Unit 2: Resonance, Filters And Attenuators

Unit 2: Resonance, filters and attenuators	11 Hours

Resonance: Definition, types, applications of resonance. **Series resonance and Parallel resonance:** circuit diagram, phasor diagram, resonance plot and characteristics. Condition for resonance. Derivation for frequency of resonance. Expressions for impedance, current, voltage, Q factor, power factor and bandwidth in terms of Q. Simple problems.

Passive Filters: Definition of Filter, cut-off frequency, pass band and stop band. Classification of filters. Ideal characteristics curve of passive LPF, HPF, BPF and BRF. Circuit diagram of T and PI configurations of LPF and HPF (Only expressions, No Derivation), Simple problems. Block diagrams to realize BPF & BRF using LPF & HPF.

Attenuators: Definition, classification and applications of attenuators. Definition of Bel, Decibel and Neper. Relationship between Bel, Decibel and Neper. Express attenuation in dB. Circuit diagram of symmetrical T and Π type attenuators (Only expressions, No Derivation).

Resonance:

Introduction :

In general, the reinforcement or prolongation of sound by reflection from a surface or by the synchronous vibration of a neighbouring object is called as Physical Resonance. The condition in which an electric circuit or device produces the largest possible response to an applied oscillating signal is called Electrical Resonance.

An a.c.circuit is said to be in Resonance when the applied voltage and the circuit current are in-phase.

Electrical resonance occurs in an electric circuit at a particular resonant frequency when the impedance of the circuit is at a minimum in a series circuit or at maximum in a parallel circuit.

Types of Resonance: Electrical resonance is of 3 types

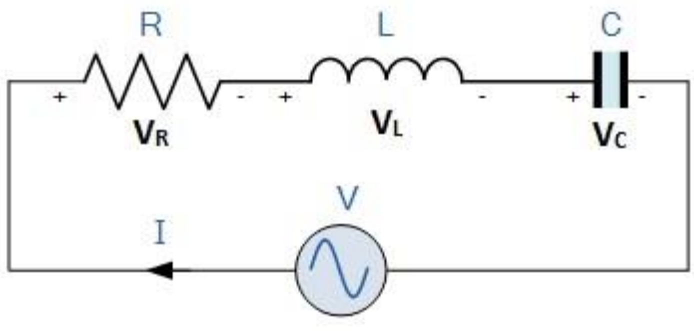
1. Series Resonance
2. Parallel Resonance.
3. Series and Parallel Resonance.

Series Resonance

A circuit in which Resistance(R), Inductance (L) and Capacitance(C) are connected in series. In this circuit, the frequency at which the inductive reactance X_L will be equal to capacitive reactance X_C is called resonant frequency f_r, and the circuit is said to be in **Series Resonance**.

Series Resonance circuits are one of the most important circuits used in electrical and electronic circuits. They can be found in various forms such as in AC mains filters, noise filters and also in radio and television tuning circuits producing a very selective tuning circuit for the receiving of the different frequency channels.

Consider a simple series RLC circuit below.



Series RLC circuit

The resistor R, Inductor L, and capacitor C are connected in series across a voltage source V. let I be the current flowing through the circuit. V_R, V_L and V_C are the voltages across resistor, inductor and capacitor.

The inductive reactance , $X_L = \omega L = 2\pi fL$

The capacitive reactance , $X_C = 1/\ \omega C = 1/2\pi fC$

At resonance, $X_L = X_C$,

$\therefore 2\pi fL = 1/2\pi fC$

□

$$f^2 = \frac{1}{4\pi^2 LC}$$

i.e.,

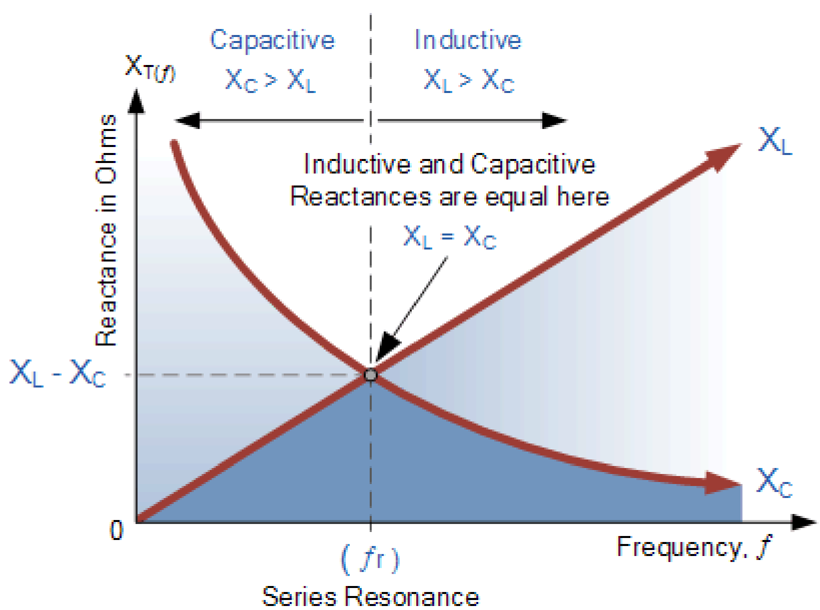
$$\mathrm{f} = \frac{1}{2\pi\sqrt{LC}}$$

Therefore Series Resonant frequency,

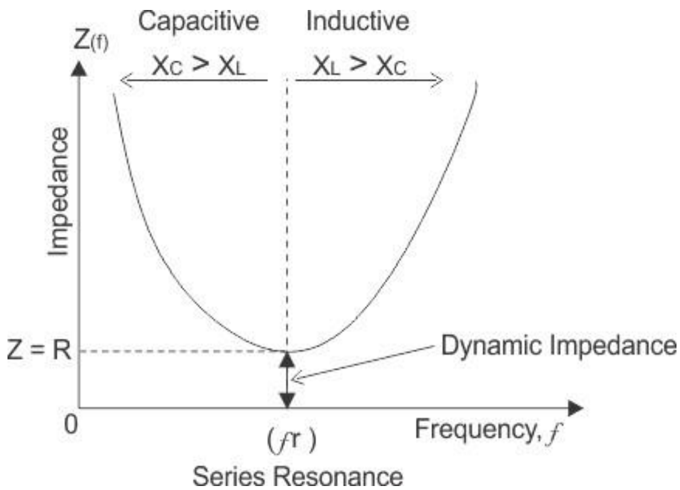
$$f_s = \frac{1}{2\pi\sqrt{LC}}\ Hz$$

Impedance at resonance

The Impedance of an RLC series circuit is defined as the total opposition offered by the Resistor, Inductor and capacitor to the flow of current through the circuit.



