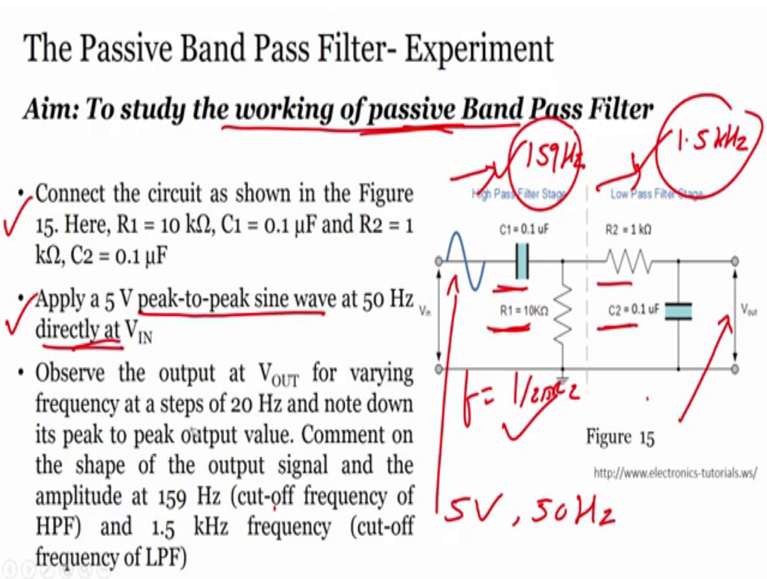
Integrated Circuits, MOSFETs, Op-Amps and their Applications
Prof. Hardik J Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture - 56
Experiment: Passive and active band pass filter

So, welcome to this module and in this module, we will be performing the experiments that we have seen the last module which is the theory part about the band pass filter so, right?

(Refer Slide Time: 00:31)



So, we have seen how the band pass filter can be designed. And how we can how we can design the passive band pass filter, and how we can design the active band pass filter, right?

So, the idea is to cascade or to integrate the high pass filter with the low pass filter. Now let us perform the experiments and let us see in reality what happens, right? So, for doing that concentrate on the screen and you see that there is a figure 15, right? Where it is a high pass filter and low pass filter values are already given values are given C 1 R 1 R 2 C 2, right?

Now, once you connect the circuit as we done here. So, our aim is to study the working of passive band pass filter there is no active component it is passive band pass filter.

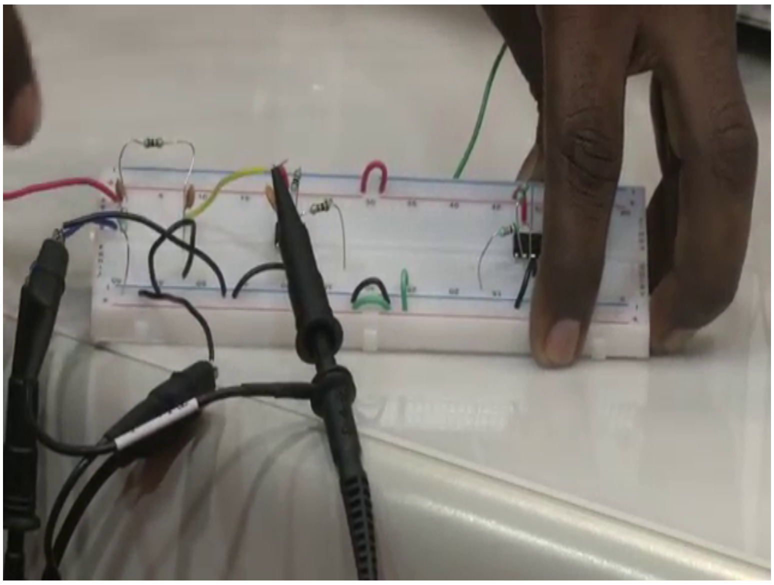
Connect the circuit as shown in figure 15, which is here will connect it here R 1 R 2 values are given 1 is done second apply a 5 volts peak to peak sine wave at 50 hertz directly at v in will apply here this voltage this voltage is your 5 volts, right? And frequency is frequency is 50 hertz frequency is 50 hertz.

Observe the output V out here we have to observe what is the value of V out for varying frequency at the steps of 20 hertz and note down it is peak to peak output voltage peaks to peak output voltage. Comment on the shape of the output and the amplitude at 159 the cut off frequency, right? At 1.5 kilo hertz cut off frequency of Low pass filter.

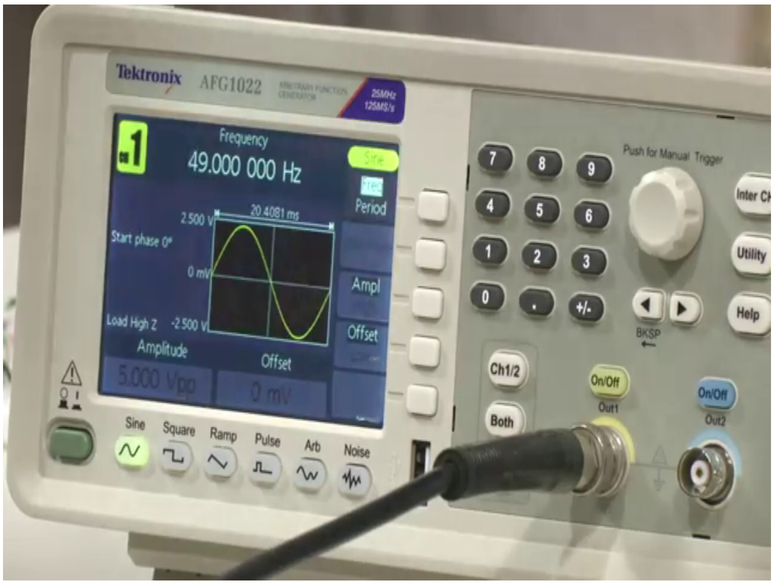
So, here we have designed the low pass filter with the cut off frequency of 1.5 kilo hertz. And here we are designed at 159 hertz the cut off frequency ok. So, we are designed this because we have how we can get this value, how we got this value again very simple I had told you earlier f equals to 1 upon 2 pi R C, right? With the formula both the values in the formula you will get this value put this formula you will get this value. Now you have the cut off frequency for low pass you have cut off frequency for high pass and let us see what we see at the output in this particular case which is the passive band pass filter.

