Electronic Systems for Cancer Diagnosis
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Lecture - 31
Basic building blocks of Electronics System: Filters

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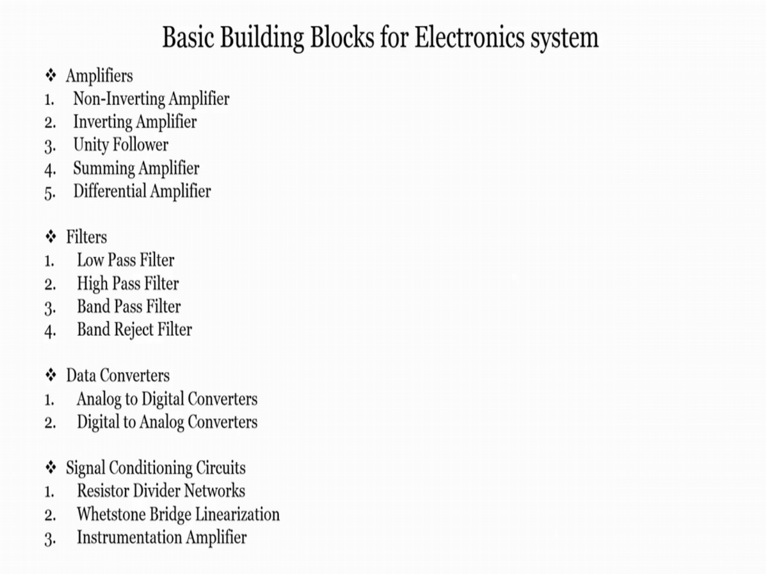

Hi welcome to this lecture, in this lecture we will be talking about Filters. Several (Refer Time: 00:33) filters low pass high pass band pass band reject.

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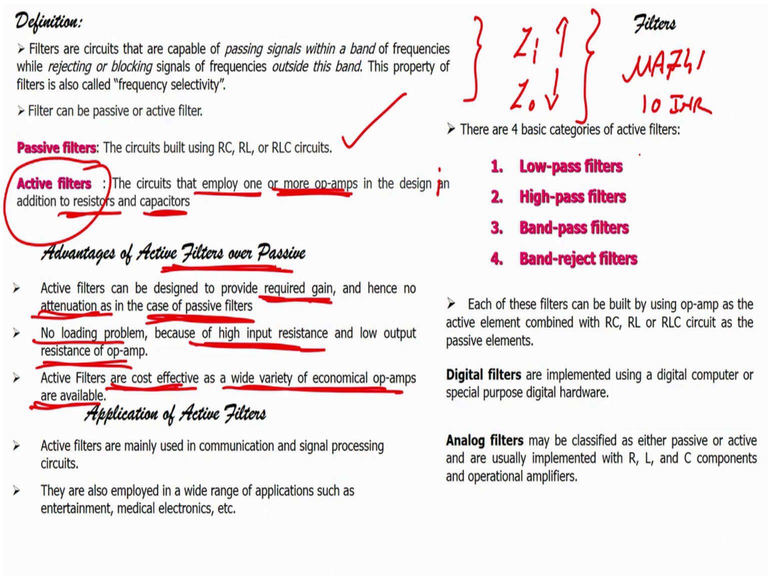

So, when you see the definition the definition of filter is extremely simple, filters are circuit that are capable of passing signals you see, capable of passing signals, within a band of frequency it will only allow the band of frequencies to pass while rejecting or blocking signals of frequencies outside the band right.

So, if you select a band of frequency that you need to pass and you are going to reject or block the signals outside their band, you can use the filters alright this property of filter is also called frequency selectivity it is also called frequency selectivity, because you are selecting the particular frequency from the bad of frequencies or from the total frequencies right.

Now, next is filters can be passive, filters can be active, filters can be passive filters can be active. So, what do you mean by passive filters the circuits built using RC RL or RLC right, either using the resistor and capacitor or resistor and inductor or resistor capacitor inductor, then these are called the passive filters right. We already have seen what are passive components what are active components these are the passive filters right.

Now, when you talk about active filters the circuit that employ one or more operational amplifiers, or any other amplifier ok. In the design and in addition to the resistors and capacitors right in addition, in addition to the resistors and capacitors than that will be your active filter that will be your active filter right.

Now, if you see what are the advantage of active filters why we have to use active filters right, why we have to use active filters why we cannot generate the circuits using passive filters, then we have to understand what are the advantages of active filters over passive filters what are advantages let us see one by one. The first advantage is that active filters can be designed to provide required gain, we can change the gain in active filters, hence no attenuation as in case of passive filters we use passive filters that will be at attenuation and there will be loss. So, we can we can use the active filter and we can provide the gain that is the advantage number 1.

Second advantage is there is no loading problem, because of high input resistance and low output resistance of op amp, we have seen the op amp characteristics where two characteristics of op amp that is the high input impedance and low output impedance correct, this is what we have seen high input impedance and low output impedance. So, because of this characteristics this is this will help us to remove the loading effect to remove the loading effect and we will see what is loading effect in the experiments as well alright. We will see how the loading effect can be removed when we perform the experiments.

So, the advantage is when we use op amp then the loading effect can be avoided. So, no loading problem in case of active filters. Third advantage over passive filter is the active filters are cost effective as wide verities of economical op amps are available, if you buy op amps 7 4 1 mu a 7 4 1 right in a bulk, it will it will give you about 10 INR 10 to 15 INR per piece right.

So, you can buy in a bulk and it is really cheap. So, why not to make of active filters when we can we do not have to spend that much money and in advantage we cannot see any loading effect. And we can also change the gain. So, if there are these many advantages of active filters over passive filters one will always go for the active filter one will always go for the active filter ok.

Now, what are the applications then what are the application active filters. Active filters are mainly used you see mainly used in communication and processing circuits and signal processing circuits. So, all the or most of the communication based applications, we will see the use of the filters and in particular active filters, they are also employed in wide range of applications such as entertainment medical electronics etcetera alright.

So, how can we design a filter or how we can use a filter in medical electronics, that can be a part of another lecture itself or another course itself ah, but we need to understand that once we understand how we can use operational amplifier as an filter, then where it can be used and what are the applications. So, main application of filters are in communication circuits right.

So that means, that when you see any communication circuit you try to see, whether it has some active filters are not same way signal processing tools, same way electronics same way of entertainment purpose, when say entertainment what does entertainment means right is it means that we are playing a video game and in the video game the circuit that we are designing has some filters in it right.

So, what are the applications of filters that also we should know right. And will see some of the advantages that I have just talked recently or right before two minutes that are the loan loading effects. So, how loading effect can be removed, if we use active filter over passive filters will see in the experiment part as well alright guys.

So, now let us see what are the four basic categories of active filter, what are the four basic categories of active filter first category is low pass filter. First is low pass filter, second one is high pass filter, third one is band pass filter, fourth one is band reject filter right four categories, low pass high pass band pass band reject right. Each of these filters can be built by using op amp as the active element combine with RC RL or RLC circuit.

Second digital filters are implemented using digital computer or special purpose digital hardware, there are two types of filter based on the based on whether it is analogue or whether it is digital. So, it can be analog filters it can be digital filters. .

Now, also on based on type based on category there are 4 low pass high pass band pass band reject, but if you want to form a digital filter that can be implemented using a digital computer, or it can be also implemented using special purpose digital hardware. While analog filters may be classified either as passive or active either as passive or active right and are usually implemented using R L and C components and operational amplifiers alright.

