# Passive and Active Filters

INDRAPRASTHA INSTITUTE *of*
INFORMATION TECHNOLOGY
**DELHI**

# Passive Filters

- Consists of passive elements like:
  - Resistor,
  - Capacitor and
  - Inductor
- Filters can be classified as :-
  1. Low Pass Filter
  2. High Pass Filter
  3. Band Pass Filter
  4. Band Stop Filter (Band Reject/Eliminate Filter)

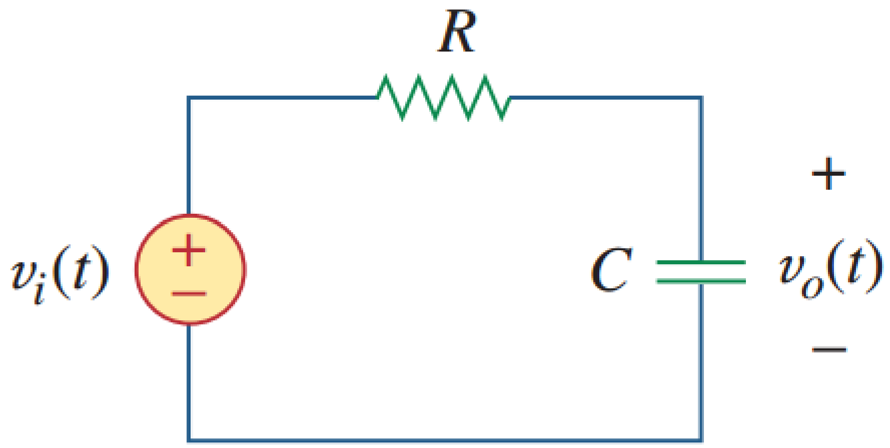
# Passive Low Pass Filter (LPF)

- LPF ideally allows lower frequencies and attenuates higher frequencies.
- One of the simplest form of LPF
  - Transfer Function:

$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{1/j\omega C}{R + 1/j\omega C}$$

$$\mathbf{H}(\omega) = \frac{1}{1 + j\omega RC}$$

  - H(0) = 1 and H(∞) = 0 ⇒ Filter is LFP



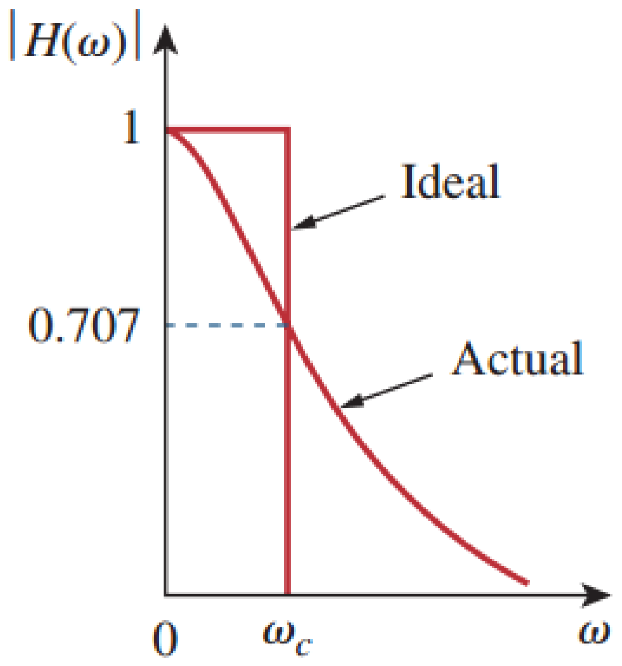
# Passive Low Pass Filter (LPF)

- $\omega_c$ is the cut-off frequency.
  - It is a frequency at which $|H(\omega)|$ drops to 70.07% of $|H(\omega)|_{\max}$ or becomes $\frac{1}{\sqrt{2}}$ of $|H(\omega)|_{\max}$.