So, I will I will like to call Sitaram to help us show the circuit on the breadboard. And then we will see how the circuit looks like these are passive, passive high pass filter and low pass filter. So, you can see the passive high pass filter and low pass filter these are connected together.

(Refer Slide Time: 03:09)



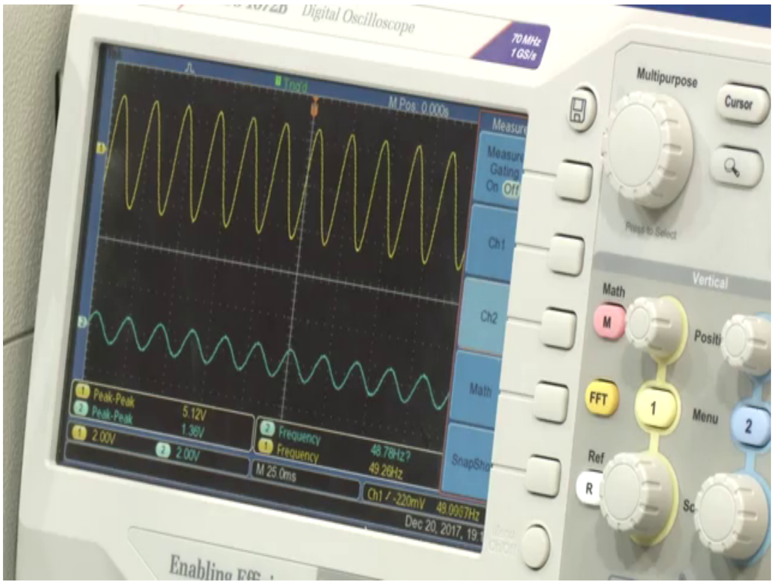
Ah if you see my pen here and this one these are passive low pass and high pass filter they are connected or integrated together. Now we are applying the signal through the frequency generator. So, you can see what is the frequency generator you will see what is signal frequency generator? And we will see that on applying the signal at frequency generator what is the output in the oscilloscope, what is the output at the oscilloscope?



So, let us focus on frequency generator let us see. So, what we see the frequency a on the frequency generator we have set around 49 hertz around 49 hertz. And the amplitude is 5 volts peak to peak amplitude is 5 volts peak to peak, right? Now on applying this signal on applying this signal in the input of the high pass filter at the input of the high pass filter, right? Ah it will pass through the input which is high pass filter and the output which is low pass filter.

However high pass and low pass are integrated together or they are connected together, let us see the output signal the output of the low pass filter, right? So, actually you do not get fuse this is nothing but high pass and low pass connected together. So, it is just band pass filter. So, input of band pass filter is a input to high pass filter and output of band pass filter is output to the low pass filter.

(Refer Slide Time: 04:45)



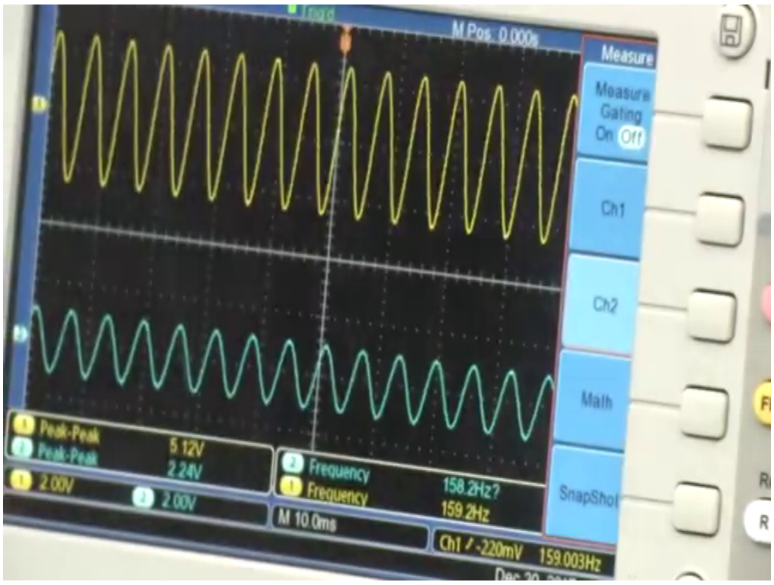
So, when you see what you can observe is at the applying 5.12 volts, right? You can see that you cannot the it is not allowing the same signal to pass through

It is not allowing same signal to pass through; that means, that it is blocking this particular frequency is blocking this particular frequency. And you will also observe very important effect that we have seen earlier con loading effect alright? We will observe the loading effect at certain point I will tell you when.

So now, we are increasing the frequency as you can see on the right bottom side right bottom of screen that is, if talk about quadrants, right? The 4th quadrant yes that one for Q 1, Q 2, Q 3 third quadrant or you can say if you Q 1, Q 2 you can say frequency 59.14 hertz and frequency 58 58.99 hertz. So, yellow one is the input signal, blue one is the output signal you can say frequency is ok, but the amplitude is not; that means, that it is not allowing the frequency to pass through this particular filter pass through this particular filter.

Now, let us increase the frequency increase in the frequency you can also see that peak to peak voltage is also increasing we will increase the value for this particular high pass filter now the frequency that we have set is 159 hertz, right? So, we will see that when you come to 159 hertz or close to 159 hertz you will see sudden jump in your sudden jump in your output, right? So, still you are not able to see.

