Integrated Circuits, MOSFETs, Op-Amps and their Applications
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Lecture - 54
Experiment: Passive and active high pass filter

Welcome to this module. And what we have seen? We have seen in the last module that what are the application of operation amplifier, right. So, when we talk about the operational amplifier we have seen filters, and in the last model we have seen low pass filter before low pass filter we have seen differentiator. We have seen integrator and how differentiator and integrator can be used right.

So, what we can do ? We have to learn more, right? You do not stop learning and this time I brought you another set of experiments, which we have already studied in the theory class. And that are another type of filter. So, if you remember, or if you recall yesterdays or day before yesterday's I do not recall whenever I have recorded the class, but some module or I think previous module, we have seen the low pass filter, right.

And we have also seen the type of filters, that is depending on the element, it can be passive filter, it can be active filter, right? If it is just a resistor of capacitors or inductors passive resistors capacitors op amp active, right. And then we have also seen the filters based on the frequency, like, if it is if it is allowing the low pass frequency to pass and it rejects high pass, then it is low pass filter, right. If it allows high pass frequency to pass, and it is low pass frequency, it is high pass filter. Same way we said band pass filter, same way we said band reject filter, and we said all pass all passes nothing but it will pass all the frequency, correct?

So, when we talk about a high pass filter, what does high pass filter means, right? It will allow a certain set of frequency that we want at high frequency it will allow and low frequency it will reject. So, if you if you again recall one was circuit for low pass filter was the capacitor at the setting a resistor was there or resistor was the stopping and capacitor was there what was that? Resistor was at the input and then you had a capacitor isn't it? And then you used the differentiator you also used indicator that also kind of filters only, right but anyway what we are trying to do today is we are understanding how we can design the high pass filter. Before we come to the designing of a high pass filter, using the using the equipment that we love to our heart, right. Which is very near to our heart; which is function generator DC power supply oscilloscopes. Every time I am using the same kind of equipment, right, more or less, and using this 3 equipment, we are performing so many experiments with the operational amplifier, right?

And of course, we use multimeter and breadboard and IC. So, let us see high pass filter in this module, and we will perform the experiment, and then we will take a break and we will continue another module, right. So, if you look at the screen today's lectures are divided into 3 parts, one is about the filters, and one about rectifiers. Then how it is 3 part? Because it filters there are many parts and rectifier we will see 2 different parts, and that is why I said it is divided into 3 parts. Or in fact, we can also say it is divided into 3 modules, alright, 3 modules ok.

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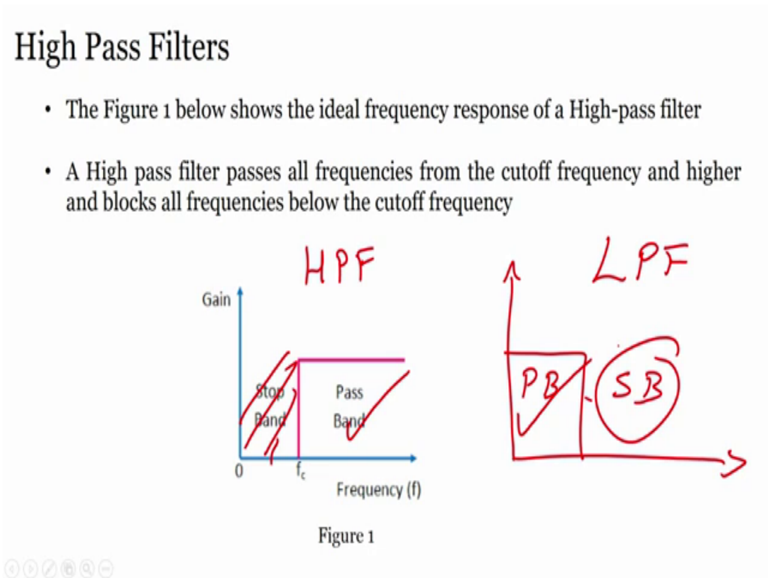

So, when you talk about the experiments let us see high pass filter. So, if you remember yesterday or day before yesterday or in the last lecture in fact, what we have seen? We have seen the low pass filter, right. Well what it will do? It will allow this is the pass band PB, this is top band SB, right? High pass filter, you see high pass filter, low pass filter, when you compare is absolutely opposite. It the frequency that is stopped here, that frequency is allowed to pass. The frequency which is passed here, that frequency is blocked here, right. So, this is the ideal plot for the high pass filter which you can see in figure one. You have y axis, which is your gain you have x axis, which is a frequency, right?

Now, we have seen that we had to write gain in decibels, we had frequency in hertz, correct?.

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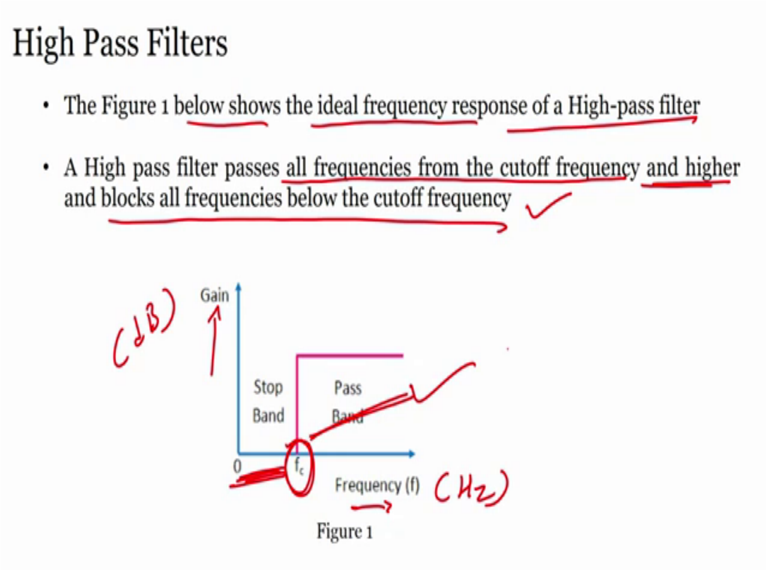

Now this is what is written, figure 1 below shows the ideal frequency response of a high pass filter, ok, a high pass filter passes all frequencies from the cut off frequency, all frequencies you see cut off frequencies here, it will pass all the frequency, from the cut off frequency and higher, and blocks all frequencies below the cut off frequency, and blocks all the frequencies below the cut off frequency. Now what happened? What was the case in low pass filter? It will pass all the frequency below the cut off frequency, in case of high pass filter, above or higher than cut off frequency, right?

So, it is very easy to remember low pass high pass you cannot forget it, because it is a same definition just a little bit of change, cut off frequency and higher and blocks all frequency below the cut off frequency. In that case, it was a cut off frequency and lower and cuts; unblocks all the frequency above the cut off frequency, very easy, above and below. In this case, it is below the cut off frequency it will block; that means, this is cut off frequency below this particular range it will block. This range above cut off frequency it will pass, right? This is what it means about high pass filter ok, now let us go to the next slide.

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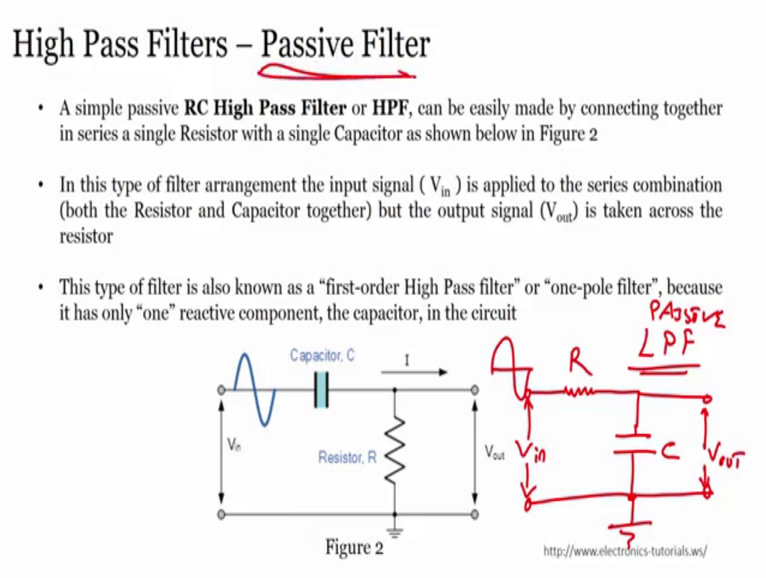

Now, we have seen the low pass passive filter, correct ? And if you remember the low pass passive filter it had a resistor, and it had a capacitor. So, if I draw a low pass filter, it has a resistor, and there was a capacitor, and we were measuring the output across the capacitor ground, right? This was our R was our C, here we were applying the input signal this was our V in, this is my low pass filter passive, passive low pass filter. What happens in high pass filter? High pass filter again passive filter, passive filter, in high pass passive filters, I have the capacitor taking place of the resistor, and resistor taking place of a capacitor in the low pass circuit, very easy.

