Integrated Circuits, MOSFETs, Op-Amps and their Applications
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Lecture - 53
Experiment: Op Amp based active low pass filter

Alright, so, what I was saying is that in case of active low pass filter, right?

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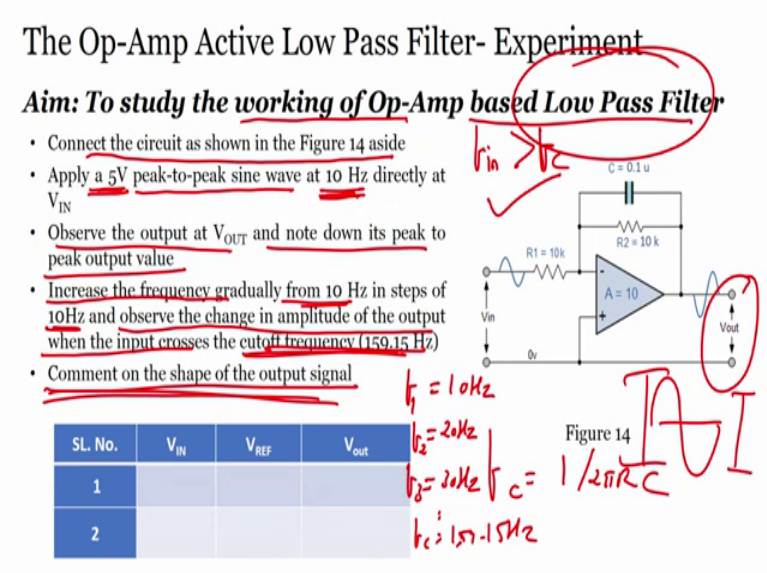

Ah In case of active low pass filter, how we can see the input signal and output signal and the relation between the input and output. So, for that we have earlier seen that how the low pass active filter works. And we already know that the frequency or cut off frequency formula is 1 upon 2 pi RC, right? We know that fc equals 1 upon 2 pi RC.

Now, we also know that we have one resistor and one capacitor. I have shown you that if you use inverting or non-inverting amplifier based on that your circuit would change. Here we are using inverting here we are using inverting amplifier, right? Now if I want to understand how this particular circuit works. I have this particular circuit works and I want to test it for the low pass filter experiment then, what I can do? What I can do? So, you see here the, the aim is to study the working of an Op Amp based low pass filter. Op Amp based low pass filter means it is an active filter, right? Active filter.

So, connect this circuit as shown in figure 14. If you have to connect the circuit in this particular format again you see we have not given a bias that does not mean that bias is not there, that does not mean the bias is not there.

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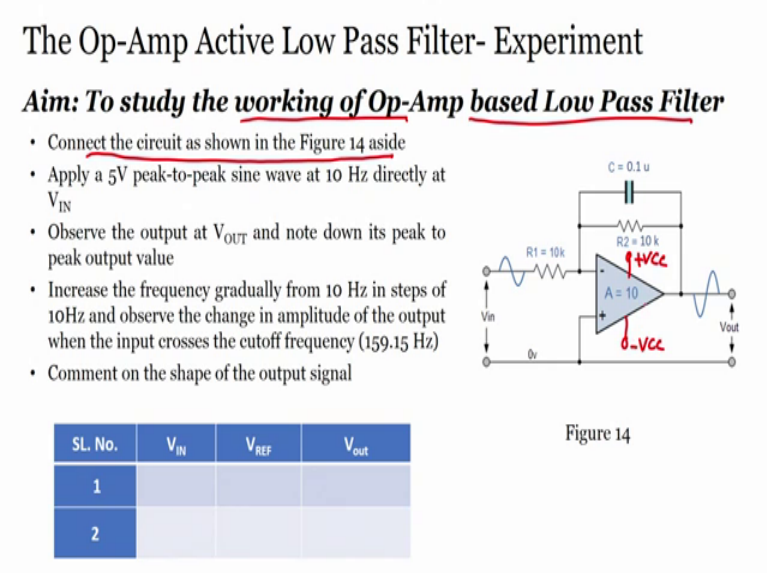

You see if you if you write it like this then also it is ok. Plus, VCC minus VCC, right? or if you do not put plus VCC minus VCC here that and also it is when you are using this schematic diagram or if you are drawing the schematic diagram of this circuit, but that does not mean that we are not applying ok. We have to apply bias voltage, we have to apply bias voltage do not forget that without bias voltage the things will not work things will, not work.