(Refer Slide Time: 06:39)

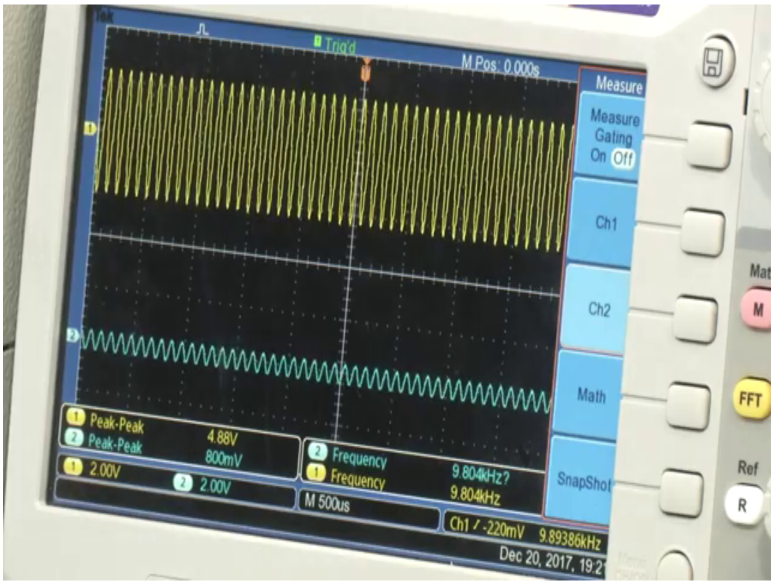


So, you see the one thing is you are this is the maximum like 159.2 hertz now it is allowing to pass, but still we cannot see the voltage at the output, right? Which is 2.4 volts and that is because of the loading effect that is because of the loading effect. Since, loading effect we can remove if we use the operational amplifier if we use the operational amplifier that is the active filter that is why; in most of the cases you will see that people do not use passive filter because there is a loading effect, in clearly see a loading effect coming into play if we keep on increasing the frequency we can pass the frequency until 1.5 kilo hertz and above 1.5 kilo hertz again you will be able to see that the voltage is decreasing significantly.

So, if you go and keep on increasing keep on increasing the frequency you see it is 1.68 kilo hertz, right? So, it is above your 1.5 kilo hertz which you have set for the low pass filter. And that is why you are able to see that now again it will start blocking the higher frequency. So, it will only pass certain band of frequency again you cannot see that significant difference or we cannot understand that significant difference in the in the output that is because of the loading that is because of the loading.

We cannot understand significant or we cannot deal any actually when the loading is there, when the loading is not there, which band is passing, which band is not passing that we cannot see because of the effect of the loading and that is why; always remember when we are going to use a passive filter their loading will come into picture.

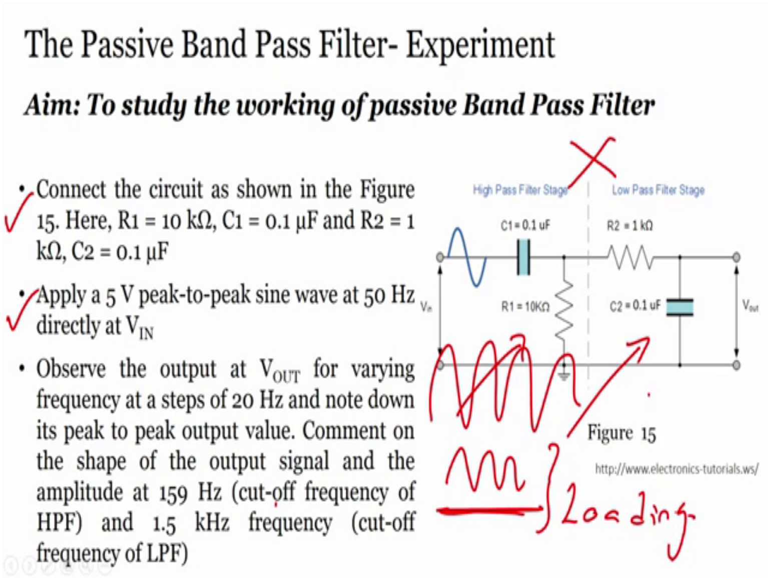
(Refer Slide Time: 08:12)



So, no more passive filter (Refer Time: 08:11) will not use, right? So now, if you come back to the screen, if you come back to the screen what we see that because of the loading effect that comes through passive filters, passive filters if you if you can come to the screen ok. You will be able to see that the loading effect comes into picture, right? That we have seen already that is why we do not use the passive filters we cannot use the we should not use the passive filters, right?

So, what is the comment on the shape of output signal output signal follows the input signal.

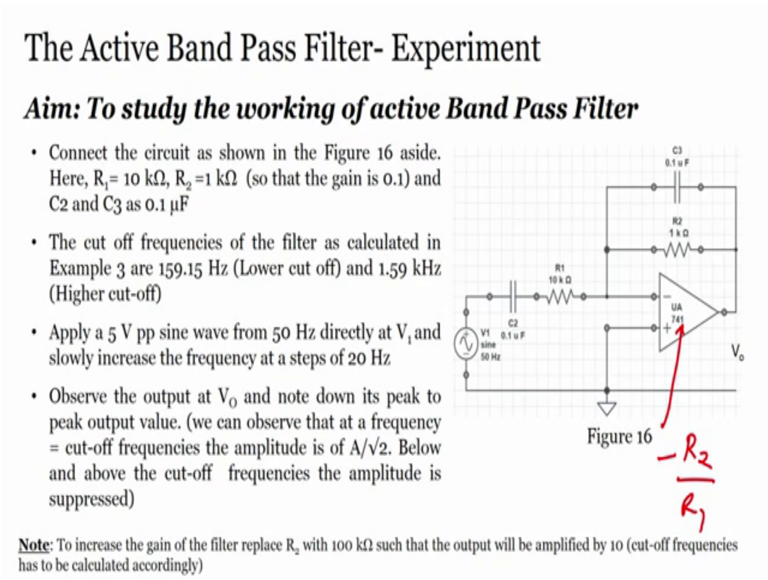
(Refer Slide Time: 08:49)



With a with a voltage which is smaller than the input signal and it is difficult to delineate between which band of frequency is allowed to pass, which band of frequency is not allowed to pass because of the effect of loading alright? So, this is our comment this is our comment when we are using the band pass filter in the experiment in the experiment.