- So, here, $\omega_c$ can be calculated as:

$$H(\omega_c) = \frac{1}{\sqrt{1 + \omega_c^2 R^2 C^2}} = \frac{1}{\sqrt{2}}$$

$$\omega_c = \frac{1}{RC}$$



# Passive High Pass Filter (HPF)

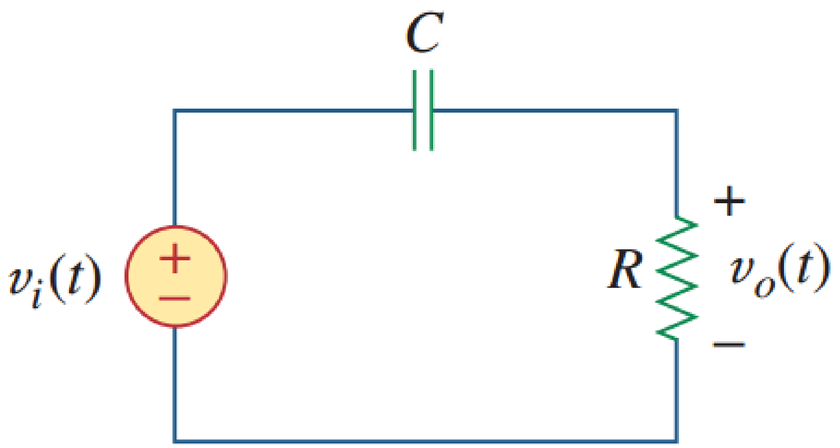
- Ideally, HPF attenuates lower frequencies and allows higher frequencies.
- One of the simplest form of HPF
  - Transfer Function:

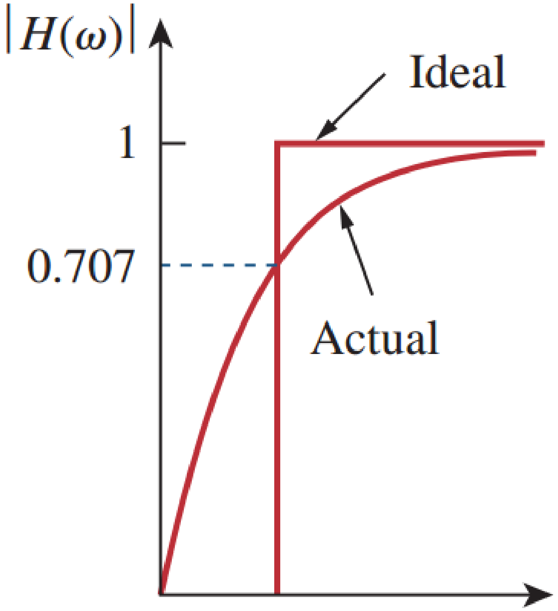
$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R}{R + 1/j\omega C}$$

$$\mathbf{H}(\omega) = \frac{j\omega RC}{1 + j\omega RC}$$

  - H(0) = 0 and H(∞) = 1 ⇒ Filter is HFP

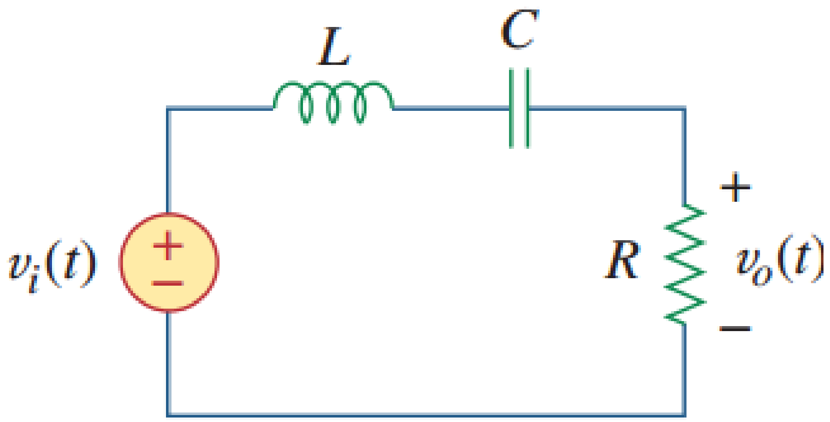
$$\omega_c = \frac{1}{RC}$$



# Passive Band Pass Filter (BPF)

- BPF allows frequencies of a particular range and eliminates other frequencies.
- Typical example of BPF
- Transfer function :




