Op-Amp Practical Applications: Design, Simulation and Implementation
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Lecture - 33
Experiment on ECG Signal Acquistion, Conditioning and Processing of PQRS wave to Compute BPM using Op-Amps

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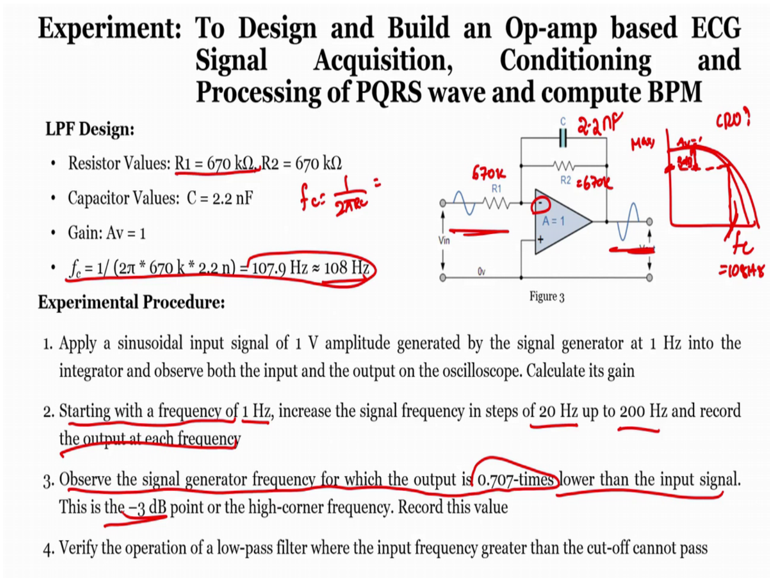

How do we do filtering circuit, right? As we have already seen in our previous modules previous things, we know how to make use of an operational amplifier and what are the advantages and disadvantages of going with an active filters one compared to the passive filters and we have also discussed about 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 cut-off frequency and the combination of R1 and R2 resistors tells us gain.

Now what value of cut-off frequency we require? We require a cut off frequency of 100 hertz. Since it is 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 cut-off frequency of 100 hertz. Now, how do we know the cut off frequency? So, in this case we are considering a resistance as 670 kilo ohms. This is R1 670 as well as R2 also as 670 kilo ohms. We are taking 670 kilo. This is also at 670 kilo and capacitor as 2.2 nano farads. Now, if I can compute the cut-off frequency, what is the formula f e 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 nano farads, it will be even 120 hertz. We can even get it or if I take a smaller value, it will be 100 hertz I mean if I take a larger where a it will be either resistance or capacitance, it will be even 100 hertz we can achieve. So, in this case by considering though the availability of resistance and capacitance, we are designing a first order low pass filter with a cut-off frequency of 108 hertz, then what about what about the gain of the system? Since R1 and R2 resistance are same, since it is an inverting amplifier, the gain is R2 by R1. 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, we will get the same output, but since it is an inverting, we will get a negative. There will be a face 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 connecting to a frequency spectrum, it will be very expensive to because the equipment 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 that particular frequency in a CRO itself, we can even compute the same thing in our laboratory 2. How do we do that? So, as we know that then we look into our the frequency spectrum of low pass filter and the gain is 1. So, if we can calculate 3 dB line right, this is nothing, but our cut-off frequency. Now, when I represent in a frequency form, we are saying this value is 108 hertz, but in CRO how do we find it.

What we do is that we know what is a maximum voltage we get, right. So, we will apply some we will we will take some function generator, we will apply 1 volt as an input signal. So, since it is also again 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 off your input signal that particular at that particular point that is nothing, but our 3 dB line and from that point, it will the output voltage will keep on decreasing, keep on decreasing.

So, that frequency if I can calculate that is nothing, but our cut-off 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 DC response and we can see the complete you know the frequency domain value 2. But, this is how the connection should looks like and we will be we will be passing, we will be using a function generator to pass from 1 hertz to somewhere around 200 hertz with in steps of 20 hertz and we will record them output at each frequency.