So, our experiment is on band pass filter, right? Now instead of passive band pass if instead of passive band pass if I use if I use a active band pass filter if I use an active band pass filter.

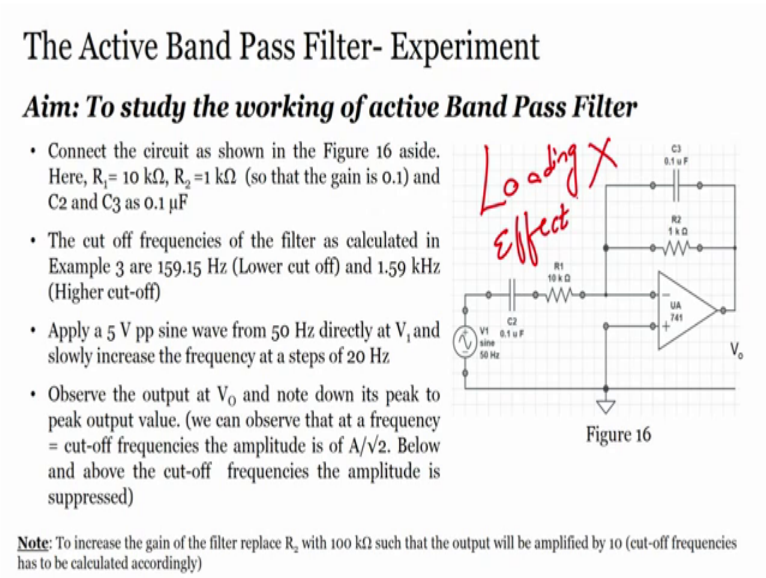
(Refer Slide Time: 09:28)



Then what will happen? Then what will happen? There is a there is a question, right? So, if you see the circuit here again we have we have high pass, we have low pass, we have the amplification with the help of R 2 R 1, right? With the help of R 2 and R 1; that means, that this is which kind of amplifier quickly see.

Let us see amplifier this is an inverting amplifier it is an inverting amplifier; that means, amplification is R 2 by R 1, right? Amplification will be R 2 by R 1 good. So, what so what we will be able to see is loading effect.

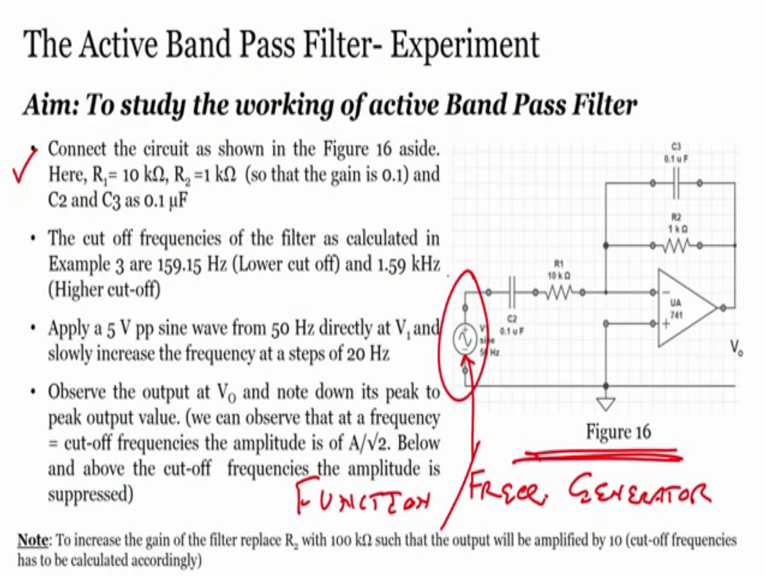
(Refer Slide Time: 10:21)



Loading effect would not occur would not occur alright? We will see this we will see this.

So, if you want to if I want to design this if I want to design this, what should I do? I have to first connect this circuit as shown in figure 16 as shown in figure 16. So, I will connect my circuit in this particular format I will apply the signal at the input using the frequency generator.

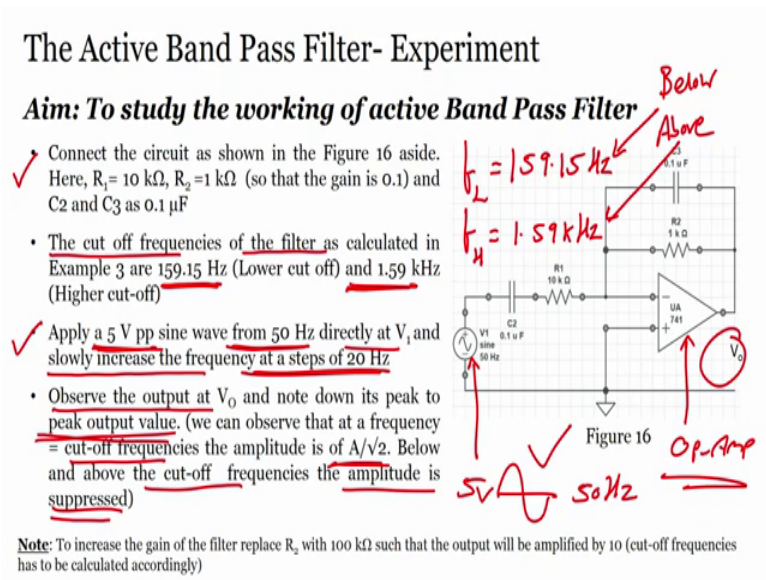
(Refer Slide Time: 10:47)



Frequency generator or function generator, right? I will apply signal at the input using frequency generator or function generator.

Then what is the next case? The next step the next step is that the cut off frequencies the cut off frequencies of this filter are calculated as 159.15 hertz 1.59 kilo hertz this if we have already seen in the example earlier in a last module, that if we use this particular circuit our cut off frequency or lower cut off frequency f L would be 159.15 hertz.

(Refer Slide Time: 11:35)



And our upper cut off frequency or higher cut off frequency f H will be 1.59 kilo hertz that we have already calculated, right?