$$\mathbf{H}(\omega) = \frac{\mathbf{V}_o}{\mathbf{V}_i} = \frac{R}{R + j(\omega L - 1/\omega C)}$$

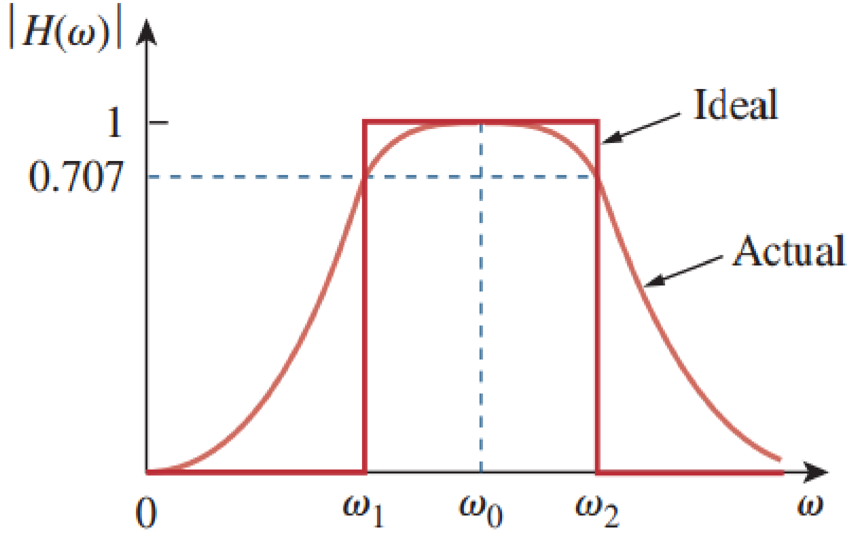
- Here, H(0) = 0 and H(∞) = 0
- How it is BPF ?
- Resonance Frequency, $\omega_0$ !!!!!
- $Z_{eq} = R \Rightarrow$ Filter allows $\omega_0$ means it is a BPF

# Passive Band Pass Filter (BPF)

- Here, $\omega_1$ and $\omega_2$ are half power frequencies i.e. power dissipated is half of the maximum power.

$$\omega_1 = -\frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$

$$\omega_2 = \frac{R}{2L} + \sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}}$$




- Bandwidth of BPF = $\omega_2$ - $\omega_1$
- Quality Factor,

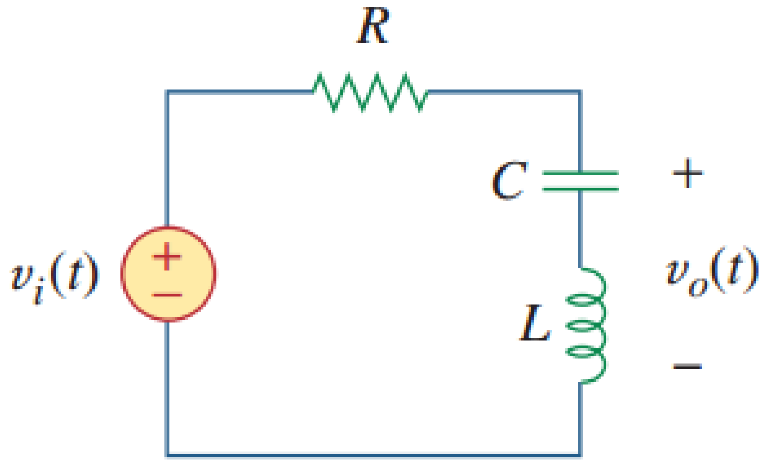
$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR}$$