So, we will observe the signal generator frequency for which is the output is 0.07 times lower than the input signal. That point is nothing, but 3 dB point. So, that point will considered as our cut-off frequency. So, in order to understand much more what we do is that we will go to multi-sim.

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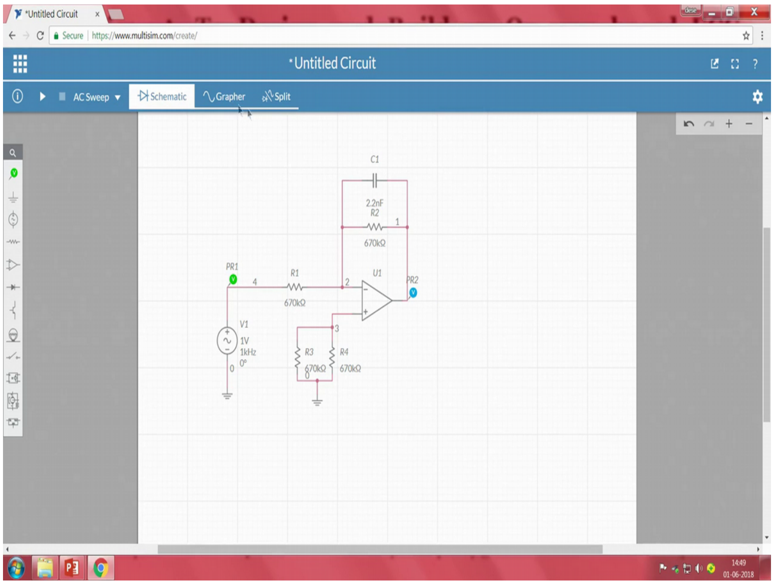

So, as we have already seen have a multi sim looks like an everything in a even our previous module, but our intention here is to design a filter and we see the frequency response as well as whatever the intitue that we have learned from the experiment from the previous experiments as well as the you know in our procedure that we explain, we will try to put the same thing here and we will try to analyse even in a time domain 2 and we will compare the frequency domain response with the time domain 2. 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 resistance. In this case, we have taken 670 ohms resistor.

So, I am replacing with 670 kilo ohms, sorry 670 kilo ohms resistor and one more resistor that is also 670 kilo ohms. So, that is a negative feed back resistor. So, I will be connecting from here to here, then what is other one? So, we also have to connect a capacitor across R2. So, what I will do, I will take a capacitor. What is a capacitor? That we have used in our periodical designs. We have used 2.2 nano farads. So, I will go with 2.2 nano farads 2.2 nano farads and 2.2 nano farads are available in the market too, right.

Then, these particular values the positive terminal should be connected to ground. So, what I will do is that the terminal connecting to ground in order to eliminate the effects due to the bias and offset currents, I will use a resistance value to resistance in parallel which are nothing, but 670 kilo ohms resistance itself, so that the effects due to the bias and offset resistance can be completely removed using this, right. That we have already studied in our previous modules. Isn't it?

So, I am taking R1 and R2 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 that 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 the system, I will one I will take here input and other one I will take output now. So, in order to understand the cut-off frequency, good good way is to go with our AC sweep. So, what I will do is that in AC sweep, I will sweep the signal from let it simulate yeah.