Now, what we are you see? We will once we connect the circuit which is shown here will apply of 5 volts peak to peak sine wave at 10 hertz. You see why? Because we want to see low pass filter. So, low frequencies should pass and the frequency which is calculated using the cut off frequency formula 1 upon 2 pi RC above that frequency it should start cutting off the things; that means, the amplitude will decrease, and you will see it will decrease by 1 by root 2 of the signal and consequently it will keep on decreasing. We will see this thing in the experiment observe the output voltage V out or note down it is peak to peak output voltage, right?

So, this is what we had to do first, first thing is we had to connect the circuit. Second is we had to apply 5 volts peak to peak at frequency of 10 hertz. Third thing is we had to

observe the V out and note down it is peak to peak output voltage. We have to measure the V out and note down it is peak to peak output voltage peaks to peak output voltage, right?

Fourth thing is we will start increasing the frequency gradually from 10 hertz in a step of 10 hertz; that means, first is frequency is 10 hertz, second f 1 f 2 f 2 is 20 hertz, f 3 f 3 is 30 hertz and so on until your cut off frequency fc which is 159.15 hertz, right? And then when we increase your frequency, right? Of the input signal greater then your frequency of input signal let us say f in is greater than fc then you will see that the role of the low pass filter then you will see the low pass filter.

So, what we say that increase the frequency gradually from 10 hertz instead of 10 hertz and observe the change in amplitude of the output, when the input crosses the cut off frequency 159.15 hertz, alright? Then after doing that we have to comment on the shape of the output signal comment is what happens to our output signal, does the amplitude remain same, does it decrease, does it increase, this signal remains same, signal changes waveform we had to see this everything and we can comment on the output signal.

This is an experiment for all of you to perform, right? You can also do the similar experiment using p spies as we have seen earlier, but the best way of doing it is using this thing that we are showing it to you, which is your breadboard, and your power supply and your function generator, and your oscilloscope, alright? So, use all these things and connect the circuit first and let us see what we get by connecting this circuit in the breadboard, alright?

So, if you can see on the breadboard, if you can see on the breadboard what we see here? What we see here are the active low pass filter active low.

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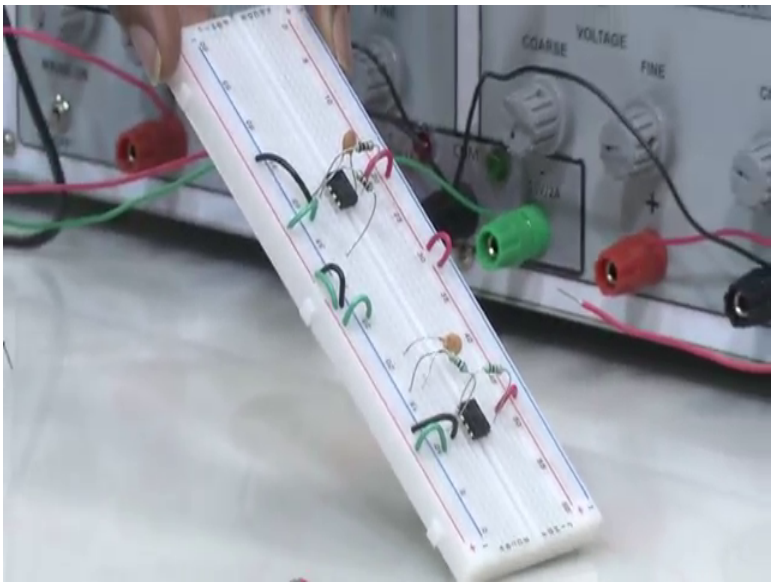

Pass filter alright this is a this is a circuit of an active low pass filter as we see there is an R there is a C, right? And we can change the we can change the we apply different signal at the input of different frequency and correspondingly for this particular circuit we will see the change in the output signal and also it is waveform. So now, first thing that we have to do is to apply the bias voltage as I said to the operation amplifier.