Variation of reactance in series RLC circuit



Impedance curve in series RLC circuit

Impedance of the RLC circuit is,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

At resonance $X_L = X_C$,

$$\therefore \quad Z = \sqrt{R^2 + (X_L - X_L)^2}$$

$$Z = \sqrt{R^2}$$

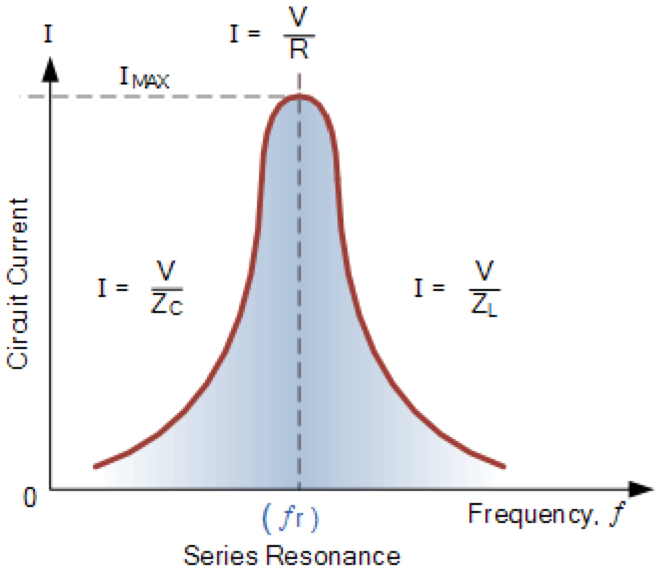
And $Z = R$.

At resonance the impedance of series RLC circuit is purely resistive in nature and is minimum. This impedance is called **Dynamic impedance.** Current at resonance is maximum and is given by -

$$I = I_R = \frac{V}{Z} = \frac{V}{R}$$

Voltage, $V = I*Z = IR$

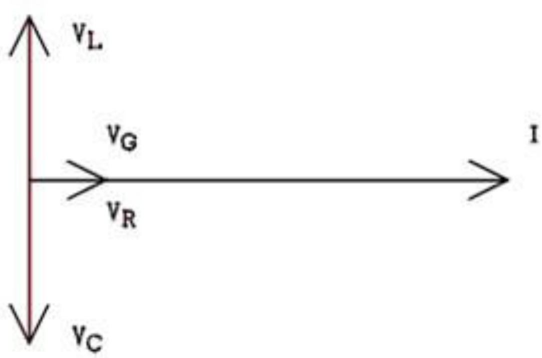
Resonance Curve :

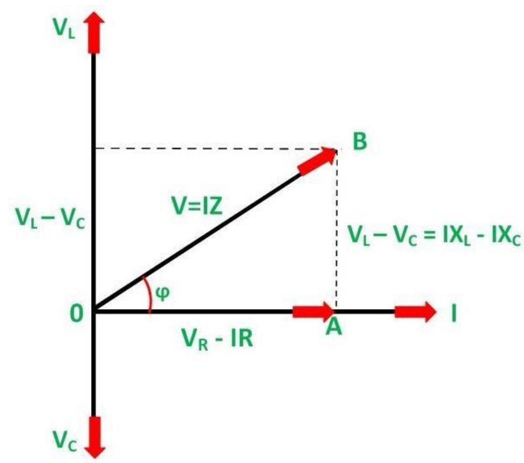


The frequency response curve of a series resonance circuit shows that the magnitude of the current is a function of frequency and plotting this onto a graph shows us that the response starts at near to zero, reaches maximum value at the resonance frequency when $I_{MAX} = I_R$ and then drops again to nearly zero as f becomes infinite. The result of this is that the magnitudes of the voltages across the inductor, L and the capacitor, C can become many times larger than the supply voltage, even at resonance but as they are equal and at opposition they cancel each other out.

As a series resonance circuit only functions on resonant frequency, this type of circuit is also known as an **Acceptor Circuit.** Because at resonance, the impedance of the circuit is at its minimum so easily accepts the current whose frequency is equal to its resonant frequency.

Phasor diagram





Phasor diagrams of series resonance

The current everywhere in the circuit will be in phase with itself. The voltage across the resistor will be in phase with the current. The voltage across the inductor will lead the current by 90 degrees, while the voltage across the capacitor will lag the current by 90 degrees. As can be seen in Figure, the total difference in phase between V_C and V_L is 180 degrees. If the two voltages are equal in magnitude, they will cancel out and the voltage across the resistor will be equal to the generator voltage. Whereas $I_C = I_L$, the only way to make $V_C = V_L$ is to have $X_C = X_L$. This is the definition of the resonant condition in a series circuit. Series resonance occurs when the capacitive reactance is equal to the inductive reactance.

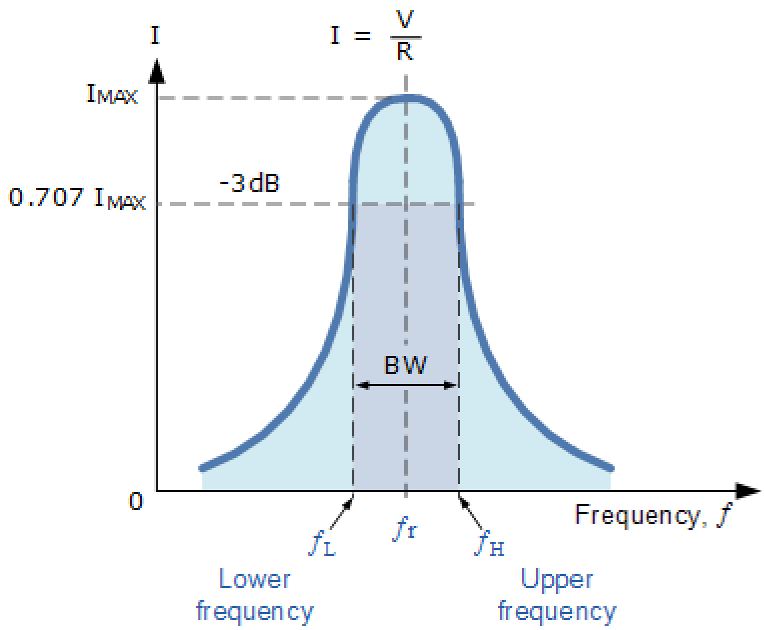
The Q factor

The Q, quality factor, of a resonant circuit is a measure of the "goodness" or quality of a resonant circuit. A higher value for this figure of merit corresponds to a narrower bandwidth, which is desirable in many applications.

More formally, Q is the ratio of power stored to power dissipated in the circuit reactance and resistance, respectively: $Q = \frac{\omega L}{R} = \frac{X_L}{R} = \frac{1}{\omega CR} = \frac{X_C}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$

Bandwidth of a Series Resonance Circuit

The bandwidth of a resonant circuit is defined as the difference between the two frequencies where the current is down to 0.707 of its maximum value (the half power points) Bandwidth is measured between the 0.707 current amplitude points. The 0.707 current points correspond to the half power points since $P = I^2R$, $(0.707)^2 = (0.5)$.



Bandwidth of series RLC circuit

Power Factor at Resonance

Power factor is defined as cosine of the angle between voltage and current at resonance.

$$p.f = \cos(\varphi)$$

At resonance, the inductive reactance is equal to capacitive reactance. The circuit behaves like a pure resistive circuit and in pure resistive circuit; voltage and the circuit current are in same phase i.e., V and I are in same phase direction. Therefore, the phase angle between voltage and current is zero and the power factor is unity.