So, main two categories of filter is digital analog, further in analog you can have active as well as passive in terms of it categories basic categories it can be divided into 4 parts, one is low cost low pass filters, high pass filters band pass filters and band reject filters. We will see each of them we will see each of them we will see each of them in this particular module ok.

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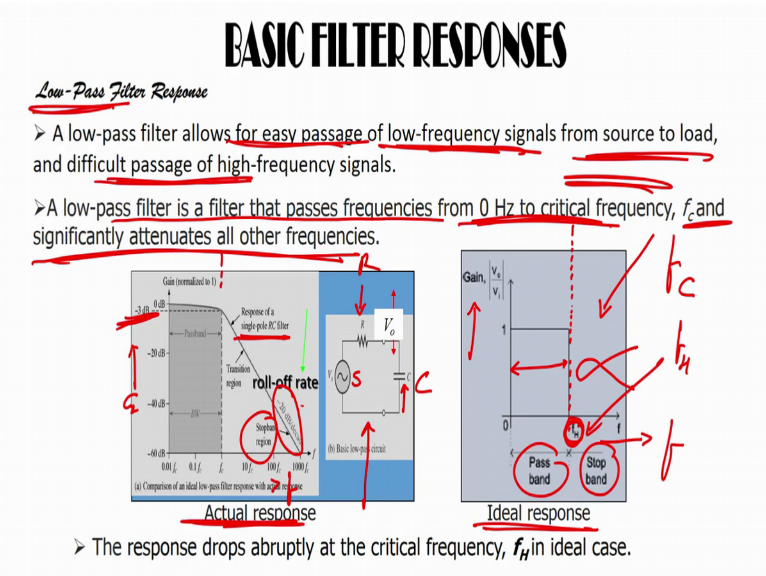

So, let us see basic filter response for the low pass filter alright. So, what does low pass filter means low pass right; that means, it will pass the frequencies which are low frequencies. So, we can if we want to if we have let us say 0 to 1 kilo hertz frequency and I want to only pass frequency from 0 to 200 hertz and any frequency about 200 hertz should not be passed, then I can design a low pass filter right. It will pass a low frequency it will block the high frequency now this high frequency which one is high frequency that we can design, we can design the filter and according to our design, it will allow the low frequency to pass it will attenuate the frequency above certain frequency or what is that frequency that is called critical frequency f C we will see in this module as well ok.

If we come back to the screen what you see is low pass filter allows for easy passage of low frequency signals easy passage of low frequency signals from source to load from source to load. So, you see here this is a circuit when you see here, what is there is a source there is a there is a resistor R and there is a capacitor C. So, just using R and C you can form a low pass low pass passive filter using just component R and C, just using components R and C you can find a low pass filter, that is your passive filter. Now, a low pass filter allows easy passage of low frequency signals, but difficult passage of high frequency signals.

So, if you see ideal curve ideal plot for the low pass filter, or ideal response of the low pass filter it will look like this you have y axis where you have gain and you have x axis where you have frequency right, x axis where you have frequency and then you have to design the filter such that above the frequency f C or f H right. So, it will not allow the frequency to pass only frequency below this frequency will be allowed to pass.

So, the frequency so you can see a sharp cut sharp cut like this right and it, look like a wall it looks like a wall right. So, wall from this side wall from this side also right sharp change right, because we want to only allow the frequency within this particular band and any frequency above this band this one should not be allowed to pass should not be allowed to pass right.

So, this frequency is allowed to pass that is why it is called pass band, this allowed this frequency is not allowed to pass or band of frequency is rejected is called top band right, you can pass the frequency you can stop the frequency, this is an ideal response of the low pass low pass passive filter or low pass active filter you will have the same response by this ideal response, but when you see actual response what you will see you will see lot of things, that first is you see there is a the cut off frequency should e here, it should it should have actually it should have like this is the ideal plot.

But in reality in practical when you when you perform the experiment is the actual response would be different, then your ideal response and here what you see here you see that it will go slowly and it will stop at certain frequency right, but will consider only frequencies that are allowed or about minus 3 dB minus 3 dB or 70 percent of the total voltage, this is the pass band as we have seen and this is the band width and this is the frequency, this is the gain this is the gain right, y axis is gain x axis is frequency.

Now this one this slope right this slope is called roll of rate is called roll of rate alright. So, this response of single pole RC filter and this is a transition region, where you can see here this is a transition region, this slope itself is a transition region and the roll of rate for this one is minus 20 dB minus 20 dB per decade minus 20 dB per decade right and this one is nothing, but your stop band region there it is nothing, but your stop band region alright.

So, now you have seen two three words first word is first word is transition region, transition region is from pass band to stop band transition region second is response of single pole RC filter, what is single pole RC filter there is only one R there is only 1 C, if I keep on increasing the resistors and increasing the capacitors there will be 2 pole RC circuit 3 pole RC filter and so and so forth alright.

So, for single pole RC filter my roll off rate is minus 20 dB per decade for 2 pole RC filter my roll off rate will be minus 40 dB per decade and so on alright. And you will we will see when we see the 2 pole RC circuit alright and this is your stop band region where the frequency would be stop. So, a low pass filter is a filter that passes frequency from 0 hertz to the critical frequency critical, frequency I said it can be denoted by f C here, it is denoted by f H right.

It is critical frequency f C and significantly attenuates all the other frequencies and significantly attenuates all the other frequencies, any frequency above the critical frequency. It will attenuate; it will attenuate means it will not allow to pass it will not allow to pass ok. So, this is your low filter low pass filter response.

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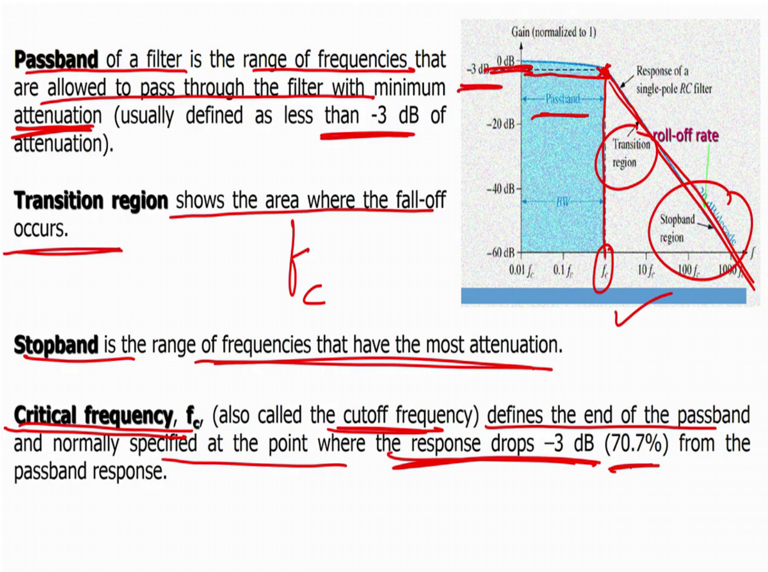

Now, if you see this is again same graph again same plot. So, pass band of a filter what is pass band this is a pass band right, a pass band of a filter is a range of frequencies that are allowed to pass the filter with minimum attenuation with minimum loss alright. And usually it is defined that less than minus 3 dB of the attenuation. Transition region transition region, what is transition region transition region shows the area where they fall off occurs right, this is you see from here now the fall off is occurring right. So, it is a transition region.