So now once we know the cut off frequency f L and f H what we will do will apply a 5-volt sine wave from 50 hertz at V 1 this is V 1 we will apply 5 volts sine wave 50 hertz. And slowly increase the frequency at a steps of 20 hertz, right? We will start increasing the frequency with the step of 20 hertz this is same like passive filter is same like passive filter, we are going to do the same similar experiment only difference is now we have op amp now we have op amp to help us op amp to help us alright?

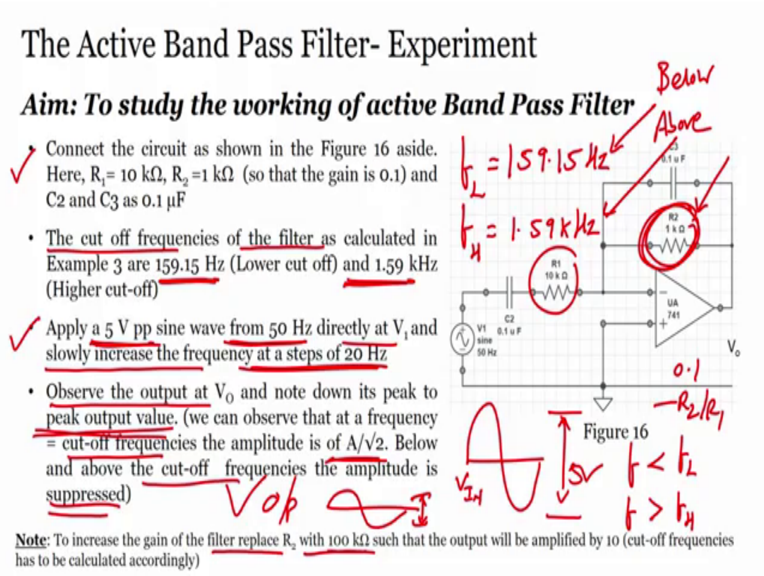
So, let us see observe the output at V o we have to observe the output at V o output voltage here at Vo and note down it is peak to peak output voltage peak to peak output voltage. And what we will we able to see; we able to see that a frequency that is equal to cut off frequency amplitude is about A by square root of 2, A by square root of 2.

While below and above the cut off frequency below and above the cut off frequency below the f L and above f H below f L above f H, below f L and above f H we will be able to see that we will be able to see that the cut off frequencies and the amplitude is suppressed, the cut off frequency is and amplitude is suppressed ok. So, the point is point is that when we are going to use the active band pass filter we are going to use active band pass filter the points that we have to remember is 1.

Once these we should have cut off frequency, which is lower cut off frequency, which is high cut off frequency to that we will when on applying 5 volts peak to peak if the you will see that the peak to peak output voltage or the frequency which is cut off frequency the amplitude is off a by root 2, and cut off frequency amplitude will be a by root 2. And below the below and above below and above the cut off frequencies the amplitude is suppressed some amplitude is suppressed means what let us see.

What do you mean by suppression of the amplitude? Let us see what is suppression of the amplitude.

(Refer Slide Time: 14:30)

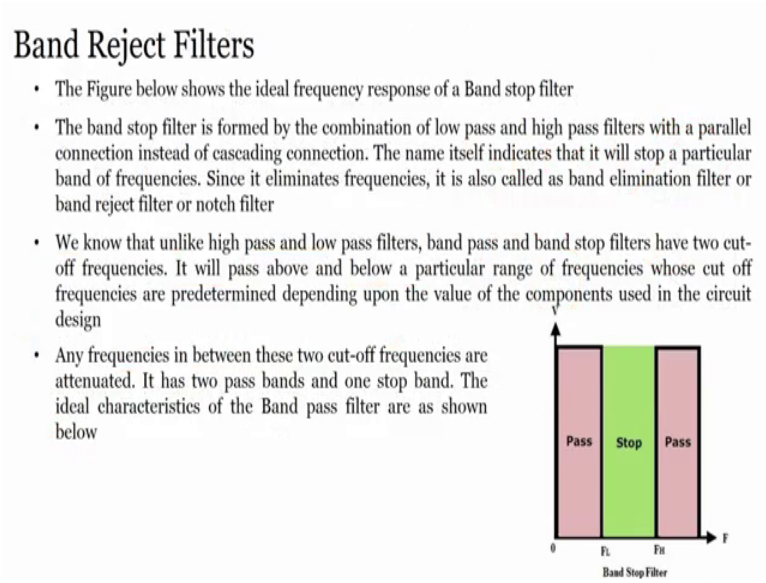


So, if I have a peak to peak voltage of 5 volts 5 volts, right? When I say that below and above cut off frequency, then my frequency is less than f L frequency is less than f L, my output my output frequency my amplitude will suppress it will be less compared to what I see what I give as a input signal what I give as a input signal my output signal is suppressed. In case of f greater than my frequency is greater than the f H frequency is greater than the f H again I will see the similar effect again I will see the similar effect; that means, when we apply output signal which is 5 volts my output will look suppressed my output will be suppressed alright?

So, another point is here we have R 1 equals to 10 kilo ohm R 2 equals to 1 kilo ohm, right? So, if I calculate my gain my gain is 0.1 gain is 0.1. If I want to increase the gain, right? The filter replace R 2 with 100 kilo ohm then if I if I want to increase the gain if I from 0.1 to 1 or to 10 I can keep on changing the value of R 2 I can keep on changing value of R 2 because I have gain which is R 2 by R 1, right? Now R 2 is 1 R 1 is 10 kilo ohm gain is 0.1 if I make R 2 equals to 10 kilo ohm 10 kilo ohm by 10 kilo ohm my gain is 1, if I make R 2 100 kilo ohm 100 kilo ohm by 10 kilo ohm my gain becomes 10, right?

So, 0.11 10; that means, that I can change my gain with a help of R 2 in case of passive filters we cannot change the gain we cannot change the gain.