Characteristics of series resonance

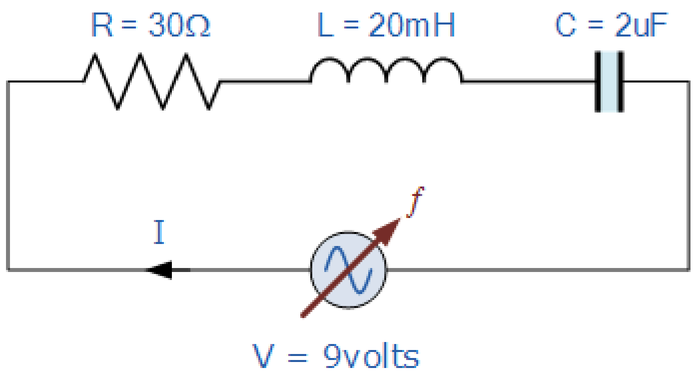
For a series RLC circuit at certain frequency called resonant frequency, the following points must be remembered. So at resonance:

1. Inductive reactance X_L is equal to capacitive reactance X_C.
2. Total impedance of circuit becomes minimum which is equal to R i.e .,Z = R.
3. Circuit current becomes maximum as impedance reduces, $I_{max} = V / R$.
4. Voltage across inductor and capacitor cancels each other, so voltage across resistor $V_R = V$, supply voltage.
5. Since net reactance is zero, circuit becomes purely resistive and hence the voltage and the current are in phase, so the phase angle between them is zero.
6. Power factor is unity.
7. Frequency at which resonance in series RLC circuit occurs is given by-

$$f_s = \frac{1}{2\pi\sqrt{LC}} \ Hz$$

8. Series resonant circuit is called as Acceptor circuit.

Example 1: A series resonance network consisting of a resistor of 30Ω, a capacitor of 2uF and an inductor of 20mH is connected across a sinusoidal supply voltage of 9 volts at all frequencies. Calculate, the resonant frequency, the current at resonance, the voltage across the inductor and capacitor at resonance, the quality factor and the bandwidth of the circuit. Also sketch the corresponding current waveform for all frequencies.



Resonant Frequency, f_s

$$fs = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.02 * 2 * 10^{-6}}} = 796 \text{ Hz}$$

Circuit Current at Resonance, I

$$I = \frac{V}{R} = \frac{9}{30} = 0.3A \text{ or } 300mA$$

Inductive Reactance at Resonance, X_L $X_L=2\pi fL$ = $2\pi*796*0.02 = 100\Omega$

Voltages across the inductor and the capacitor, V_L, V_C

$V_L = V_C$

$V_L = I* X_L = 300mAX\ 100\Omega$

$V_L = 30$ volts

Note: the supply voltage may be only 9 volts, but at resonance, the reactive voltages across the capacitor, V_C and the inductor, V_L are 30 volts peak!

Quality factor, Q :

$$Q = \frac{X_L}{R} = \frac{100}{30} = 3.33$$

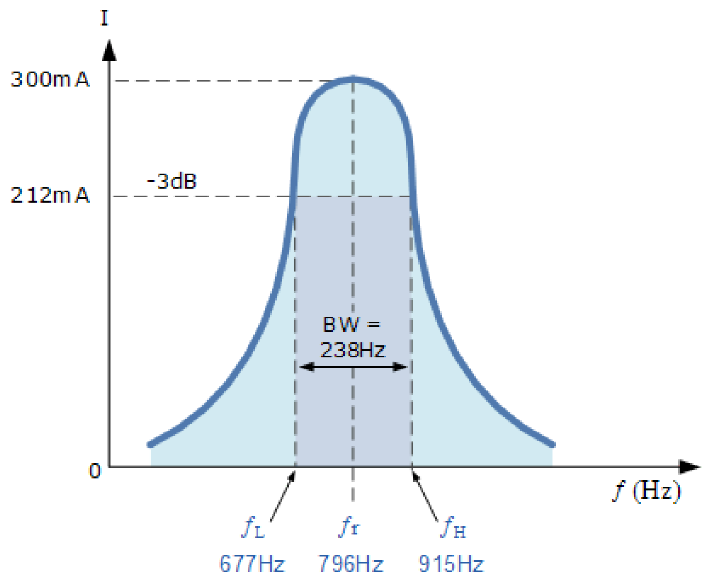
Bandwidth, BW

$$BW = \frac{f_s}{Q} = \frac{796}{3.33} = 238Hz$$

The upper and lower -3dB frequency points, f_H and f_L

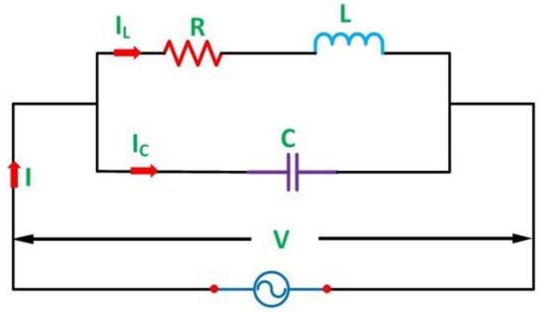
$$f_L = f_s - \frac{1}{2} * BW = 796 - \frac{1}{2} * 238 = 677Hz$$
$$f_H = f_s + \frac{1}{2} * BW = 796 + \frac{1}{2} * 238 = 915Hz$$

Current Waveform

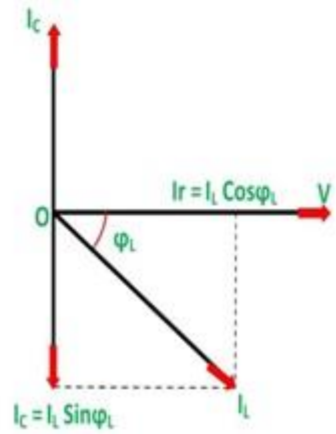


Parallel Resonance or Anti Resonance:

Parallel Resonance is defined as "The resonance that results when circuit elements are connected with their inductance and capacitance in parallel, so that the impedance of the combination rises to a maximum at the resonant frequency."



Parallel resonant circuit



Phasor diagram

Consider an Inductor of L Henry having some resistance of R ohms connected in parallel with a capacitor of capacitance C farads. A supply voltage of V volts is connected across these elements. From the phasor diagram, I_LSinØ, the reactive component of I_L will be in phase opposition to the capacitive current I_C.

Also, $I_C = V/X_C = V.\ 2\varpi fC$

$$I_L = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + X_L^2}} = \frac{V}{\sqrt{R^2 + (2\pi f_p L)^2}}$$

The net reactive current = $I_C - I_{L*}\sin\ \Phi_L$

The net active current = $I_{L*}\cos\ \Phi_L$

At resonance, the value of the net reactive current must be zero.

