Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture – 25
Operational Amplifier as a High Pass Filter

So, welcome to this module and in this particular module, we will see how the high pass filter can be designed using the operational amplifier. So, guys, until now what we have seen? We have seen how you can use operation amplifier for designing the low pass filter.

So, and we also seen what are the passive and active filters. So, when you talk about the low pass active filters what we have seen we have to use a amplifier and in this particular case, the last module; what we have seen? We have used a operational amplifier. Now how we can design a high pass active filter using operation amplifier that is the thing that we had to learn in this particular module, alright.

So, if you if you see the screen what you can find is there are high pass filter is a filter that significantly attenuates. So, if you can please show the screen please.

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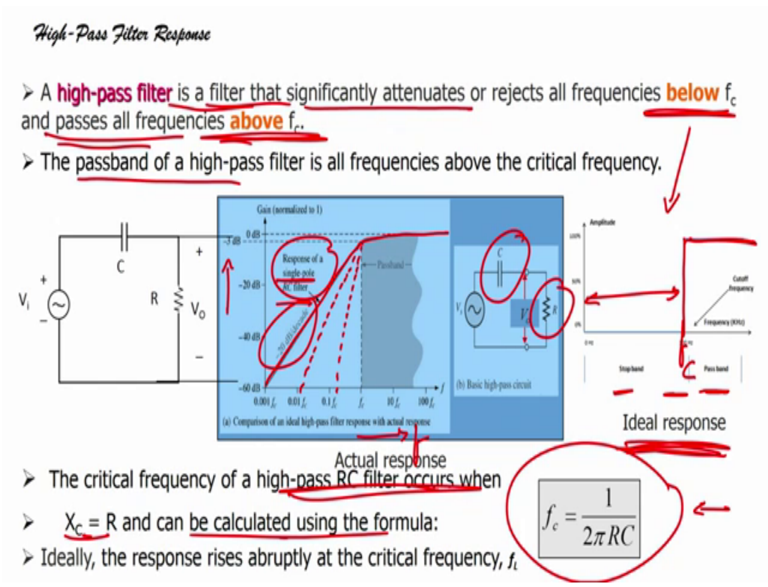

A high pass filter is a filter that significantly attenuates or rejects all the frequencies below f c below f c and pass passes all frequencies above f c. So, what is that filter a filter is that all the frequencies below f c it will reject while above f c it will it will pass.

So, what is that f c? F c is our critical frequency we have seen in the last lecture, what is f c? F c is nothing, but our critical frequency. So, now, when we hear the main thing is that you will see which is different than the low pass filter is the is the placement of the R and C, right, in the low pass filter, there was the resistance was here resistor was here and capacitor was in this particular place correct in high pass filter we have capacitor followed by the resistors followed by the resistor.

The passband of a high pass filter is all frequencies above critical frequencies. So, now, let us see what exactly a high pass filter is. So, if you see this particular plot what we find is that it will allow or it will allow frequencies which are above critical frequencies.

In the last module, what we have seen we have seen low pass filter; that means, the frequency below critical frequencies were allowed to pass right band frequencies below for critical frequencies were allowed to pass while in case of high pass filter the band of frequencies above critical frequencies are allowed to pass, right. So, this is an ideal response as you can see there is again of brick wall, it is a ideal response exactly at f c, it will stop the frequencies right here this is a stop band and this is a pass band this is a stop band this is a passband, right.

So, now if I draw a gain versus frequency gain versus frequency what I see is that I will have a plot like this, I will have a plot which is which is exactly opposite to that of a low pass filter which is exactly opposite to the low pass filter. Now what is the next again, I can see the response of single pole you now know what is single pole we have discussed in the last module what does single pole means and what you mean by first order what you mean by second order low pass filters and now we will see the high pass filters here a single pole R C filter that is only 1 R, 1 C, you can generate a voltage across this resistor and then you can see that because it is single pole R c or first order R c filter it has a role of rate of 20 dB per decade it is a role of rate of 20 dB per decade.

If I have second order low V second order high pass filter, then I my role of rate would be 40 dB, third order high pass filter my role of rate would be 60 dB. So, as you increase the order you reach your; you reach your ideal response correct.

