Electronic Systems for Cancer Diagnosis
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Lecture - 32
Basic building blocks of Electronics System: Filters (contd.)

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

Now, how we can design high pass active filter using operational amplifier that is the, that is the, thing that we had to learn in this particular module, all right. So, 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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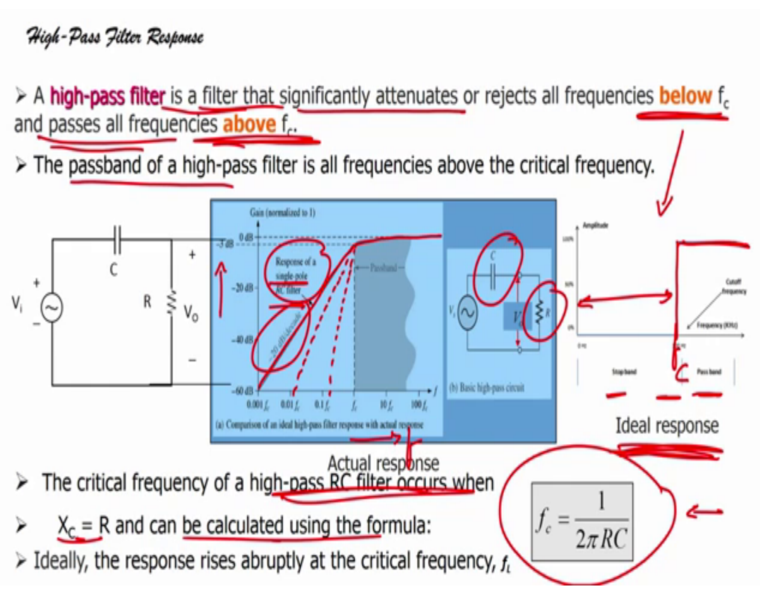

A high pass filter, is a filter that significantly attenuates or rejects all the frequencies, below f c, below f c and pass passes all frequencies above f c ok. So, what is that filter? A filter is, that all the frequencies below f c it will reject, while above f c it will; pass.

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 apply here the main thing that you will see, which is different than the low pass filter 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 pass band, of a high pass filter is all frequencies above critical frequency. 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, 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 of frequencies, below critical frequencies; were allowed to pass and in case of high pass filter, the band of frequencies above critical frequencies are allowed to pass right. So, this is the ideal response, as you can see; there is again a break wall. It is a ideal response exactly at f c. It will stop the, frequencies right here. This is the stop band, and this is a pass band; this is a stop band, this is a pass band right.

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 single pole is, we have discussed in the last module, what does single pole means, and what you mean by first order? What do you mean by second order low pass filters? And now we will see the high pass filters.

Here single pole R C filter there is only one R one 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 Cfilter, it has a;, roll off rate of 20d b per decade, is the roll off rate of 20 dB per decade. If I have second order; second order high pass filter. Then I by roll off rate will be, 40 dB, third order high pass filter, my roll off 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, when what is the formula? Formula is similar to your, formula is similar to your low pass filter. That is f c equals to 1 upon 2 pi R C right, same; 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 C equals to R can be calculated using the formula which is here, which is given here, ideally the response rises abruptly; at the critical frequency, f L hm. So, here critical frequency would be f L.

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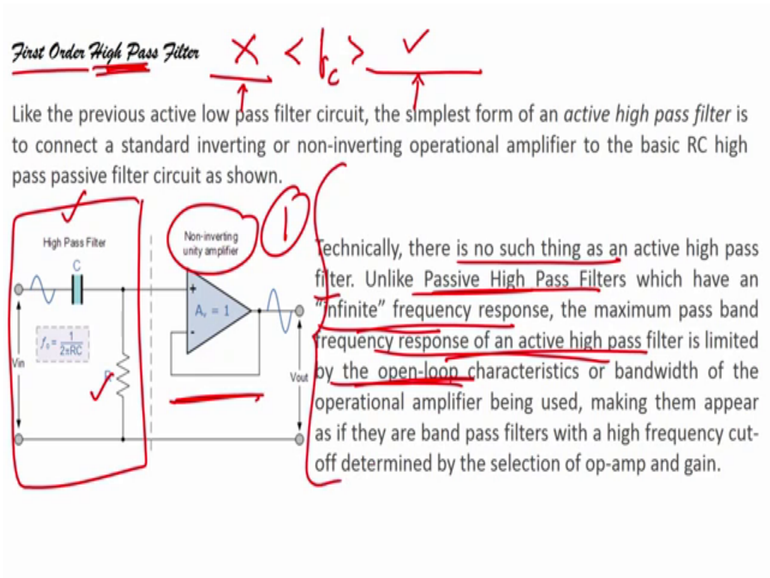

Now, if I talk about, active filter right. Active filter, first order high passes. So, three things, first is first order; first order, because 1 R 1 C. Then high pass, because it will allow; the high frequency to pass frequency which is above my critical frequency, right? Frequency which is greater than my critical frequency, 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 right. Then we have active filter, active filter, because we are using a non inverting amplifier; we are using a 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 we 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, all right. 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, that 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 1, but if I want the 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, as an high active high pass filter, unlike passive high pass filter; 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 bandwidths are op amp being used.