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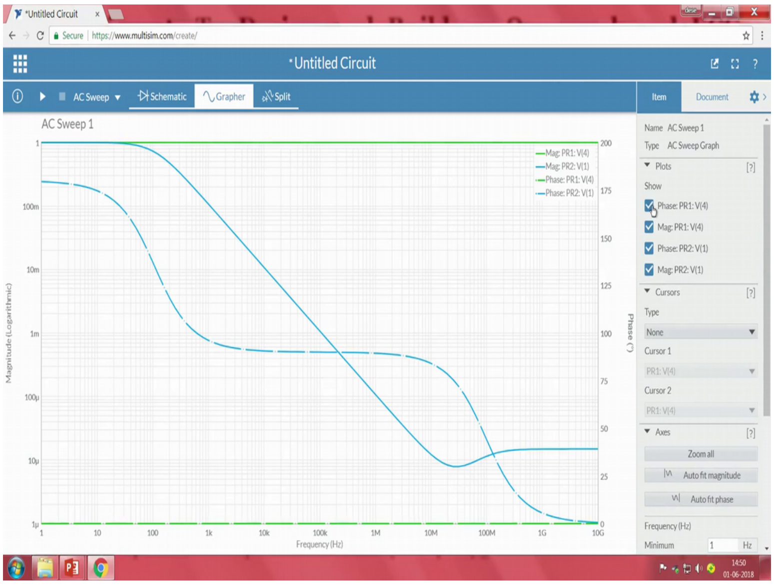

So, here what I will do is that the minimum hertz is of 1 hertz. I am doing and the maximum say I will go with 200 hertz right, then we may not require the peak values, sorry face values. So, I will remove all the face values I only put a magnitude values or even greater than minimum 0 and maximum somewhere around the 1000 hertz I will put or 1 hertz to 1000 hertz, right.

Let me run once again AC sweep. Phase I am removing it, then till 1 mega I will put 1 mega. So, now we can see the signal one mega right now green represents what when we look into our figure we can see here green is nothing, but my input and blue is nothing, but 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 decreasing right, but at what frequency how do we calculate our cut-off frequency. As we know that 3 dB line we have to consider that 3 dB line since n it is 1. 3 dB line will be 3 magnitudes below to 1. So, in order to do that what I will do that I will do I will zoom the frequency domain. So, in order to zoom that I will change these frequency values to somewhere around 1 1 kilo hertz.

Now, this is 1 dB, the below 1 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 come 733.68 milli dB or if I put a curser I will put x axis curser. So, I will be slowly varying observe the C2 curser I will be a varying a two 99 sorry where is that 3 dB line. So, the C2 value should be, so let us take somewhere around 100 hertz, then I will take y axis curser. So, because we require to take 700 700 mille magnitude so slowly I will be increasing observe dy 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 mille somewhere close to this. I have enabled to do that because of the resolution. 1 kilo hertz because of the resolution I can not see that or oh also I can little bit zoom the vertical scale. So, maximum minimum I will say somewhere around 1 mille, right. Now, if I see 125, 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 CRO? So, in order to understand what we do is that going with AC sweep I will go with interactive. So, here starting from 1 hertz will change and we will observe the input and output frequencies. So, I will increase a time division. I am increasing 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 an output because we are using an inverting. There is a gain phase difference and the amplitude wise it is one and the same. Now, I will slowly increase a frequency. There is no change in our gain. So, with the rate of 28, I will go with the 20. I will make it as single or auto and in order to visualize I will decrease a time division, right. Then, again I will go with 40, right. So, in order to understand that let me put a curser. So, what I will do is that I will go with the cursers and make it as x y axis curser.

So, at what point we have to see we have to see a pointed 0 0.07. So, I will put the curser 1 at 707 mille volts. So, we can see right now the curser yes. So, curser 1 is at 707 whenever this blue colour line is below the 707 that frequency is nothing, but our cut-off frequency, right. So, I will increase. So, I will increase 250 no not decreased at. So, I will go with the 60 no change not lesser than 707 mille volts 80 not even. So, I go with 100, right almost close. Now, we will increase one by one. So, before going that what I will, so is at little bit time divisions I will increase it. So, that is easy to 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 mille volt. Even if I increase it 109 right, 110 started slowly decreasing it 120 decreased. So, that particular value is nothing, but our cut-off frequency. So, in order to visualize by using a time domain signal by looking into CRO, one way to do is slowly decrease your, slowly increase your input frequency whenever whenever it goes to 3 dB line which is nothing, but 0.707 volts to that of your 70 percent is of your maximum voltage that is nothing, but 707 mille volts. Whenever the input voltage is lower than 707 or just at that point of 707 mille volts that frequency is nothing, but our cut-off frequency.

