Electronic Systems for Cancer Diagnosis
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Lecture – 40
ECG Signal Processing to calculate BPM (contd.)

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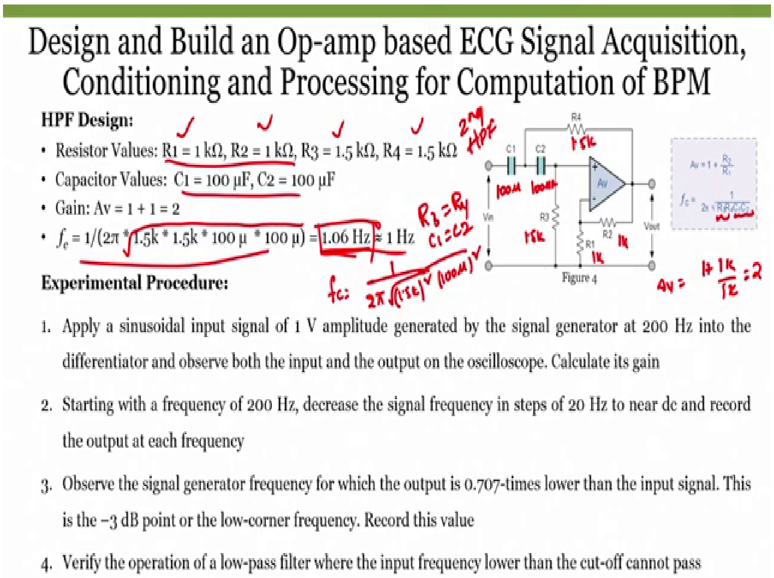

Now so, previous one, we have seen the first order low pass filter. Now, this is our second order high pass filter right. Why this is called second order? When we see, we have two combination of R and C capacitors, two combination of R and C pets right. So, one if I have one combination of C and R, it is called first order high pass filter. If I have 2 combinations, this is called second order high pass filter.

Now, because we have a two capacitors and two resistors, the cutoff frequency will be calculated as 1 by 2 pi into root of R 3, R 4 and C 1, C 2 right. Just recall our high pass filtering sessions, we you can easily understand that. And since this is connected to the positive terminal, the input is connected to the positive terminal of an operational amplifier, this is an non inverting type right. Since, it is a non-inverting type high pass filter, so high pass filter, the gain of the system is nothing but 1 plus R 2 by R 1.

So, the resistance that we use, the values of resistance R 2 and R 1 that we choose decides the complete gain of the system, right. So, in this case, we require two design a cutoff frequency somewhere around close to either 0.5 Hertz or 1 Hertz right. So, in this case, we do we choose we have chosen a resistance values as well as a capacitance value so that when we calculate cutoff frequency, we got a value as one Hertz. But how do we calculate? The cut off frequency is 1 by, 1 by sorry there is a wrong in the formula. It is nothing but 1 by 2 pi into root of root of R 3, R 4 and C 1, C 2.

So, in this case, we have chosen R 1 and R 2 as 1 kilo and 1 kilo. So, any of the this is a 1 kilo Ohm, this is 1 kilo Ohm. So, when we calculate a gain, gain is nothing but 1 plus 1 k by k which is nothing but 2. So, if I apply 1 volt, I will get an output as 2 volts. If I apply 0.5, I will get an output as 1 volt right. Apart from using R instrumentational amplifier, some amount of gain can also be given can also be applied by using this operational amplifiers too, right. Then, we have chosen R 3 and R 4 resistances 1.5.

So, this is 1.5 k and this is also 1.5 k right and, what about C 1, C 2? So, both C 1, C 2 we have used 100 microfarad and this is also 100 microfarad. So, when I calculate f c, f c is a nothing but 1 by 2 pi into root 1.5 k square into 100 micro square right because R 3 is equal to R 4 in this case, as well as C 1 is equal to C 2. So, C 1, C 2 I can write it as C 1 square; R 3, R 4 I can write it as R 3 square. So, 1.5 k whole square and 100 micro square. So, when we calculate, the value will be almost equal to 1 Hertz, the value we got is 1.06 Hertz so which is equal to 1 Hertz right, right. Now, how do we understand?