So, you will see that Sitaram is going to apply the bias voltage if we can focus on the breadboard, he will be applying a bias voltage plus VCC and minus VCC to the to the operational amplifier, to the operational amplifier. You can see here in the breadboard he has applied plus VCC minus VCC to the Op Amp.

Now next thing he has to do is he has to apply 5 volts peak to peak 5 volts peak to peak to the to the input to the input of the non-inverting amplifier or into the input of the filter to the input of the filter. First we will see whether it is 5 volts or not; whether it is 10 hertz or not. So, we have to first understand the signal that he is applying is it 5 volts is it 10 hertz. So, we have to check the frequency generator first we will check the frequency generator and we will see can you show frequency later ok.

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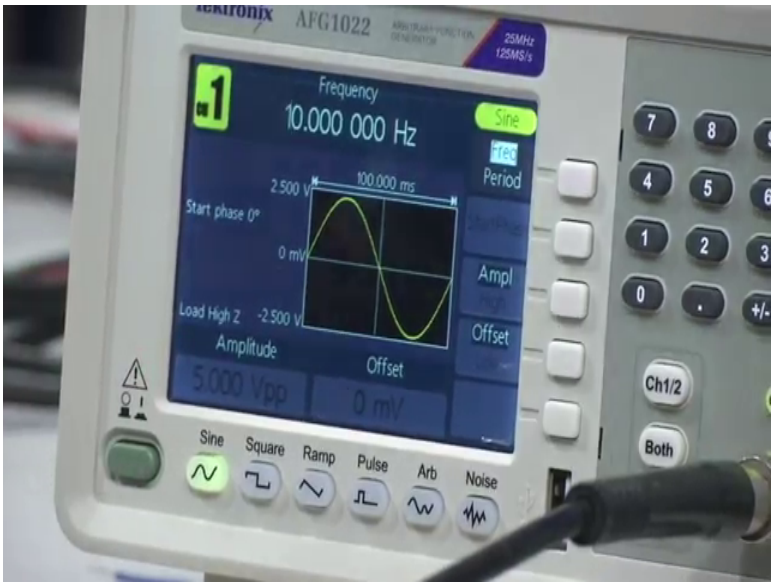

So, the frequency as you can see it is 10 hertz, right? The peak to peak voltage is 5 volts you see minus 2.5 to 2.5 this is a pied 5 volts, right? And you can see here amplitude is written as 5 volts peak to peak Vpp the signal that is applied he has applied to the circuit is sine wave is sine wave.

Now he is connecting the output of the filter, right? To the oscilloscope and he is also connecting the input from the function generator to the oscilloscope just to understand that if we change the input what happens to the output alright? So, when we see both input and output signals simultaneously then what we observe here is at 5 volts peak to peak.