So, we have seen that it is nothing, but somewhere around 108 hertz right; even though if I increase the frequency, it is not suddenly attenuating with to even below than 500 mille. The reason is the rolling factor, the role of factor of first order filter is 20 dB per decade because of very smaller rolling factor, it will also allow particular band of frequency to pass through, but we require a cut-off. We do not have to pass a frequency at 150, that is what our power line or multiple frequency, but since role of 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 will do 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 bread board and use a function generator as well as an ocular scope and we visualize the same thing and we will observe it what particular frequency it is reaching to 707 mille volts.

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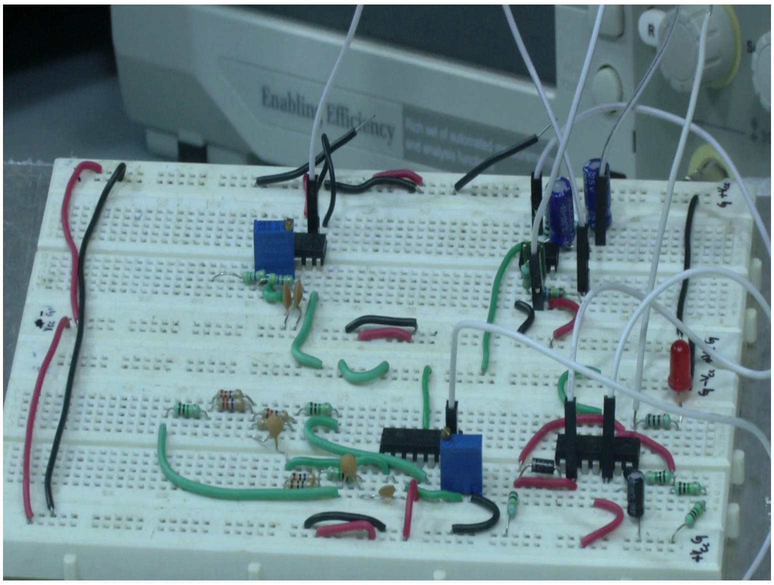

We look into the bread board. This is the complete signal conditioning as well as the processing circuit that we are going to use in this particular case study. So, if we observe here this part is our instrumentational amplifier part. This part contains low pass filter. If I see I am using 2 nano farad, this is our 2 nano farad that green colour wire here we can see. Sorry this green colour this capacitor is our 2 nano farad 2.2 nano farad capacitor and these are our two resistors; one is here and other one is here 670 kilo ohms, right. This is tl 0 a to ic. So, it has a dual Op-Amp one side of Op-Amp we 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 2. So, the same circuit I have made it to on a bread board and we will apply a input from the function generator, right and we will observe the output in our ocular scope. So, how we do that? So, first thing since it is an active 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 bread board.

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 R, 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 resistor. So, here we can see this input resistor to this input resistor we have connected this white colour wire, right. So, from one side of operation you know CRO ocular scope we use wires and we will be connected to the same point, so that we can see the input signal 2. So, here I am connecting it to ocular scope 2. This is the input to ocular scope input signal is connected as an input to the ocular scope 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 ocular scope and connecting it to the output. So, output here is 7th pin, right. So, 7th pin is this one and this is the ground.

So, what we have done here? So, from our voltage supply we have connected plus 15 and minus 15 to their respect to inputs provided on the bread board, so that here by using wires we have already connected to the all ICS. Whenever I switch on the all the ICS which ever we used on the bread board will be powered with a plus 15 and minus 15, ok. Then from the function generator using the function generator, we will generate different frequency input, sinusoidal frequency signals starting from 1 hertz up to more than 100 hertz, so that we can observe at what at what frequency the input is becoming 707 mille volts, right.

