Electronic Systems for Cancer Diagnosis
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Lecture – 39
Experiment on Op – amp based ECG Signal Acquisition, Conditioning and Processing for Computing BPM

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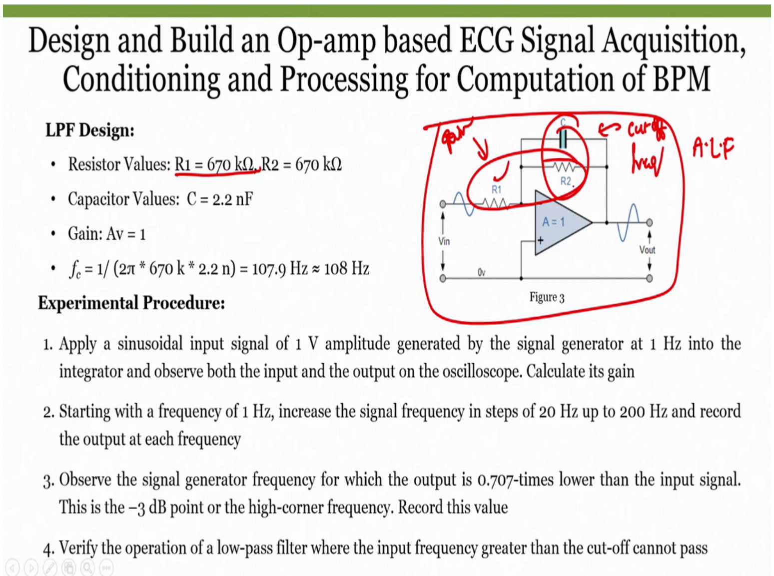

How do we do filtering circuit? Right, as we have already seen in our previous modules previous things we know how to make use of an operational amplifiers and what are the advantages and disadvantages of going within active filters when compare to the passive filters. And, we have also discuss about the design, just recall what we have discussed and if I see here this is our active low pass filter right. So, the combination of R and C tells our cutoff frequency and the combination of R 1 and R 2 resistance tells us gain.

Now, what value what value of cutoff frequency we require? We require cutoff frequency of 100 hertz. Since, it is a low pass filter I do not want to see odd multiples of our power line interference; that means, 150 hertz, 300 hertz everything. So, we will be using low pass filter with a cutoff frequency of 100 hertz. Now, how do we know the cutoff frequency? So, in this case we are considering a resistance as 670 kilo ohms, this is R 1 670 as well as R 2 also as a 670 kilo ohms.

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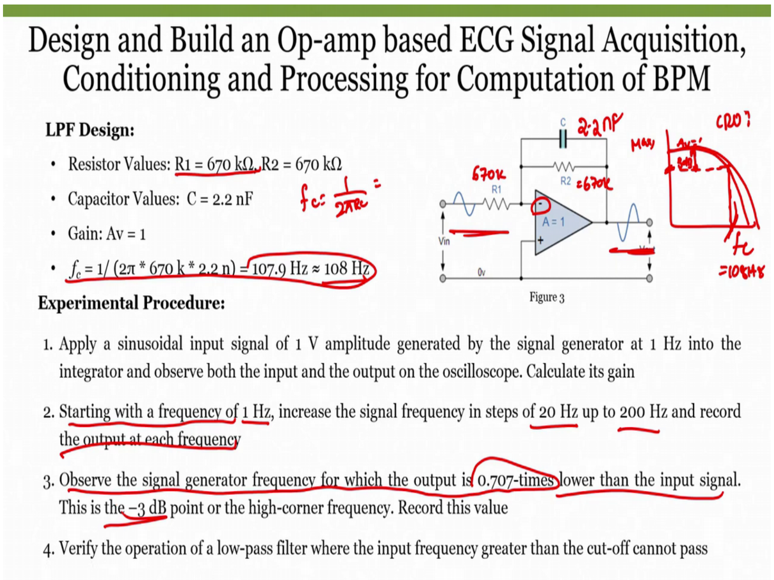

We are taking 670 kilo, this is also as 670 kilo and capacitor as 2.2 nanofarads. Now, if a if I can compute the cut off frequency, what is the formula? f c is equal to 1 by 2 pi R c right. So, when we calculate everything we will get a cut off frequency somewhere around close to 108 hertz. If I take 2 nanofarads it will be even 1 1 128s we can even get it or if I take a smaller value it will be 100 hertz to. I mean if I take an larger value it will be the resistance or capacitance it will be even 100 hertz we can achieve.

So, in this case by considering the availability of resistors and capacitors we are designing a first order low pass filter with a cutoff frequency of 108 hertz. Then what about what about the gain of the system? It since R 1 and R 2 resistors are same, since it is an inverting amplifier the gain is R 2 by R 1. So therefore, the gain is 1 in this case. So, what are the input we get without any amplification? With an amplification factor of 1 you will get the same output, but since it is an inverting we will get a negative. There will be an half phase shift of 180 degree.