Stop band stop band is a range of frequency that have most attenuation you see here maximum attenuation occurs here, it is a stop band right and finally, we have critical frequency very important critical frequency also denoted by f subscript C also called cutoff frequency right, because this frequency you see this one is a cutoff frequency, because above this frequency the response the frequency would not allow to pass. And in actual response you will see the slowly it is going to the region, where frequencies are minimum number of frequencies are allowed to pass so, the right.

So, critical frequency defines the end of the passband and normally specified at the point, where the response drops to minus 3 dB or 70.7 percent from the passband response right 70.7 percent of the passband response, when this falls here right and the critical frequency is nothing, but the end of passband here right. And it will be nothing, but 70.7 percent of the passband response or we can say minus 3 dB alright so, these are the regions within a filter.

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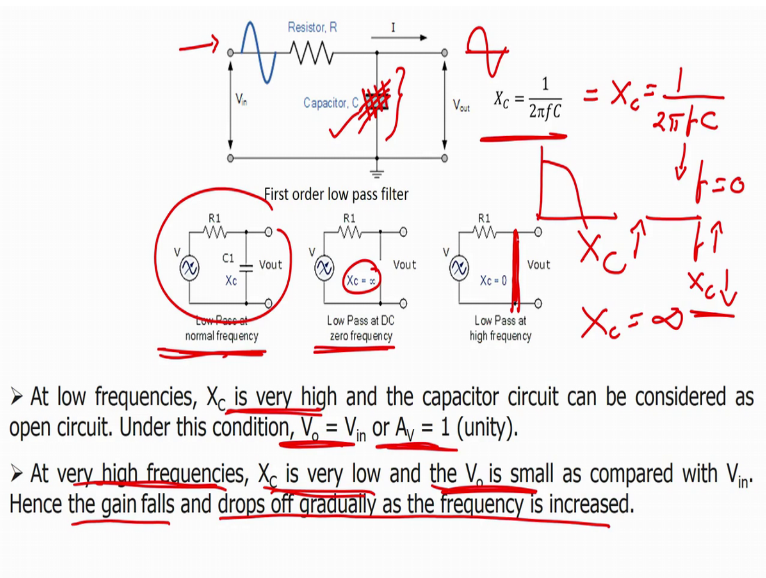

Now, if I want to design this filter, it is very simple I use one resistor, use one capacitor I apply a voltage what I see is that you know the formula X equals to 1 upon 2 pi f C for capacitor right. So, what will happen for low frequency? For low frequency, the capacitor the capacitor would be not conducting right it will not conduct. So, what will happen that at low frequency X C is very high right; it is very high why because the frequency is very high. So, X C is 1 upon 2 pi frequency is very low right frequency is extremely low why because we are passing low frequencies right.

So, for low frequencies X C would be X C would be high where X C would be very high capacitor can see the as an open circuit so; that means, that it is not there is not conductive right is open circuit. So, even you see on the screen please when the capacitor is not conducting, you can see here right; that means, it is an open circuit. So, whatever single is there in the input with lower frequency you will see at the output, you will see at the output right.

So, low pass at normal frequency right low pass at DC frequency DC frequency is infinite X C would be infinite right DC is what f equals to 0 DC signal is frequency is 0. So, x would be X C would be nothing, but infinite right under this condition V o equals to V in or a V equals to unity you can see here in this particular condition low pass from 0 to certain frequency that is our f C it will pass the frequencies.

And what will happen at very high frequencies at very high frequencies X C is very low and V o is small as compared within V in as the gain falls and drops off gradually as the frequency is increased, as the frequency is increased; that means, that if I keep on increasing the frequency my X C will keep on decreasing and; that means, that it is considered now as the shorted it is shorted right. Now, it is not conducting right in this case at lower frequency, it was not conducting now it is completely shorted it is shorted.

Because at high frequency the X C would be X C would be less and that is why it is shorted; that means, the output you will see slowly fading down slowly fading down. And finally, there will be no frequency that can pass through this particular circuit alright easy extremely easy. So, you just understand the role of the capacitor, if you understand the role of capacitor if you understand the role of capacitor the filter becomes very easy to understand right, the filter becomes extremely easy to understand alright.

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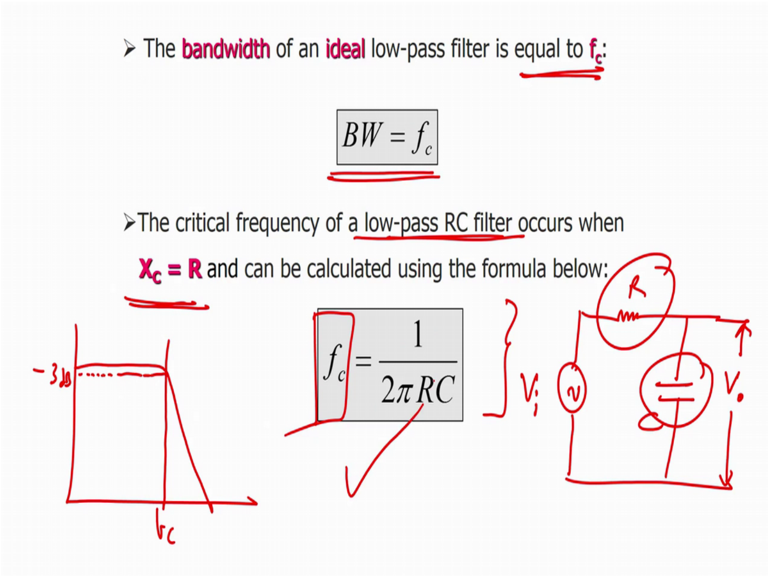

The bandwidth of an ideal low pass filter the bandwidth of an ideal low pass filter is equal to f c is equal to f c. So, bandwidth is equal to f c right the critical frequency of a low pass filter occurs when X C equals to R and can be calculated using the formula f c equals to 1 upon 2 pi RC; that means, that if I design a filter, if I design a filter then what will I have a resistor, I will have a capacitor and then I will have a output voltage V o correct CR signal right.

So, depending on the value of R depending on the value of C I can see elect my critical frequency, I can select my critical frequency critical frequency is frequency at which the attenuations starts right, we have seen right we have considered this minus 3 dB like this is not it right.

So, critical frequency of low pass filter RC filter occurs, when X C equals to R and can be calculated using the formula f c equals to 1 upon 2 pi RC f c equals to 1 upon 2 pi RC.

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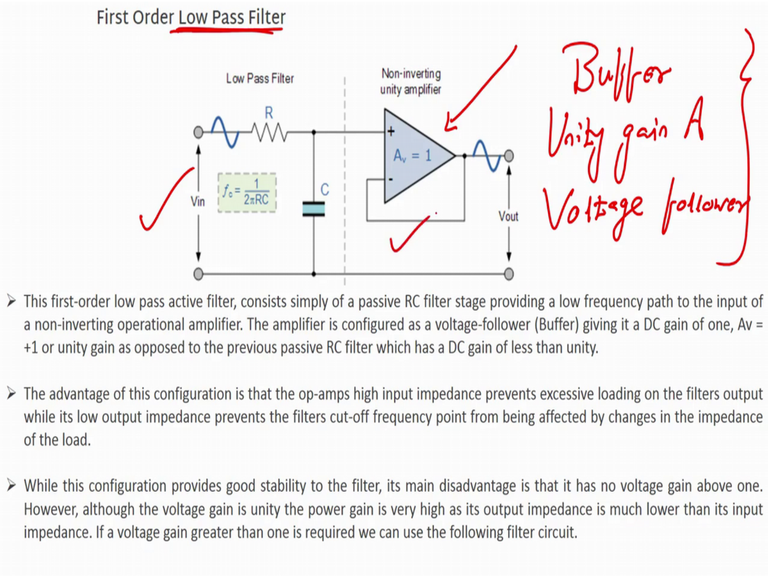

Now, now what to do let us see alright let us see so, until here what we are looking at low pass filter, but they were passive filters passive filters means if you this was not there op amp was not, there right we are looking only on this circuit where resistor and capacitor was there right. Now, we are looking at low pass active filter, low pass active filter.