It is interchange the position, right? Here if you see on the screen the resistor where it was there in low pass filter now we are keep placing a capacitor, where there was capacitor now we are placing a resistor, right, it is just interchanging the components. So, you cannot also forget the high pass filter circuit and low pass filter circuit when it comes to passive, right, very easy.

So now, now let us, clear our slide and see the first sentence of this slide, a simple a simple passive RC high pass filter, RC because there is a resistor, there is a capacitor, there is a resistor; the resistor and a capacitor. Low a simple RC high pass or high pass filter. I told you yesterday, last lecture low pass filter, high pass filter ok.

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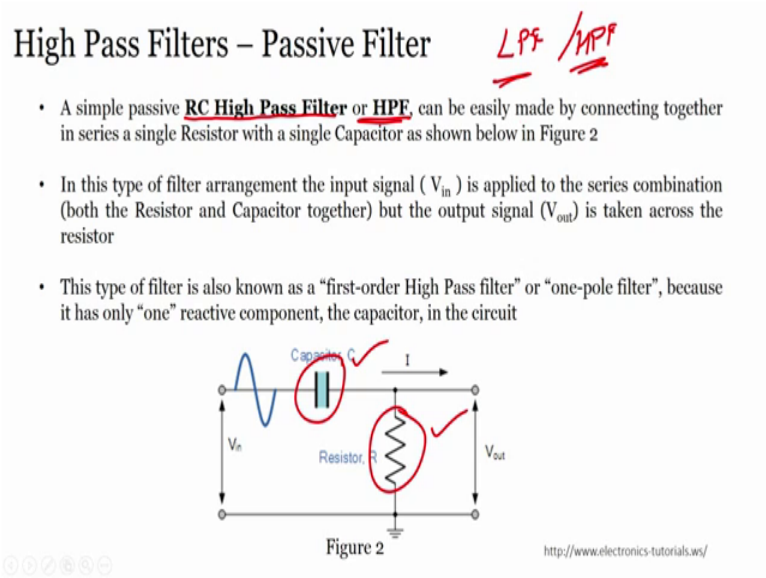

So, LPF, HPF, here we are written HPF, it is a high pass filter. So, simple passive high pass filter, can be easily made by connecting together a in series a single register with a single capacitor as shown in figure 2, as shown in figure 2, right? In this type of filter arrangement, the input signal V in input signal which is here, right, this one is applied to the series combination of both resistors and capacitors together. You see this capacitor is in series with register, right, this capacitor is in series with this resistor. So, the input signal is applied to the series combination of capacitors and resistors one. But the output signal is taken across the resistor, output signal is taken across the resistor, you can see here the V out is taken across the resistor, alright?

So, this type of filter is also called first order high pass filter. you remember when we use one R and one C, we also called it is first order high pass or first order low pass filter, this is first order high pass filter, right. Or it is also called one pole filter if you see screen, you will see we have also return it is called so called one pole filter, because it has only one reactive component, that is a capacitor in the circuit, right. Same thing exactly same sentence we have used in the low pass passive filter, that it is a first order low pass filter instead of high pass we suggest low pass, low pass if we will or one pole, because only one reactive component that is capacitor in the circuit, right?

So, it is very easy to understand high pass filter, let us quickly see what we have said, first thing that we have said is that a simple are a simple high pass filter can be can be designed by using one capacitor and one resistor, right. Second thing that we have said is that the signal is applied the signal is applied across series of this capacitor and a resistor, ? And the output is taken across the resistor. Finally, we say that this is a first order high pass filter or one pole filter. Because there is one reactive component and that is the capacitor, easy? Extremely easy to understand the high pass passive filter right.

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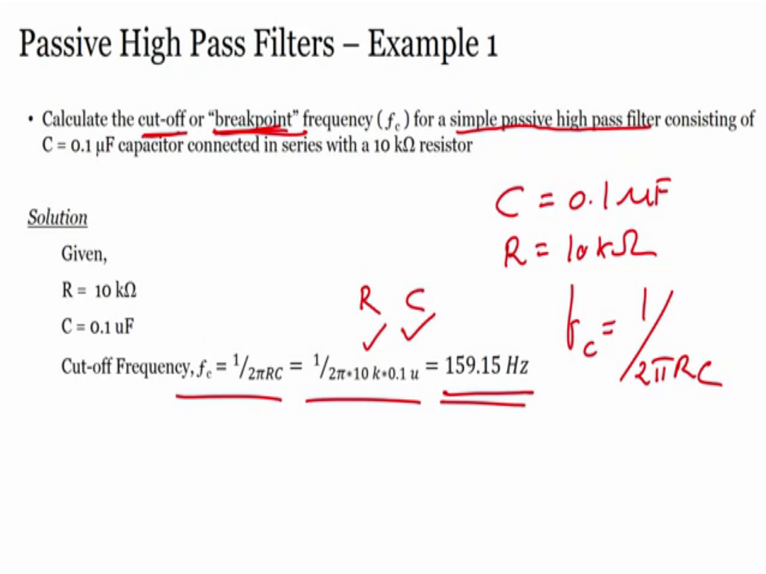

Let us go to the next slide. So, let us see this example, let us see the example, the example is that if you are asked to calculate if you are asked to calculate, the cut off frequency or break point frequency. So, cut off is also called break point, break point frequency for a simple passive high pass filter, for a simple passive high pass filter consisting of capacitor C equals to 0.1 micro farad connected in series with resistor R equals to 10 kilo ohm, right?.

What you have to find? Here to find the cut off frequency. Now we already know fc equals to 1 by 2 pi RC, right. We substitute the values so, if you see fc 1 by 2 pi RC that is 1 upon 1 upon 2 pi into 10 k 10 k is your R 1.1 micro farad is your C, right. When you solve it, you will find 159.15 hertz ok, very easy, extremely easy. The substitute the value and you will get the answer substitute the value will get the answer, alright.

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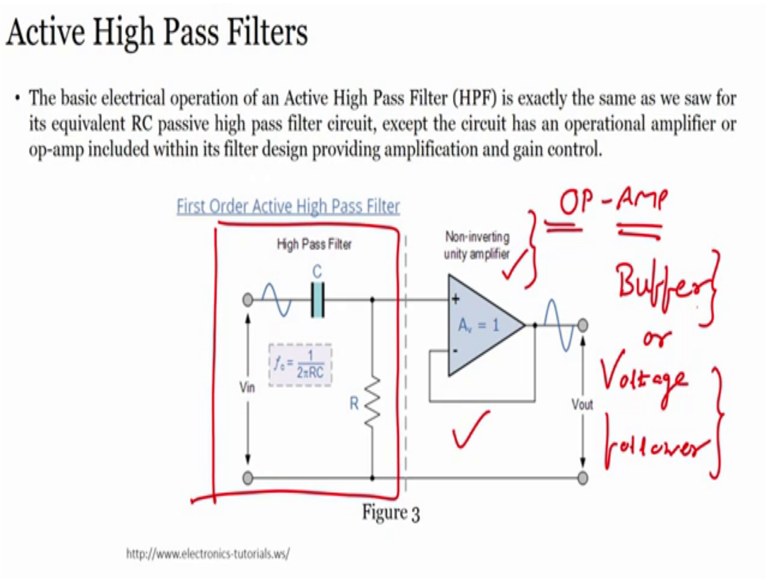

Now, how about active high pass filter, right. Now we are we have seen we have just seen passive high pass filter. Passive high filter was just one capacitor in series with a resistor, right? But when we talk about active high pass filter, we have to use active component, and active component is nothing but our amplifier our op amp op amp, right. What is op amp ?.

You all know, op am is nothing but operational amplifier. This is an active component, here we are using our favourite non-inverting unity amplifier, or buffer or voltage follower, right, is non-inverting unity gain amplifier or you can say buffer or you can say voltage follower. 3 names of the same circuit which is this one, right?

So, when we connect the passive high pass filter to the non-inverting unity amplifier, then we get active high pass filter, then we can get active high pass filter. We also see the instead of unity gain amplifier, we can also use inverting and non-inverting amplifier. So, we will see that in the next slides probably.

Now let us remove this same thing is written in on the slide, what is it written? That the basic electrical operation of an active high pass filter is exactly the same as we saw in the equivalent RC passive high pass filter, except that the circuit has a operational as an operational amplifier or op amp. Included within it is filter design, included within it is filter design providing amplification and gain control providing amplification and gain control.