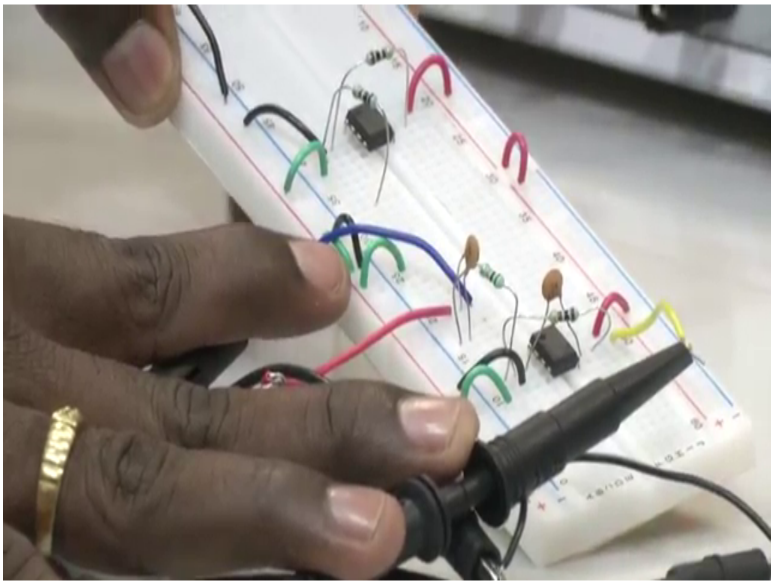
(Refer Slide Time: 16:26)



So, if this is the case if this is the case let us let us actually implement the circuit implement the circuit on the breadboard on the breadboard and let us see what happens what happens to our output voltage when we apply 5 volts peak to peak sine wave, right? when we apply 5 volts peak to peak sine wave.

So, let us see on the breadboard Sitaram is back and he will show you the filter he will show you the filter on the breadboard yes.

(Refer Slide Time: 17:03)

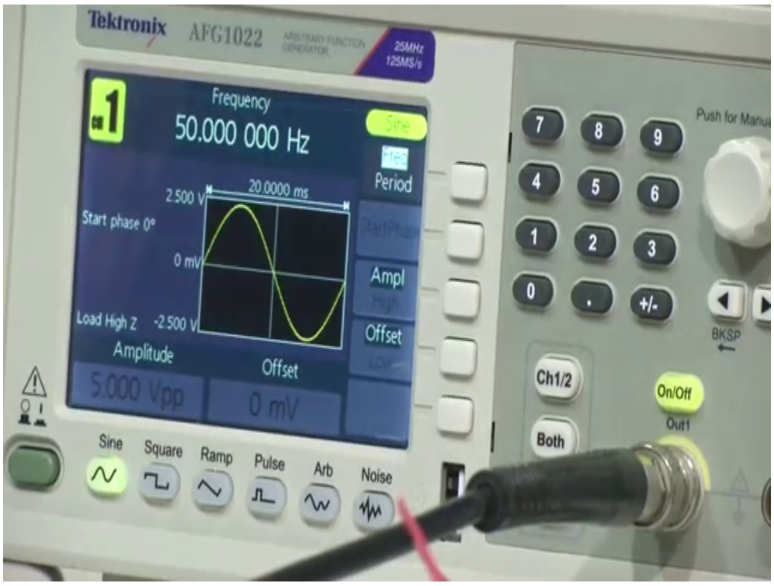


Later bit more yes that is excellent. So now, what you see is you have a high pass filter you have a low pass filter, you have the operational amplifier, you have the operational amplifier. So now, you are using this operational amplifier in a inverting mode inverting mode that is why the gain of this can be changed by using R 1 and R 2 this by changing this you can change the gain alright?

For now, we have kept gain of 0.1 we have see we have kept the gain of 0.1 and we have we are applying the input to the high pass filter we are applying to the input to the high pass filter and then we will look the output at the low pass filter. So, again this is band pass filter. So, input at the band pass and input output at the band pass. So, the only change between passive and active is that here we have op amp and we can change the gain we can change the gain alright?

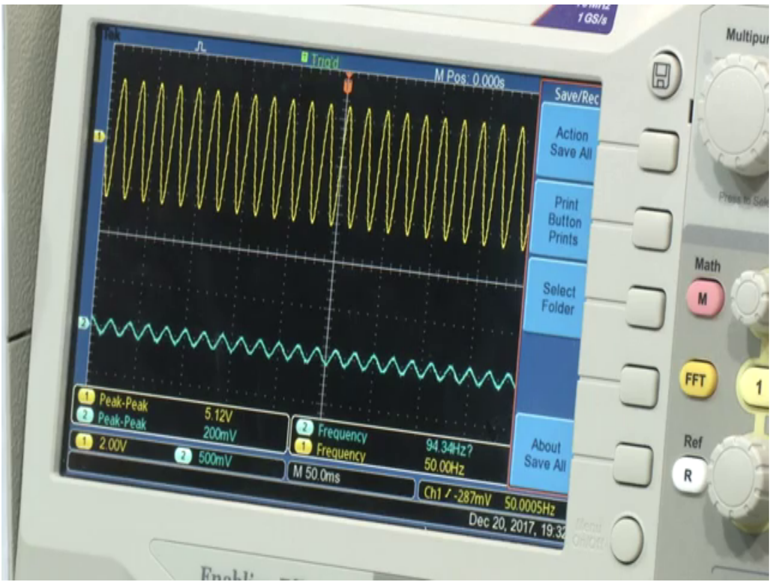
So, let us see let us apply the signal let us apply the signal you we have because of op amp is there.

(Refer Slide Time: 18:07)



We are using the dc power supply through dc power supply we have already applied plus minus 15 volts as bias voltage. Now if you see the screen what you observe you observe that a frequency of 50 hertz is given and amplitude is given as 5 volts. The frequency is 50 hertz amplitude is 5 volts. In this particular case this particular case my output voltage my output voltage with is a voltage on the oscilloscope what is the output voltage?