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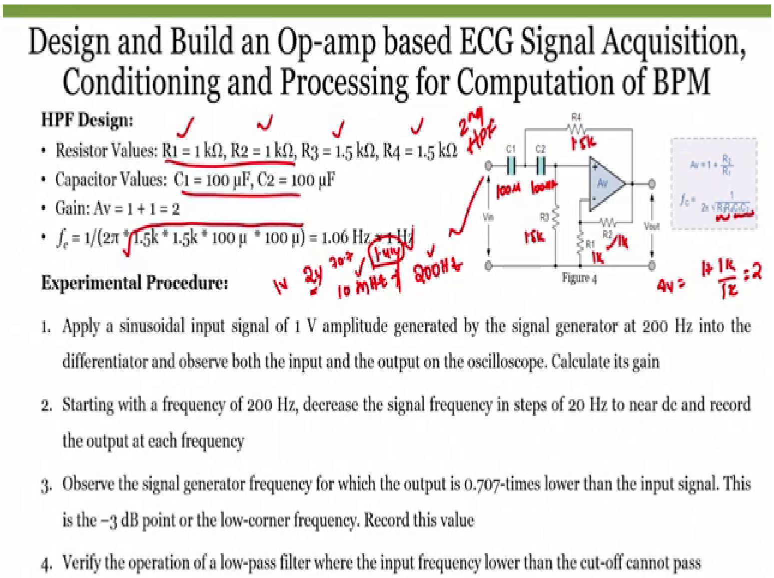

So, similar to that of our low pass filtering circuit even in this case, what we do is that we will connect we will connect this particular circuit, we will do the circuit design in a circuit design simulation software, we are using Multisim we will go with a Multisim, we will use the same resistance values and capacitance values. Since, this is a cutoff frequency of a 1 Hertz, we will go from somewhere around 10 milli sorry, 10 milli Hertz to some greater than 100 Hertz, somewhere around 200 Hertz we can go right, we slowly increase from this frequency to this frequency and we will use an input signal of 1 volt. Now, since against 2, we will get an output as 2 volts that we also we can observe.

And as long as, as long as output is 70.7 percent of my input, so since we are using the output is of 2 volts, so that means, 1.414 as long as the input is lower than 1.414; that means, the signal is completely attenuated. That is the 3 dB line. So, when the input is higher than 1.414; that means, the signal is being passed, that is greater than our 3 dB line. So, that point wherever it is almost equal to 1.414 volts, I can say this is our cutoff frequency, right this is a cutoff frequency of our high pass filter. Now we will go to, we will go to our simulation, I will create a one more circuit.

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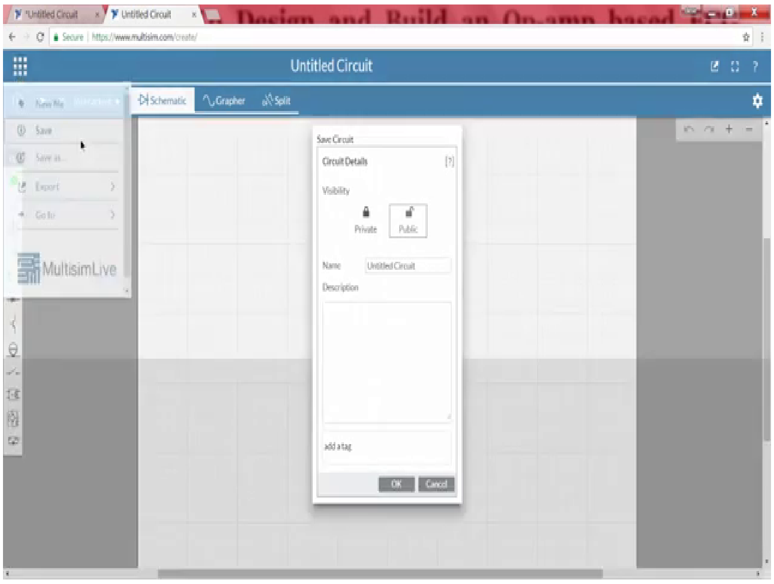

So, I will say if this circuit as high pass filter, save, name I will write it down as high pass filter and the cutoff frequency we are using is 1 Hertz in this case so, 1 Hertz.