Then, I_C - I_{L*}sin Φ $_L$ = 0 i.e., I_C Φ = I_{L*}sin $_L$

From impedance triangle sin $\Phi_L = X_L/Z$

□

$$\frac{V}{X_C} = \frac{V}{Z} * \frac{X_L}{Z}$$

i.e.,

$$X_L X_C = Z^2$$

OR

$$\omega L * \frac{1}{\omega C} = Z^2 = R^2 + (2\pi f_p L)^2$$

$$\frac{L}{C} = R^2 + 4\pi^2 f_p^2 L^2$$

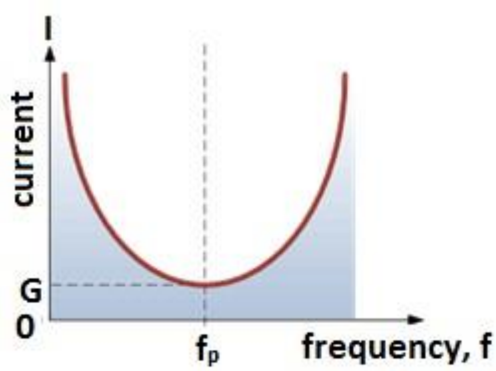
$$f_p = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} = \frac{1}{2\pi L}\sqrt{\frac{L}{C} - R^2}$$

If the resistance is neglected, then

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

Thus if the resistance in the inductance branch is neglected, the resonance frequency of the parallel circuit becomes equal to that of series circuit.

Current at resonance:



Current curve

At resonance, the net reactive component of current is zero and hence the source current I must be equal to the active component of the current.

i.e., $I = I_L \cos \emptyset$

Or $I = \frac{V}{Z} . \frac{R}{Z} = \frac{VR}{Z^2}$

However, $Z^2 = X_L X_C = \frac{L}{C}$

Hence , $I = \frac{VR}{L/C} = \frac{V}{L/CR} = \frac{V}{Z}$

Where Z is the impedance at resonance, given by

$$Z = \frac{L}{CR}$$

Thus at resonance, the net impedance is given by L/CR and is known as **Dynamic impedance** of the parallel circuit at resonance. This impedance is resistive only. The current is minimum at resonance and the circuit is referred as **rejector circuit**.

Q factor of parallel circuit

Q factor is defined as the ratio of current circulating between the two branches of the parallel circuit to the line current. It is the current magnification.

Hence Q factor is given by

$$Q = \frac{I_C}{I}$$

But

$$I_C = \frac{V}{X_C} = \omega CV$$

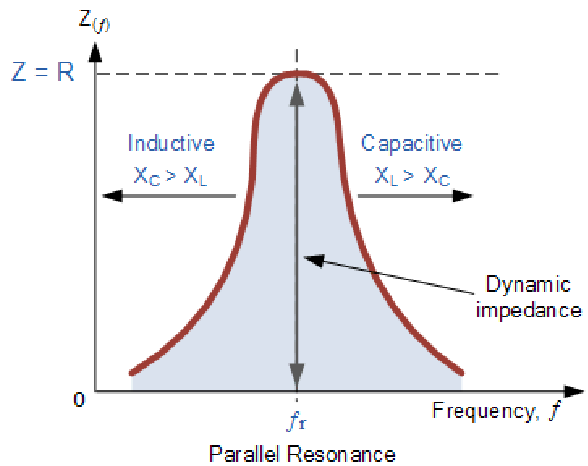
However

$$I = \frac{V}{Z} = \frac{V}{L/_{CR}} = \frac{VCR}{L}$$

Hence Quality Factor

$$Q = \frac{\omega CV}{VCR/_L} = \frac{\omega L}{R} = \frac{2\pi f L}{R}$$

Impedance at resonance:

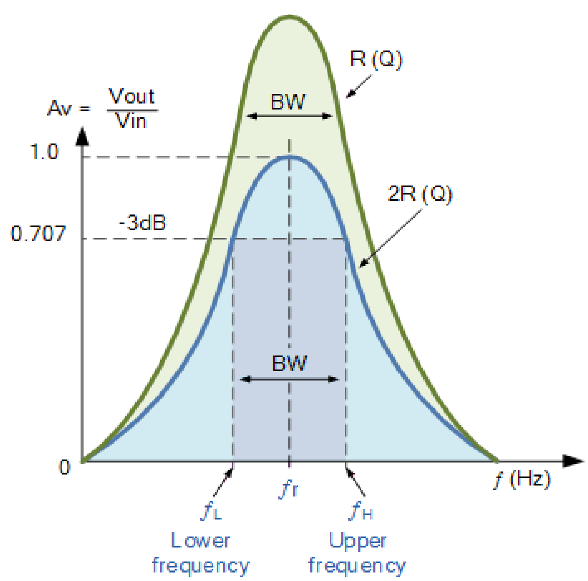


Impedance curve

$$Z = \frac{L}{CR}\ Ohms$$

Bandwidth:

The bandwidth of a resonant circuit is defined as the difference between the two frequencies where the current is down to 0.707 of its maximum value (the half power points) Bandwidth is measured between the 0.707 current amplitude points. The 0.707 current points correspond to the half power points since $P = I^2R$.



Bandwidth curve

Example 1: A coil with resistance of 20Ω and inductance of 0.2H is connected in parallel with a 100μf capacitor. Calculate the frequency at which the circuit will act as a noninductive resistance, impedance, Quality factor and bandwidth at resonance.

Solution: The parallel resonant frequency is given by

$$f_P = \frac{1}{2\pi L}\sqrt{\frac{L}{C} - R^2}$$

$$= \frac{1}{2\pi * 0.2}\sqrt{\frac{0.2}{100*10^{-6}} - 20^2}$$

f_p = 31.8Hz.

At resonance, the circuit offers only a dynamic resistance, the value of which is given by L/CR ohms.

Dynamic Resistance,

$$Z = \frac{L}{CR} = \frac{0.2}{100\mu * 20} = 100\ ohms$$

Quality Factor

$$Q = \frac{2\pi f L}{R} = \frac{2\pi * 31.8 * 0.2}{20} = 2$$

Bandwidth,

$$BW = \frac{f_P}{Q} = \frac{31.8}{2} = 15.9\ Hz$$

Characteristics of parallel resonant circuit:

The following conclusions are made from the above overall discussion aboutthe **Parallel Resonance.**

1. The circuit impedance is purely resistive, because there is no frequency term present in it. 2. The impedance (Z) will be very high, because the ratio L/C is very large at parallel resonance.

3. The value of circuit current, I = V/Z is very small because the value of Z is very high.
4. The current flowing through the capacitor and the coil is much greater than the line current because the impedance of each branch is quite lower than that of circuit impedance Z.
5. Since the parallel resonant circuit can draw a very small current and power from the mains, therefore, it is also called as **Rejector Circuit.**

Applications of resonance:

1. Stripping carrier waves from a modulated waveform on the receiving end. So intelligence signal can be amplified. Filtering out unwanted Harmonic frequencies by shunting them to ground.
2. Resonance is used for tuning and filtering, because it occurs at a particular frequency for given values of inductance and capacitance.
3. It is used in many different types of oscillator circuits. An important application is for tuning, such as in radio receivers or television sets, where they are used to select a narrow range of frequencies from the ambient radio waves. In this role the circuit is often referred to as a tuned circuit.