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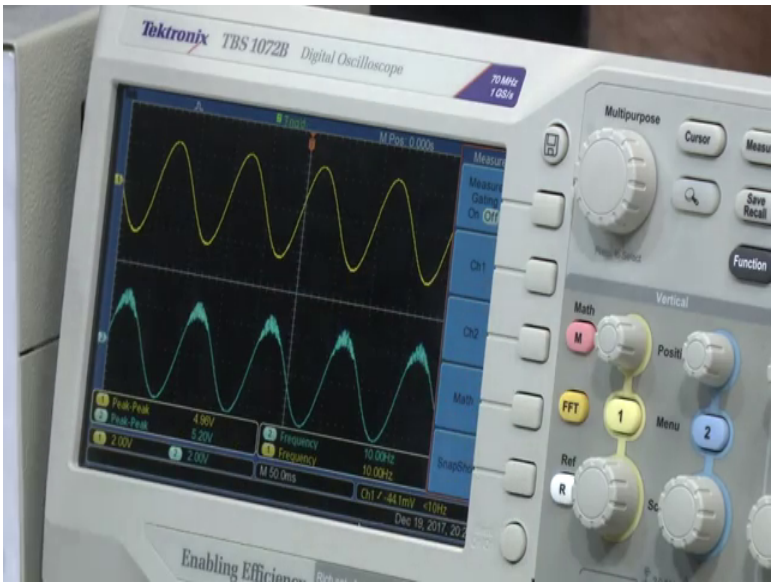

Your input and output the voltage remains almost same, right? 5 volts 4.98 volts and then the frequency is 10 hertz you see the frequency is 10 hertz.

Now, sometimes you will be looking at the clipping of the signal or the noise in the signal that may be due to the probe that may be due to the loose connection in the in the circuit. So, do not think that that is because of the circuit is because of the probes that you are using if it is not connected properly, but it will let us see you can increase the frequency in step of 10 hertz there are single is to 20 hertz. So now, he is increasing to 20 hertz, you can see the function generator see the function generator yes 20 hertz. Now please focus on the oscilloscope, oscilloscope and again you can see that are in oscilloscope the frequency is 20 hertz.

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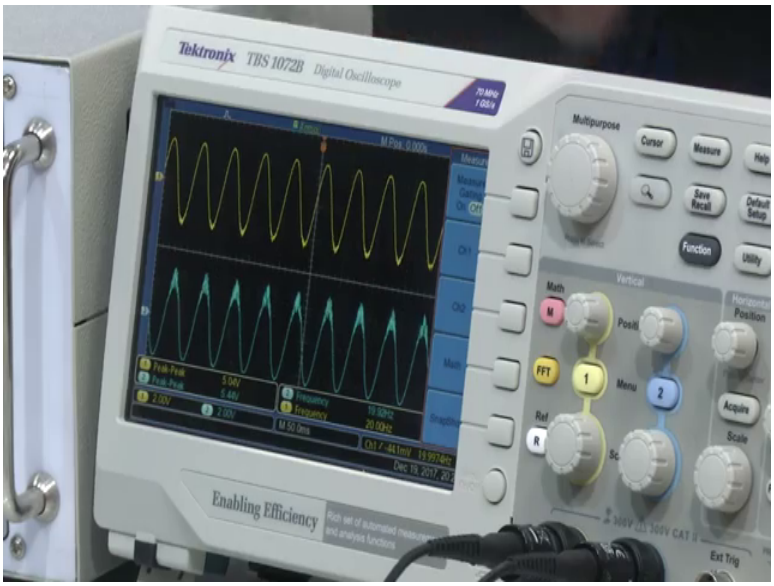

So, for 20 hertz is 20 hertz now, now you just look at the oscilloscope and let him change to 30 hertz.

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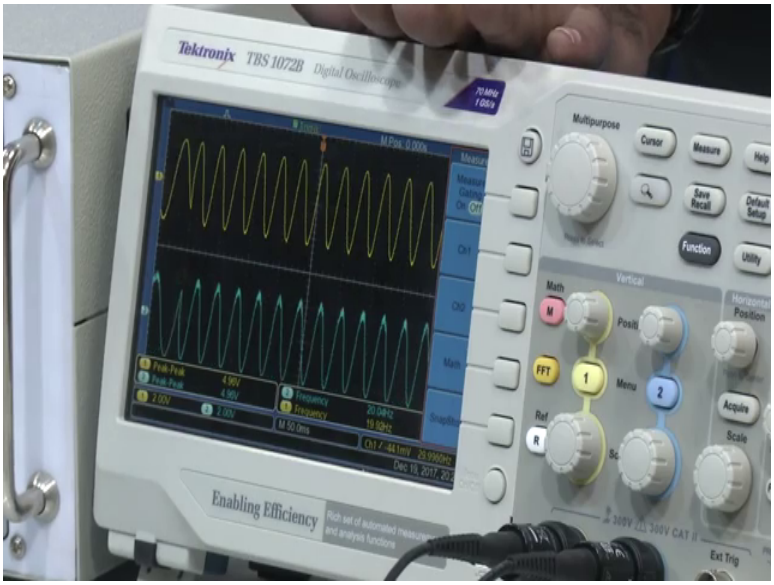