Now the critical frequency of a high pass R C filter occurs when; what is the formula? Formula is similar to your formula is similar to your low pass filter that is f c equals to one upon 2 pi R c right same formula, we have used for the low pass filter as well, right. So, this is the critical frequency formula for active filter for the high pass filter and here x equals to R can be calculated using the formula which is here which is given here idly the response rises abruptly at the critical frequency f l hm.

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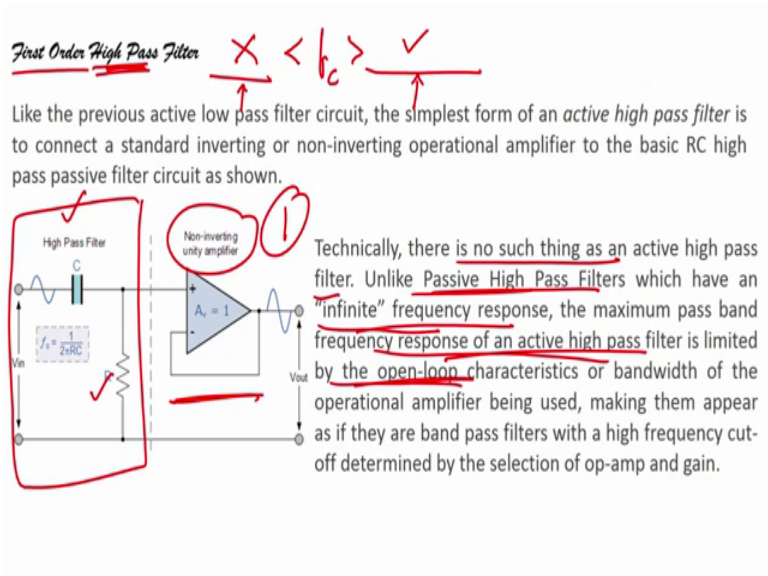

So, here critical frequency would be f l. Now if I talk about active filter right active filter first order high pass. So, 3 things first is first order first order because 1 R, 1 C, then high pass because it will allow the high frequency to pass frequency which is above my critical frequency, right, frequency which is greater than my critical frequency is allowed to pass frequency which are less than my critical frequency it will stop right. So, this will be my stop band this will be my pass band, alright.

Then we have active filter active filter because we are using a non inverting amplifier we are using it non inverting amplifier. So, this we will all we will see in the experiment part also how we can design the inverting amplifier how we can design an non inverting amplifier how we can design integrator how you can design differentiator what is the role of ground what is the role of loading effect we will see everything in the experimental section as well, alright.

So, if you see back screen what you will see is like the previous active low pass filter the simplest form of active low high pass filter is to connect a standard inverting or non inverting operation amplifier to basic R C high pass active filter high pass passive filter; that means, said we have this passive filter and you are connecting this passive filter to either inverting or non inverting or unity gain amplifier right if here the gain is one, but if I want a higher gain I can use inverting or non inverting amplifier here we are using unity gain amplifier right. So, technically there is no such thing and then hike active high pass filter unlike passive high pass filter we which have an infinite frequency response the maximum pass band frequency response of active high pass filter is limited by open loop characteristics right we have seen or bandwidth our op amp being used.

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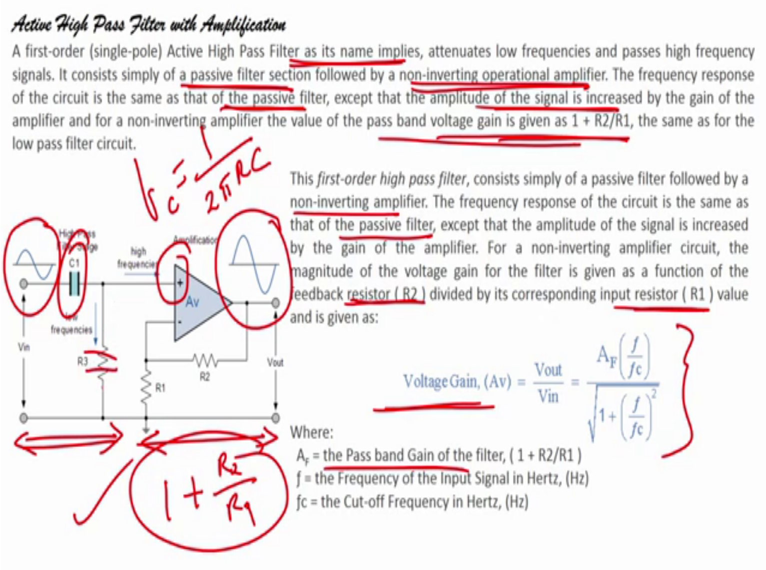