When you have to have low pass active filter you have to have an amplifier, you have to use a amplifier. And if we use here what is amplifier the amplifier is nothing, but unity gain amplifier we have seen the op amp right, we have seen the circuit of op amp. When it was used as a buffer right buffer unity gain amplifier, unity gain amplifier or voltage follower voltage follower right. This three things we have seen all three things is same circuit which is right shown here right buffer unity gain amplifier or voltage follower one and the same one and the same right.

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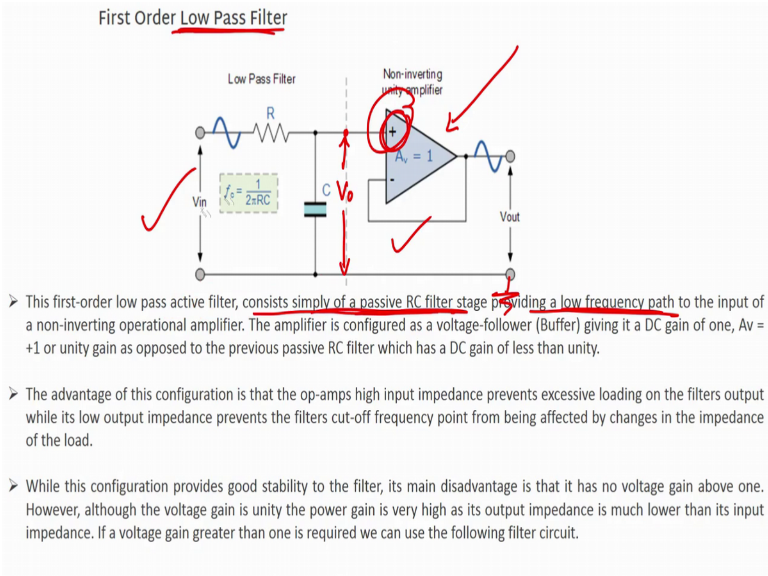

So, now if I connect a unit gain amplifier with a low pass filter which is my RC filter, it becomes my active filter. So, the first order low pass active filter consists simply a RC filter stage providing a low frequency path to the input of non-inverting operational amplifier, it is what inverting or non-inverting it is not inverting, because the signal is applied to the non inverting terminal of the operational amplifier.

So, this is the RC filter whatever the output is here, we were measuring output here right V o is output is with respect to ground right. So, this is ground if I have told you earlier also, if you do not see a ground assume that there is a ground ok. And then with respect to ground with respect to ground, if this is the voltage that is generated that is fed to the non-inverting terminal of the operation amplifier right it is to the none inverting terminal. So, that is what is written active filter or first order low pass first order always remember, I have told you first order second order right.

The first order low pass filter and that to active filter consist of RC filter stage providing a low frequency part to the input of a non-inverting operational amplifier, the amplifier is configured as a voltage follower or a buffer or a unity gain amplifier giving it a DC gain of 1 right or Av equals to plus 1 or unity gain as opposed to previous RC filter which has a DC gain of less than unity right.

So, just RC filter will have DC gain of less than unity of course, but when we use a unity gain amplifier will have a DC gain of 1. The advantage of this configuration is that op amps high impedance prevents excessive loading you see, high input impedance prevents excessive loading of the filters output while it is low output impedance prevents the filters cut off frequency point, from being affected by changing in the impedance of the load right.

Advantage right first advantage is high input impedance that will prevent the excessive loading right. And second would be second would be the low output impedance which prevents the filter cut off frequency from being affected by the changes in the impedance of the load, if I connect this further and if I change the load right, it will not be affected, because I have low output impedance of this particular amplifier alright load resistor if you change it will not affect the filter response.

While this configuration provides good stability to the filter its main disadvantage so, what is the drawback right what is the drawback let us see what is the drawback? So, the drawback is or disadvantage is that it has no voltage gain you see why because whatever voltage you apply here right.

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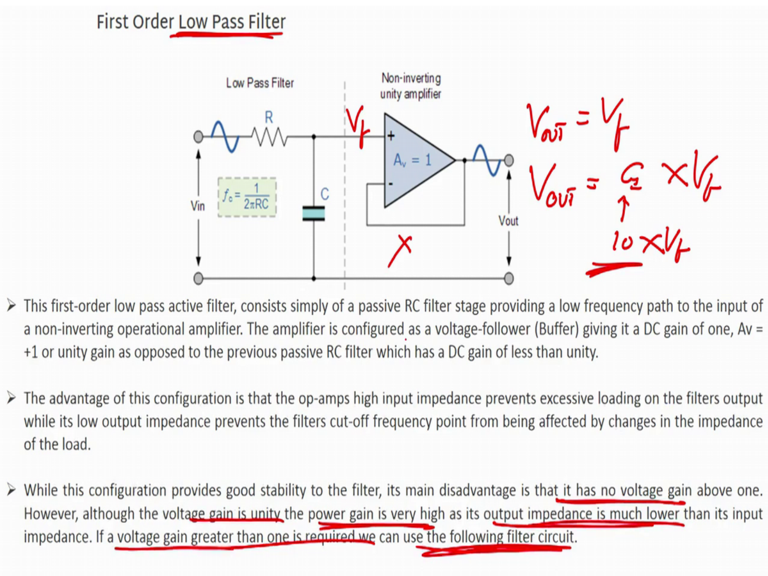

Which is a output of your filters? I will say V f output of filter, then when we see V out V out would be similar to V f, because voltage gain is it is the unity gain amplifier. So, voltage gain is 1 so; that means, that there is no actually voltage gain in the output of the operational amplifier that is the disadvantage right; however, although the voltage gain is unity the power gain is very high right.

Because it can follow the voltage, but it will also increase the current it will increase the current. So, power is very high as it is output impedance is much lower than its input impedance, if a voltage gain greater than one is required we can use the following circuit, which circuit if I want a voltage gain; that means, my V out should be sum gain into V f whereas, my gain can be 10 into V f. So, how can I have 10 I cannot use this circuit right I have to use another circuit. What is that another circuit?

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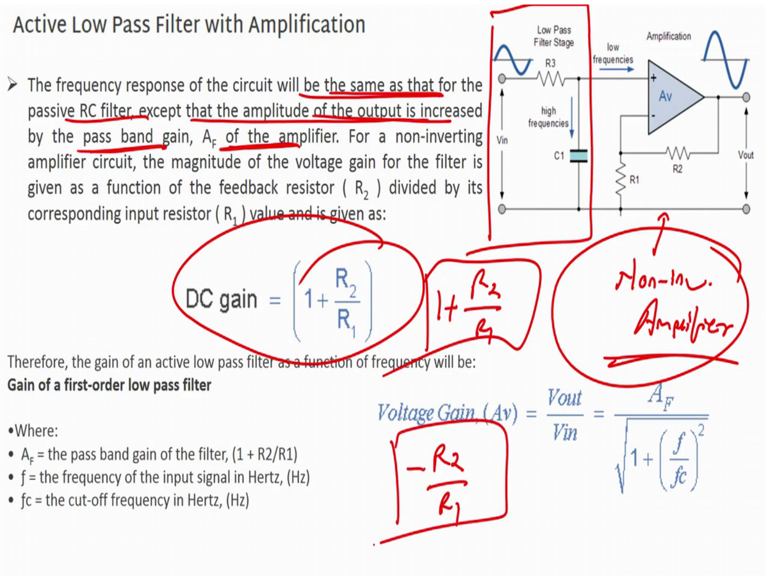

Another circuit is active low pass filter with amplification active low pass filter with amplification. So, what is low pass filter low pass filter is shown here right and here, I have connected a I have connected a non-inverting amplifier, you see here what is my circuit non inverting amplifier correct.