Now how do we know since, see if I want to understand the circuit I should look whether it is cutting off at that particular frequency, I have to have a frequency spectrum. And, you know the connecting it to a frequency spectrum will be very expensive to because, the occupant itself is very expensive. So, what we can do is that if I can visualize, if I can visualize whether the designed filter is cutting off at the particular frequency in a CRO itself we can even compute the same thing in our laboratory too. How do we do that? So, as we know that when we look into our frequency spectrum of low pass filer and the gain is 1.

So, if you can calculate the 3 dB line right this is nothing, but our cutoff frequency. Now, when I represent the frequency form we are saying this value is 108 hertz. But in CRO how do we found it? What we do is that we know what is the maximum voltage we get right. So, we will apply some we will apply we will take some function generator, we will apply 1 volt as an input signal. So, since it is also a gain of 1 we will get an output as 1 volt. Now, we will slowly increase the frequency, we will slowly increase the frequency and we will observe what is the change in the amplitude. Whenever we see 3 dB line which is nothing, but half input voltage or 0.70 times that of your input signal.

That particular free at that particular point that is nothing, but our 3 dB line and from that point is the output voltage will be keep on decreasing keep on decreasing. So, that frequency if I can calculate that is nothing, but our cutoff frequency. But, to give the frequency domain visualization what I will do is that in a simulation I will show you the AC response as well as with a DC response. And, we can see the complete you know the frequency domain value too. But, this is how the connection should be looks like and we will be passing we will be using a function generator to pass from 1 hertz to somewhere around 200 hertz's within steps of 20 hertz.

And we will record then output at each frequency. So, we will observe the signal generator frequency for which the output is 0.707 times lower than the input signal that point is nothing, but the 3 dB point. So, that point we will consider as are cutoff frequency. So, in order to understand much more what we do is that we will go to multisim.

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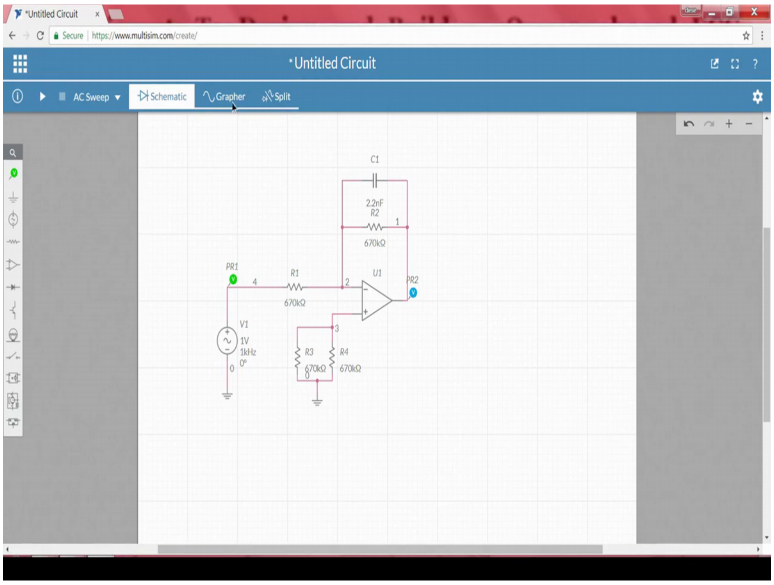

So, as we have already seen how a multisim looks like and everything in a even previous module, but our intention here is to design a filter. And, we see the frequency response as well as whatever the intuitive that we have learned from the experiment from the previous experiments as well as the you know in or procedure that we explain. We will try to put the same thing here and we will try to analyze even in a time domain too and we will compare the frequency domain response with the time domain too.

So, in such case what I need now? First I have to take my operational amplifier. So, I will go to op amp and I will select an op amp here right. Then I have to take resistors, in this case we have taken 670 ohms resistor. So, I am replacing with 670 kilo ohm sorry 670 kilo ohms resistor and one more resistor that is also 670 kilo ohms.

So, that is a negative feedback resistor. So, I will be connecting from here to here. Then what is the other one? So, we are also have to connect a capacitor across R 2. So, what I will do? I will take a capacitor, what is the capacitor that we have use in our theoretical designs? We have used 2.2 nanofarads. So, I will go with a 2.2 nanofarads 2.2 nanofarads and 2.2 nanofarads are available in the market to right, then this particular values the positive terminal should be connected to ground. So, what I will do is that rather than connecting with ground.

In order to eliminate the effects due to the bias and off set currents I will use a resistance value 2 resistors in parallel which are nothing, but 670 kilo ohms resistors itself. So, that the effect due to the bias and off set resistance can be completely removed using this right, that we have already studied in our previous modules, isn't it. So, I am taking R 1 and R 2 resistor and these two we are connecting it in parallel.