So, what kind of high pass active filter we can design and what will be the voltage gain in case of active high V active high pass filters. So, right what we have seen now is that we are using active high pass filter with unity gain amplifier right with unity gain amplifier here, but what if I want to amplify the signal then I need to use the I had to use the inverting or non inverting amplifier here I am using a non inverting amplifier as you can see the output of the filter is fed to the non inverting terminal of the operational amplifier.

Is not it correct. So, a first order a first order active high pass filter as it name applies as it name implies attenuates low frequencies and passes high frequency signal correct it consists simply of a passive filter passive filter section followed by a non inverting operational amplifier we have seen here this are passive filter right and this is our non inverting op amp the frequency response of the circuit is same of the act passive filter frequency response is same the formula would be f c equals to one upon 2 pi R C, right, except that the amplitude of the signal is increased by the gain of the amplifier right because here we have a non inverting amplifier my DC gain would be nothing, but one plus R 2 by R 1, right.

So, we can change the gain and that is why the symbolic representation of the signal at the input and the output we can see that the output is magnified version or amplified version of the input, correct. So, what we have seen the frequency response of the circuit is same as of passive filter; however, the amplitude of signal is increased by the gain of the amplifier and for a non inverting amplifier the pass band voltage gain is 1 plus R 2 by R 1 we already talked about it and that is the same as for the low pass filter.

The first order high pass filter consists of passive filter followed by an non inverting amplifier it is shown here the frequency response of the circuit is same as that of passive filter right for in non inverting amplifier circuit the voltage gain for the filter is function of feedback resistor R 2 divided by R 1 voltage gain here is a f; f by f c of under root of 1 plus f by f c whole square right.

We have seen what is a f. The f is something, but pass band gain formula is same which is same formula of a low pass filter the only difference here is now we are passing the signal through the capacitor and then it feds to the register earlier the signal were passing through resistor and the capacitor was placed here in the low pass filter right that is only one difference which you will find in low pass and high pass active filters these are very basic circuits of the operation amplifier. So, there should be no problem in understanding these kind of circuits super easy right super easy.

F c is a cutoff frequency in hertz that we have seen earlier also.

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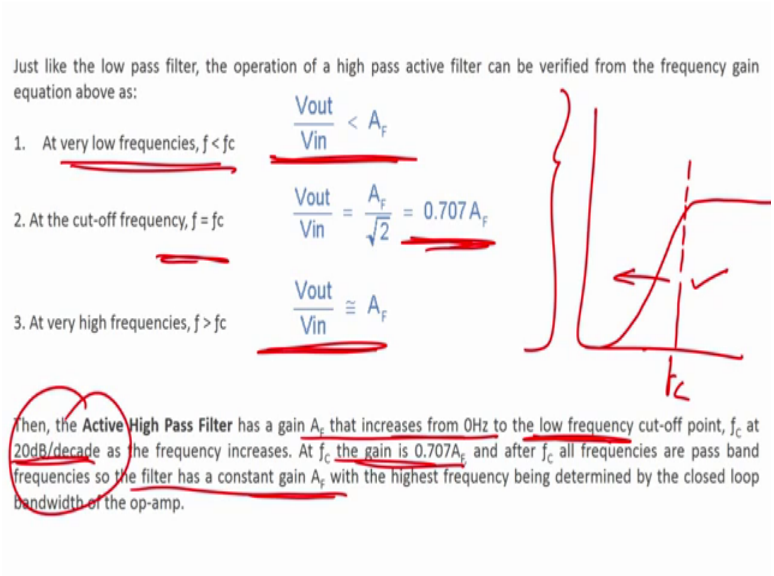

So, in this case, if I use this particular formula and if I see that at very low frequencies what will happen at very low frequencies my v out by v in will be extremely less than a f, but when f equals to f c, I will have the similar value point seven 0 seven, but at very high frequency my value will be equal to a f. So, then the active filter then the active filter the; so, what does that mean from the from the equation that we have found what; what we mean is that in the case of active filter it has again a f that increases from 0 hertz to low frequency cutoff point, right, if you see the screen, then you will understand better that active filter has a gain a f that increases from 0 hertz to low frequency cutoff point and f c has a 20 dB decade right a 20 decibels per decade.