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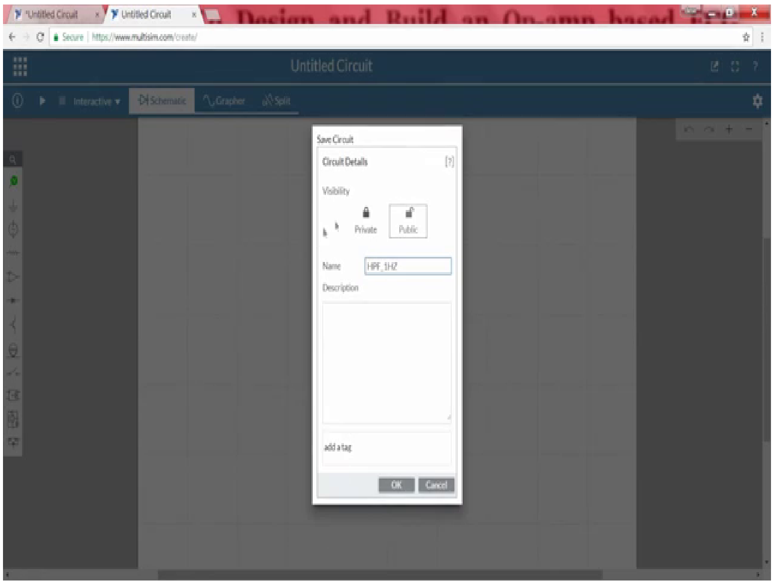

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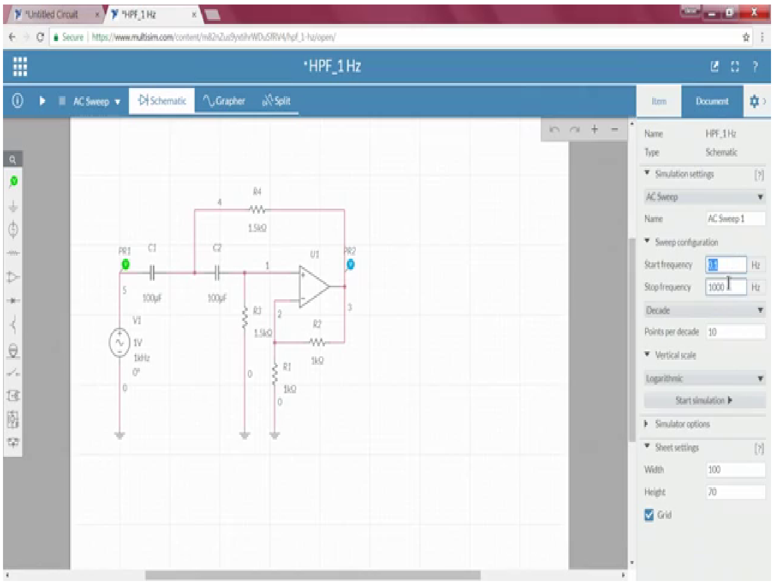

So, what we need, we need to use operational amplifier, I am taking operational amplifier and we are using two capacitors and two resistance and what resistance value we have consider? When you see R 1 and R 2, R 1 and R 2 we defined here as a feedback and a normal resistance right, this is R 1 and this is R 2. So, I will use the same resistance value as well as the same R 1 the notations 2.