So, that it will compensate for the effects due to the bias currents as well as the base basically, for the bias currents. Then I have to apply some AC voltage right and the other terminal should be connected to ground, I will take it to ground; this is my input. So, in order to visualize a system I will one I will take here input other one I will take output. Now so, in order to understand the cutoff frequency good way is to go with our AC sweep. So, what I will do is that in AC sleep I will sweep the signal from ok.

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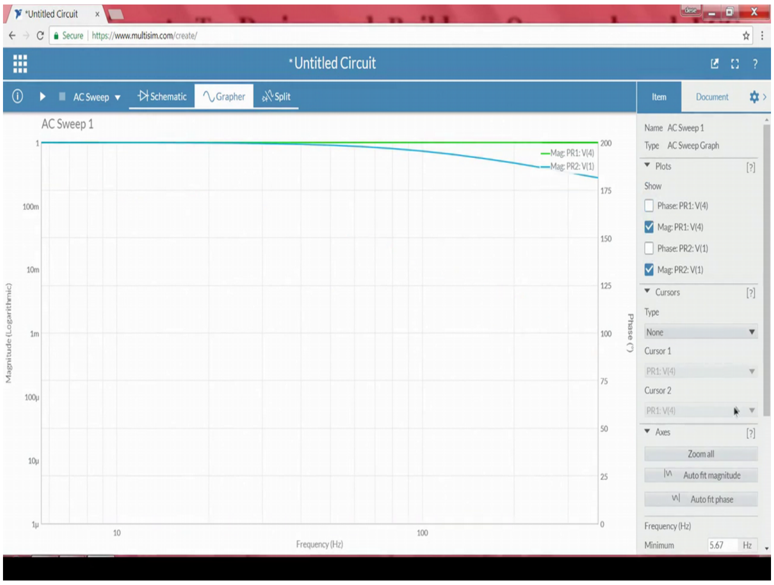

Let us simulate yeah. So, here what I will do is that the minimum hertz is of 1 hertz, I am doing and the maximum say I will go with 200 hertz right. Then we may not require the peak values sorry phase values.

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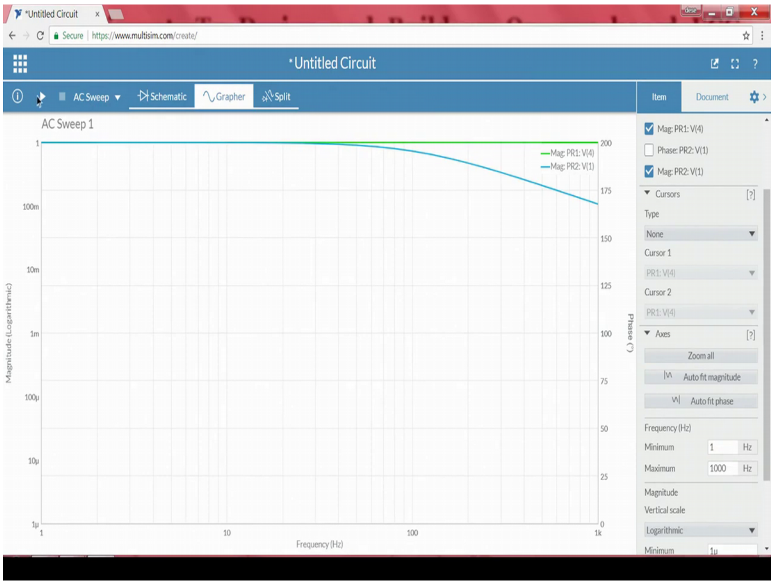

So, I will remove all the phase values, I only put magnitude values or even greater than minimum 0 and maximum somewhere around 1000 hertz I will put or 1 hertz to 1000 hertz right. Let me run once again AC sweep ok. Phase, I am removing it then till 1 omega I will put 1 omega. So now, we can see the signal 1 omega right.

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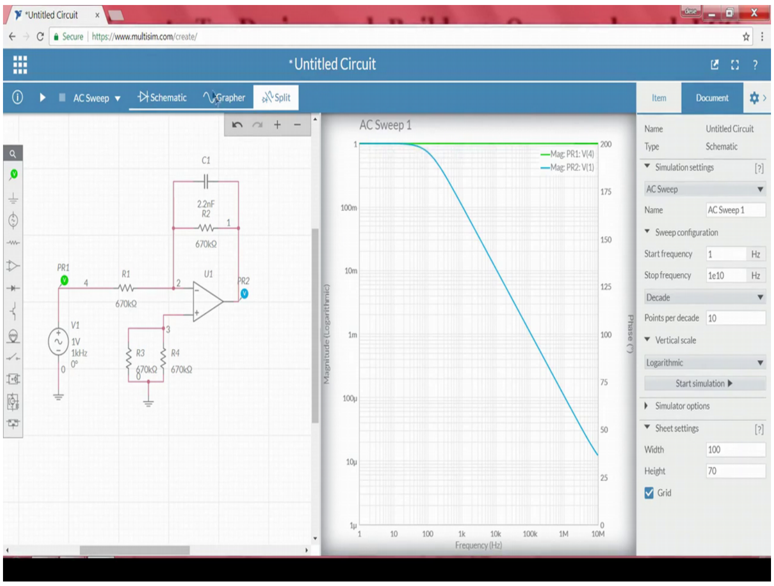