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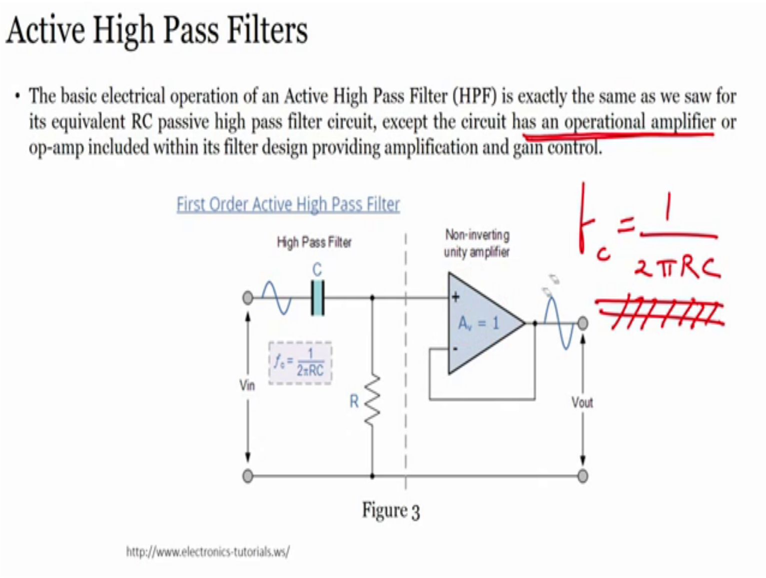

Here again remember your formula remains same fc equals to 1 upon 2 pi RC, fc equals to 1 upon 2 pi RC, alright?

So, when we connect this C, the R in series with the non-inverting unit again, because you see non-inverting we are applying to non-terminal. So, unity gain voltage follower, right? Unity gain amplifier because the gain is 1, a V equals to 1, right, this we all remember. So, it is very easy to define your active high pass filter, very easy to define active high pass filter. Now when you see here this is grounded, do not do not think that is not grounded. If we do not show that it is not grounded is not correct, because when you are taking voltage you are applying voltage and you are measuring voltage is always with respect to ground, it is always with respect to ground.

So, this is grounded, this is grounded alright. So, do not think that this circuit is not correct, this circuit is absolutely correct. So, do not get confused when you do not see any ground, when you apply voltage is nothing but voltage difference between 2 points, right. One point is your signal another point is ground.

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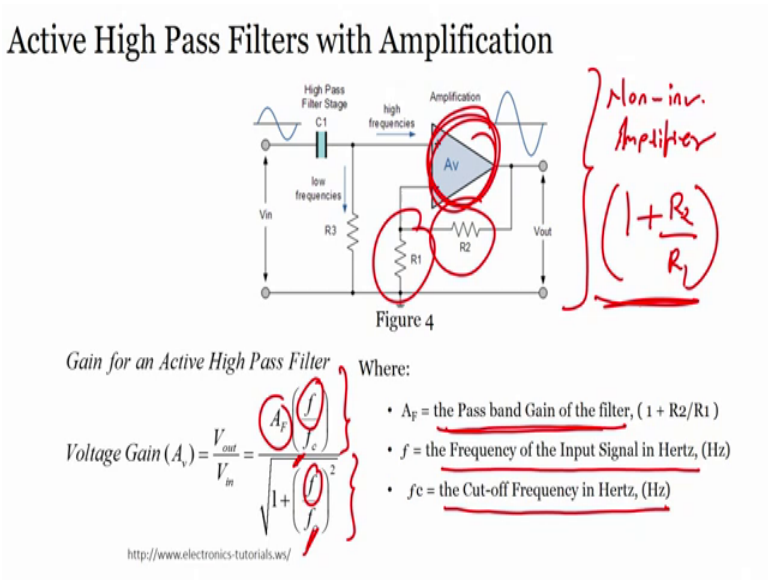

Now, let us see if I use, a non-inverting amplifier a non-inverting amplifier for the amplification along with the passive RC filter, along with passive RC filter. So, this becomes my active high pass filter with amplification, how amplification? Because now I have R 1 and R 2 in the for the amplification, for the changing of the gain, you can change the gain with the help of R 1, we can change the gain with the help of R 2 or a actually in combination of R 1 and R 2, right.

Now voltage gain for this particular active high pass filter is also given by V out upon V in and here V out is AF into fy fc, and V in is one square root of 1 plus f by f c whole square. This again we have seen in the theory class, how the voltage gain can be defined, right. So, we have to just remember that this is voltage gain.

Now, AF is a pass band gain of the filter, and is nothing but 1 plus R 2 by R 1, why 1 plus R 2 by R 1? Because this is non-inverting amplifier, non inverting amplifier, alright? Non-inverting amplifier will have a gain of 1 plus R 2 by R 1, we know that, right. Second f so, this AF we know now we are talking about this f, or this f, f is the frequency of the input signal in hertz. F is the frequency of the input signal in hertz ok, then what is this f c this component fc, fc is your cut off frequency in hertz.

So now we know the formula of voltage gain, and what exactly the terms within the voltage gain R, first is your pass band gain, which is 1 plus R 2 by R 1. Second is of frequency for the input signal, third is your cut off frequency, frequency is given in hertz, easy? Extremely easy, right.

What we what we can see in this particular circuit ? One thing that we had to notice in this particular circuit is that the input signal that you are applying if you consider the voltage peak to peak voltage V in C V out the voltage has been amplified peak to peak voltage is higher when it comes to the output value output voltage, right?.

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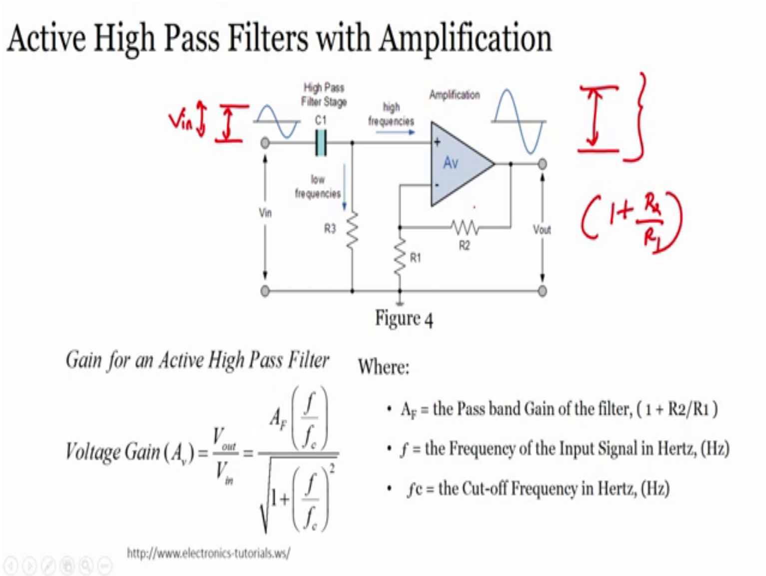

That amplification is because you have the you have the amplification of 1 plus R 2 by R 1, right.

So, this will not only amplify the signal, if it also act as a high pass way, it is a high pass filter along with amplification, right? If you use unity gain amplifier, then it is high pass filter without amplification. We use inverting amplifier high pass filter with again amplification the formula would be different, alright.

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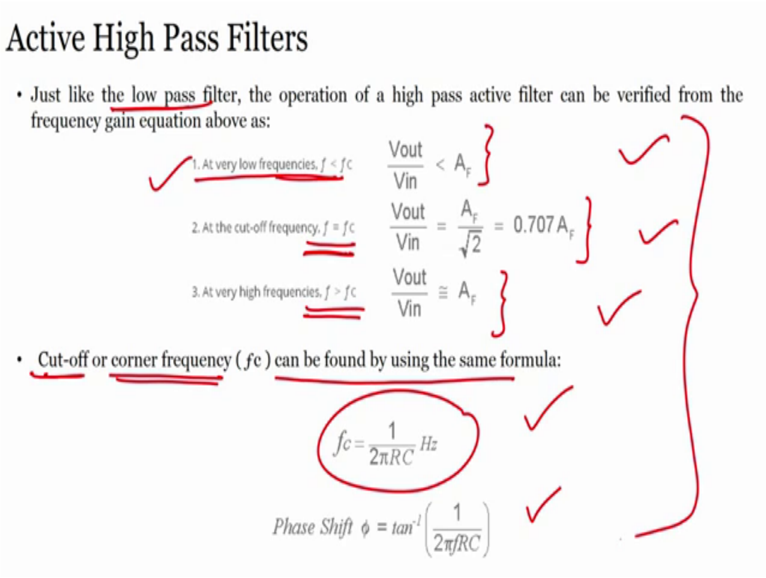

So, if you go to the next slide now, you remember this thing, right. We have already discussed in the last module, that when you talk about low pass filter, when talk about low pass filter, this would be V out by V in would be greater than AF, right. We have seen that, this would be same, and this would be less than.