So, R 1, I am keeping it here and rotating it and I am also taking R 2. This is the R 2, R 1 R 2 are same resistance value. So, I do not have to change the resistance, I will be connecting it here, negative feedback right. So, the gain, the input resistance and the gain resistance the feedback resistance which decides the gain of an op amp is done.

Now, what else, we have to do the filtering partner which is nothing but C 1, R 4 is one part; C 2, R 3 is another part. So, I will take two resistors again. So, one is R 3, this is our R resistance and the value that we choose is 1.5 k, change it to 1.5, sorry this is this should be 1.5 k right. Then, we will choose one more resistor as a feedback which is a positive, 1.5 k this point and this terminal should be connected at this point and this should be connected at the positive terminal.

Now, what about the other one; other one has to connected to ground. Then what else? I have to take capacitance. So, I will go with two capacitance; one is C 1 and other one is C 2. So, the value of resistor capacitance that we use is 100 microfarad, 100 micro, even here 100 microfarad. Now, let me make connections here. So, this particular point has to be connected here and this point has to be connected here, right. So, with this combination of a circuit, we can observe we can observe high pass filtering at a frequency at a cut off frequency of 1 Hertz.

So, in order to observe that signal, so we have to connect the input source. So, I will take an AC voltage, I will connect it here and this is grounded. So, one terminal one probe, I will be connecting at the input. So, both the input and output I can visualize; other one is at output side. So, this is nothing but our green colour represents the input signal and the blue colour represents output. So, to visualize in a frequency domain, I will change the settings from interactive to AC sweep. So, what do you mean by AC sweep?

AC sweep is an internal function what it does is that rather than you keep on changing your input frequencies at particular frequencies, the system has already pre-programmed such a way that, it the input signal frequency we will start from 1 Hertz to the minimum frequency that you set to the maximum frequency that to set with an intervals of some default parameter, default values. It will keep on increasing the values and you can observe the output voltage at this particular point right. So, I will go to the grapher, let me run it, we can see the signal now.

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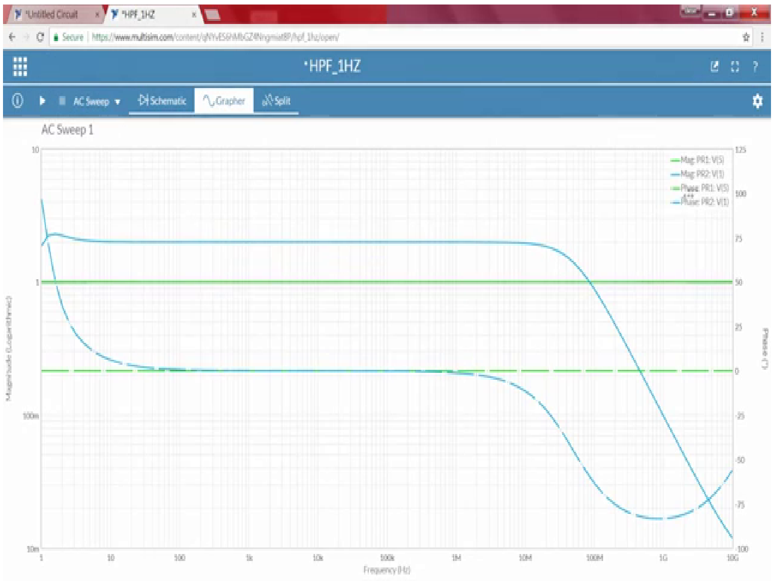

So, since you also have a phase I do not want to look into the phase. So, I will remove both the phases. Now, here we can see input is green right and output is this one, is not it? Now what I need, the input frequency and this frequency, so this I will make it as 200 whereas this I will make it has somewhere around 0.01 Hertz.

So, in this case for the sweep configuration I have change the some setting parameters, we change the start frequency is 0.1 Hertz and the stop frequency is 1000 Hertz here and the points per decayed is 10. So, only thing what we have to do is that once we select the sweep, we have to go to the settings, from the settings here we have to change the parameters to 0.1, 1000 Hertz and how many points per decayed we require?