(Refer Slide Time: 18:38)

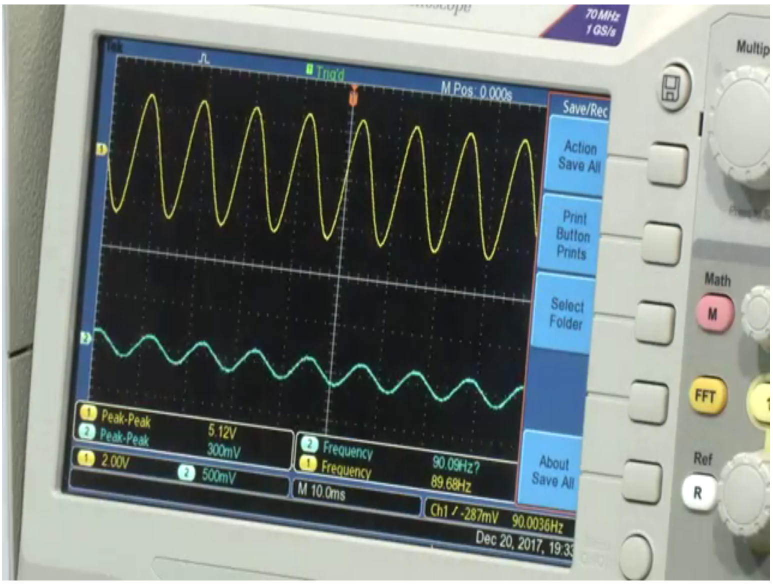


Let us see if you can zoom in excellent. Now what we see is my frequency 50 hertz what was my frequency or the low frequency f L my low frequency f L was a 159.15 hertz. So, this is 50 hertz it will not allow in that is why you can see peak to peak voltage look at this 200 milli volts not allowing very clear to see, right? It is suppressed that is what we are discussed the signal which is input signal at the output is completely suppressed below f L, right? Below f L.

It will also gets suppressed above f H we will see that alright? Now let us increase in terms of 20 hertz as we have written in the experiment. So now, we increase it from 50 to 70 hertz we see that still it is suppressed because it is below f L the frequency cut off frequency of the high pass filter. Now we increased to 90 increased to 90 yes. So, you can see here also the function is generated the he has increasing 90 hertz, right? Ah, but every time we do not have to really focus on function generator.

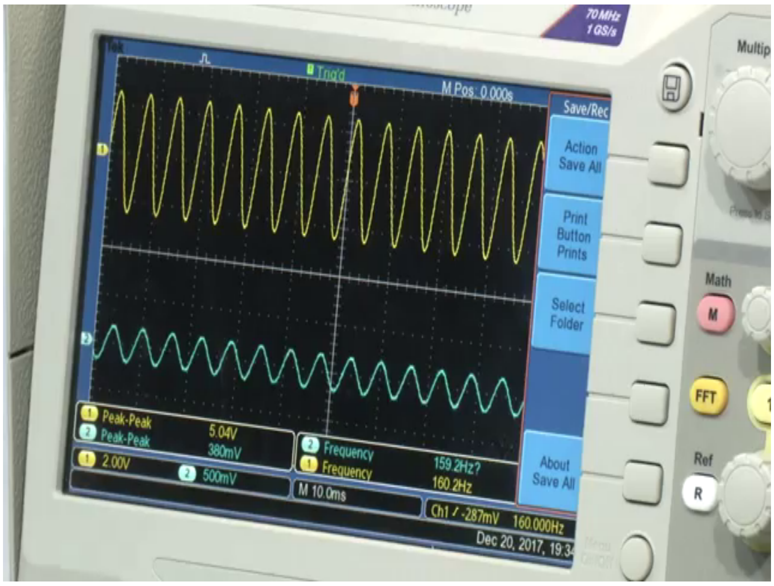
Because the same signal whatever we are changing we can also see on the oscilloscope that is why; we are not showing every time when he changes the 90 hertz 100 hertz you can easily see on the oscilloscope alright? You see here whether the blue and black yellow one is 90 hertz 110 hertz now he will change it to 110 change it to 110 ok.

(Refer Slide Time: 20:00)



You can see now still it is not allowing to pass let us go further let us make 130; 130 still same, let us make 150 still same, let us increase it to 160.

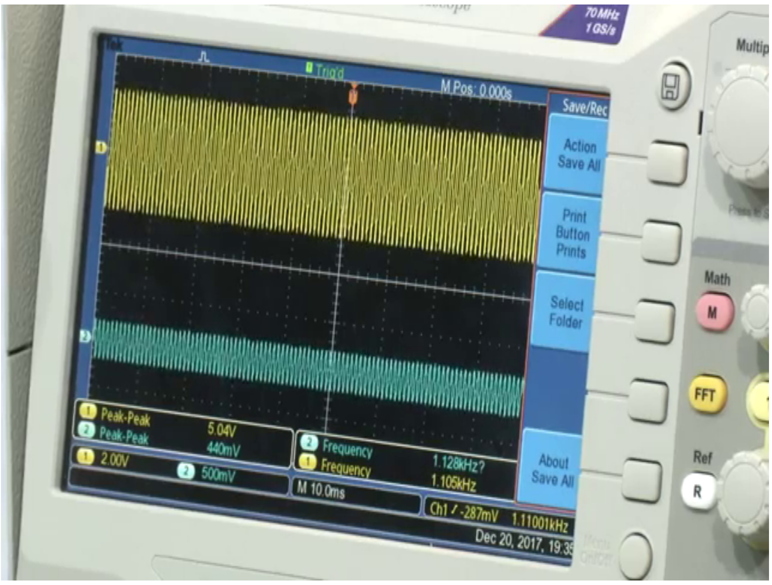
(Refer Slide Time: 20:28)



Now, you can see again write the gain is quite 0.1 oh I see I forgotten he helped me to understand why I was I was confused why the gain why your voltage is not increasing, right? Why your voltage is not increasing, but the point is here we have set the gain of 0.1 gain of 0.1 means whatever the voltage is there if you multiply by 0.1 the output will even decrease, right? Output will even decrease. So, you see if I am teaching you still I forget then you are learning you would also forget, right?