So, frequency response of circuit will be same as that of the RC filter except that amplitude of the output is increased by the pass band gain a f right. So, we now have DC gain of R 1; R 1 R 2 by R 1 plus R 2 by R 1 right, why because we have seen in non-inverting amplifier our DC gain is 1 plus R 2 by R 1. If I use inverting amplifier I will have DC gain of R 2 by R 1 that will be my gain right.

So, for the non-inverting amplifier I have a gain of 1 plus R 2 by R 1 thus by changing the value of R 2 and by changing the value of R 1, I can decide what will be the gain of this particular filter circuit and thus it becomes active low pass filter with amplification with amplification right.

So, therefore, the gain of active low pass filter as a function of frequency will be voltage gain equals to V out by V in equals to A F under root of 1 plus f c by f C whole square, this you have to remember this is the voltage gain of the active low pass filter alright. Now, there is a there is a derivation to derive this we are not interested in deriving this particular equation alright, but I can always tell you which book to refer, if you want to understand how this equation is derived right.

So, you can ask me if you are interested to understand how this equation is derived, if not you should understand how you can implement the circuit, how you can design the circuit that is the idea of this particular course that you at the end of this course you are able to design. The filter circuits design several circuits analog circuits using operation amplifier using MOSFET and so on and so forth.

So, let us go back here where A F in this particular case A F is the pass band, gain of the filter A F is the frequency of the input signal, f C is the cut off frequency alright this we know correct.

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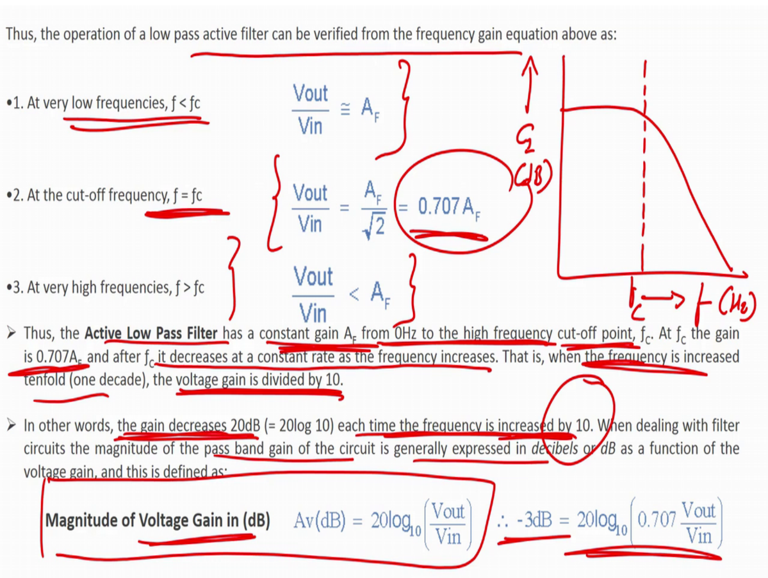

So, thus the operation of a low pass filter can be verified. So, at very low frequencies f less than f C my output would be V out by V in equals to A F right.

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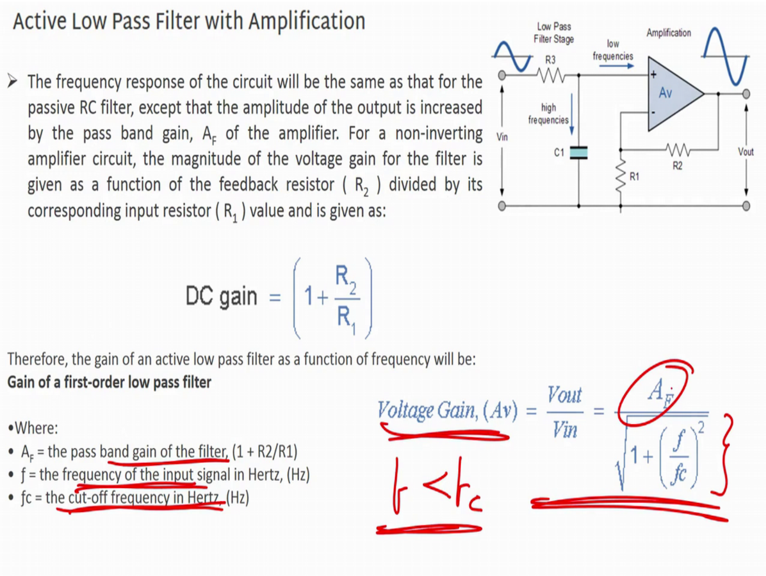

You see this one if my f is less than f C f is less than f C in this particular case right then my V out will be nothing, but A F right V out would be nothing, but A F at f equals to f C my a V out would be V out by V in would be A F by root 2 or 0.07 A F at high frequency it will be less than A F this is very simple right.

You will find in lot of books same equation correct, thus the active low pass filter has a constant gain A F from 0 hertz to high frequency cut off point f C at f C the gain is 0.707 of A F and after f C it decreases constant rate as the frequency increases. This is similar thing what this graph shows it is a gain versus frequency graph f C right frequency is given in hertz gain we calculate in terms of decibel right.

So, when the frequency is increased tenfold, that is the voltage gain is divided by 10 at that time the f C is decreases the constantly. In other words the gain decreases the gain decreases, each time the frequency is increased by 10 the gain is increased right or gain is decreased by 20 decibels each time the frequency is increased by 10, when dealing with the filter circuits the magnitude of the pass band gain of the circuit is generally expressed in decibels or function of voltage gain and it is given by this particular equation which you can see here.

Magnitude of voltage is nothing, but A equals to 20 log V out by V in or minus 3 dB right magnitude of voltage gain in decibel so, minus 3 dB equals to 20 log 0.707 V out by V in correct. So, this shows how you can derive the this how you can derive the formula for formula for the magnitude of voltage gain, in case of the low pass active filter in case of the low pass active filter right.

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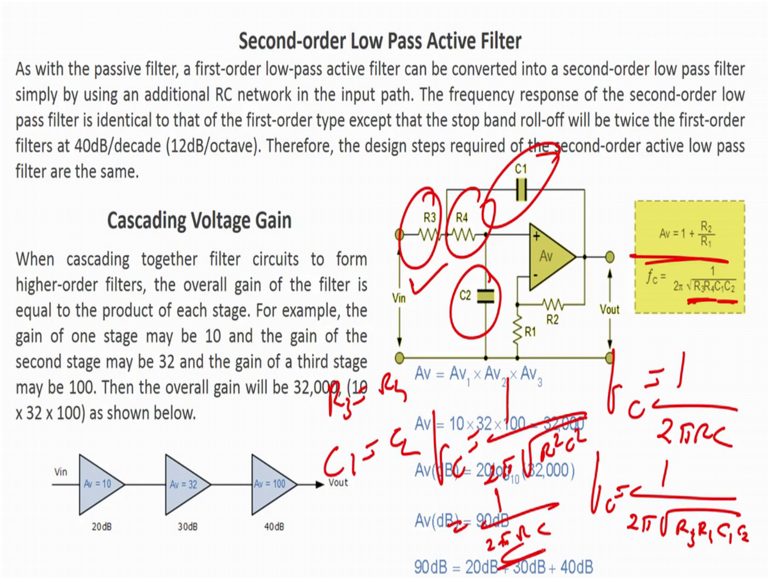

Now, let us see second order low pass active filters. So, now, if I increase one more capacitor and one more resistor one more capacitor and resistors right, it will become second order there are 2 R and 2 C gain remains same Av equals to 1 plus R 2 by R 1.