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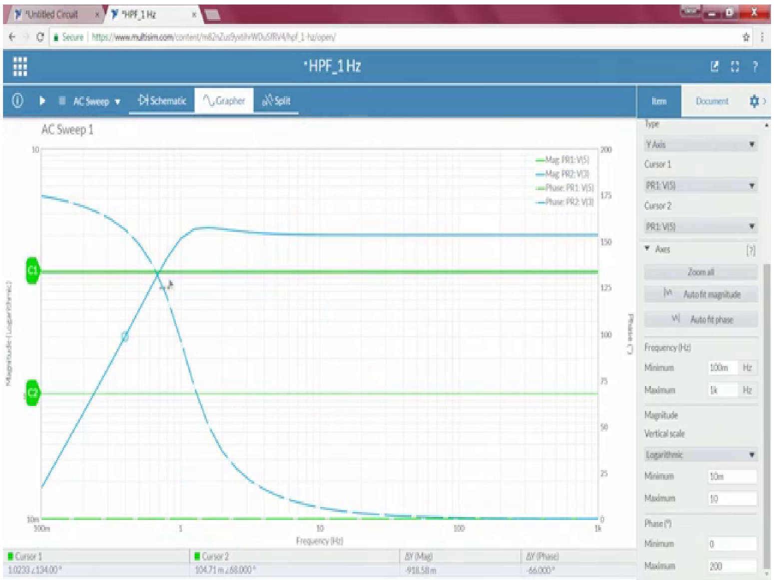

Once it is done when we start simulation, it starts you know simulating it. So, in this case, even if you observe the input is green and output is blue, so what I will do is that, I will change since I may not require both the phases, I will remove the both the phases, I have both the magnitudes, I making curses temporally off right now. So, observe carefully here, the green indicates are input signal and the blue indicates are output signal right, now. So, this is a logarithmic scale, the magnitude is completely logarithmic here we can see the magnitude is completely logarithmic and the green is at 1 dB, 1 magnitude.

But, what about the blue, why it is in 2 dB? If you remember correctly, the gain of an op amp is 2. So, that is the reason, the output is having double than that of the output of magnitude is double than that of the input magnitude. Now, what about at different frequencies, when you see no matter what at what frequency are at the input is always having and magnitude of 1, but whereas, the output depends upon the frequency, it is slowly increasing, increasing, increasing and one particular point, it has become to 2 dB

Now, if I want to calculate the cutoff frequency of this particular filter right, the characteristics if I see, it looks like our high pass filter characteristics. So, whatever we design is also high pass filter; one is one is cutoff frequency. Now, if you want to visualize, what I will do is at I will take a curser, I will go with an amplitude cursor y axis cursor and I will put C 1 at 1.7 right because that 3 dB line is nothing but 3 dB to our maximum amplitude maximum amplitude is 2, so, 2 minus 3 dB. So, the magnitude should be 2 minus 0.3, it should be is somewhere around 1.7 right.

So, I will keep somewhere around close to 0.7 value, one point, minus one point sorry this is C 1 1.8 sorry. So, I will be keeping close to 1.7, that is our 3 dB magnitude of minus 3. So, here this point is nothing but our, so when I observe it, pre magnitudes when you observe that this is very close to the 1 Hertz right. Or, one way to look into that is rather than going into this, we can go to interactive and we will split it let me closes will split it will change the frequency from 0.1 Hertz itself right, let me run it.