Comparison of Series and Parallel resonance

Specifications	Series resonance circuit	Parallel resonance circuit
Impedance at resonance	Minimum , Z=R	Maximum, Z=L/CR
Current at resonance	I=V/R, Maximum	I=V/(L/CR), Minimum
Resonant frequency	$f_s=1/2\pi\sqrt{(1/LC)}$	$f_p=1/2\pi\sqrt{((1/LC)-(R^2/L^2))}$
It magnifies	Voltage	Current
It is known as	Acceptor circuit	Rejector circuit
Power Factor	Unity	Unity

Filters

A filter is an electrical network that can transmit the signals within a specified frequency range. This frequency range is called pass band and the other frequency band where the signals are suppressed is called attenuation band or stop band. The frequency that separates the pass band and attenuation bands is known as cut-off frequency. There may also be two cut-off frequencies in the entire zone of operation of filter. The cut-off frequency is represented as f_C in case of single frequency or by f_1 and f_2 in case of more than one, f_1 indicates the lower cutoff frequency and f_2 indicates the upper cutoff frequency.

Pass band:

A pass band is the range of frequencies that can pass through a filter. For example, a radio receiver contains a bandpass filter to select the frequency of the desired radio signal.

Stop band:

A stopband is a band of frequencies, between specified limits, through which a circuit, such as a filter or telephone circuit, does not allow signals to pass through it. **Ideal filter**

An ideal filter would transmit signals under the pass band frequencies without attenuation and completely suppress the signal with attenuation band of frequencies with a sharp cutoff profile.

Practical filters

Practical filters do not ideally transmit the pass band signal un-attenuated due to absorption, reflection or due to other loss. This results in loss of signal power. Also the filters do not completely suppress the signal in attenuation bands.

Properties of Filter

1. **Characteristic impedance**: The Characteristic impedance Z_0 of a filter matches with the circuit to which is connected throughout the pass band. This prevents reflection loss in the combination.
2. **Pass band characteristic**: The filter should have minimum attenuation in its pass band range and high attenuation in the stop band range. The degree of attenuation is generally expressed by the attenuation constant α with an unit neper or decibel.

3. **Cut-off frequency characteristic**: The filter should possess frequency distinguishing property in the pass band or stop band. It should be capable of identifying lower as well as higher cut-off frequency for transmitting signals through it.

Classification of Filters

Filters may be classified according to-

i) The relation between the arm impedances (series arm impedance Z_1 and shunt arm impedance Z_2), the filters are categorized as

a. Constant-K filter or prototype filter

b. m-derived filter

ii) The frequency characteristic filters are classified as

a. Low pass filter- LPF

b. High pass filter- HPF

c. Band pass filter- BPF

d. Band stop filter- BSF or Band Elimination filter or Band rejection filter.

iii) The type of technique used in signal processing

a. Analog filter

b. Digital filter.

iv) The type of elements used a. Active filter and

b. Passive filters

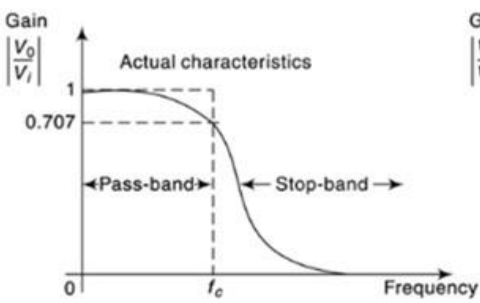
iv) The operating frequency range

a. Audio frequency (AF) filters

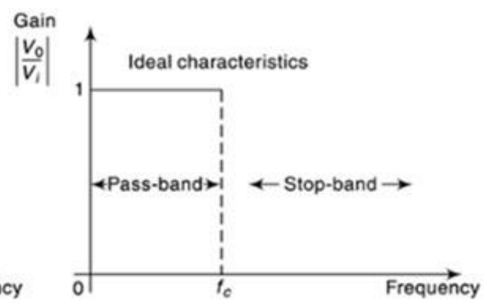
b. Radio Frequency (RF) filters.

Ideal characteristics curve of passive LPF

Low pass filter is a circuit that has constant output (or gain) from zero to a cut-off frequency, f_C ,and attenuates all frequencies above f_C. The ideal and practical characteristics of LPF are as shown.



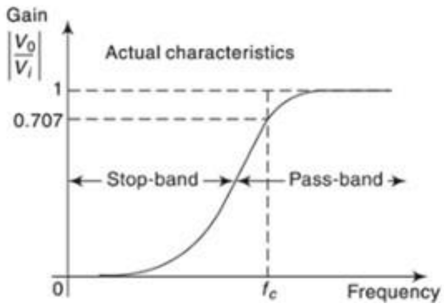
Practical characteristics



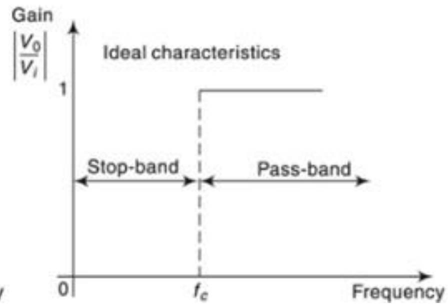
Ideal characteristics

Ideal characteristics curve of passive HPF

High pass filter is a circuit that attenuates all signals of frequency below the cut-off frequency, f_C, and has a constant output (or gain) above this frequency. The ideal and practical characteristics of HPF are as shown.



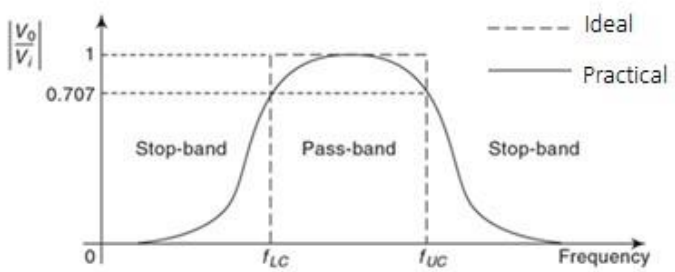
Practical characteristics



Ideal characteristics

Ideal characteristics curve of passive BPF

Band pass filter is a circuit that passes a band of frequencies between two cut-off frequencies f_{LC} and f_{UC} and attenuates all frequencies outside the band. The ideal and practical characteristics of BPF are as shown.