But my frequency formula earlier for single order was 1 upon 2 pi RC right f C equals to you see, where is it f C equals to 1 upon 2 pi RC if I use this right, then my gain my frequency formula becomes f C equals to 2 pi right here in this case R 1 C 1 R 2 C 2 so, f C equals to 1 upon 2 pi.

Now I have under root of R 1 or R 3 in this case right in this case as say R 3 R 4 C 1 C 2. So, if I have R 3 equals to R 4 and C 1 equals to C 2, then my f C will be 1 upon 2 pi under root of R square C square or 1 upon 2 pi RC correct what I am saying is that if you see this circuit if you see this circuit and if you see the formula for the critical frequency the formula for critical frequency is f C equals to 1 upon 2 pi under root of R 3 R 4 C 1 C 2, which is the this particular circuit it is does not matter R 3 R 4 I can say R 1 R 2 does not matter right.

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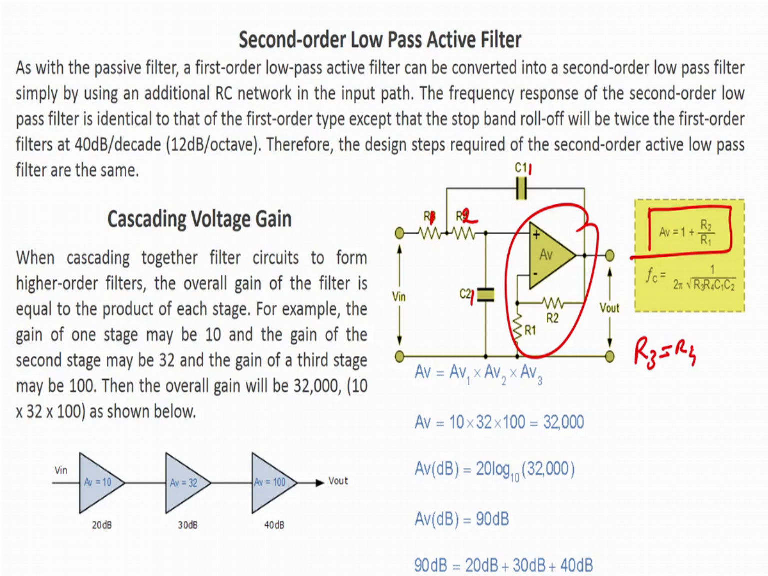

I can say C 1 C 1 2 1 that does not matter point is that there are 2 resistors, 2 capacitors and then there is of course, this inverting amplifier there is an non inverting amplifier right, there is a non-inverting amplifier the gain of non-inverting amplifier is Av equals to 1 plus R 2 by R 1 the frequency formula is 1 upon 2 pi under root of this particular 2 resistors and C 1 and C 2.

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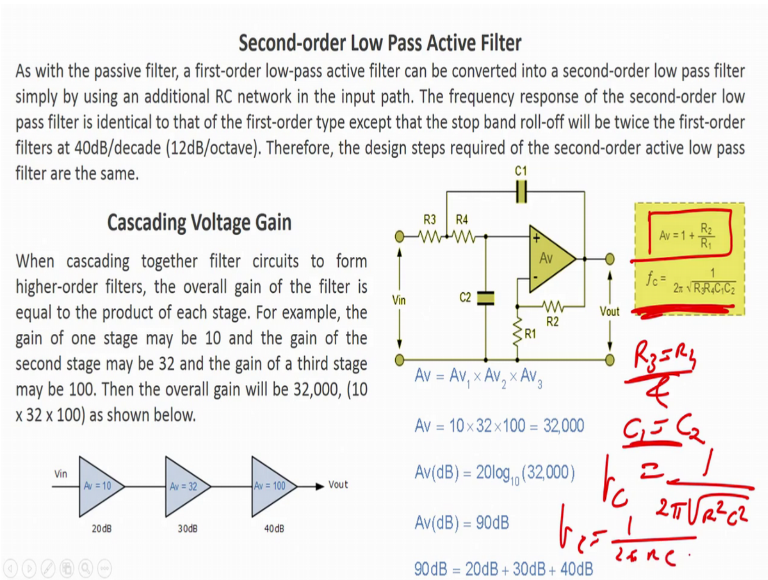

Now, if what I say is that if I have R 3 equals to R 4 in this particular case R 3 equals to R 4 and C 1 equals to C 2 my f C, this particular formula will become 1 by 2 pi R square

C square, because R 1 equals to R 4 C 1 equals to C 2 so; that means, f C will be nothing, but 1 upon 2 pi RC 1 upon 2 pi RC right, which is which is similar to my similar to my first order low pass active filter right, critical frequency formula becomes similar to my first order low pass active filter any way let us see.

As with passive filter a first order low pass active filter can be converted into second low pass active filter, by using additional RC network the frequency response of the second order low pass active filter, is identical to that of first order except that the stop band roll off rate will be twice the first order.

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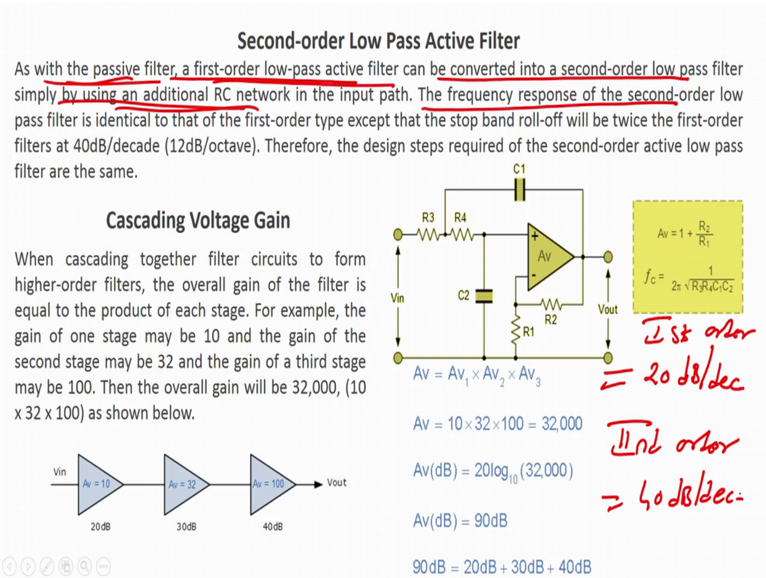

That means, if you if you see the first order filter, you will see 20 dB per decade right, that was the formula right that the roll off rate was nothing, but 20 dB per decade in case of this is for the first order first order low pass filter.

In case of second order low pass filter mu roll of rate right will be 40 dB per decade, 40 dB per decade that is what is written that the roll off rate increases roll off rate increases.