So, that input is now changed to 30 hertz you can see the voltage we had consider voltage or alright? So, peak to peak voltage is almost same almost a 4.96, 4.96. So, yellow one is your input and blue one is your output. So, you have to understand in terms of input and output, you see that the voltage is same peak to peak voltage and the frequency is also it is allowing 29 hertz to 30 hertz to pass let us see the next one.

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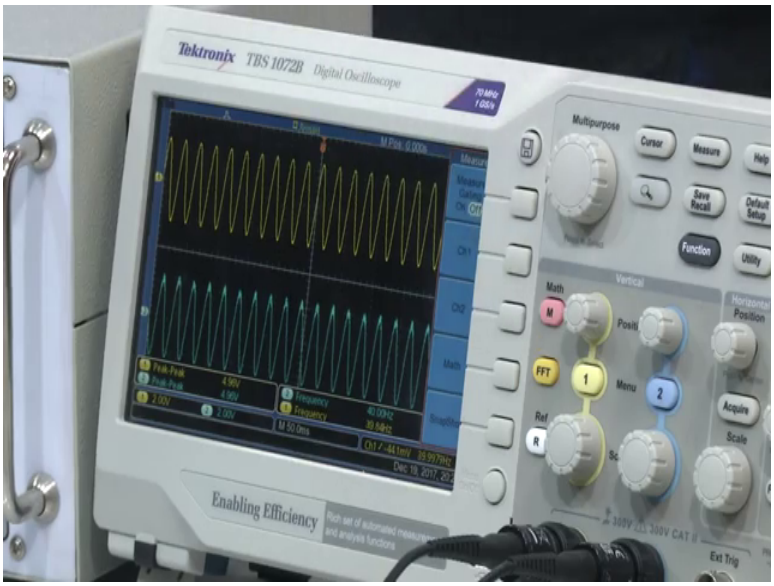

Here you can see the next one is increasing to 40 hertz for 40 hertz what happens the input voltage, right? The input voltage peak to peak 4.96 the output voltage is 4.96 frequency input is 40 hertz output frequency is 40 hertz.

So, it is working well next which is 50 hertz let us see 10 by 10 by 10 step of 10. 50 hertz excellent it is still working let us go to 60 hertz let us go to 60.

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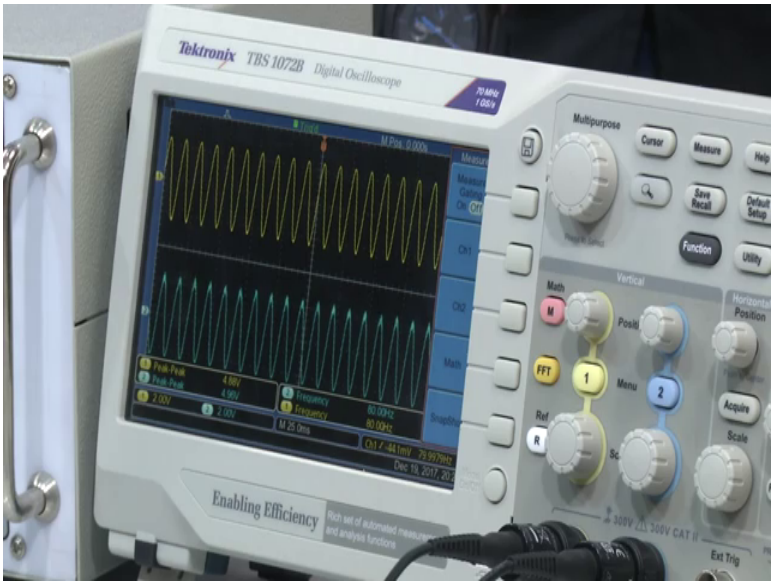

