Analog Circuits
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Week -05
Module- 03
Filters

Hello, welcome to another module of this course analog circuits, so in the past few modules we have been covering topics on frequency response and frequency compensation. In this module, we shall be studying about an interesting circuit analog circuit which is very widely used and basically, they are frequency shapers so such a circuit is known as a filter.

So, a filter what if you know we know what a filter is in the our day to day life but as applicable for analog circuits the word filter means a circuit that filters certain frequencies that is allows certain frequencies to pass through it and does not allow certain frequencies to pass through so let us study a little bit more about filters.

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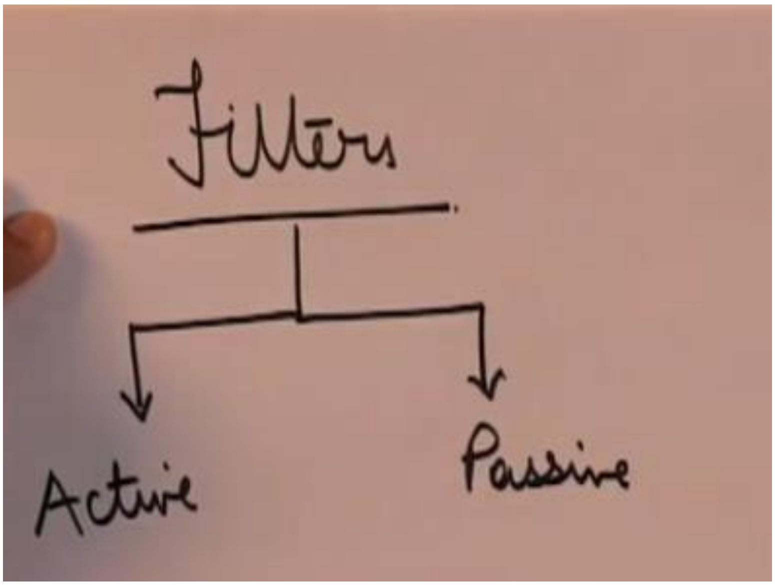

So, when I say they are frequency filters what do I mean, broadly this filter term filter as applicable for analog circuits can be classified into 2 parts active and passive filters okay now ideally the frequency response of a filter should be something like this.

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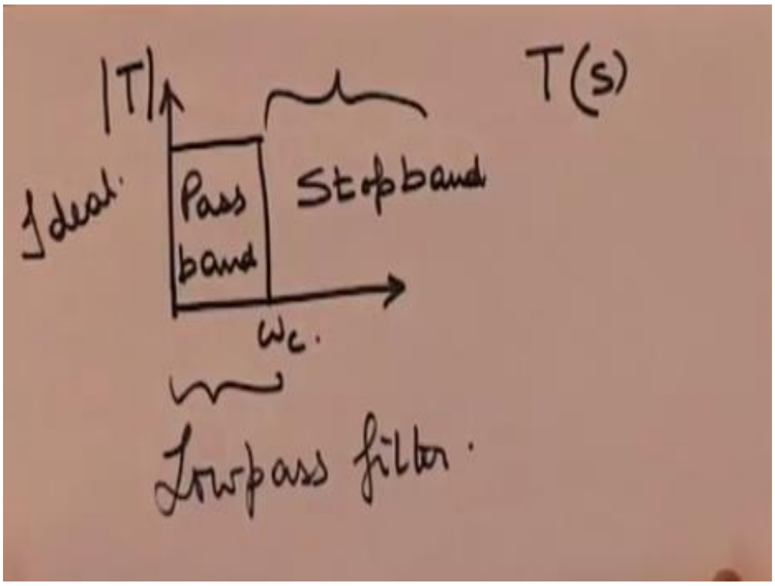

If suppose TS represents the transfer function of a filter, then a low pass filter is said to be 1 which has a characteristics like this, so here if I call the separation between the pass band and the stop band I denote that frequency by this term omega C then omega C represents the boundary between the frequencies that are allowed to pass through that low pass filter and the frequencies which are not allowed to pass through the filter the frequencies which are allowed to pass through the filter lie in what we call as the pass band and the frequencies which are not allowed the line stop band.