If I have 2 second order I will have 40 dB per decade third order 60 dB per decade at f c equals to 0.7077 a f, this one right and after f c all frequencies are pass band frequencies the filter has a constant gain of a f, right. So, see; that means, if I start plotting the graph what I will see is I will see that it has plot like this right where this is my f c all frequencies above cutoff frequency that will be passed all frequencies below this cutoff frequency will be stopped; however, there is a role of rate like I said and this is a single order then role of rate is of 20 dB per decade right ok.

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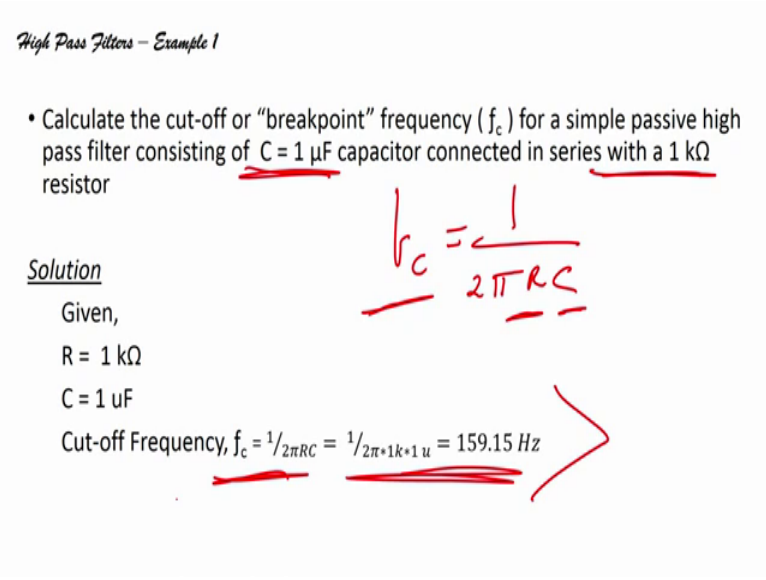

So, if I take an example if I take an example. So, if calculate the cutoff frequency or break point frequency f c; so, f c formula we can directly write one upon 2 pi R c or one by 2 pi R C for a simple passive; passive high pass filter consisting of capacitor c equals to one micro farad. So and connected in series with one kilo ohm resistor I have value of R I have value of C. So, I can find the value of f c, I can find value of f c, right.

So, my critical frequency or cutoff frequency f c is nothing, but one by 2 pi R C which is equivalent to 159.15 hertz is equivalent to 159.15 hertz. So, this is how I can calculate the cutoff frequency of the high pass filter.

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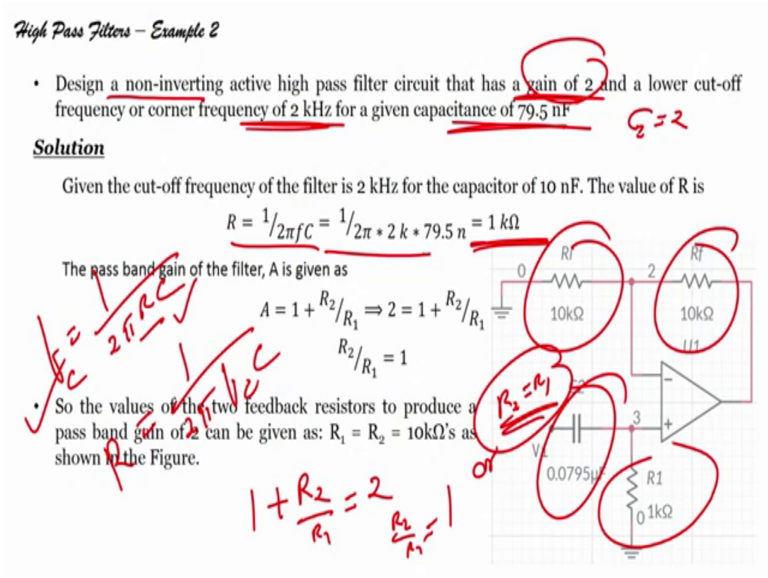