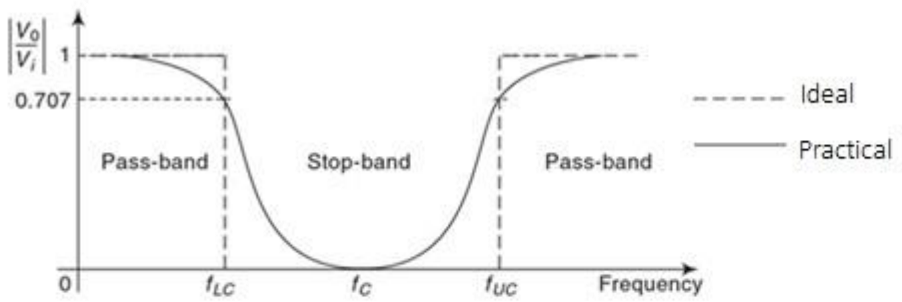


Characteristics of BPF

Where f_{LC} and f_{UC} are the lower and upper cut-off frequencies respectively.

Ideal characteristics curve of passive BSF

Band stop filter is a circuit that rejects or attenuates a band of frequencies between two cut-off frequencies f_{LC} and f_{UC} and allows or passes all frequencies outside the band. The ideal and practical characteristics of BSF are as shown.



Characteristics of BSF

Where f_{LC} and f_{UC} are the lower and upper cut-off frequencies respectively.

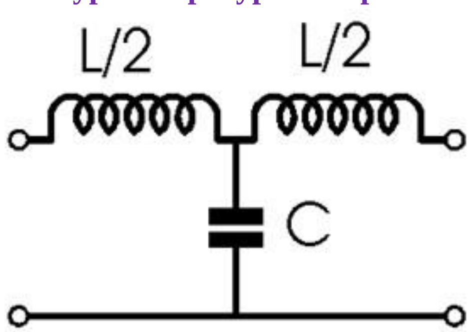
Constant-K or Prototype filters

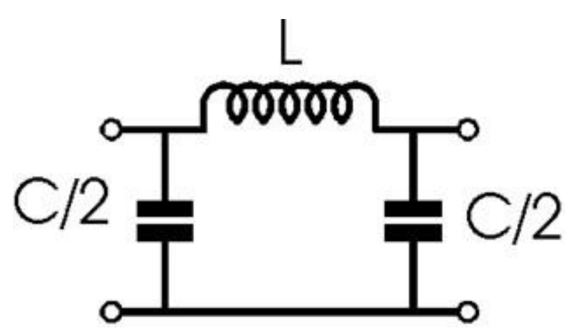
In constant-K filter, the series arm Z_1 and shunt arm Z_2 impedances are such that

$$Z_1 Z_2 = R_0^2 = K(\text{constant})$$

Where R_0 is a real number and independent of frequency. It is called as design impedance of the section. Any filter where this relationship is maintained is known as constant-K type or prototype filter.

Constant –K T-type and pi-type Low pass filter





T-Section

pi-section

Low pass filters are used in a wide number of applications. Particularly in radio frequency applications, low pass filters are made in their LC form using inductors and capacitors. Typically they may be used to filter out unwanted signals that may be present in a band above the wanted pass band. In this way, LPF only accepts signals below the cut-off frequency.

Low pass filters using LC components, i.e. inductors and capacitors are arranged in ether a pi or T network. For the pi section filter, each section has one series arm and two shunt arms on either side . The T network low pass filter has one shunt arm and either side two series arms. In the case of a low pass filter the series arms are inductors and shunt arm are capacitors.

The design equations for constant-K LPF

The design impedance being Ro and the cut-off frequency $f_{C,}$ both being known, the design components L and C of the filter can be found from the following equations

1. $Ro = \sqrt{\dfrac{L}{C}}$

2. $f_C = \dfrac{1}{\pi\sqrt{LC}}$

And expressions for the inductance and capacitance are given by

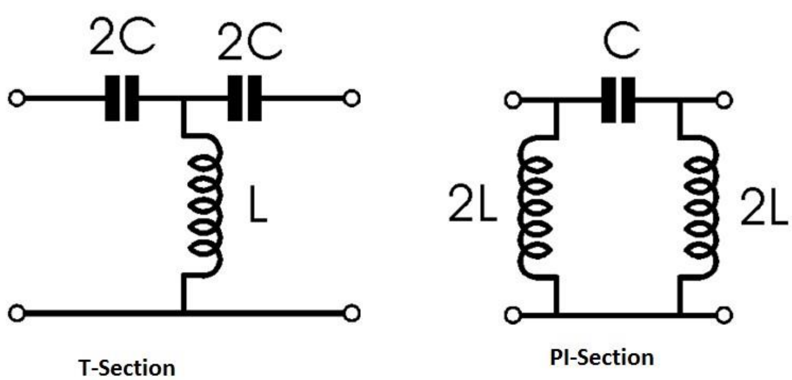
3. $L = \dfrac{R_O}{\pi f_C}$

4. $C = \dfrac{1}{\pi R_O f_C}$

Where
Ro = Design impedance in ohms
C = Capacitance in
Farads

L = Inductance in
Henries f_c = Cutoff
frequency in Hertz

Constant –K T-type and pi-type High pass filter



High pass filters are used in a wide number of applications and particularly in radio frequency applications. For the radio frequency filter applications, the high pass filters are made from inductors and capacitors rather than using other techniques such as active filters using operational amplifiers where applications are normally in the audio range.

High pass filters using LC components, i.e. inductors and capacitors are arranged in ether a pi or T network. The pi network has one series arm, and two shunt arms on either side of a series arm. The T section has one shunt arm and two series arms on either side of a series arm. In case of high pass filter the series arm are capacitors, whereas the shunt arm are inductors and hence the high pass filters pass the high frequency signals, and reject the low frequency signals.

The design equations for constant-K HPF

The design impedance being Ro and the cut-off frequency f_{C}, both being known, the design components L and C of the filter can be found from the following equations

1. $$Ro = \sqrt{\frac{L}{C}}$$

2. $$f_C = \frac{1}{4\pi\sqrt{LC}}$$

And expressions for the inductance and capacitance are given by

3. $$L = \frac{R_O}{4\pi f_C}$$

4. $$C = \frac{1}{4\pi R_O f_C}$$

Where
Ro = Design impedance in ohms
C = Capacitance in
Farads L = Inductance
in Henries f_c = Cutoff
frequency in Hertz

Example 1. Design a low pass filter (T and π) to have a cut off frequency of 796Hz and load impedance of 600Ω. Solution:
The cur-off frequency,

$$L = \frac{Z_0}{\pi f_c} = \frac{600}{\pi * 796} = 0.24\,Henries$$

$$C = \frac{1}{\pi Z_0 f_c} = \frac{1}{\pi * 600 * 796} = 0.67\mu F$$

Values of T-section L/2 = 0.12 H
C = 0.67 μF

Values of π-section L = 0.24 H
2C = 0.33μF

Example 2. Compute the values of a high pass filter (T and π) to have a cut off frequency of 10kHz and load impedance of 600Ω. Solution:

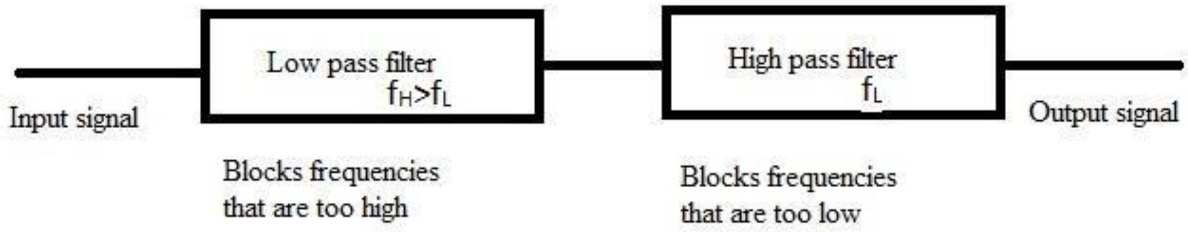
$$L = \frac{Z_0}{4\pi f_c} = \frac{600}{4\pi * 10k} = 4.77\ mH$$

$$C = \frac{1}{4\pi Z_0 f_c} = \frac{1}{4\pi * 600 * 10k} = 0.013\mu F$$

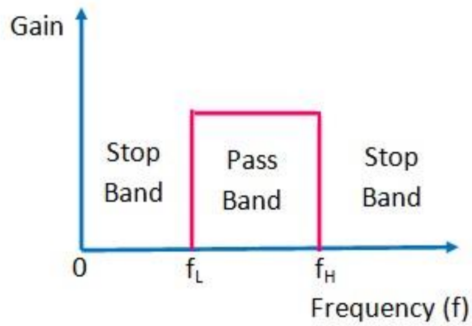
Values of T-section L = 4.77 mH
2C = 0.026 μF

Values of π-section 2L = 9.54 mH
C = 0.013 μF

RealizingBPF using LPF & HPF



Block diagram of BPF using LPF and HPF

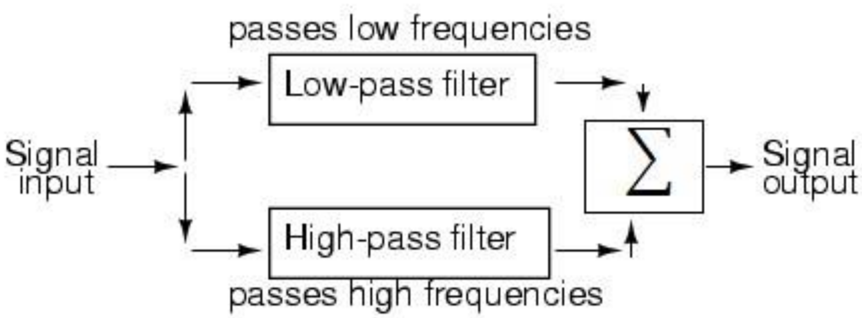


Ideal characteristics

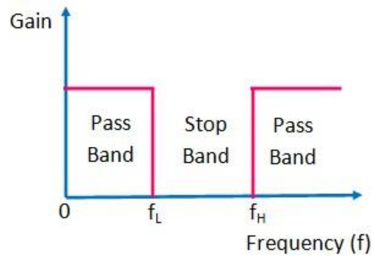
Band pass filter can be realized by the combination of both low pass filter and high pass filter. The name of the filter itself indicates that it allows only a certain band of frequencies and blocks all the remaining frequencies. In audio applications, sometimes it is necessary to pass only a certain range of frequencies, this frequency range do not start at 0Hz or end at very high frequency but these frequencies are within a certain range, either wide or narrow. These bands of frequencies are commonly termed as Bandwidth.

Here the low pass filter pass all signals up to frequencyf_H and blocks all the frequencies above f_{H}, whereas the high pass filter allows signals above frequency f_L and blocks all signals below f_L.

RealizingBSF using LPF & HPF



Block diagram of BSF using LPF and HPF



Ideal characteristics

Band stop, also called *band-elimination*, *band-reject*, or *notch* filters, this kind of filter passes all frequencies above and below a particular range set by the component values. BSF can be made out of a low-pass and a high-pass filter, just like the band-pass design, except that the two filter sections are connected in parallel with each other instead of in series as shown in figure.

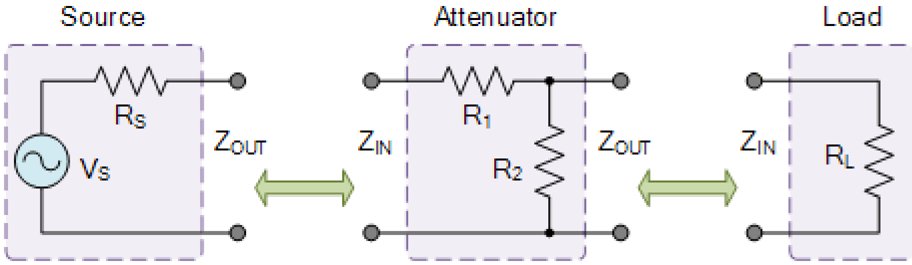
Here the low pass filter allows all signals up to frequency f_L and blocks all signals above f_L, whereas the high pass filter blocks all signals upto frequency f_H and allows all signals above f_H.

Attenuator

An attenuator is a four terminal network, inserted between a source and load, which is used to incur a specific amount of loss for current and voltages.

OR

Attenuator is a two port resistive network which is used to reduce the signal level when used between a generator and load. Figure below shows an attenuator in the form of a two port (four terminal network) inserted between the generator (source) and the load.



Attenuator block

Power loss in any network represents attenuation. The attenuation is measured in decibels (dB) or nepers.

Bel:In Electronics and Communications ,Bel is a logarithmic expression of the ratio between two signal powers, voltage or current.

$$\text{Bel} = \log_{10} (P_S/P_R)$$

The bel, however, is larger than is needed in practice and therefore, a unit one-tenth of bel was adopted by engineers and named as decibel.

Decibel: Abbreviated as dB, and also as db and DB is one tenth of Bel

i.e.,Decibel = $10\log_{10}(P_S/P_R)$ or Decibel = $20\log_{10}(I_S/I_R)$

Neper: is defined as the natural logarithm of ratio between two signal powers, voltage or current level.

Neper = $\log_e (P_S/P_R) = 10\log_e(I_S/I_R)$

The attenuation is defined by the square root ratio of the input power (P_s) to the ouput (P_R) Thus, attenuation = $P_S / P_R = (N^2)$ say. (N being the attenuation)

$$\text{i.e.,} \qquad N = \sqrt{\frac{P_S}{P_R}} = \sqrt{\frac{I_S^2 R}{I_R^2 R}}$$

(since in any resistive network, power loss is given by I^2R)

$$\square\ N \square \frac{Is}{IR} \ldots\ldots\ldots\ldots.1$$

Similarly N, the attenuatioon = V_S / V_R ………..2

(as Is*R =Vs and $I_{R*}R = V_R$)

Thus attenuation can also be expressed in terms of ratio of input to the output current or voltage.

Here N indicates the level of attenuation. However N, attenuation is expressed in some unit i.e., Decibel or Neper.