So, the point is in case of high pass filter in case of high pass filter. Just like low pass filter, the operational pass filter can be can be verified using formula following formulas first at very low frequency, when f is less than fc, you are out V out by V in will be less than AF, that is the first thing that we can use to verify the active high pass filter; that, at very low frequency you will find that V out by V in is less than your gain. Second, at the cut off frequency that is f equals to fc, cut off frequency f equals to fc, your V out by V in is AF by square root of 2. AF by square root of 2 or 0.707 AF, 0.707 AF. At very high frequency; that is, f greater than fc, V out by V in is equal to AF, right?

So, we have 3 things first, at very low frequency, we have V out by V in is less than f at cut off frequency we have V out by V in equals 2.07 AF, at very high frequency, we have V out by V in is equal to AF. These 3 things you have to remember, these 3 things we have to remember. Now the cut off frequency or the corner frequency fc can be found by using the same formula, f equals to 1 upon 2 pi RC. We have discussed this, right? It is same for here, where if you want to measure the phase shift, then phase shift is given by phi equals to 10 inverse of 1 by 2 pi RC, right. So, formula for frequency formula for phase is given here, alright? So, again remember when you have active high pass filter, then you should understand that 3 different things one is f less an fc what will be V out by V in when f is equals to fc what will be V out by V in when f is greater than fc what will be V out by V in. When it comes to frequency f equals 1 by 2 pi RC when it comes to phase pi equals to 10 inverse a 1 by 2 pi RC.

So, 1 by 2 by now, once we know these things, then we can we can take an example.

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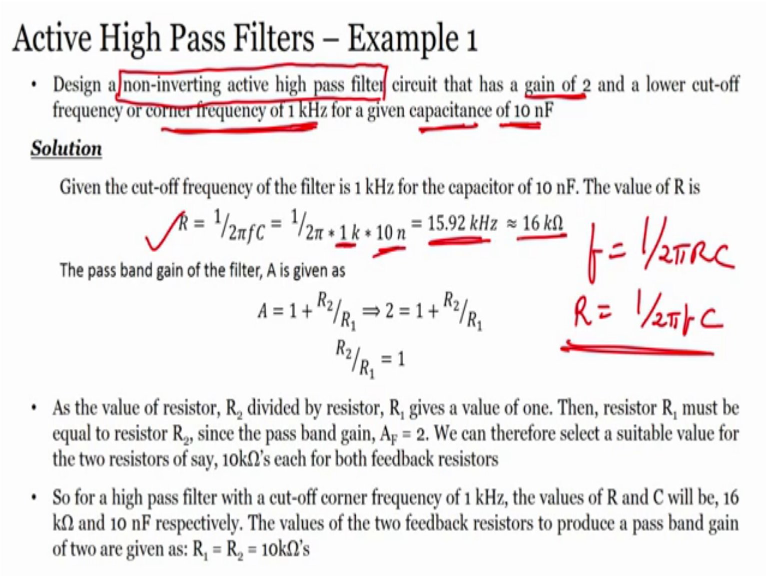

Let us see whether we can solve it, alright? So, what is the example, read, design a non-inverting active high pass filter, that has a gain of 2 and a low cut off frequency or corner frequency of 1 kilo hertz for a given capacitor of 10 nano farad. So, we have few information, we have gain of 2, we have capacitance of 10 nano farad, we have cut off frequency or corner frequency of 1 kilo hertz, this is given what we have to design a non-inverting high pass filter, active high pass filter. This we have to design, alright?

So now we know that what is the formula for f? F equals to 1 upon 2 pi RC of 1 divided by 2 pi RC. So, R will be 1 divided by 2 pi fc, right? This is capacitor this is frequency. So, if I substitute the values in this particular formula, which is right over here, I have 1 up divided by 2 pi what is f? f is 1 kilowatts of 1 kilo watts into 10 nano farad is my capacitance. So, I will get a value of R equals to 615.92 approximately, we can write 16 kilo ohms, right. Now the pass band gain of the filter A is given by you remember, it is a non-inverting, you see here the question is design a non-inverting active filter.

So, pass band gain is 1 plus R 2 by R 1, this is the pass band gain. So, what is A? A is given gain of 2, equals to 2, right? This is A equals to 1 plus at where A value is given.

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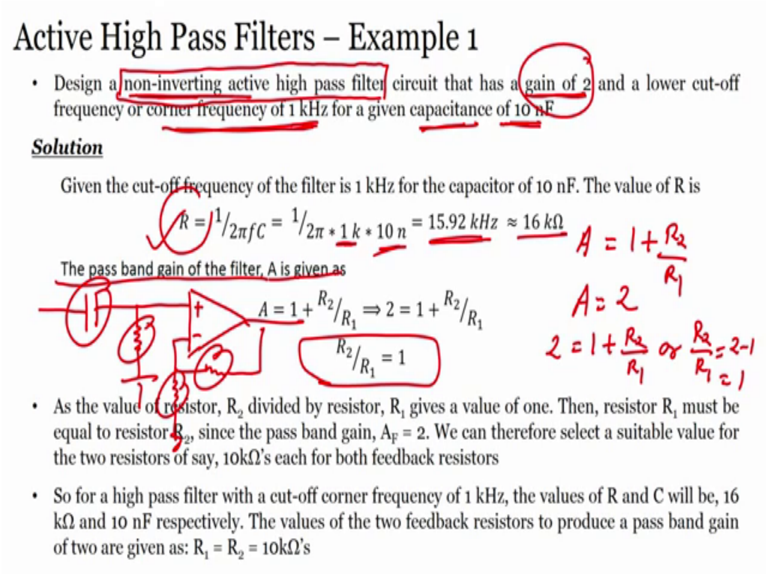

So, 2 equals to 1 plus R 2 divided by R 1, or we can say R 2 by R 1 equals to 2 minus 1 equals to 1. This is the formula, this is the solution. Now we know what is the value of R 2 by R 1 we know what is the value of R, right. So, can we design it, yes, we can design it. So, if I now connect, if I now connect, a capacitor a resistor, right. And ground it I connect my invert non-inverting amplifier, right? And I have resistor here, I connect here, I have here, now I know R 2, I know, R 1 I know R I know C, correct? So now, I can design the active high pass filter, I can design active high pass filter, so easy, super easy, ok.

So, I have found R 2 by R 1, I also found value of R, now what to do? Now what to do as value of R 2 divided by resistor R 1 gives value of 1, right? Then the resistor R 1 must be equal to R 2 C if R 2 by R 1 equals to 1, implies R 2 equals to R 1 into 1 which is equals to R 1.

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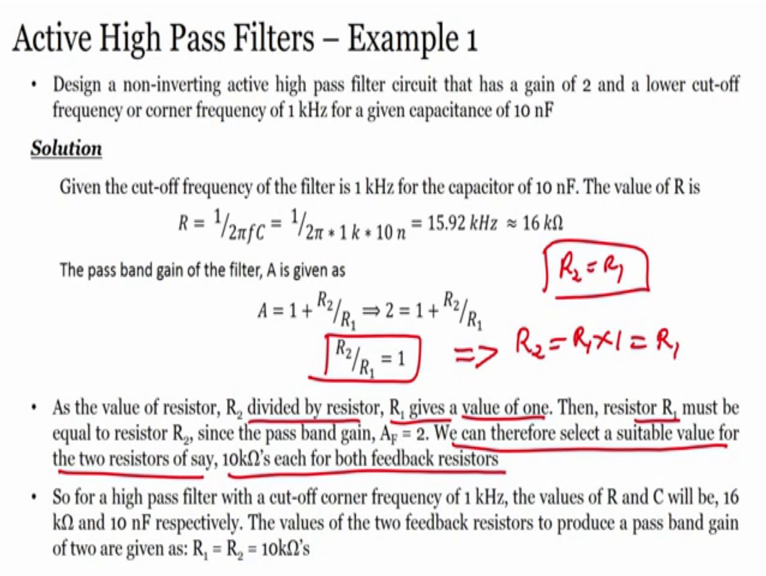

So, R 2 should be equal to R 1, correct? R 2 R 2 should be equal to R 1. That is what is the same, we can therefore, select a suitable value of 2 resistors, say 10 kilo ohms each for the feedback resistor, then you can select any value that you want to select, you can select R 1 equal to R 2 equals to 10 kilo ohm, alright? That is a one value.

Now, for a high pass filter with a cut off frequency of 1 kilo hertz, the value of RNC will be 16 kilo ohm, and then 10 nano farad you see C is already given. R we found are we have found, R is nothing but 16 kilo ohm, right. C is there, R is there, that is what he is saying the values R and C will be 16 kilo ohm, and 10 nano farad respectively.

So, the values of feedback resistor, to produce a pass band gain of this particular active high pass filter is nothing but R 1 equals 2 R 2 equals to 10 kilo ohm you can give 1 kilo ohms also, alright. So, here we have selected 10 kilo ohms R 1 equals to R 2 equal to 10 kilo ohm. So now, we have value of resistor, we have value of capacitor, we have value of feedback resistors. So, from here we can design the active high pass filter. So, if you are given a question to design active high pass filter, right.