Now, green represents what? When we look into our figure we can see here green is nothing, but my input and blue is nothing by output. So, one thing is clear that the input and output are having the same gain right amplitude of 1 right, magnitude of 1. So that means, both are having the same gain, but after particular frequency if I closely observe the output is attenuating right.

The magnitude is decreasing right. But at what frequency, how do we calculate our cutoff frequency? As we know that the 3 dB line, we have to consider the 3 dB line; since it is 1 3 dB line will be 3 magnitudes below to the 1. So, in order to do that what I will do is that, I will do I will zoom the frequency domain so in order to zoom that I will change this frequency values to somewhere around 1 kilohertz.

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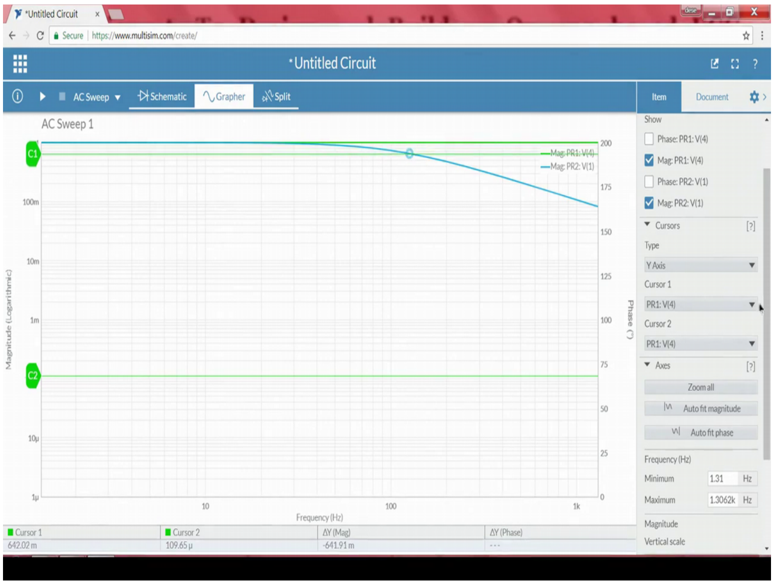

Now, this is 1 dB the below one is 1 dB, this is other dB and this is this dB. So, this frequency right somewhere around 700 right, this is 1 and this is 700. So, approximately 3 dB line. So, when I see that what is the frequency at this point? We can see we can see here 100 hertz comma 733.68 milli dB or if I put a cursor I will put x axis cursor. So, I will be slowly varying observe the C2 cursor I will be varying it to 99 sorry where, as that 3 dB line. So, the C2 value should be so, let us take somewhere around 100 hertz then I will take y axis cursor.

So, because we require to take 700 milli magnitude so, slowly I will increasing observe d Y delta Y here. So, this particular value right so, 750 800 slowly decrease 694. So, this is nothing, but my line. So, this is my if I observe this point this point will be, this particular point will be 700 milli somewhere close to this ok. I am unable to do that because, of the resolution 1 kilo hertz. Because, of the resolution I cannot see that or also

I can little bit zoom the vertical scale. So, maximum minimum I will say somewhere around 1 milli. Now, if I see 125 so, we can understand that somewhere close to 100 hertz right. Now how do we do the same thing? How do we understand when we look into when we are looking into the CRO?

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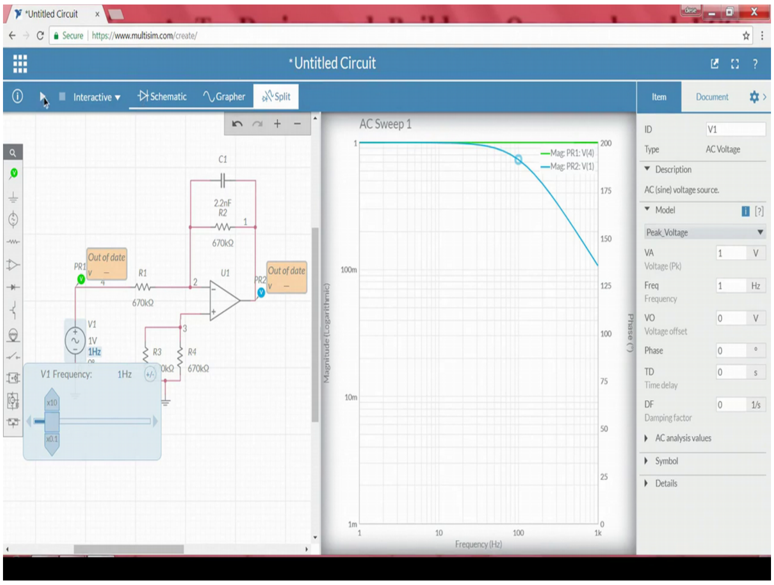