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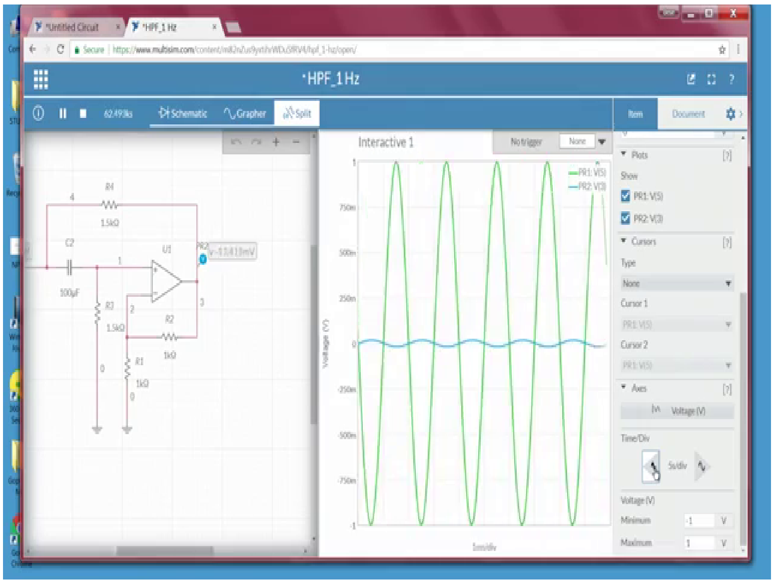

So, we will change the settings to right. So, what is happening? Now the peak voltage that we get is nothing but 2 volts right as we know that. So, in order to understand that, what I will do is that rather than going with a low high value, we will go from lower value so, make it as 100 Hertz.

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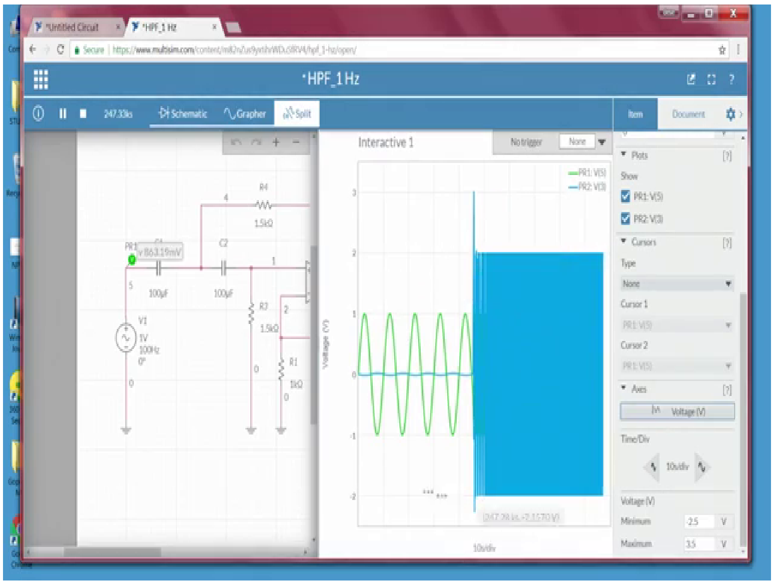

Now, go to the settings.

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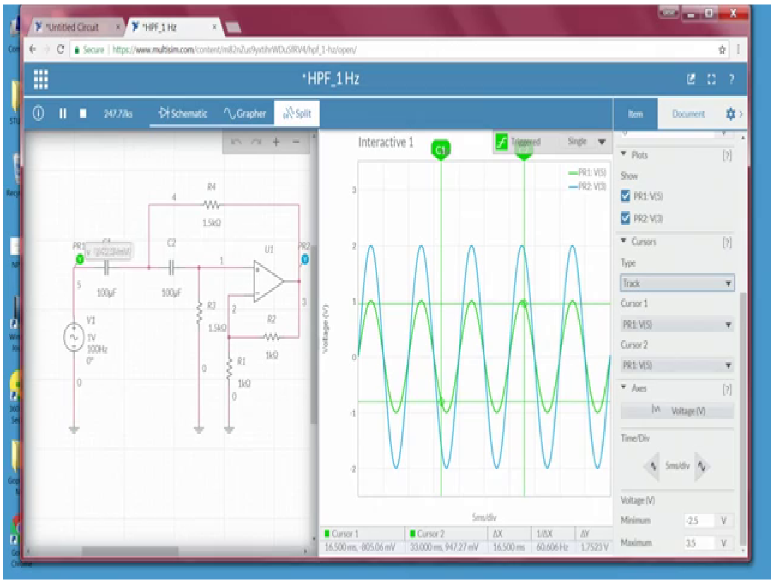