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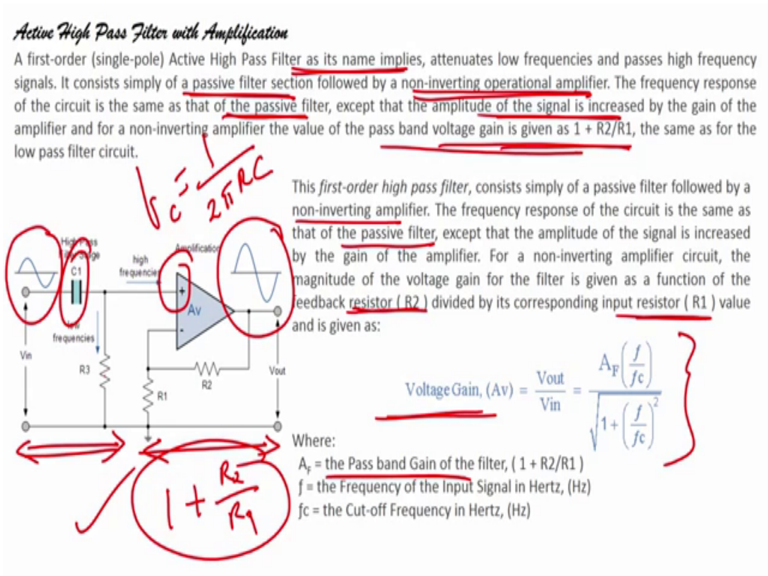

So, what kind of high pass active filter we can design? And, what will be the voltage gain in case of active high pass, active high pass filters? So, what we have seen now, is that we are using active high pass filter, with unity gain amplifier right; with unity gain amplifier here. But what if I want to amplify the signal? Then I need to use the, I have 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 isn't 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 signals correct. It consists simply of a passive filter, passive filters action, followed by a non inverting operation amplifier.

We have seen here, these; the passive filter right and this is our non inverting op amp. The frequency response of the circuit is same of the passive filter. Frequency response is same, the formula would be f c equals to 1 upon 2 pi R C right. Except that the amplitude of the signal is increased, by the gain of the amplifier. why? Because here we have, a non inverting amplifier, my DC gain would be nothing, but 1 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 consist of, passive filter followed by non inverting amplifier; it is shown here. The frequency response of the circuit is same as that of passive filter right, for a non inverting amplifier circuit, the voltage gain for a filter is function of feedback resistor R 2 divided by R 1 voltage gain here, is A F f by f c under root of 1 plus f by f c whole square right.

We have seen what is A F? A F is nothing, but pass band gain; formula is same; which is same formula of low pass filter, the only difference here is now, we are passing the signal through the capacitor. And then it feds the resistor, earlier the signal were passing through the 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 operational amplifier. So, there should be no problem in understanding, this kind of circuits, super easy right; super easy. f c is the cut off frequency in hertz, that we have seen earlier also.

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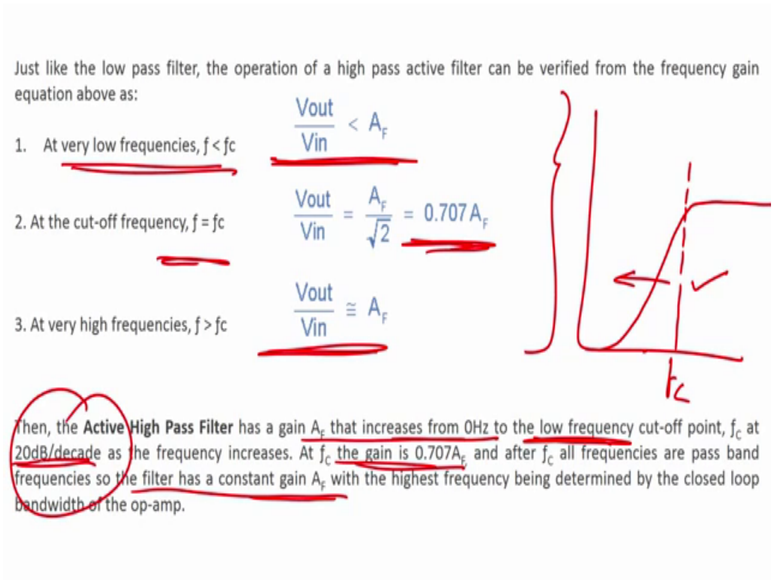

So, in this case; if I use this particular formula, and if I see that at very low frequencies; what will happen? at very low frequencies my out by V in will be extremely less than A F. But at f equals to f c, I will have the similar value 0.707, but at very high frequency my value will be equal to A F.