So, in order to understand what we do is that rather than going with AC sweep I will go with interactive. So, here starting from 1 hertz we will change and we will observe the input and output frequencies.

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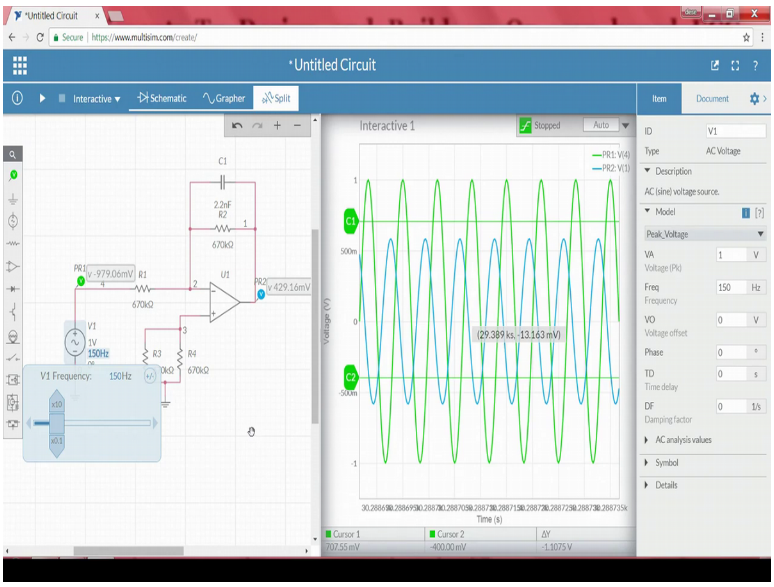

So, I will increase a time division I am increase in time division. So, we can see that we can easily observe the phase difference. So, I will make it auto, we can see the phase difference. This is R input the green colour one, the blue colour one is nothing, but our output because of we are using inverting there is a k gain phase difference. And, the amplitude wise it is one and the same; now I will slowly increase the frequency there is no change in our gain; so, with rate of 20 hertz so, I will go with a 20.

I will make it as single or auto and in order to visualize I will decrease the time division right then again I will go with a 40 right. So, in order to understand that let me put a cursors. So, what I will do is that I will go with a cursors and make it as an X axis Y axis cursor. So, at what point we have to see? We have to see a point at 0.707. So, I will put the cursor 1 at 707 milli volts. So, we can see the right now the cursor yes so, cursor 1 is the 70.

Whenever this blue colour line is below the 707 that frequency is nothing, but our cutoff frequency right so, I will increase. So, I will increase to 50 no not decreased yet. So, I will go with 60 no change not lesser than 707 milli volts, 80 not even. So, I am going with 100 right almost close, now we will increase one by one. So, before going that what I will do is that a little bit time divisions I will increase it so, that easy to we view, increase right somewhere around close to 105 almost coming close.

Now, I will increase to 107 right even little bit higher so, I will go with 108 right. If I see that if the input is at 108 hertz, the output voltage is 707.55 milli volt; even if I increase it 109 right 110 started slowly decreasing it 120 decreased. So, that particular value is nothing, but our cutoff frequency. So, in order to visualize by using a time domain signal by looking into CRO one way to do it slowly decrease your slowly increase your input frequency. Whenever it goes to the 3 dB line which is nothing, but 0.707 volts to that of your 70 percentage of your maximum voltage there is nothing, but 707 millivolts.

Whenever the input voltage is lower than 707 or just at that point of 707 milli volts that frequency is nothing, but our cutoff frequency. So, we have seen that it is nothing, but somewhere around 108 hertz right; but, even though if I increase the frequency this is not suddenly attenuating it to even below than 500 milli. The reason is the rolling factor, the role of factor of first order filter is 20 dB per decayed because, of very smaller rolling factor it will also allow particular band frequency to pass through. But we require a cut we do not have to pass a frequency at 150; that is what our power line odd multiple frequency.

But, since roller factor can be you know if I observe at 150 hertz we can see that right, only it is even much more below than our cut off frequency. So, we do not have any problem. Now, we will simulate we have done the simulation, we will do experimentally the same thing. Since, we do not have a frequency spectrum we will show you how to do the same analysis in our using our breadboard. And, use a function generator as well as an oscilloscope and we visualize the same thing and we will observe it what particular frequency it is reaching to 707 millivolts.