Do not do not worry it is very easy to identify easy to solve this equation. Because given some little bit of information, we can design the active high pass filter by the formula that we already know, right. It is inverting amplifiers or remember inverting amplifier 1 plus R 2 by R 1 you non-inverting amplifier minus R 2 by R 1 right.

So now we know in non-inverting amplifier 1 plus R 2 by R 1 one thing is done gain is given yes, 2 equals to 1 2 plus 2 R 2 by R 1. So, R to by R 1 equals to 1 R 2 equals to R 1 R 2 equals to R 1 we select one value, done. Now you are given a value of frequency, value of capacitor, but you are not given value of resistor correct. So, f equals to 1 upon 2 pi RC. So, R equals to 1 upon 2 pi fc, you get value of R now we have value of R you have value of C you have value of R 1 you have value of R 2 your value of frequency. So, everything you have. So, you can easily design your active high pass filter, so easy, super easy, right?

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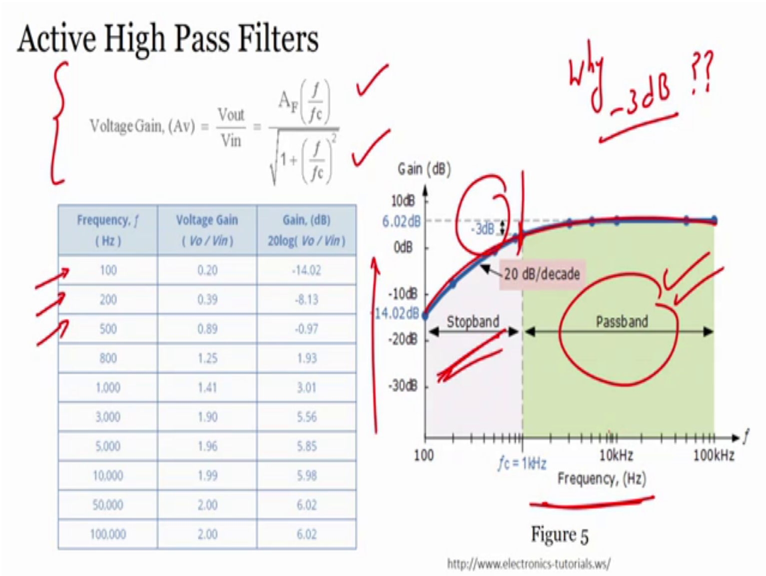

So, let us go to the next slide. And what we see is for a given set of value so, we have voltage gain, this is the formula we already know, right. For this, if I keep on changing the frequency, you see keep on 100 hertz 200 or 500 hertz, right? I have different voltage gain, I have voltage gain Vo by V in, for that if I change it to gain in terms of decibels. I can plot frequency versus decibel or frequency versus gain.

And I can get this particular plot, against this particular plot. Here you will see that, it allows the frequency from this onwards, the pass band is here and it does not allow the frequency below this particular range. Which is your minus 3 dB, you understand 3 dB. I asked you earlier also, I am asking you again, why ? Why 3 dB ? Why? Find it out,.

So, we have here stop band, we have here pass band; that means, this is your active high pass filter, right. We have frequency we have gain, gain frequency stop band pass band, we can design this, can we design this? Let us see.

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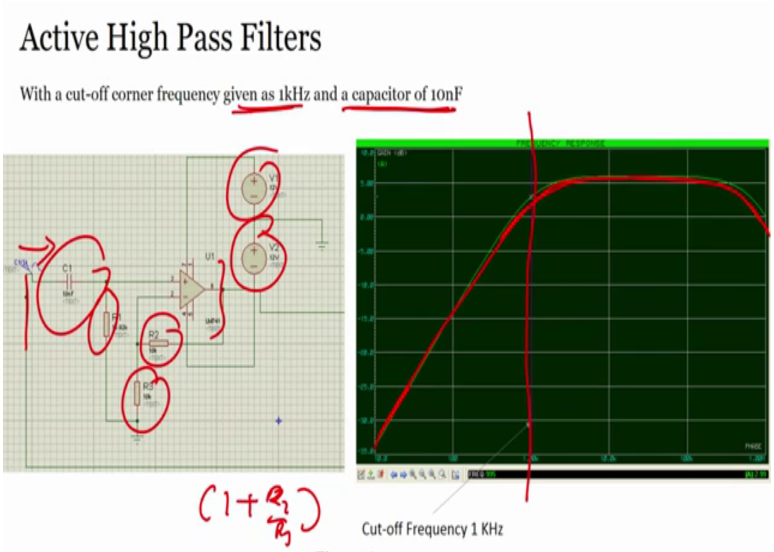

Figure 6

So, again with (Refer Time: 30:10) of Sitharam, right, we all know him, we got this circuit which is from p spice. And using this p spice model, he has generated this particular plot. And from here the question is with a cut off frequency given as 1 kilohertz and a capacitor of 10 nano farad what you will get? What will be your pass band? What will be a stop band? What will be your pass band? And what will be a stop band, right?

So, you see here this is bias voltage, right, this is R 2, this is R 3, R 2 R 3 is 1 plus R 2 by 3, this gain. R 1 capacitor becomes your filter, right, so when you apply signal here, right. then you can measure the voltage across output 6, and you find that you get the peak like this, and here you have to find the your cut off frequency is given, you have to find what is a stop band and what is a pass band, alright. So, you can perform the same simulation using pspice, if you have the provision of using that particular software, ok.

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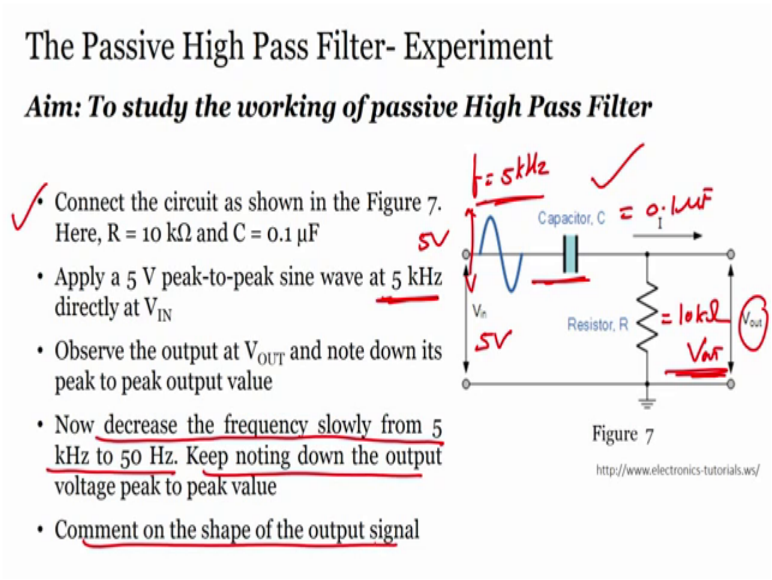

So, let us see if I really want to perform the experiment, and what experiment I will do? I will connect this passive high pass filter, and apply different signal at the input different signal when I say is I will change the I will start with 5 volts peak to peak and I will observe the output, and I will I will decrease the frequency, you see, I will skip on decrease the frequency.

So, here if you see the circuit which is here R is given, C is given, I am using the value of capacitor equals 2.1 micro farad. I am using resistor equals to 10 kilo ohm, right. I am applying 5 volts as input and applying 5 kilo hertz as a frequency this by voltage peak to peak voltage is 5 volts. And my frequency is 5 kilo hertz. For this particular signal, right, I have to observe what is my V out, what is my V out V out, right?

So, and now what I will do? Once I observe the V out, right, I will start decreasing the frequency slowly from 5 kilohertz to 50 hertz, from 5 kilo to 50 hertz. We still keep on decreasing the frequency. And with each decrease of frequency, we will or a step of frequency, we will see this output voltage which keeps changing, and you will see what kind of signal or what kind of the shape of signal we observe at the output, right. So, we will do this experiment so, the one thing that we have now learn is that for generating this 5-volt peak to peak 5 kilo hertz we are using we are using for here, function generator, right.