So, we can see 2, 2, 2 volts, 2 2 volts, I will increase, I will decrease a time division. So, that we can see the signal from here we it is clearly observed that the input is green colour, output is blue in colour, the peak to peak value is 2 volts the input signal whereas, output peak to peak is 4 volts. Since it is a 4 volts right, why this is 4 volts because of the gain as 2, the gain here is 2. And moreover since it is a non-inverting type of input, we cannot see any change in the phase shift. It is always following the input right that we can clearly observe.

Now, to understand that, we will create a cursor, so cursor should be put it. So, I will take y axis cursor, the amplitude cursor and this as should be placed at 1.414 volts. So, I will be moving this cursor, will move the cursor y axis cursor 2 1.414. If we observe here, this is at 1.6, slowly to 1.412, 1.41 to approximately 1.41. So, whenever the input voltage, so what I will do right now, right now I am at 100 Hertz, I will slowly decrease from 100 Hertz to 10 milli Hertz. So, at what point at what frequency the input is equal to this C 1 threshold is nothing but our my cutoff frequency. So, what I will do I will decrease slowly which a factor of 20. So, go with 80.

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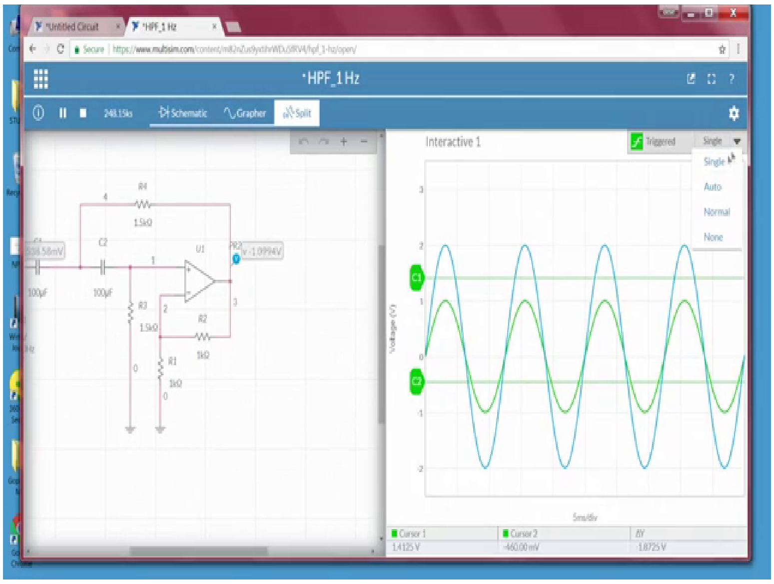

I am going with 80. So, I will make it as auto right. So, automatically it will change it.

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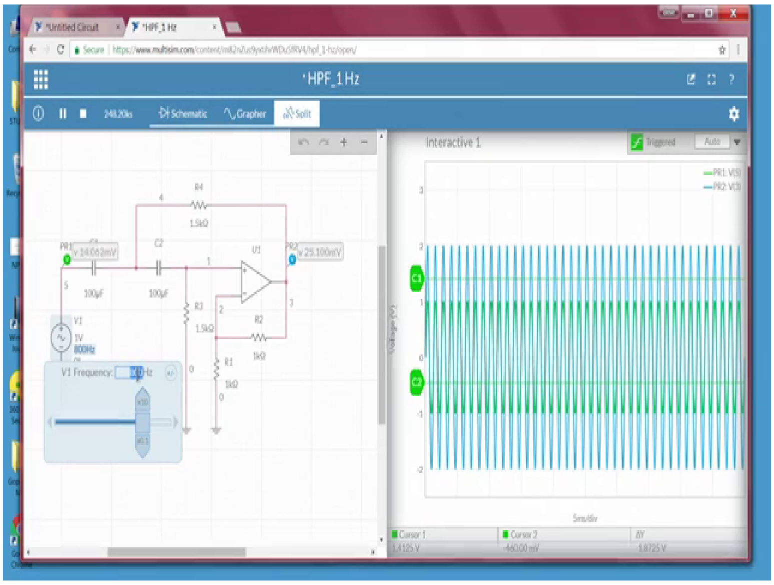