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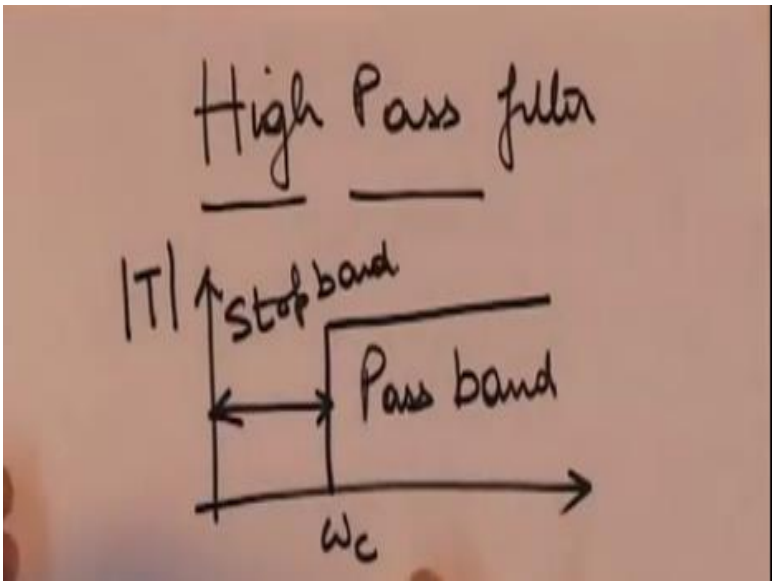

So, the stop band for a low pass filter as you can see is infinite whereas the pass band is finite, similarly we can define what we called a high pass filter so high pass filter the keywords are high and pass, so it means higher frequencies will be allowed to pass through such a filter so the response again will be the inverse of the low pass filter this will be my pass band this is my cutoff frequency and this is my stop band.

So, lower frequencies will be not allowed to pass through the filter and higher frequencies will be allowed you know we can obtain various filter by a combination of this low pass and high pass filter to such filters are what we call band pass filter and band stop filter so a band pass filter.

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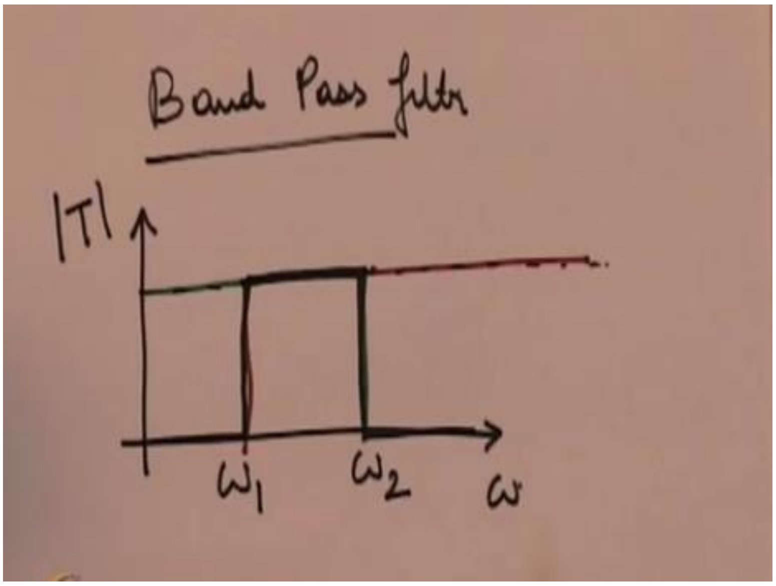

So in a band pass filter what we have is a frequency response like this ok, so here the first part if we expand this and this if we consider only this part and this is a high pass filter with a cut off frequency omega 1 and this part if I represented by the green marker this is a low pass filter with a cut off frequency omega 2 and a combination of the 2 gives a band pass filter like this, in this case the high pass cut off frequency is lower than the low pass cutoff frequency what happens if the high pass cutoff frequency is higher than the low pass cutoff frequency then we get what is known as a band stop filter.

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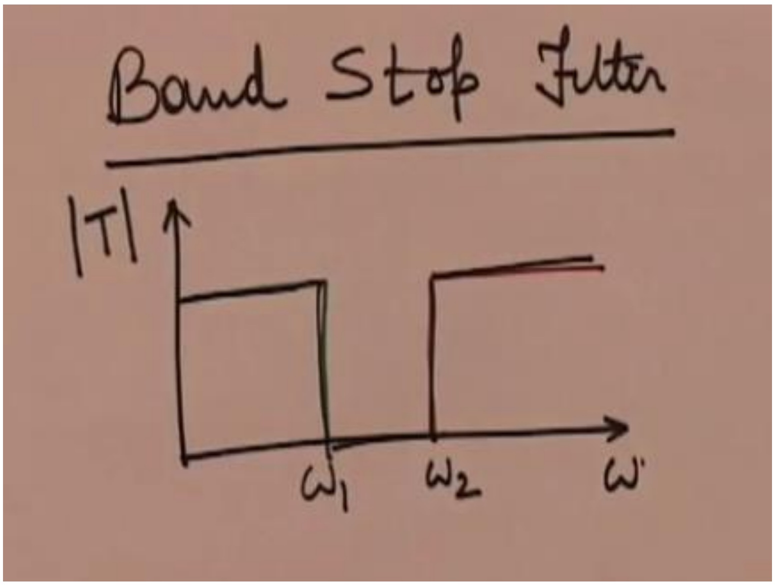

So this is a low pass filter this green line and this red line represents a high pass filter and a combination of the 2 gives a frequency response which is like this so it is like whereas in the if I go back to the band pass filter for a moment the band pass filter is a filter which allows a band between omega 1 and omega 2 the frequencies band between omega 1 and omega 2 to pass through all other frequencies are not allowed in the case of a band stop filter it is the reverse here, we have the band between omega 1 the frequency bandwidth in omega 1 and omega 2 not allowed to pass and all other frequencies are allowed to pass.