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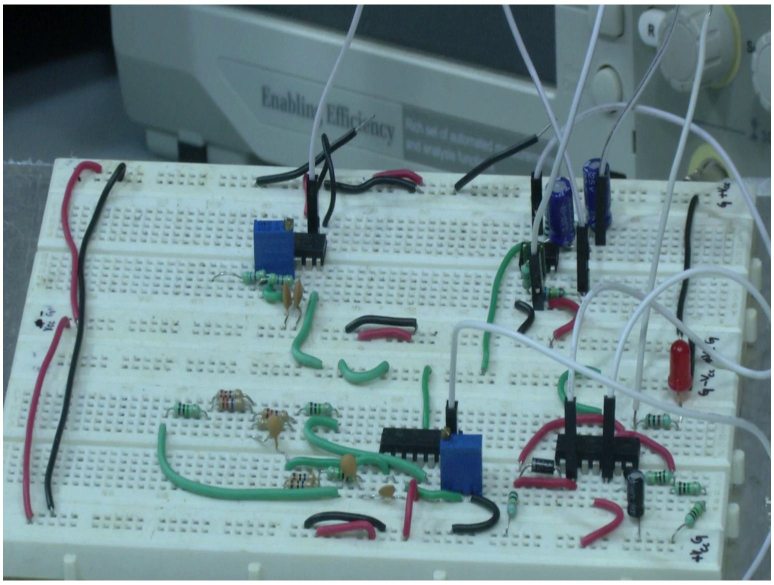

When we look into the bread board, this is a complete signal conditioning as well as a processing circuit that we are going to use in this particular case study. So, if you observe here, this part is are instrumentational amplifier part, this part contains low pass filter. If I see I am using 2 nanofarad, this is our 2 nanofarad the green colour wire. Here we can see sorry this green colour, this capacitor is our 2 nanofarad capacitor 2.2 naofarad capacitor. And, these are our 2 resistors, one is here other one is here 670 kilo ohms right.

This is a TL082 IC so, it has a dual op amp; one side of op amp you are using low pass filtering. Now, we will see this low pass filtering circuit, how it works right and the connections I have already discussed in the simulation as well as even our power point too. So, the same circuit I have made it on a breadboard and we will apply an input from the function generator right and we will observe the output in our oscilloscope. So, how do we do that? So, first since it is an active filter we have to power it. So, we will take a voltage source, we take a voltage source; we will connect plus 15 plus 15 and minus 15 to our breadboard.

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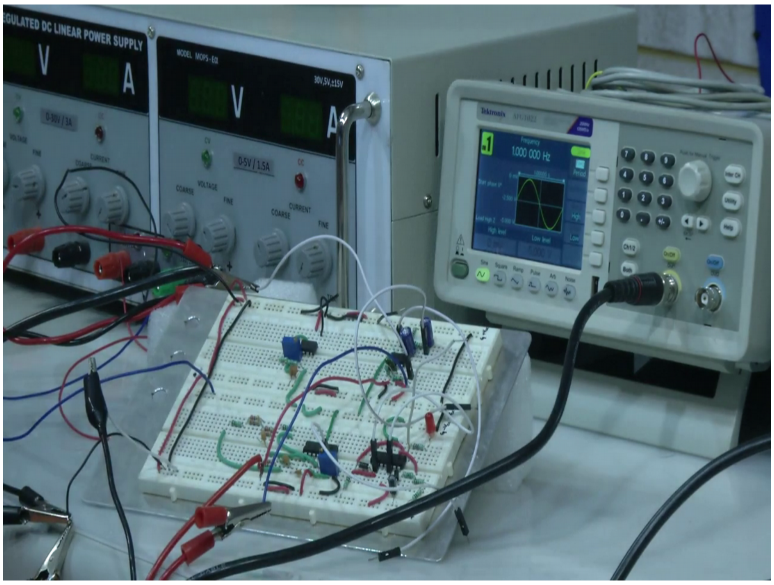

So, now what we are doing is onto this particular part wherever we have designed a filter low pass filter which is similar to that are the experiment that the connection that we have seen in our simulation as well as our you know presentation; we can see one side of an operational amplifier is a low pass filter. So, now by using a function generator so, function generator it is being connected to the input register. So, here we can see this input register to this input register we have connected this white colour wire right. So, from one side of operation you know CRO oscilloscope we use a wires and we will connected to the same point; so, that we can see the input signal too.

