuit is operable only at those particular frequencies
- For the case of a BPF, bandwidth is the range of frequencies that fall between the upper cutoff frequency and the lower cutoff frequency
- Mathematically, its (f_H - f_L)
- The higher the Bandwidth, more frequency channels can be introduced which allows possibilities for higher rates of data transfer
- BUT, this comes with a sacrifice !! Guess what…

The Quality Factor

- The actual width of the pass-band between the two corner frequency points determine the 'Q'-factor of the circuit
- It measures "how selective" the circuit is towards a given spread of frequencies
- The lower the value of the Q- factor, the wider is the bandwidth of the filter (less selective); higher Q signifies narrowband circuit (highly selective)

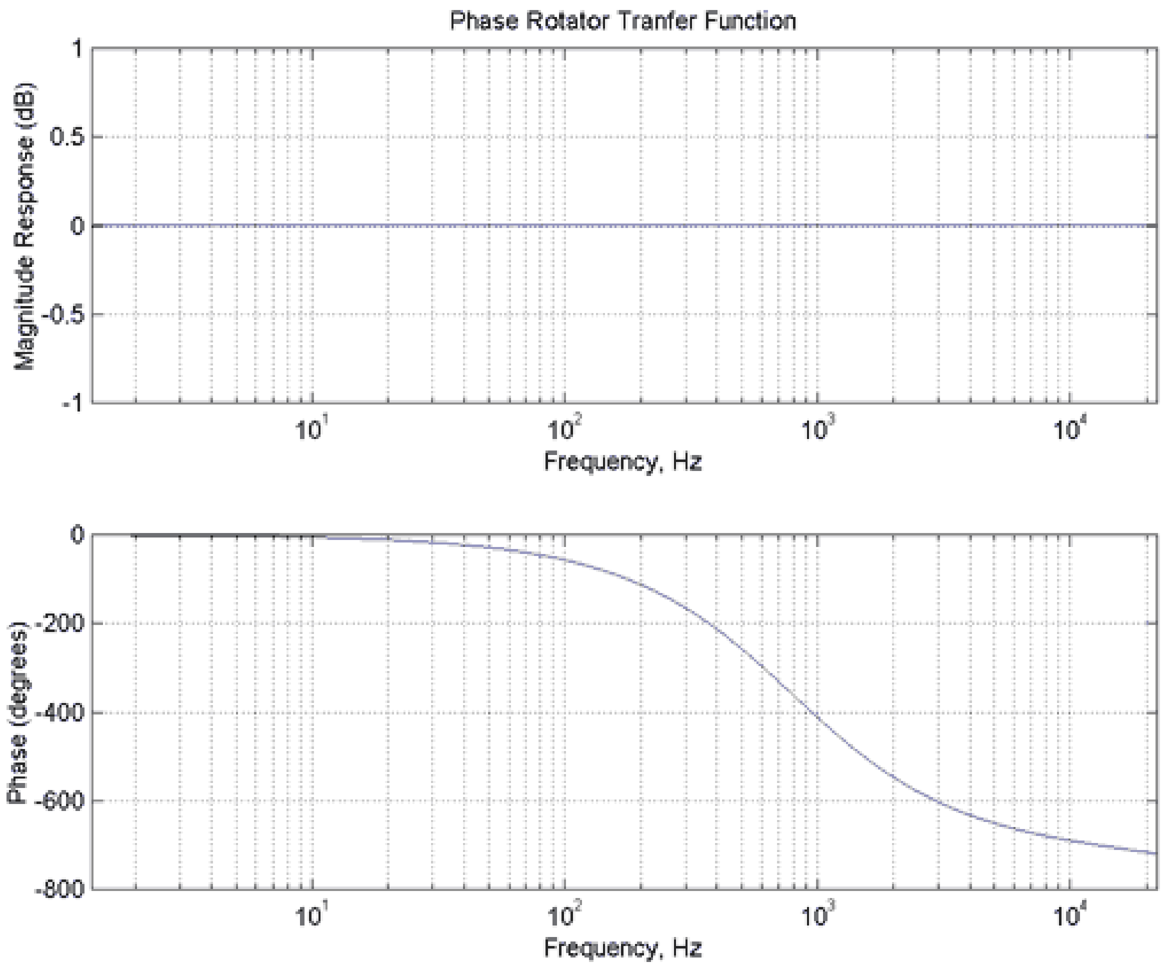


The All Pass Filter



- As the name suggests, it passes all signals, irrespective of their frequencies
- Then what's the use of this 'seemingly useless' circuit?
- Well, it acts as a phase shifter which introduces a 180° phase shift to the applied signal (phase rotator)

Frequency response of the active APF



Higher order filters

- Higher order filters are necessary for a better roll-off
- Addition of an extra frequency dependent element (capacitor or inductor) increases the order of the circuit by one
- The roll-off rate is **-20n dB/dec**, where 'n' is the order of the filter
- Rapid transition band (high roll-off) introduces disturbances or oscillations in the passband edge (Gibbs phenomenon) -> Why?

Responses of various order filters