So, then the active filter, then the active filter the; so what does that mean? From the, equation that we have found; what we mean is, that in the case of active filter, it has a gain A F. That increases from 0 hertz to low frequency cut off 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 cut off point.

And f c has a 20 d B decade right. 20 decibel per decade, if I have two second order, I will have 40 dB per decade, third order 60 dB per decade, at f c equals to 0.707 A F, this one right. And after f c all frequency error pass, and frequencies the filter has a constant gain of A F right. So, see ah; that means, if I start plotting the graph, what I will see is, I will see that ok. It has plot like this, right where this is my f c. All frequencies, above cut off frequency, that will be passed. All frequencies below this cut off frequency will be stopped; however, there is a roll off rate like I said and this is a single order then roll off rate is of 20dB per decade right, ok.

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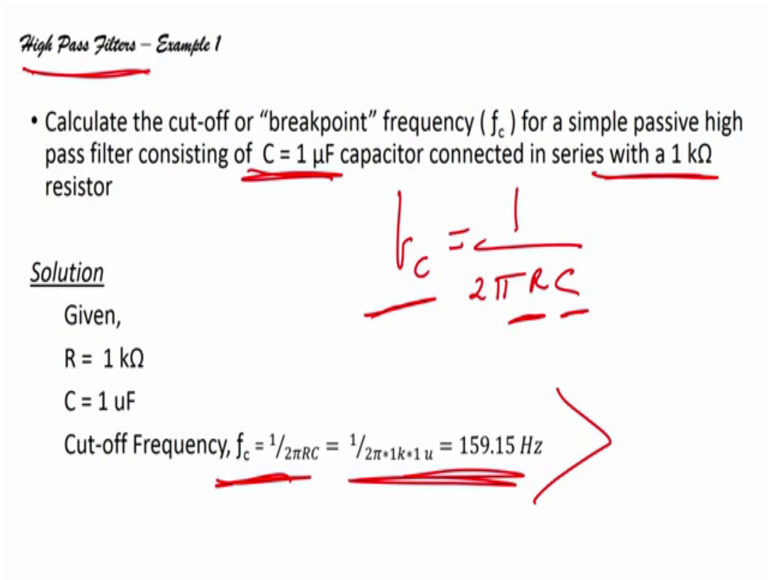

So, if I take an example, if I take an example. So, if calculate the cut off frequency or breakpoint frequency f c ok, say f c formula we can directly write 1 upon 2 pi R C or 1 by 2 pi R C, for a simple passive; passive high pass filter, consisting of capacitors C equals to 1 micro farad ok. So and connected in series with 1 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 cut off frequency f c is nothing, but 1 by 2 pi R C which is equivalent to 159.15 hertz, is equivalent to 159.15 hertz. So, this is how I can, I can calculate the cut off frequency of the high pass filter.

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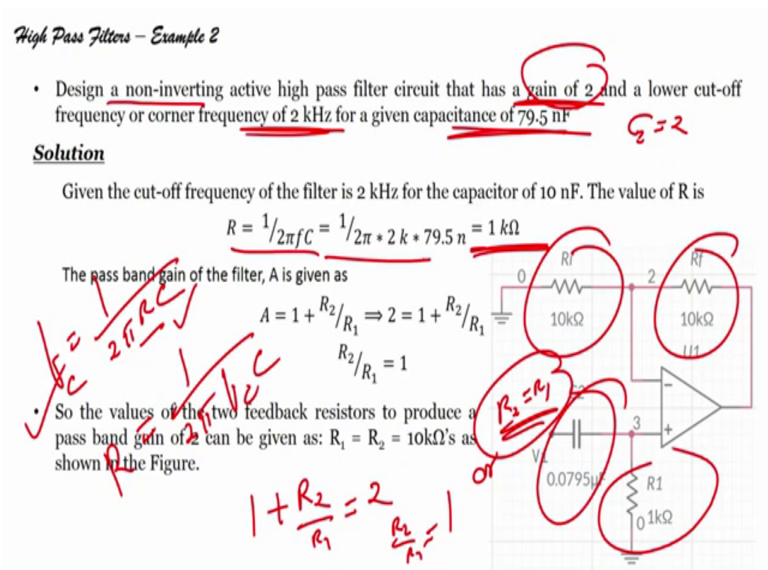

Let us say, another example design, that you see you have to design ok. Design a non inverting active high pass filter such that gain equals to; low, lower cut off frequency or corner frequency is 2 kilo hertz. And capacitance of 79.5 nano farad, all right; these three things are there. So, first is 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, frequency is given, C is given. So, I can find R f equals to, or f c equals to 1 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 1 upon 2 pi f c into C. I substitute the value and what I will have? I will have value of R.