So, here I am connecting it to oscilloscope 2, this is the input to oscilloscope; input signal is giving connected as an input to the oscilloscope and ground to ground. Then what is other one? We also have to see the output so, another probe we are taking another probe of oscilloscope and connecting it to the output. So, output here is seventh pin right so, seventh pin is this one and this is to ground. So, what we have done here? So, from our voltage supply we have connected plus 15 and minus 15 to their respective inputs provided on the bread board. So, that here by using wires we have already connected to the all the IC's; whenever I switch on the all the IC's whichever used on the breadboard will be powered with a plus 15 and minus 15.

Then from the function generator using the function generate we will generate different frequency input sinusoidal frequency signals starting from 1 hertz up to more than 100 hertz. So, there we can observe at that at what frequency the input is becoming 707 milli volts right so, 0.707 volts. So, that is being connected as an input to the system to the low pass filter. So, at a point of input resistance which is nothing, but a R 1 resistance and output is taking it seventh pin of op amp. This is since it is a TL082 so, we are using the second op amp of TL0 82. So, the output is at the seventh pin so, we have connected to the seventh pin.

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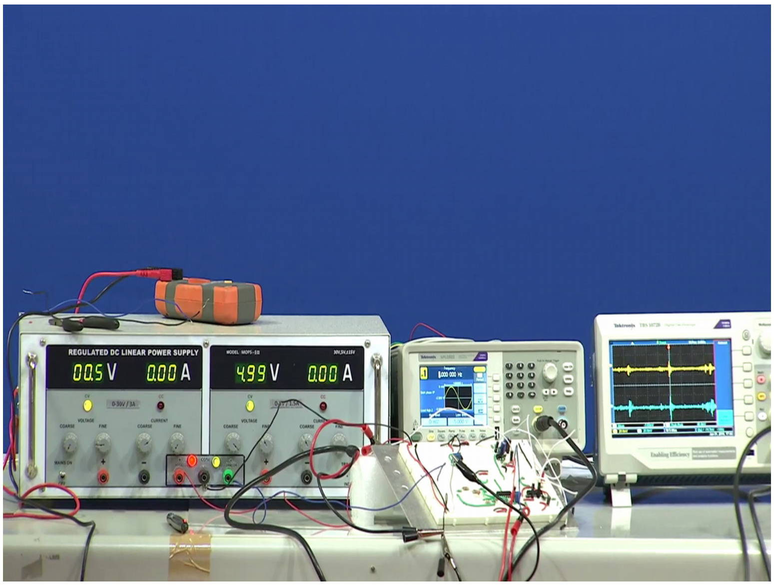

Now, I will switch on the power supply ok, you switch on the power supply and make it as how to scale; switch on function generator, increase the scale. So, the input voltage applied is so, here we have to change the input voltage. So, the amplitude I am going to the amplitude setting it as 1 volt, 1 volt and offset I will make it as 0 offset as 0 0 volts right.

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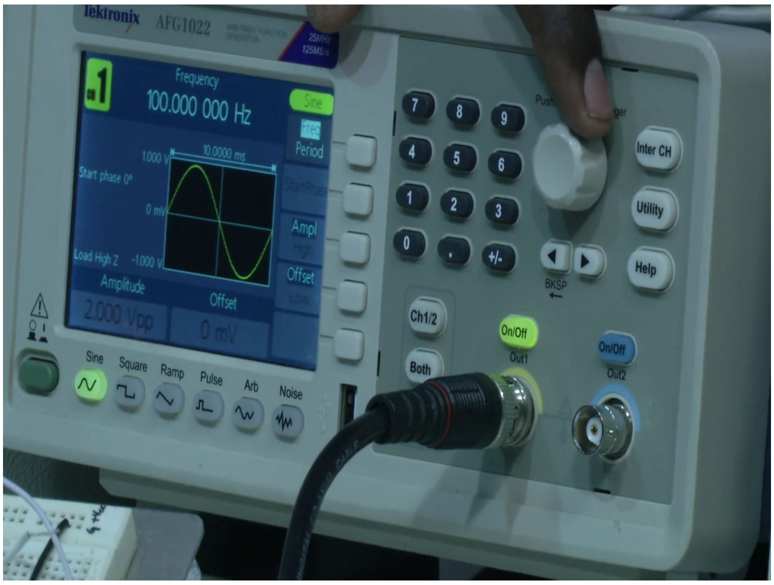

So, we can see so, rather than taking this what I will do is that 1 volt p 2 volts peak to peak we will apply. So, we will go to high sorry amplitude to 2 volts peak to peak. So, we can see 1 volt input as well as 1 volt output.