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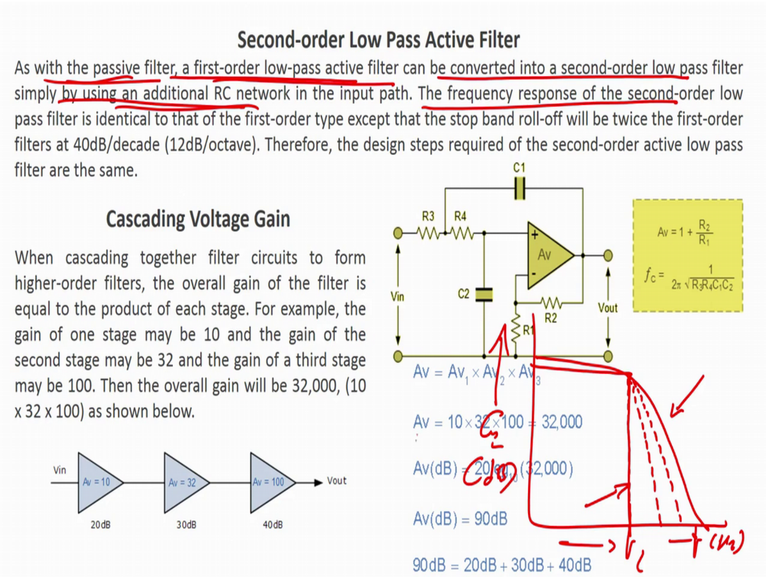

So, if I keep on increasing the roll off rate my filter first response was this, if my roll off rate increasing is this the response would be similar to this, still my roll off rate is increasing response will be this is my ideal response right this is my ideal response it should look like this right.

So, increasing the roll off rate; that means, that my actual response is getting closer to my ideal response, my actual response is getting closer to my ideal response always remember, when you plot the graph y axis is gain which can be in decibels y axis is frequency this is your critical frequency e f C this is your frequency f is always in hertz.

So, you have to write hertz it would write gain write always unit ok, always you have to plot when you plot the graph, you always write units very important very important anyway. So, let us go to the next line that is that the frequency response second order pass filter is identical to that of first order except that the stop band roll off rate will be twice of the first order low pass filter, which is 40 dB per decade.

Therefore, the design steps required for second low pass order filters are the same ok. So, this is the circuit and this is the formula, now if I if I use this is an example, you see if I have a cascaded voltage gain when cascading together filters to form high order filters the overall gain of the filter is equal to the product of each stage.

For example gain of this stage may be 10 and gain of stage may be 32 the gain of third stage may be 100 right. So, for example, what is what is saying then if I cascade my filters and my first stage is 10, second stage is 22 third stage is hundred these are gain right. Then the overall gain will be 32000, because 10 into 32 into 100 correct. So, Av equals to nothing, but Av 1 plus Av 2 Av 1 into Av 2 into Av 3. So, Av equals to 10 into 32 into 100 32000 so, Av in decibel 20 log 32000 that will be 90 dB right.

So, if I see 90 dB; that means, the 90 would be nothing, but 20 30 and 40 correct 90 dB, would be anyway 20 dB plus 30 dB plus 40 dB very easy cascading voltage gain in case of the filters in case of the filters.

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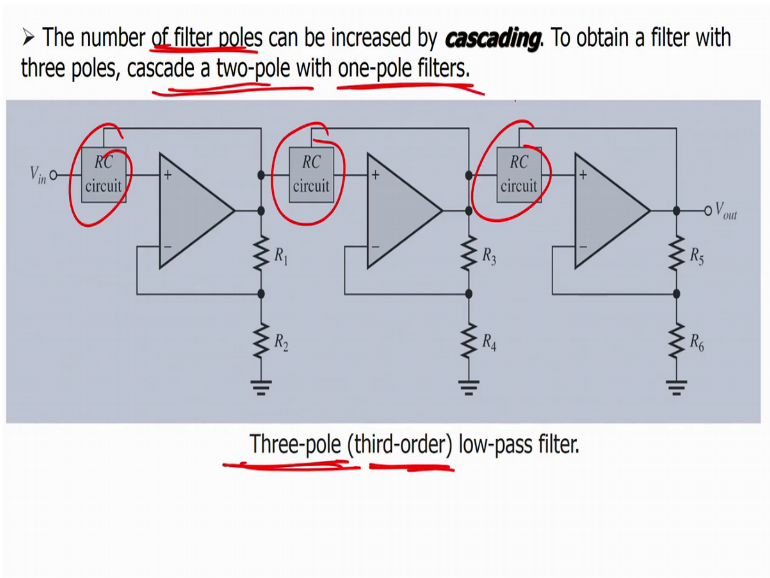

Now, number of filters now number of filters can be increased by cascading right, number of filter poles that is from 1 RC to 2 RC to 3 RC here, you can see 3 R and C right 1 RC 2 RC 3 RC right, then we see these are 3 pole or third order low pass filter.

To obtain filter with 3 poles cascade 2 pole filters with 1 pole filters easy very easy right.

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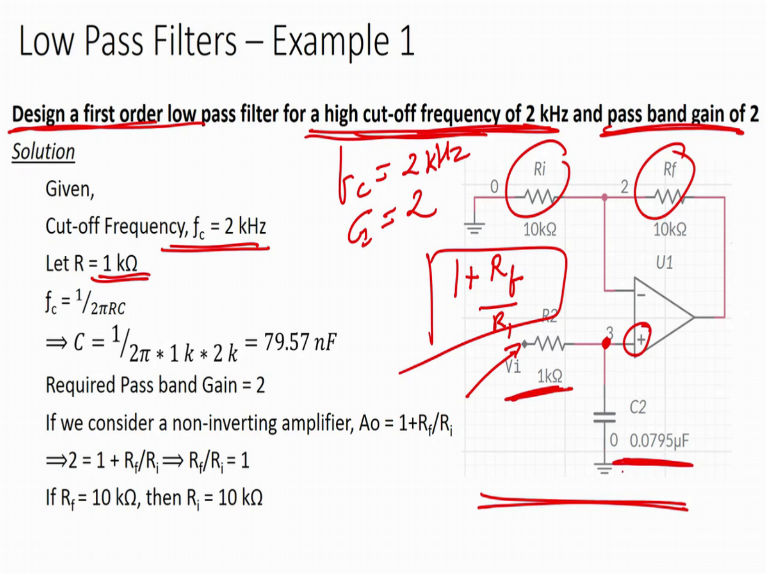

Let us see now let us see now example of low pass filter. So, you see here this circuit is given ok. So, what is the question design a low pass filter design a low pass filter for a high cut off frequency of 2 kilo hertz alright. So, we have to design a filter for the cut off frequency f C is given what 2 kilo hertz and pass band gain right pass band gain is given 2 right.

Where is the input is here you see input is here, where is it on the non inverting terminal. So, this looks like this looks like non inverting amplifier correct. So, non-inverting amplifier non inverting amplifier what is the DC gain one plus what is the here feedback R f and R i 1 plus R f by R i this we know right this we know.

So, f c is given R is given right where is R is 1 kilo ohm right C is also given so, f c equals to 1 upon 2 pi RC right, we know that right this formula what is the formula for the first order low pass filter for critical frequency f c equals to 1 upon 2 pi RC we know it beautiful.