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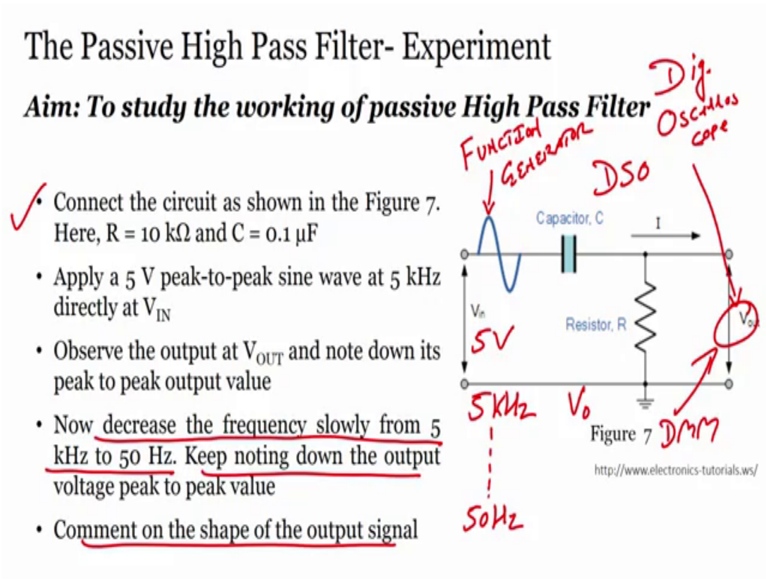

For voltage at output V out we are using oscilloscope, correct? And we can also measure the just a voltage if you want to measure, we can measure voltage with your digital multimeter. This is digital oscilloscope or it is also called DSO, alright?

So, what we will see? We will see that what kind of at for 5 volts, 5 volts, 5 kilohertz what is the output, and then we will keep on changing from 5 kilo hertz we will go down to 50 hertz, and we will again see the output voltage Vo in the oscilloscope, alright? So, let us see this experiment, and for performing this experiment, I like Sitharam to help us, and he will be showing us the circuit. So, if you can see the circuit which is holding, right?.

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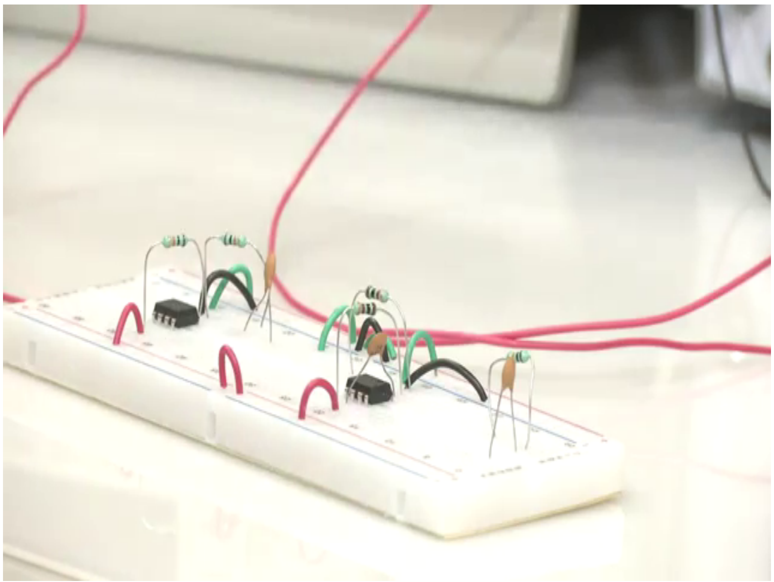

This is your RNC resistor and capacitor, and using this RC you can form your high pass passive filter. High pass passive filter is a filter, because your capacitor is at the input and resistor is following the capacitor, alright. So, you can apply signal at the input of the capacitor and ground of the resistor, right?

So, one is input another one is ground. This terminal and this terminal of the resistor, these are in series, they are in series, alright? There is a high pass, high pass passive filter, that is what we are working on, alright. So, he has this breadboard, now as usual, first of all we have to generate this signal, and we also have to apply the bias voltage to the op amp. Later on, because, right, now this is a passive filter, for passive filter we do not require to apply the voltage, for passive filter we required to apply the biased voltage because there is no active, component, right. So, we can directly apply the signal to the capacitor, and we will observe the output across the resistor using the oscilloscope.

So, he is right now connecting the function generator to the input of the capacitor.

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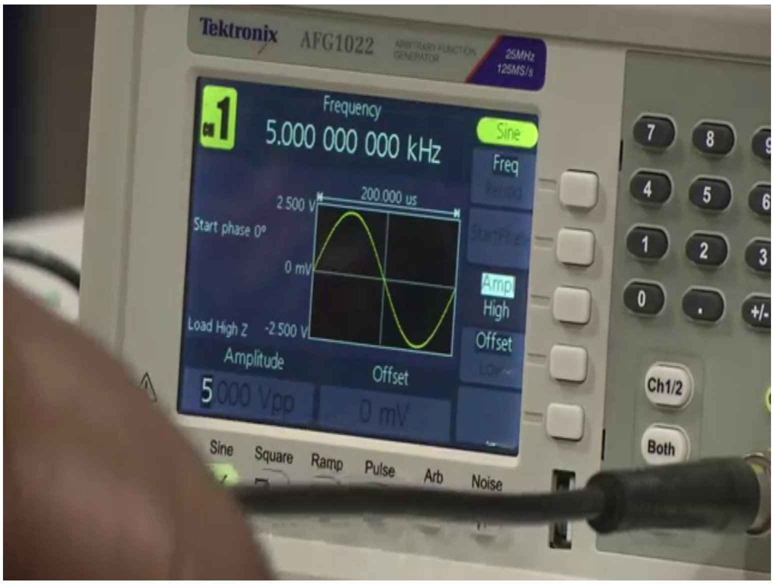

So, what you can see? He has applied 5 kilohertz frequency 5 kilos frequency, and the amplitude is 5 volts peak to peak. Amplitude is 5 volts peak to peak, right? So, you can see one is ground, and the input is given to the capacitor, now we have to connect the output to the oscilloscope. So now, all of you know how we can do it, right? We have to connect the so, if you can give me one probe do you have one probe in the probe like this oscilloscope, alright.

So, look at me, see I will show you something, I am holding this probes, right? One is longer one, one is a shorter one, one is longer one, one is shorter one. This is the probe that we connect to the oscilloscope, alright? Is a probe that we connect to the oscilloscope, right? You can see, ok? Now we have that is that is good enough. We have a longer probe, longer in terms of length or shorter one. Shorter one this one goes to the oscilloscope the shorter one is connected to the ground. A longer one is connected to the signal, alright? That is what we do. Right now, if you see, when you see in the on the breadboard, what you can see? The longer one wherever you see is connected to the signal, and the shorter one is connected to the ground, alright. So, can you bring it little bit this side yeah. So, if you see there are lot of probes, always a longer one is connected to the input, and the shorter one is connected to the probe. Now if we concentrate on the oscilloscope, what we see? What we see is, we have applied, we applied 5 volts peak to peak. So, he has changed we have applied 5 volts peak to peak.

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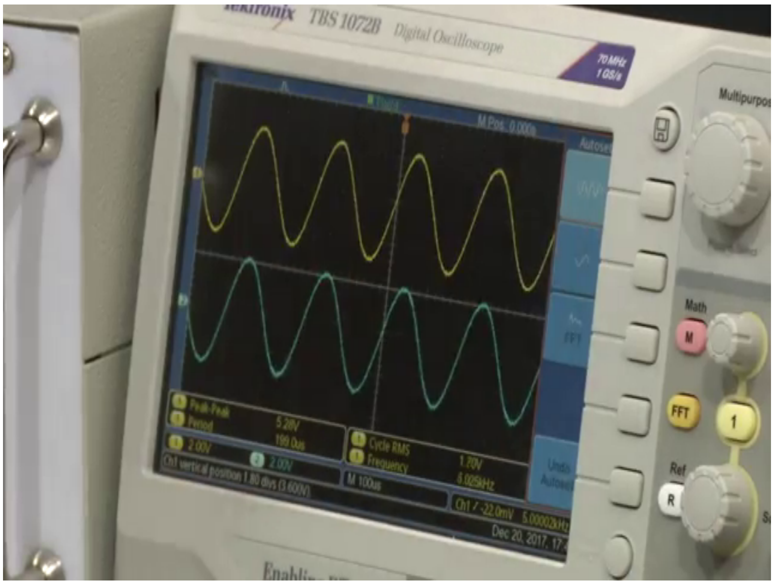

And at the output we can see, 5 volts peak to peak, now it is 5.28, 5.28, that is different that is fine? So, yellow and blue are the input and output, and you can see that the output is following the input, right. The frequency is 5 kilo hertz, voltage peak to peak voltage is 5.28 volts.

Now, as we have seen on the screen that we were going to change from 5 kilohertz to 50 hertz. So, he is going to change slowly in terms of 500 can you change in terms of 1 kilohertz 1 kilo hertz. So now, 4 kilo hertz 5 minus 1 is 4 kilo hertz. Now we are applying 4 kilo hertz, amplitude is same, let us see the oscilloscope, let us see the oscilloscope. And we will see that it is still following there is no problem.