Now in practice what happens is such an ideal filter is very difficult to achieve there are some combinations but that is for later and for a higher level course where we can nearly achieve such ideal responses but for simple circuits using simple lumped elements it is very difficult to obtain such ideal characteristics so in such cases what we have to get or what we can realize is not an ideal filter like that but a filter with some more frequency limitation so in practice what we get is something like this.

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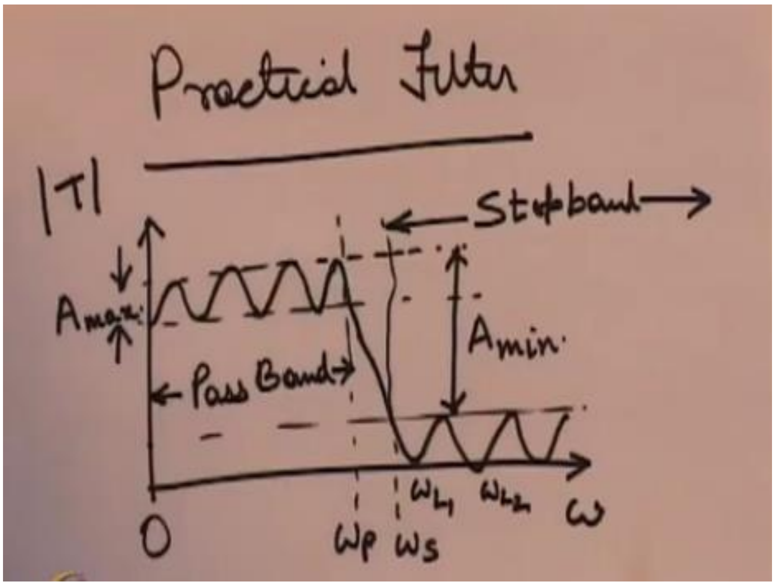

So practical filter will be something like this, so this is what we call a practical filter implementation instead of defining strict pass bands and stop bands where either frequencies are allowed or not allowed we now define for a practical filter the pass band as the range of frequencies where the attenuation of the signals can be till a maximum extent only that is if this is the pass band between DC and Omega P then the maximum attenuation allowed in the pass band is a max and the stop band.

we define from the frequency omega S such that the minimum attenuation that has to take place in the stop band is a min so now we do not describe our system in terms of either pass or not pass passing a frequency we now define in terms of the attenuation level that should be present in the band so for the past band there should be a maximum attenuation the attenuation of the signal should not be more than a certain value and in the stop when the attenuation should have a minimum value that is it must have attenuation above the minimum value.

So with this definition of our practical filter we can start to explore some practical topologies now I must say that between these frequencies omega p and Omega s this is an undefined region this neither this region range of frequencies between omega p and omega s they neither lie in the pass band nor in the stop band.

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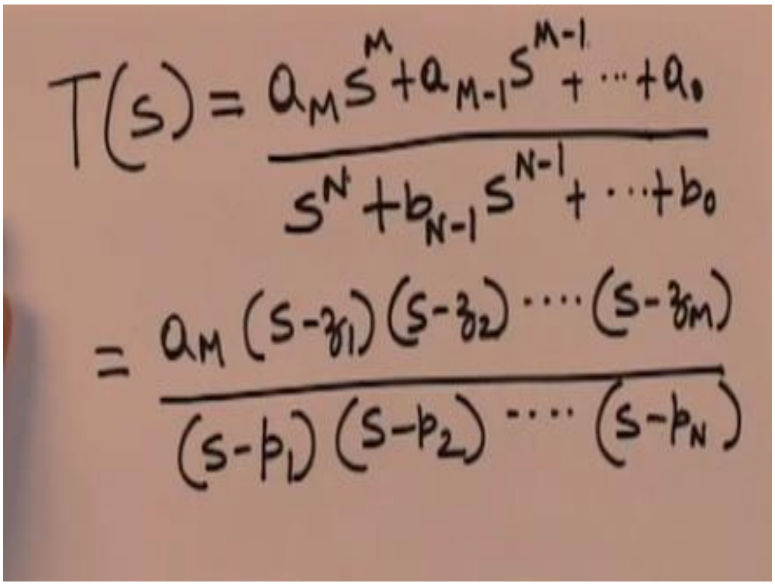

So let us study some of the some of the properties of the transfer function describing a filter suppose the transfer function of a filter is given now this is in a polynomial for that the numerator and denominator both are in terms of a polynomial if we now writer in a factored form the numerator and denominator polynomials then we will get something like this so now if we try to plot the poles and zeros of such a system before that you know let us suppose that the frequency response of this filter is of this form.