So, it is absolutely if you forget the point is try to understand why you are not getting it immediately I was confused that I am applying 5 volts why I am not getting output voltage as 5 volts because my gain is 15.1, but if I increase the gain we will see in another application if I increase the gain you will see the change alright? Now I am increasing the frequency I will go till 1.5 kilo hertz can you go till 1.5 kilo hertz.

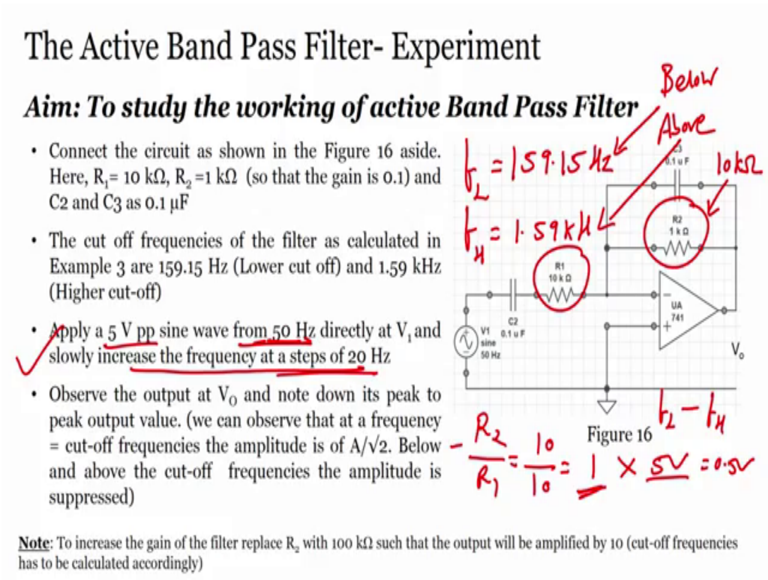
(Refer Slide Time: 21:38)



If I go to 1.5 kilo hertz now if I go above 1.5 kilo hertz you will see you will see suddenly again the gain will be less. So, I keep on increasing 1.5 kilo hertz above 1.5 kilo hertz you will see the gain will decrease and the output voltage will even decrease suddenly you see 220 and 210, 200. Now again it is suppressing the signal it is again suppressing the signal.

But what if I can change the gain to 1; so, what if I change the gain to 1. So now, he is trying to put another value which is higher value; that means, you come on the screen I will show it to you. So now, what I am talking is now here we had R 1 R 2 equals to 1 kilo ohm.

(Refer Slide Time: 22:34)



R 1 equals to 10 kilo ohms; that means, R 2 by R 1, right? Was 1 by 10 which is 0.1 that why whatever signal it was passing, right? The band it was passing was getting multiplied with this particular voltage by this particular factor; that means, 5 volts by 0.1 will give us 0.5 volts correct.

So, you could see the output generally it was close to 400 milli volts or 300 something milli volts, right? When we where within this we were above the f L were above f L. And or we between f L were between f L and f H you would have seen the voltage which was around 350, 400 milli volts, right? But when let us see if I if I reduce this and if I change the factor to 1; that means, I have R 2 of 10 kilo ohm I have R 1 of 10 kilo ohm in both the cases in both the cases if I change my R 2 in this particular case if I change my R 2 to 10 kilo ohms to 10 kilo ohms my gain would be my gain would be 1.

So, in this particular case let us see how the circuit will work, let us see how the circuit will work, right? We will do the same experiment; that means, that will apply 5 volts and will start from 50 hertz start from 50 hertz and increase the frequency at the step of 20 hertz increase the frequency at step of 20 hertz, right? Let us go back to the breadboard let us go back to the breadboard and what we see here what we see here is now the resistor this resistor, right? He has kept it to make the total value close to 10 kilo ohm close to 10 kilo ohm 500 ohms.

So, he has to again get a another resistor another resistor because we want value which is 1 value which is 1, but if you do not have if you do not have that is fine. So, what is the value of resistor that you have 10 k 10 k and the another resistor.

10 k.

So, then we have 1.

But cut off frequency (Refer Time: 24:52)

So, do we have another one that is fine. So, the point is connect it back connect it back. So, you so the point that I was making is if I if I change my resistance value, if my change my resistance value I could see the change in the output signal, right?

Right now, we do not have this register and I do not want to you know invest this time of yours in understanding that if I change the resistor what will happen, but the point is if I if you change the resistance here and if you convert and you keep the value same, right? Away you have to understand that the output will depend output will depend the based on the gain of the amplifier based on the gain of the amplifier alright?

So now what we have seen, we have seen an active band pass filter and we have seen a passive band pass filter as an experiment. The next in the next module we will see band reject filter. So, the point is until now what we have understood we understood the theory of the filters, then we have seen low pass, then we have seen high pass, then we have seen band pass, then we have seen active band pass, we have seen passive band pass, we have seen active low pass, we have seen active passive low pass, we have seen active high pass, we have seen passive high pass this thing we have covered.

The next would be based on the frequency, right? You remember low pass, high pass, band pass all 3 checked. What is remaining? Band reject band reject; that means, a particular frequency you have to reject from the rest of the band, that frequency I do not like that frequency I will reject it. So, to create that frequency to create that particular or reject that particular frequency we need a filter the filter that will reject that particular frequency is called band reject filter, band of frequency which is rejected which is undesired unwanted that will be rejected from the band of frequency that why it is a band reject filter.

Again, for band reject filter we will see how we can design this band reject filter using operational amplifier. The one thing that you got in this particular module is that if I use a passive circuit, passive circuit then there will be a effect of Loading if I use active circuit the loading will not come into play, correct? Now try to perform it by yourself if you cannot get the answer if you are confused if you are if you are struck somewhere feel free to ask, do not ask without trying at home or trying in the laboratory, right? Try first you have some genuine question ask.

And we will try to get you back as soon as we can in your forum I will I will help you to get the answer of whatever your question is and also there are tas who will help you out to understand how the things work ah. So, feel free to ask me questions if you are stuck in your experiments alright? So, in the next module we will see what is band reject filter? Till then, you take care, I will see in next module bye.