So, 707 volts that is being connected as an input to the system to the low pass filter. So, at the point of input resistance which is nothing, but R1 resistance and output as taking at 7th pin of Op-Amp. This is since it is a tlc rate 82. So, we are using the second Op-Amp of tlc rate 82. So, the output is at the 7th pin. So, we have connected to the 7th pin. Now, I will switch on the power supply, we switch on the power supply and make it as at scale, switch on function generator, increase the scale.

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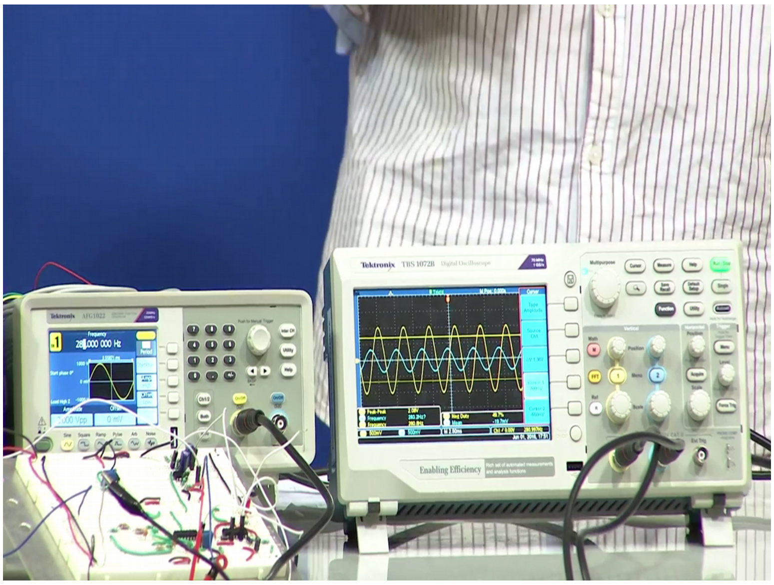

So, the input voltage applied is, so here we have to change the input voltage. So, the amplitude I am going to the amplitude setting it as 1 volt 1 volt and offset I will make it as 0 offset as 0 0 volts, right. So, we can see rather than taking this what I will do is that 1 volt 2 volts peak to peak, 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.

Now, to visualize the signal, I will just increase the 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 1-1 point that is 0 position. So, yes 0 division and we an offset of 500 mille even I have to remove the offset here. So, I will go to offset, make it 0 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 the input and output, this is because of our inverting amplifier. So, we know that inverting amplifier we will have a 180 degree phase shift because of that now that 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 a voltage that we have to consider to calculate our cut-off frequency? 707 mille volts. So, what I do is that in order to understand I will create a curser and I will create amplitude curser, right. So, I will put the curser at 707 mille. So, since we have even more you know range what I will do is that I will increase, I will decrease that width of it.

So, I am making it as 500 mille as one block even for the negative to 500 mille now by using asorry I will change the division 0. So, one division now it is equal to 5 mille volts for both the input as well as output 2. I will go with a curser I will put a 707 mille volts. So, I will go to curser 1 right now it is 180 mille I will go slowly I will go 707 mille volt 525 80, yes 700 mille 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 are 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 into 20 hertz, right. Now, it is 10 hertz. Observe the input and output I am changing the knob there.

Now, when I see the output, still the amplitude is still following, right. It is even greater than the ray. That means this is not our cut-off 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 again 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 cut-off frequency, then 80 even observe it is even greater than the threshold value. So, the threshold is 700 to mille right. Then, again I am going to 100, right. When we look into the ocular scope, I can see that very close to the cut-off very close to our 3 dB line, right very close with the 3 dB line 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. You can see 1 0 to 1 2 3 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. Then specially 70 700 mille volts right. So, but if it is greater than this value, you can 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 will recall our filter and we know that the output will not remove the output will be attenuated above the 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 cut-off frequency after 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 interference due to odd 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 will look into the high pass filter when we go to the presentation.