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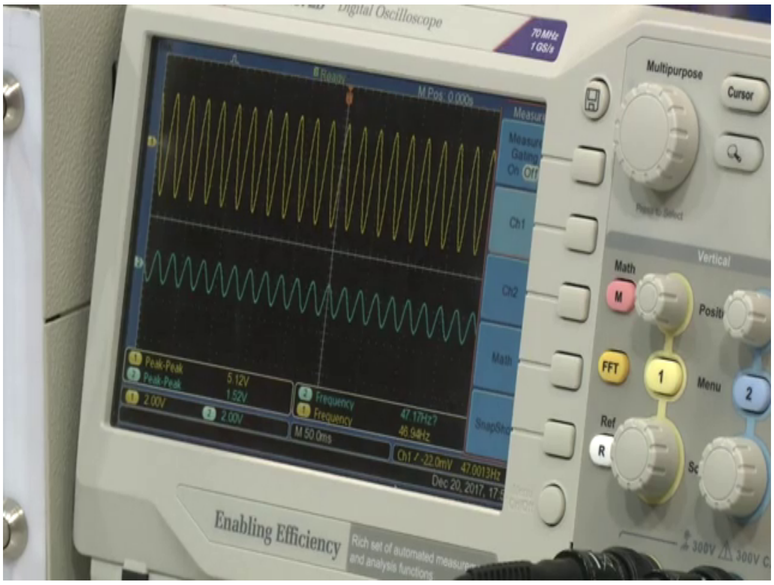

Filter is working fine, this is passive filter and these high pass filter, alright remember this. So, low pass low frequency should not pass, alright? Now from 4 kilohertz, we are sending to 3 kilo hertz, you see they are changing the 3-kilo hertz still it is working well, no problem.

So, let us change to 2 kilo hertz, 2 kilo hertz no problem, 1 kilo hertz, 1 kilo hertz, 400 hertz, ok. What is the fc that we have calculated? 100 hertz, 150 hertz? So, the cut off frequency, the cut off frequency that have calculated is about 150, 160 hertz. So, you until that you will be able to see that the this input and output are working well, the frequency is going well, you see that 300 hertz 300 hertz is allowing to pass, then we can reduce it to 200 hertz is still allowing to pass, no, now you see the peak to peak voltage. Peak to peak voltage is decreased, you see peak to peak voltage when a blue 14.08 volts, but where the input signal is 5.0 volts. Now the peak to peak voltage start in decreasing, right?

If I go for 159 hertz, it is decreasing, because now this is slightly below our cut off frequency. Slightly below our cut off frequency. So, you observe the peak to peak voltage, at the output which is in blue colour which is 3.68 volts, your input is 5.12 volts, and your frequency is frequency is 159.2 hertz, right? So, the output voltage would be 5 divided by square root of 2. And that is how you can calculate the output voltage, how it will change with respect to input below the cut off frequency. So, if I still go on decreasing it, you can still see there is a change, right. So, I am decreasing 250 hertz, close to 50 hertz, right. And I see that my output voltage has been reduced to one point 8 4 volts, and I cannot pass the frequency, see the voltage is decreased. The voltage is decreased, this is using the passive components, right. So, it is a active filter, sorry, it is a high pass filter using passive component.

Now, let us see and so, what we observed? We observed that the output voltage, the output voltage decreases when we come below the cut off frequency, when we come below the cut off frequency the output voltage decreases, right.

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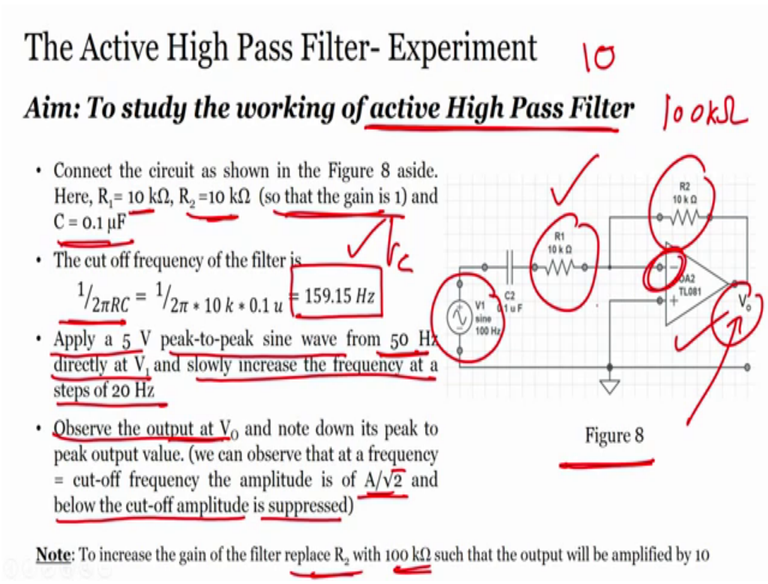

So, let us now see if we want to design, active high pass filter, alright, if you want to design active high pass filter. we continue where we have left in the last module, and that was the that was high pass filter using passive components. And we have seen the experiment how the experiments results were there when we applied input signal how the output signal was changing with respect to input signal. And we could see that for the cut off frequency of 159 hertz, below that this the frequency could not pass that is the active high pass the high pass filter came into play, alright.

So now if I use active high pass filter; that means, I am now using operational amplifier, I am using operational amplifier. In this particular case if I want to study, active high pass filter, I have to connect my circuit as shown in figure 8. Shown in figure 8, right, so, here the circuit is shown in figure 8, R 1 equals to 10 kilo ohm, R 2 equals to 10 kilo ohm so that gain is 1, and C equals to 0.1 micro farad, C equals to 0.1 micro farad. The cut off frequency we all know, cut off frequency is 1.21 by 2 pi RC.

So, still the cut off frequency is 159.15 hertz, 160 hertz. Now here what we will do? See everything is same, except that now we are using the active component. Except where we are using the active component. We will again apply a 5 volts peak to peak sine wave from 50 hertz directly at V 150 hertz directly at V 1 and slowly increase the frequency at steps of 20 hertz, right.

So, what we will see? Now we will apply low frequency, and we keep on increasing to the high frequency. In the passive filter, what we have seen, we started with the high frequency, and we reduced down to the frequency which was below 160 hertz. Here we are doing opposite, we start from 50 hertz, we increase it at a step of 20 hertz or 50 or 100 hertz does not matter when we will see the experiment.

We will see observe the output at V o we have to observe the output which is at here Vo. And note down it is peak to peak value ok, we can observe that at a frequency cut off a by root 2, and below the cut off amplitude is suppressed. We will see how the voltage at the output changes when we go or when we when we pass the cut off frequency fc, alright. And to increase the gain of filter replace R 2 with 100 kilo ohm. So, right now see R 2 and R 1 both are kept at 10 kilo ohm R 2 and R 1 has kept a 10 kilo ohm. If I increase, if I want to gain increase, the gain then I change R 2 to 100 kilo ohm, then my gain would be 10, 10 plus 1 or 11.

Yeah, it is inverting no it is inverting amplifier, it will be 10, right. My gain would be 10 inverting, inverting amplifier alright, right. Now my gain is 1, because R 2 and R 1 both are 10 kilo ohm, R 1 equals 2 R 2 equals to 10 kilo ohm so, my gain is 1 ok.

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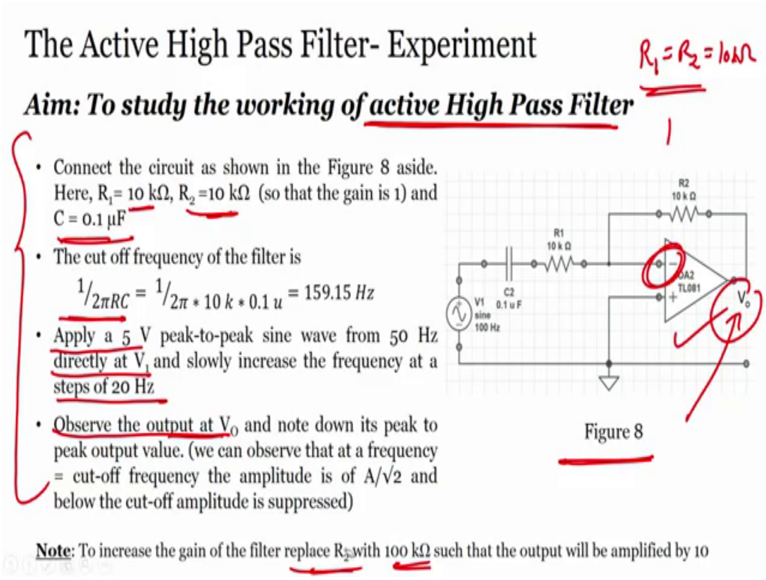

So, let us do this experiment, let us do the experiment, and see what signals we see the at the output of this circuit. So, let us see on the breadboard please on the breadboard, now we can we can see he is showing us the circuit of the high pass filter, active filter.