Attenuation (D) in decibels is given by

$$D = 10\log_{10}\frac{P_S}{P_R} = 10\log_{10}\left(\frac{I_S^2}{I_R^2}\right)$$

$$= 20\log_{10}\left(\frac{I_S}{I_R}\right) \qquad \ldots\ldots\ldots\ldots..3$$

Also

$$= 20\log_{10}\left(\frac{V_S}{V_R}\right) \qquad \ldots\ldots\ldots\ldots\ldots.4$$

Substituting N from equations (1) and (2) equations (3) and (4) become

$$D = 20\log_{10}(N)$$

$$\text{And} \qquad N = \text{Antilog}\left(\frac{D}{20}\right)$$

Relationship between decibel (dB) and Neper (nep)

Attenuation in decibels is given by

$$D = 20\log_{10}(N)$$

$$= 20\log_{e}(N) \times \log_{10}(e)$$

$$= 20\log_{e}(N) \times 0.434$$

$$D = 8.686\log_{e}(N)$$

Attenuation in Neper being given by $\log_e(N)$, the relationship between decibel and neper is given by

Attenuation in dB = 8.686 * attenuation in neper

OR

Attenuation in neper= 0.1151* attenuation in dB

i.e.,**one neper = 8.686 dB**

and

One decibel = 0.1151 nepers.

Classification of Attenuators

Attenuators may be classified into

i) Symmetrical Attenutors ii) Asymmetrical Attenuators

They may provide fixed or variable attenuation. A fixed attenuator is also called as pad.

i) Symmetrical Attenutors are resistive networks connected between source and load having equal input and output resistances ($R_1 = R_2$).

ii) Asymmetrical Attenuators are also resistive networks connected between source and load having unequal input and output resistance when looked into from input and output terminals respectively.

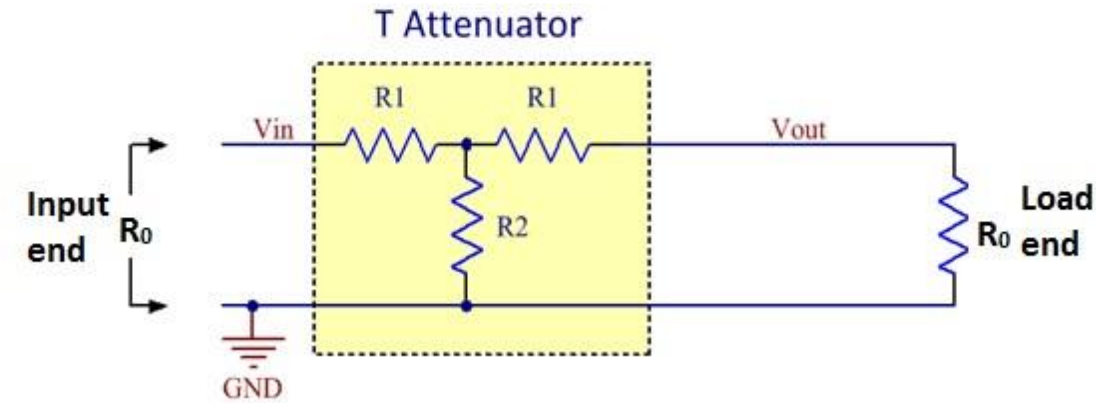
Attenuators can be further classified, based on how series and shunt arms are connected, as (i) T type attenuator

(ii) pi type attenuator

(iii) Lattice type attenuator

(iv) Bridged T type attenuator

Symmetrical T type attenuator



Symmetrical T-type attenuator

Figure above represents Symmetrical T type attenuator also known as pad. It is one of the most common types of attenuators. The series arm impedances are given by R_1 and the shunt arm impedances by R_2. A voltage source with internal resistance $R_O$is applied at the input ports while the output feeds a resistor R_O equivalent to the characteristic impedance of T-network section.

Expressions

If N= I_S/I_R and R_O is the internal resistance of the source are given, then series and shunt arm reisitances are given by

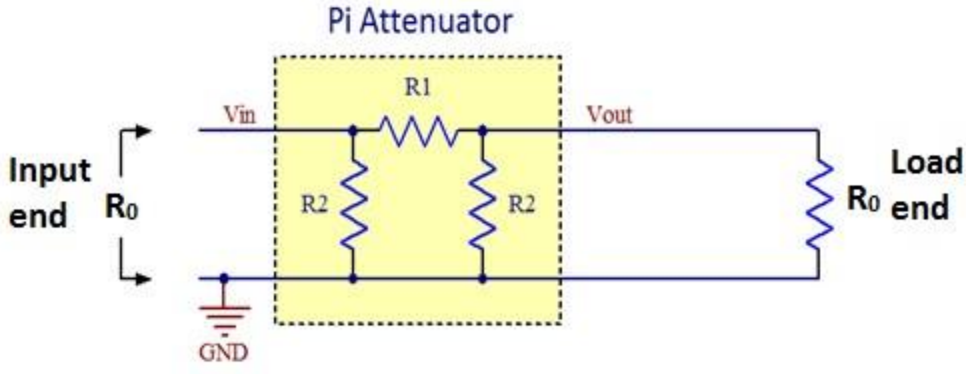
$$R_1 = \frac{N-1}{N+1} \text{x} R_o$$

And

$$R_2 = R_O \frac{2N}{N^2-1}$$

These are called as design equations of T-type symmetrical attenuator

Symmetrical pi type attenuator



Symmetrical pi-type attenuator

Figure above represents Symmetrical pi-type attenuator also known as pad. It is one of the most common types of attenuators. The series arm impedance is given by R_1 and the shunt arm impedances by R_2. A voltage source with internal with internal resistance $R_O$is applied at the input ports while the output feeds a resistor R_O equivalent to the characteristic impedance of pi-network section.

Expressions

If N= I_S/I_R and R_O is the intrenal resistance of the source are given, then series and shunt arm reisitances are given by

$$R_1 = \frac{R_O\left(N^2-1\right)}{2N} \quad \text{and}$$

$$R_2 = \frac{(N+1)}{(N-1)} \times R_O$$

These are called as design equations of pi-type symmetrical attenuator

Applications

1. A resistive attenuator may be used for matching between circuits of different resistive impedances. These components may therefore be used in place of a transformer
2. Variable attenuators are used in laboratories for obtaining small values of voltage and current for testing purposes. Typical examples of variable attenuator is a volume control of communication receiver.
3. Resistive attenuators are also used in high frequency signal transmission
4. Attenuators are also used to enhance the magnitude of the input impedance of equipment.
5. T and pi type attenuators used as an inserted network between a signal generator and a load such that there is no reflection from the load to signal generator.
6. Asymmetrical attenuators are most commonly used for perfect matching of impedances between source and load.

Read more: http://circuitglobe.com/what-is-parallel-resonance.html#ixzz4TYeB77WA
http://www.electronics-tutorials.ws/accircuits/parallel-resonance.html
http://circuitglobe.com/what-is-parallel-resonance.html **http://www.electronics-tutorials.ws/accircuits/series-resonance.html**
http://www.radio-electronics.com/info/rf-technology-design/rf-filters/simple-lc-lowpassfilter-