Hertz now he is just changing the scale which is horizontal position. So, you can see clearly 60 hertz is also allowing voltage is also ok, now we keep on increasing to 70

hertz, 80 hertz for 80 hertz also we can see the same value. So, you see from 10 hertz we have started until 80 hertz there is no change, there is no change; that means, of the filter is allowing the frequency to pass through all these are low frequencies. And if you remember our fc is about 159 or 160 hertz, right? 3 what is written here frequency fc cut off frequency 159.15 hertz; that means, what we are assuming is once it reaches this value and above it will start changing the amplitude or it will not allow the frequency to pass alright?

So, let us see and now we go back to the oscilloscope, we go back to the oscilloscope and here we see he is increasing to 120 hertz. For 120 hertz what we see? The signal is still 120 hertz is allowing 120 hertz the voltage input and output you see yellow and blue is similar 5 volts. Now let us go to next one which is your 130 hertz ok. So now, you see these the oscilloscope in oscilloscope what is the signal frequency is 130 hertz peak to peak voltage is 4.96, 4.96 speak to you 5.12 which is almost similar.

Let us increase further 150 good. So, for 150 also you see for 150 hertz also we are still looking at the signal and still it is 150 hertz; that means, it is allowing 150 hertz signal to also pass through the RC filter. Here you again see the voltage and you see that the voltage is also similar 4.96 volts; that means, there is no deterioration in your signal until 150 hertz.

Now, let us increase the signal slowly in terms of not 160 hertz 150 by 10 step by step of 10 hertz. So, 160 hertz 160 hertz you look at the amplitude it is almost same let us increase little bit more yeah go little bit higher ok. Now you see slowly the amplitude will start decreasing, alright. As he increases the frequency the amplitude should start decreasing is it decreasing.

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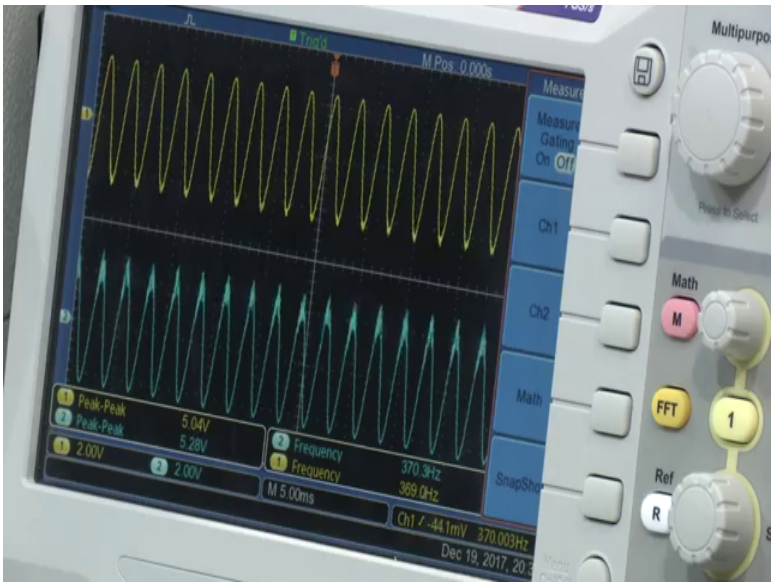

So, what is the what is the value of resistor that we have used? Let us let us quickly cross check why the why above 1.5, 159 hertz it is not decreasing, right? So, we go back to we go back to ours slide and we see what are the value of R 1 R 2 and C. C is 0.1 micro farad, C is 1.1 micro farad R 1 is 10 kilo ohm, R 2 is 10 kilo ohm for that, what is the value of fc?