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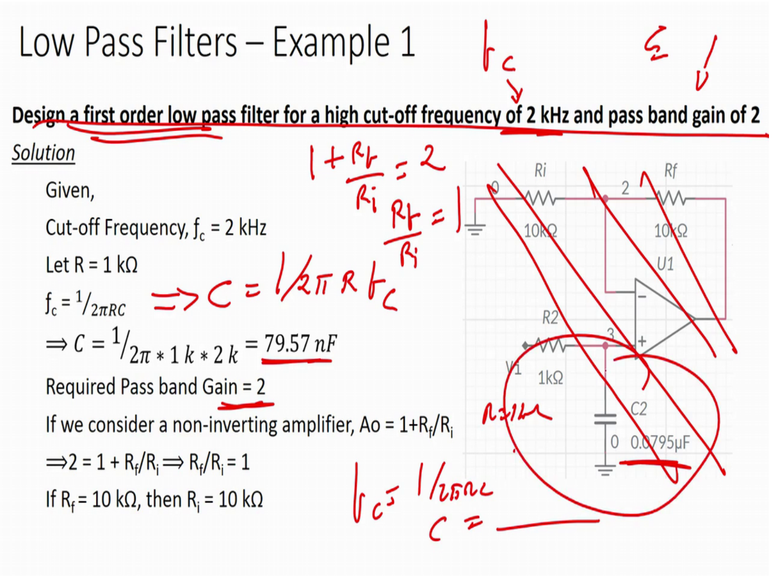

Than C would be implies C equals to 1 by C equals to 1 by 2 pi R into f c right C equals to 1 upon 2 pi R into f c. So, when you solve this when you substitute the value you know value of f c you know value of R, then you get C equals to 79.57 nano farad or this is the value right, required pass band gain is two so; that means, we have formula 1 plus R f by R i equals to 2 correct.

Now, if there is a case; that means, my R f by R i R i would be 1 2 minus 1 right, now what is my R f I do not know right I do not know suppose you have to design it right, because design a low pass filter. Suppose this things are not given this things are not given and you are only given the value of R you are only given the value of R right or that is also not given, let us say that is also not given, then how can do you design the filter how you can design the filter right.

Only if I give you only if I give you this particular problem that you have a cut off frequency f c of 2 kilo hertz and gain of 2 based on that how you can design the filters. So, now, since we know f c equals to 1 upon 2 pi RC we can say let us R equals to 1 kilo ohm right and C we can find, then we can substitute R and C is available.

Now 1 plus 2 pi 1 plus R f by R i that is your non inverting amplifier gain, when you substitute the value of R f and R i, we do not know value of R f and R i but we know value of gain. So, we know that R f by R i will be equal to 1, because 1 plus R f by R i equals to 2 so, R f by R i equals to 2 minus 1 you will 1.

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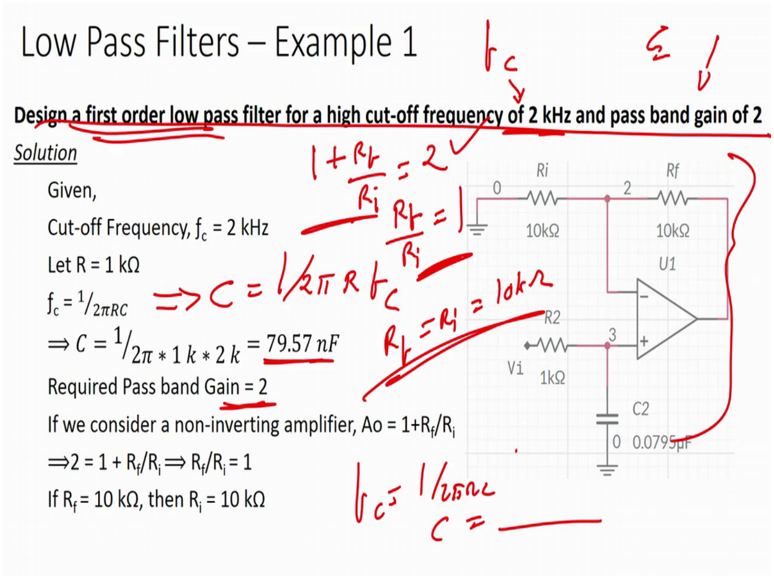

So; that means, that R f R f right should be equals to R i, we can take any value let us say 10 kilo ohms now you have value of R f R i, you have value of C you have value of R. And then you can be based on this particular values, you can design this low pass low pass filter low pass active filter right easy super easy right.

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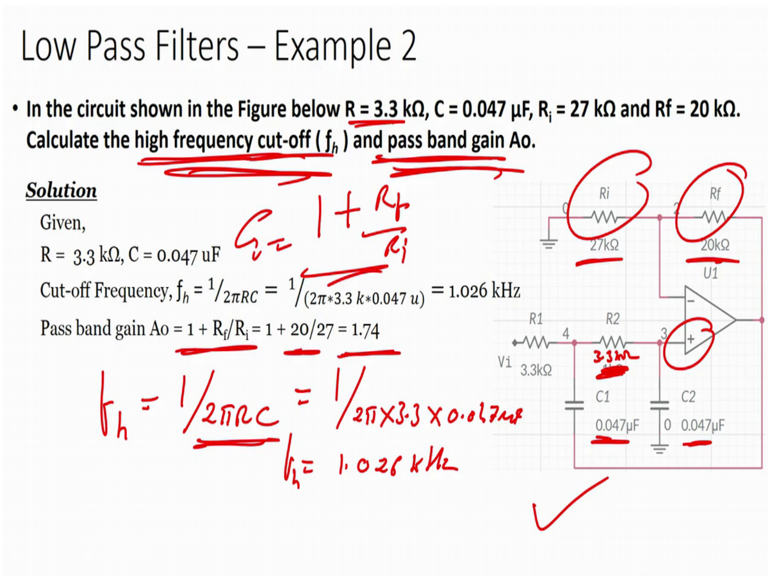

Let us take one more example if there was easy in the circuit shown figure. So, now, if you are given a circuit R equals to 3.3 kilo ohm is already given right C equals to 0.047

Pico micro farad, both capacitors are same R i also given 27 kilo ohm R f is also given 20 kilo ohm calculate the frequency high frequency cut off or f h and pass band gain A o.

Two things you have asked one is to find the cut off frequency. So, f c equals to or high cut off frequency can also be generated by f h, f h is equals to 1 upon 2 pi RC I have all the values, because you see R is just R it is given right R; that means, that this both resistors should be equal both resistor should be equal sorry, R is given which is your 3.3 kilo ohm right and then your capacitor C is given 0.47 this one.

So, now if I substitute the value I will have 1 upon 2 pi what is R 3.3 into what is C 0.047 micro farad 0.047. So, this is not 1 kilo ohm you consider this also 3.3 kilo ohms alright. So, what will be answer will be 1.026 kilo hertz what is that by f h that is my high cut off frequency.

Now, what I am asked I am asked to find the pass band gain what is pass band gain, this is the again your non inverting amplifier we know the pass band gain R f by R i value is given yes R i given yes very easy gain, equals to this particular formula, substitute the value and you will see gain of 1.74 you will find the gain of the low pass active filter, you will find the gain of the low pass active filter alright guys.

So, the point is the point is given the values, you can design the circuit right and given the circuit, you can find out the values both ways now you can do it given a values, you can design a circuit of a filter and given a circuit you can find the values of the filter what are the values of the filter cut off frequency gain, resistor, capacitors correct. So, in this particular module what we have seen is low pass low pass filter, we have seen the passive filter, we have seen the active filter, we have seen the some of the examples of low pass and high pass low pass active filters right.

Now, in the next module what will see, will see the how the high pass active filters can be used how we can use the high pass active filters ok. So, I will see you in the next module and let us see how we can design the operational amplifier, how we can design the high pass active filters using the operational amplifier alright. Till then, you just look at the thinks that I have taught you in this particular module and I will see you in the next class till, then you take care bye.