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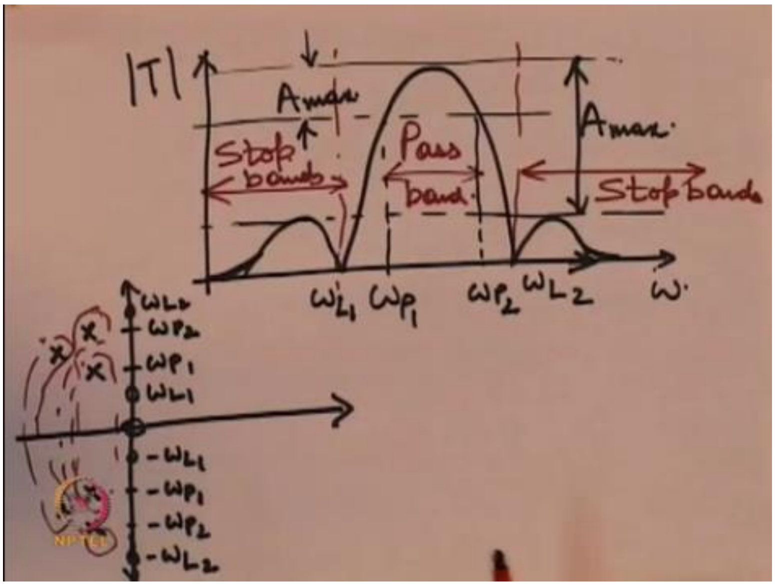

Now suppose the pole zero placement of this filter is like this so you see one thing that here the response suppose this is my magnitude is of the transfer function is represented along the y axis and the as usual the frequencies along the X axis and you see that in the response this omega L1 and omega L1 is a frequency.

So you see that at omega L1 there is a dip and not only there is a dip but it actually touches 0 similarly at omega L2 the response actually touches 0 which means that at omega L1 and omega L2 there should be a zero present and not only at omega L1 and omega L2 also at -0 omega L1 and - omega L2 so that is what we have represented it here omega L1 and omega L2 have 2 0's similarly at - omega L1 and -omega L2.

We have another 2 0 now the poles this poles will as we already know since the transfer function let us go back to the transfer function this is a polynomial with real coefficients both the numerator and denominator are polynomials with real coefficients hence the poles will either be real or will be present in conjugate complex conjugate pairs and that is what we see here so these 2 constitute 1 complex conjugate pair similarly these 2 also can constitute 1 complex conjugate pair and these 2 also constitute 1 complex conjugate pair.

So also is there any other 0's present yes there is also a 0 present at DC which is represented by this 0 okay that is the 0 at DC and there is also another 0 present at infinite frequency omega = infinity which is which tallies with the frequency response since here the curve asymptotically will approach infinity so these are some important features of in the transfer function of any filter that how the placement or the location of the lowest values of the magnitude will correspond to the actual placement of the 0's, the other thing that we have to notice this omega P omega P represents the poles of the system.

So at omega p is the response should be very high now this is seen here where we see that this omega p1 and omega p2 are actually the 3 db frequencies or I should say they are the frequencies where the maximum attenuation in the pass band is realized so this then constitutes our pass band the gap between omega p1 and omega p2 that is the frequencies corresponding or the values on the Y axis corresponding to the poles.

These 2 poles suppose they are imaginary values are omega p1 and omega p2 then they correspond to these 2 edges of the frequency response and everything else is a stop band, so here my these stop band consists of frequencies and these frequencies so from here till omega L2 till infinite and from 0 to omega L1 these are my stop bands I should correct my definition of the stop band at all frequencies other than the pass band.

It is this frequencies from 0 to omega L1 and omega L2 to infinite but this frequency range omega L1 to omega p1 and omega p2 to omega L to these are those undefined region so in summary in this module we saw what a filter is what are the various types of filter namely low pass high pass band pass and band stop and also how the location of the poles and 0's of the filter transfer function correspond to the location of the lower and higher magnitude values of the filter.

We usually use the magnitude bode plot to describe the response of a filter although for some more sophisticated filters like constant group delay filters we also consider the phase plot of a of the transfer function of filter so in this in this module or in this course whenever we talk about the filter response we shall be referring to the magnitude response of the filter.

Now in this module, we have seen some more general properties of the filter, in the next module we shall be looking at some specific prototypes or some specific function used to realize specific filters also we shall be seeing later on how these filter how from a prototype we can achieve specific low pass high pass and band pass frequency responses, thank you.