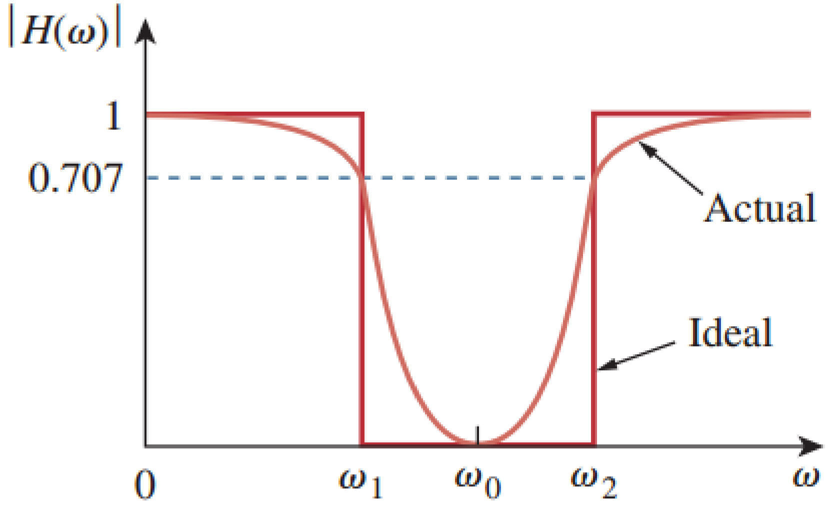
Where $\omega_0 = \frac{1}{\sqrt{LC}} = \sqrt{\omega_1 \omega_1}$

# Passive Band Stop Filter

- It rejects a particular range of frequencies and allows rest of the frequencies.
- Example of band stop filter :
  - Transfer Function

$$H(\omega) = \frac{V_o}{V_i} = \frac{j(\omega L - 1/\omega C)}{R + j(\omega L - 1/\omega C)}$$



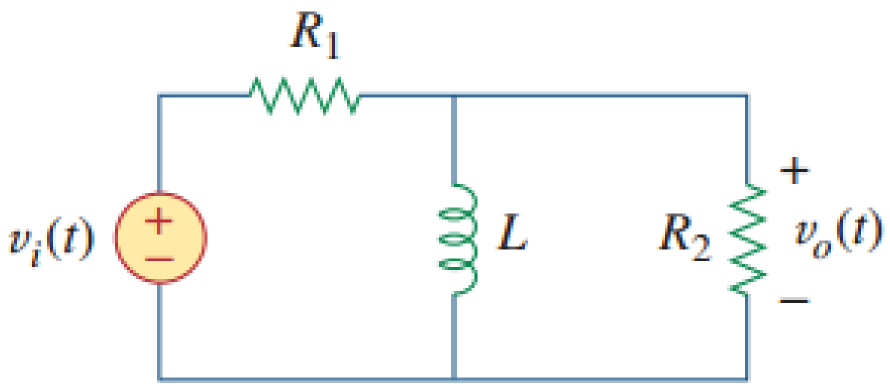




- Here, H(0) = 1 and H(∞) = 1.
- But at resonance frequency,

  $v_0 = 0 \Rightarrow$ Filters does not allow $\omega_0$

# Practice Problem

1. Obtain the transfer function. Identify the type of filter the circuit represents and determine the corner frequency.
   Take $R_1 = 100\ \Omega = R_2$, $L = 2$ mH.



# Practice Problem

2. Design a bandpass filter of the following form with a lower cutoff frequency of 20.1 kHz and an upper cutoff frequency of 20.3 kHz. Calculate *L*, *C*, and *Q*. Take $R = 20\ \text{k}\Omega$.