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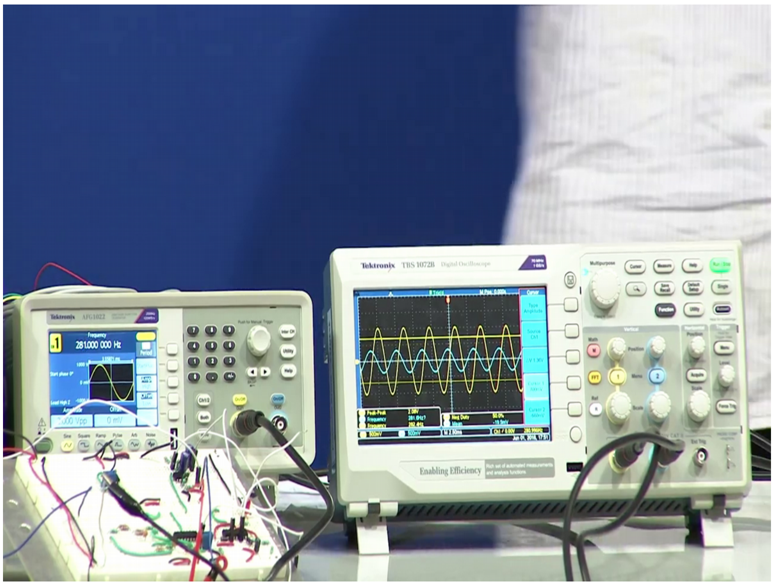

Now, to visualize the signal so, I will just increase the scale, scale to 1 volt both the input as well as an output and make it at single point. So, I am shifting the both signals to one point that is 0 position. So, yes 0 revision and we have an offset of 500 milli even I have to remove the offset here. So, I will go to offset make it 0 volts now, there is no offset we can see that. Now, slightly change increase the scale right; so, yellow represents our input signal right and the blue one, the second one is our output signal. When we observe there is an phase difference between input and output, this is because of our inverting amplifier.

So, we know that inverting amplifier will have a 180 degree phase shift because of that now, but what about the amplitude we have to look about the amplitude now isn't it. So, what is the voltage below which we have to consider, what is the voltage that we have to consider to calculate our cutoff frequency? 707 milli volts. So, what I do is at in order to understand I create a cursor and I will create amplitude cursor right. So, I will put the cursor at 707 milli; so, since we have even more you know range what I will do is that I will increase, I will decrease the that width of it. So, I am making it as 500 milli as one block even for the negative to 500 milli. Now, by using a sorry I will change the division 0.

So, one division now it is equal to 500 milli volts for both input as well as output too, I will go with a cursor I will put at a 707 milli volts. So, I will go to cursor 1 right now it is a 180 milli, I will go, slowly I will go till 707 milli volt 525 580; yes 700 milli volts. So, I will observe by changing the frequency input frequency we will see at what particular frequency the output voltage is below the that particular threshold that we have set right. The threshold is 707 now, we will slowly change the frequency at an interval of 20 hertz. So, when we look into the function generator right, when we look into the function generator I will go to the frequency and I will change it to 20 hertz right.

Now, it is a 10 hertz observe the input and output I am changing the knob there. Now, when I see the of output still it the amplitude is still falling right, it is even greater than the line; that means, this is not our cutoff frequency. Now, I will change it to 20 going here going to 20. What is the frequency we are getting? Right observe the frequency, frequency is same amplitude even above the threshold value so; that means, even this is not. I will increase to 30-40 in this case I will go to 40 observe the output right. Even more even more right, now go to 60 40, 50 and 60 observe same.

So, even that is not our cutoff frequency then 80 even observe it is even greater than the threshold value. So, the threshold is it is 700 milli right, then again I am going to 100 right. When I look into the oscilloscope, I can see that very close to the cutoff very close to our 3 dB line right very close to the 3 dB line, which means that which means that this is our almost near to our 3 dB line. So, I will slowly increase, I will slowly increase the input frequency and we will see at what point it is started decreasing it. So, to visualize it I will increase, I will change the scale. So, we can see 102 103 4 5 6 7 8.

Now, if I clearly observe here when we zoom into this particular point, at this point it is slightly below than that of our threshold value. This threshold is 70 700 milli volts right so, but if it is greater than this value; again see the value is slowly decreasing; that means, the output is attenuating right. We can observe that value is slowly decreasing, the amplitude the output see we can observe that only the output amplitude is decreasing. Now, when we recall our filters we know that the output will not remove, the output will be attenuated; above the cut for a low pass filter above the threshold frequency sorry above the cut off frequency the output will not be removed, it will be attenuated. So, here we can see higher the frequency the amplitude of the output is slowly decreasing.

So, from this experiment we can conclude that the cutoff frequency of the filter is somewhere close to 108 hertz right. Even with our theoretical design we got 108 hertz, even with our simulation design we got 108 hertz. So, this particular filter, this particular operational amplifier, this particular circuit we will use this for our low pass filter circuit. So, that the power line inference due to or multiples will be completely removed by using this low pass filter. Now what next? We also require to have notch filter as well as high pass filter; now we will look into the high pass filter circuit right, we look into the high pass filter. So, when we go to the presentation.