Let us say another example design. Now you see you have to design; design a non inventory active high pass filter such that gain equals to 2 low lower cutoff frequency or corner frequency is 2 kilowatts and capacitance of 79.5 nano-farad, alright these 3 things are there

So, first is gain equals to 2. So, I have gain equal to 2, right, non inverting amplifier non inverting amplifier my gain is 1 plus R 2 by R 1 is given as 2. So, R 2 by R 1 will be equal to 1, right or R or R 2 will be equal to R 1 very easy right. Now frequency is given c is given. So, I can find our f equals 2 or f equals to one upon 2 pi R C; R is given f c is given sorry, here what is given C is given.

C is given f c is given then R equals to R will be one upon 2 pi f c into C, I substitute the value and what I will have value of our now I know the value of R I know that what should be R 2 and R 1 R 2 and R 1 should be equal to 1 or R 2 should be equal to R 1. So, I can design R 2 R 1 I know the capacitor I found the value of resistors thus I can design this particular circuit which is shown here which is shown in the bottom right which is this particular circuit right I can design this circuit given this particular values which is the value of again value of the cutoff corner frequency and the value of the capacitance.

So, if I am given these values and if I am if I had to find the value if I had to design the circuit that is my high pass active filter I can design by using this particular values or if I am given a circuit I can design my I pass filter both the ways I can do it.

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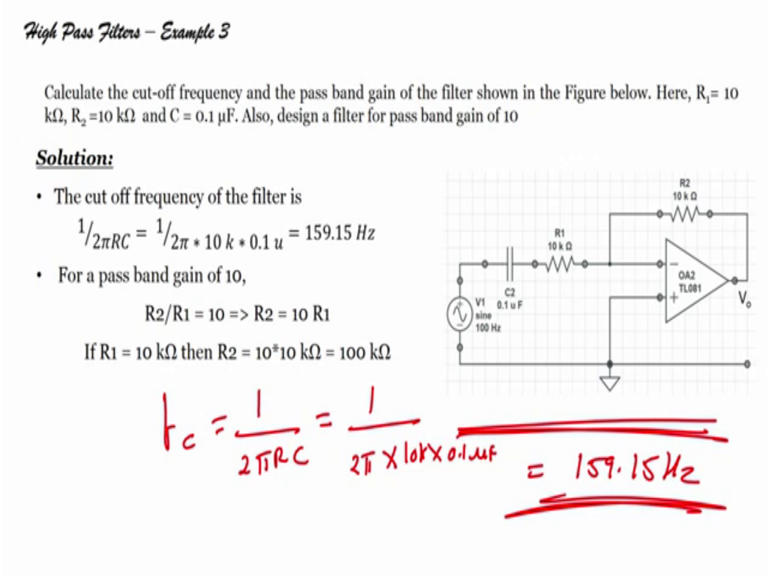

So, let us see one more example calculate cutoff frequency and the pass band gain of filter shown in the figure. So, suppose you are given this figure right. So, what is this figure this is nothing, but my this is nothing, but my high pass active filter right high pass active filter now what I had to find I had to find the I had to find the cutoff frequency; that means, I had to find f c right f c is one upon 2 pi R C.

Now, R 1 is given R 2 is given c is given right. So, I can write down one by 2 pi into 10 k into point one microfarad this will be nothing, but 159.15 hertz right. So, f c is nothing, but 159.15 hertz correct. So, now, I know; what is my critical frequency I can calculate critical frequency using this particular formula.

What is the next question next question is for a pass band gain of 10 that is I have a gain of 10, right.