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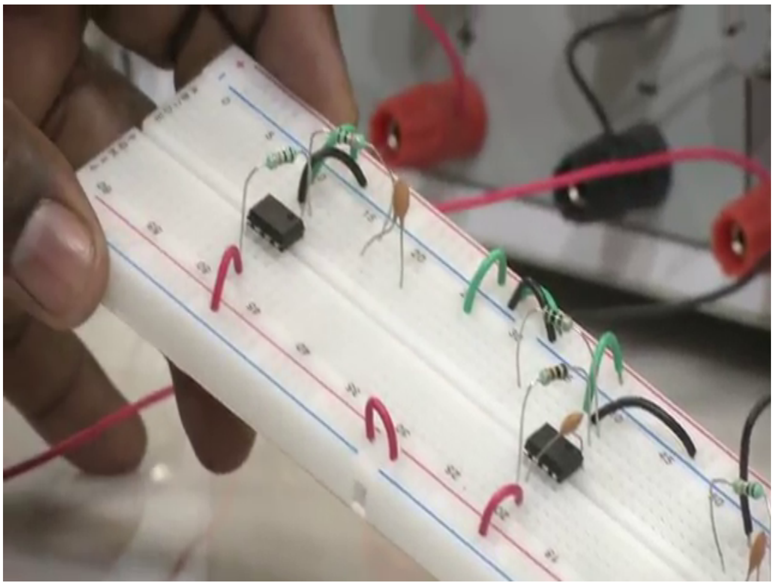

And here we can see the capacitor and the resistor, right, capacitor and the resistors. Similar to the circuit that we have seen on the screen which is similar to the circuit on the screen. Here we are using operational amplifier, here we are using operational amplifier. So, when we have to use operational amplifier, the first thing that we have to do is apply the biasing voltage, this biasing voltage is given by the DC power supply. So, you can see he is connecting DC power supply to the operational amplifier; that means, he is applying bias voltage to the op amp.

Now once he has applied the biased voltage, he has to apply the input voltage input signal to the capacitor of the active high pass filter. So, he is applying the input voltage, right? At the capacitors of the active high pass filter, this capacitor is connected to the resistors connected to the inverting terminal. So now, the input signal that we have decided is, we had to apply 5 volts and 50 hertz, right? And he has to also connect the output of the operational amplifier to the oscilloscope as usual, because we are looking at the change in the output on the oscilloscope, correct?

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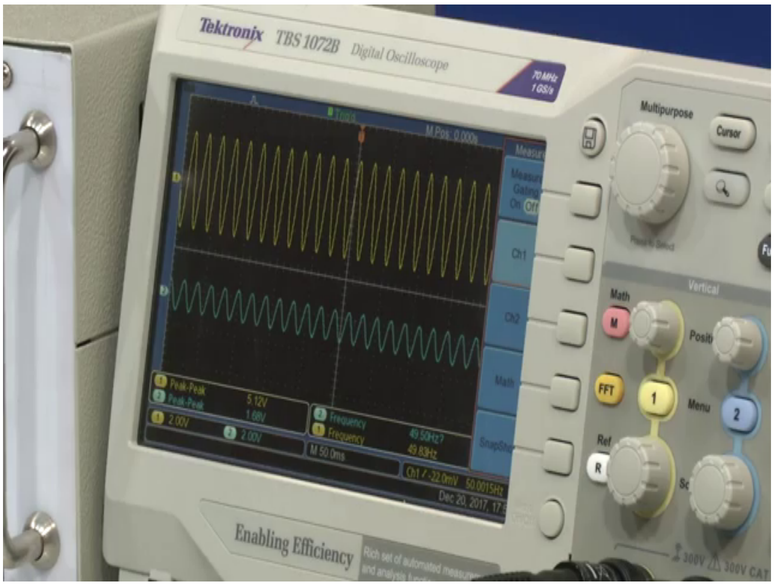

So, if you if you see input signal at 50 hertz, you see the yellow one is your input, and the blue one is your output, you see that for the input of 5 volts, for the input of 5 volts, the output is 1.68 volts set 50 hertz frequency at 50 hertz frequency. Now if I increase the frequency from 50 hertz to next which is the 70 hertz, what I see that still my output is 2.16 which is not equal to 5 volts.

And I cannot still pass the frequency, now I keep on increasing the frequency in slowly in steps. So now, we go to 90 hertz, and I see it is still not allowing to pass go to 100 go to 100, and still I cannot see their frequency can be passed, you see you have to understand in this way. Not from the just that you can see the frequency of the input and output similar that is not the case that is not the case. You have to see the peak to peak voltage, look at the peak to peak voltage, alright.

So, here you can see the peak to peak voltage is 2.88 volts, and the input signal is 5.12 volts so, you understand from that point of view. Now we are increasing to 100 hertz, let us increase to 120 110, 120 excellent, 120 still we cannot see.

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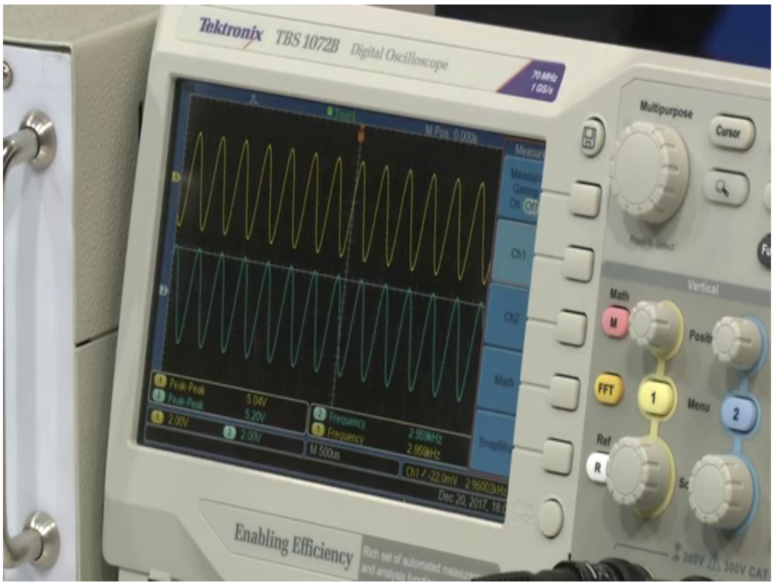

But you see the now it is 3.20 volts ok, 150, 153.60. It is still not allowing our cut off frequency was 159.15 hertz. So, let us see now 159, or 160 can we keep up 160 160 hertz. Still not allowing, let us see little bit, little bit now it is 5 5 by root 2. So, still we had 3.76 so, let us still increase the frequency. see so now, we have 5 by root 2. So, 4.72 is it?.

Yeah, so now, we have see 460 hertz and now we see that it is very close to our input signal 5 volts, right, is keep on increasing the frequency now at a higher frequency. We will see it exactly follows your input signal it follows the same peak to peak voltage of an input signal you can see it is from 1.5 kilo hertz, right. And you can increase to 2 kilo hertz you increase to 2.2 kilo hertz increase to 2.5 kilo hertz, and you will see that keep keeping increasing the frequency will also allow the output signal to follow the input signal, and thus, this active high pass filter is working well. This active high pass filter is working perfectly well, right?

So, what we see is, if we want to design a passive high pass filter or if we do want to design active high pass filter, the idea is very simple, that in a passive high pass filter your formula is 1 upon 2 pi RC active high pass filter your formula still remains 1 upon 2 pi RC, but here you have an advantage of changing the gain because it is active high pass filter, you can change the gain by changing the value of resistors R 2 and R 1, while in the case of the passive filter, you cannot change the gain, right; that is the only change.

Another thing that you have to understand here is that it is very easy to understand how to apply the input signal how to check the output signal and at what cut off frequency designed by us the signal will not allowed to be passed, there is for the high pass filter, certain low frequency below the cut off frequency will not allow to be passed for the low pass filter the frequency above the cut off frequency will not allow to be passed, right?

So now with this particular set of experiments, I hope that you are able to understand how you can design a low pass and high pass RC filters that is passive filters, and low pass and high pass active filters that is RC and op amp, right? learn about it, read about it once again from the theory class, understand the experiment, read this particular set of module or look at it, right.

Other than reading look at the module see again and again then you will understand, what are the things that we are performing, if you have access to the laboratory, right, please go and perform this experiment, right. You can perform the experiment along with a mentor you can perform the experiment with your friends, and see how you can design active high pass filter, how you can design an active low pass filter, how you can design a passive high pass filter, how can is an a passive low pass filter, alright?.

So, with this particular experiment, I hope that you understood something further regarding how to apply the operational amplifier to for the application of a filter. And I will see you in the next class with the next set of filter which is the band pass filter and band reject filter. Till then, you take care, I will see you next class, bye.