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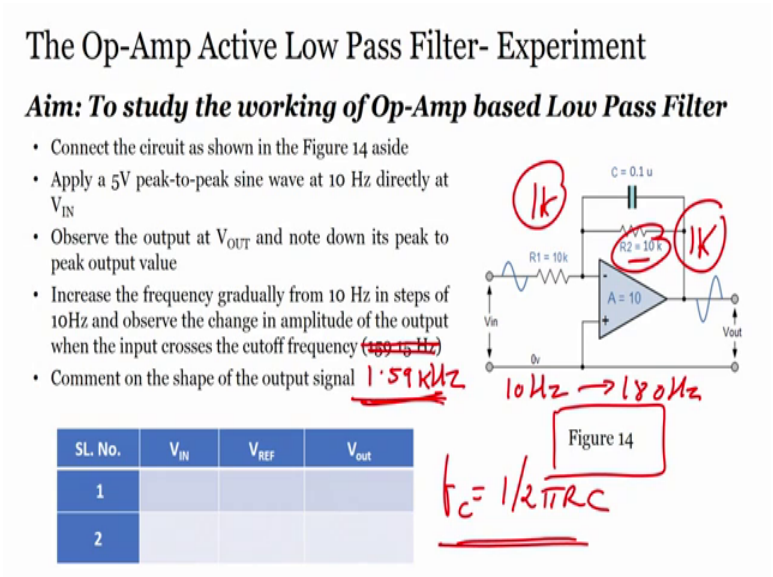

So, guys you do one thing let us see what is the value of fc in terms of 1 upon 2 pi RC. If I use this value what is the value of fc value of fc is 1 ok. So, here what we have done

instead of why we were not able to see the change in the amplitude, because instead of 10 kilo ohm instead of 10 kilo ohm he used a resistor of one kilo. So now, totally this value what we are looking at 159.15 hertz will change, right? Will change.

So, we have now 1 kilo ohm, we have 1 kilo ohm in this case my fc would be 1.59 kilo hertz 1.59 kilo hertz. So, is it not 159 hertz, but one point this one this value this value guys is not anymore 159 is 1.59 kilo hertz alright? Why because instead of 10 kilo ohm here we have used 1 kilo ohm we have used 1 kilo ohm.

You see the if you change these values suddenly. So, big difference in your fc, right? So, so understand this very correctly that if you if the circuit is given and if you do not use the same component with the same values which are given in the circuit your measurement would be wrong, your measurement would be wrong alright. So now, in this case let us increase the frequency. So, we have seen from 10 hertz he increased to some 180 hertz and we could not see any change, right?

Let us see above 180 hertz above 1 kilo ohm. So now, let us keep increasing the frequency till 1 kilo hertz. And let us see on the oscilloscope let us see on the oscilloscope ok. So, right now we have you can keep 1 kilo hertz that is fine. So, what is our cut off frequency? Cut off frequency the new cut off frequency that we are calculated based on R 1 and R 2 equals to 1 kilo ohm is 1.59 kilo hertz, alright? 1.59; that means, what we are assuming is that the active low pass filter will allow the frequency until 1.59 kilo hertz and above that it will not allow; that means, you can see the change in the peak voltage.

So, let us see let us keep on increasing 1.1 can you make it 1.1 kilo hertz 1.1 ok. Now you see there is a change in the peak to peak voltage it is 4.16 volts for 4.15. Now you can increase keep on increasing and then you can see the change in the voltage you can see that is 3.52 volts, 3.52 volts you keep focusing on this change in voltage and change in frequency.

So, the if you if you keep on increasing can you keep on increasing alright you see here. So, if he keeps on increasing the input frequency the output is now decreasing, right? Not only voltage, but also your frequency.