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 value of a gain, value of the cut off corner frequency; and the value of the capacitance?

So, if I am given this values, and if I am, if I have to find the value, If I have 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 high pass filter both the ways I can do it.

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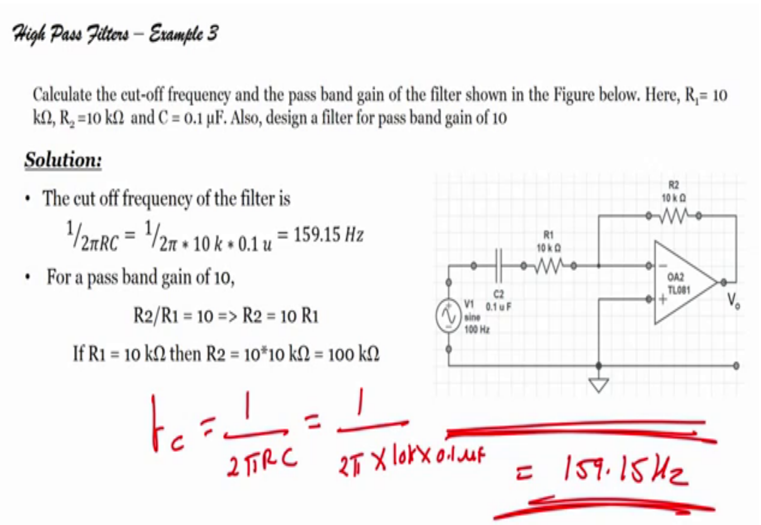

So, let us see one more example, calculate cut off frequency; and, and the pass band gain of filter, shown in the figure. Now suppose you are given this figure right. So, what is this figure? This is nothing, but my; this is nothing, but my high pass active filter right, high pass active filter. Now what I have to find? I have to find the cut off frequency; that means, I have to find f c right. f c is 1 upon 2pi R C ok. Now R 1 is given, R 2 is given, C is given, right. So, I can write down, 1 by 2 pi into 10 k into 0.1 micro farad; 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 my critical frequency, using this particular formula.

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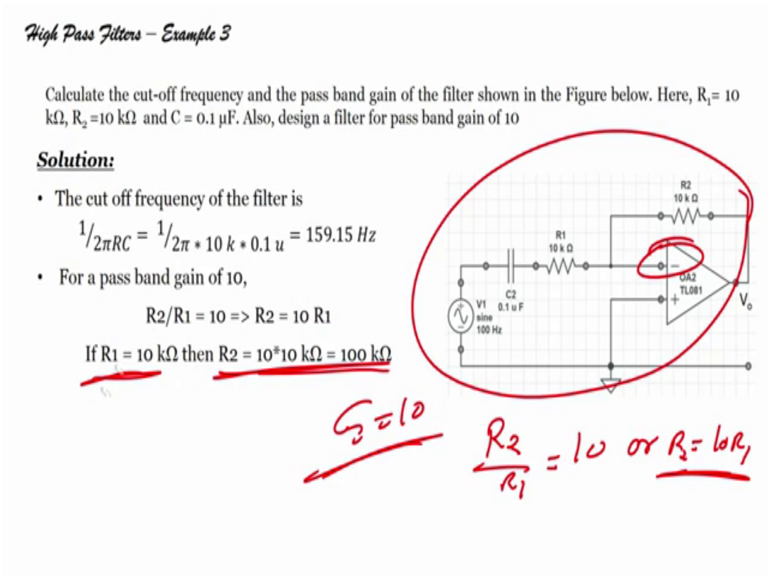

What is the next question? Next question is; for a pass band gain of 10. That is I have a gain of 10, right. So, here it will be R 2 by R 1 equals to 10 right. Why? Because the inverting amplifier, is a inverting amplifier. So, R 2 by R 1 equals to 10 or, or R 2 would be equal to 10 times R 1 right. So, if I take R 1 equals to 10 R 2, would be 100 kilo ohm, easy super easy right, super easy to design or find, or to calculate the cut off frequency, given this 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, what 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 from of you right.

So, now the point is that, with the operational amplifier, with the operational amplifier, we can design filters with the operational amplifier. We can design filters, that can allow a certain band of frequency 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 filters 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 its opposite of that all right.

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 the following module we will also see, how the band reject filter work? So, that is the main four filters that we have talked about right low pass high pass band pass and band reject all right.

So, let us see in the next class, how we can design a band pass filter using an operational amplifier, how we can design a band pass filter using operational 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 all right. So, I will catch you in the next class, next particular module. And we will see how the op amp circuits can be used as a band pass filter till then you take care bye.