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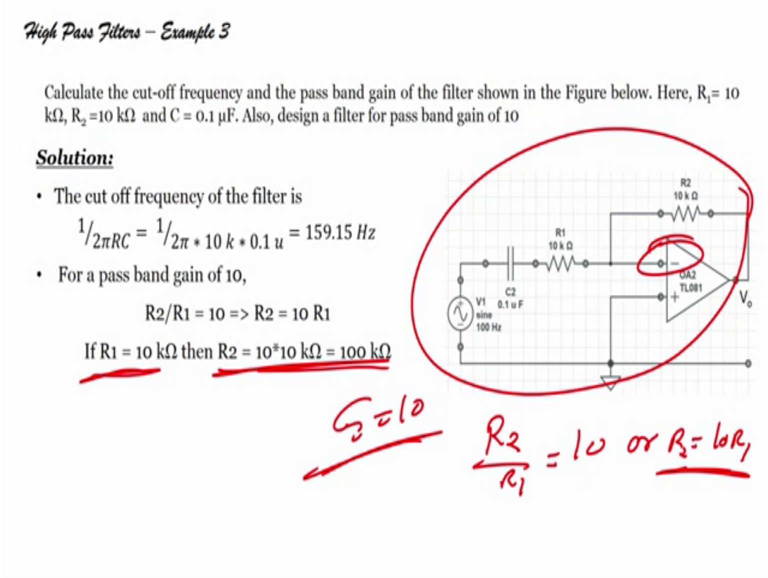

So, here it will be R 2 by R 1 equals to 10, right why because inverting amplifier it is a inverting amplifier. So, R 2 by R 1 equals to 10 or R 2 would be equal to 10 times R 1 right.

So, if I take R 1 equals to 10, R 2 would be hundred kilo easy super easy right super easy to design or to calculate the cutoff frequency given the circuit right. So, now, we have seen if we are given the value we can design the circuit if the circuit is there we can find the values circuit is there we can find the values, right.

So, what we have seen in this particular module, we have seen that we can design a active filter we can design a active filter using the operational amplifier and then if you are given a circuit then you can find the values of the resistor capacitors or frequency and or if you are given the values you can design the circuit which is this particular problem which is a problem in front of you right.

So, now the point is that with the operation amplifier with the operation amplifier we can design filters with the operation amplifier we can design filters that can allow a certain band of frequencies to pass and certain band of frequency to stop, right. So, we have seen, in this particular module high pass filters we have seen high pass filters the main difference between high pass and low pass filter that you guys have to remember is that in the high pass filter the capacitor is at the starting and the resistor is next; in the low pass filter we feed the value to resistor and then to capacitor right.

So, the signal goes to the resistor and then it goes to the capacitor, but in the high pass filter it is opposite of that alright. So, we have seen low pass we have seen high pass now in the next module we will see how the band pass filter works and in your following module we will also see how the band reject filter works. So, that is the main four filters that we have talked about right low pass high pass band pass and band reject alright.

So, let us in the next class how we can design a band pass filter using an operational amplifier how we can design band pass filter using operation amplifier till then, you solve this kind of questions like what I have shown it to you there are millions of questions that is available online try to solve few more questions and you will get a better idea right. So, we will start we are starting at a very basic level where you are you are asked to find the formula of a cutoff frequency right while given everything is given. So, there should be no mistake in this right or if for the given values of resistors or capacitor or vertical frequency how you can design the circuit. So, it is it is really-really simple, alright.

We are at a very very basic stage. So, you should not be able to you should not commit any mistake in designing such a simple circuits alright now one more point that I wanted to tell you is that when some sometimes you are asked that design high cut filters high cut active filters. So, what I have seen that when you are as high cut active filters high cut is low pass right it is cutting high frequency it is not high pass. So, when you are given this kind of problem just read it thoroughly it is this high cut is it low cut is it high pass is it low pass what does that mean low pass and high cut same high pass low cut same right.

So, understand this when you when you are doing a problem read it thoroughly when you are asked a question understand listen the question carefully then you respond alright listen carefully everything then only you respond then it will help you not only in your exams that will help you also in your interviews alright.

So, I will catch you in the next class next particular module and then we will see how the op amp circuits can be used as a band pass filter till then you take care, bye.