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Your frequency is also not allowing and your voltage is also getting smaller and smaller and smaller; that means, your peak to peak voltage is getting changed. So, we have recalculated based on 1 kilo ohm, and what we found is the cut off frequencies 1.59 kilo hertz, right? 1.59 kilo hertz. So, based on that you now can see a practical experiment, where changing the frequency changing the input frequency we can see the change in output frequency, but above the cut off frequency there is a change in the amplitude peak to peak voltage. At the same time at certain frequency to be not allowed to pass and this is the role of the high active filter low pass active filter, why low pass active filter?

Because we are using R we are using C and we are using operational amplifier. And now here we are using a non-we are using inverting of amplifier as an Op Amp we can also use non-inverting amplifier in case of the low pass filter. So, if it is non-inverting amplifier it is still active filter it is inverting amplifier is still an active filter, but the formula of fc remains same fc equals to 1 upon 2 pi RC make no mistake that if you if you use the R of 10 kilo ohm and R of 1 kilo ohm there is a huge change in your cut off frequency, right? Huge change in a cut off frequency.

So, the error that you see when we were performing the experiment that we were assuming that the frequency would be much lower, which is 159 hertz assuming that r one and R 2 are 10 kilo ohms, and we were we were we were surprised that oh it is not reworking, but it was not working because the resistors value were not get that in kilo

ohm and in fact, they were 1 kilo ohms, but when we converted back to when we when we calculated our cut off frequency value then we found that the fc value is about 150 1.59 kilo hertz and then when we perform the experiment we could see that theoretically and experimentally the data is matching all alright.

So, let us quickly recall about this particular is a big, big module as you see most of my modules are like half an hour to 40 minutes this is more than 1 hour, right? And it is about 1.20 minutes. So, the reason is because I do not want you to miss out on the filters. While reading this module probably you have taken already 2 or 3 breaks that is fine you take your break you can stop this the advantage of NPTEL videos are you can stop any time, right?

Ah Get fresh come back and with a fresh mind and again focus. So, it is on you how you want to study, but the point is filters are extremely important application of the operational amplifier they are used in almost all communication systems and that is why; I did not want you to miss anything in the side we tried to put more emphasis on the filter, we understood what are the low pass filters, we understood what are the passive low pass filters, we understood how can you divide the filters in digital filters analogue filters based on element. And then we can derive filters in terms of frequency, right? Low pass, high pass, band pass, band reject and all pass and then.

Today we have just seen the low pass. So, you assume that if you have taken so much time in understanding low pass filters how much time you will take for high pass and band pass. So, the do not worry about that the advantage of like I said the NPTEL courses is that you can pause anytime and start anytime it is it is with you it is in your hand when to stop, right? If you are in my lecture you cannot stop me speaking in between and say ok. I have to go out ah, but if you are at your home and you are looking at YouTube videos or the videos, which are uploaded now you can always stop it is it is with you.

So, look at it, understand it, focus it these are very important experiments that I am trying to show it to you. again understand that those people who are blessed to have all the equipment in the laboratories whose those who have facility to use this equipment for them it may be ok. This is the same thing we already know, but there are a lot of people

who do not have access to even the simplest equipment and for those people I think this course or this particular module is little bit useful alright.

If you have any questions, once you once you find out yourself the answers to the questions that I asked. If you still cannot find the answer please feel free to ask me, right? My t a s are there I am there to help you out. So, do not worry about it try to experiments if you have facility in your laboratory and try to do this experiments once again even you have carried out the experiments with that, for this particular module we will finish it right over here and I will see you in the next module with another set of experiments.

So, to understand and so, to understand how you can apply the theoretical knowledge of the operation amplifier, of the indicator circuit and into the experimental point of view. And we will perform the experiments we will get some data and we will have much more hands on right will get hands on experience of how we can we can really work on the things of course, still it is virtual way of getting hands on.

So, I cannot use a real terminology of hands on, but at least you can see how the experiments are done in the laboratory, right? So, with that I will see you in the next class by that time you take care of yourself bye.