Then, I will go with a 6 oh sorry 800, it has gone go to 60, we can see still it is at 2, 40 still the same, 20 still the same. So, since we have to observe even at a smaller values smaller frequency, I will increase the time division. So, easy to visualize, then change the frequency slowly from here to 10, same then slowly decrease 9.5, 7, 6, 5, 4 slowly decreasing it. Now, if we carefully observe when we observe our characteristics, whenever it is coming close to the cutoff frequency, the input amplitude is little higher even here we can observe at this point right.

The gain should be 2, but slightly there is an higher gain at the frequency close to the cutoff frequency value right, that we have seen. This is because of our Butterworth filter. It is a second order high pass Butterworth filter, is not it? So, when we will remember our recall our Butterworth filter characteristics, the gain will be slightly increase near the cutoff frequency right. So, the same thing we can even observe here to slowly decrease again.

See whenever our it is 1 Hertz, started decreasing it 500 milli Hertz, it is even lower than that of our C 1. So, that means, the value somewhere between 1 Hertz to 500 milli Hertz. So, in order to understand what I will do is that, here I will slowly increase to 600 milli. Observe the value, no then 0.7 Hertz, 700 milli, not even close go to 0.8, 705 sorry, 0.8 milli Hertz, coming close to that value, I will go with a 0.9 right.

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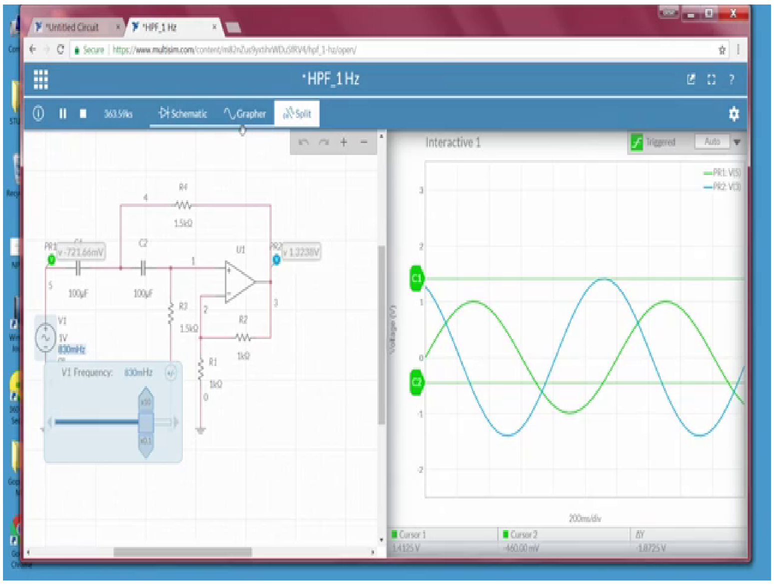

So, the cutoff frequency is somewhere around 0.8 to 0.9. Now, I will decrease little bit 895, 870, 865 right. When I see somewhere around 825 to 830 milli Hertz is the cutoff frequency of this particular filter, right. So, this is the cutoff frequency, but theoretically we got somewhere around 1.06. So, because of the second order filter and that it is a Butterworth filter but when we do then experiment, we go somewhere around 830 milli right. Now, we will also look into, so I hope this is clear right. Now, with a simulation what we do is that we look into the board.

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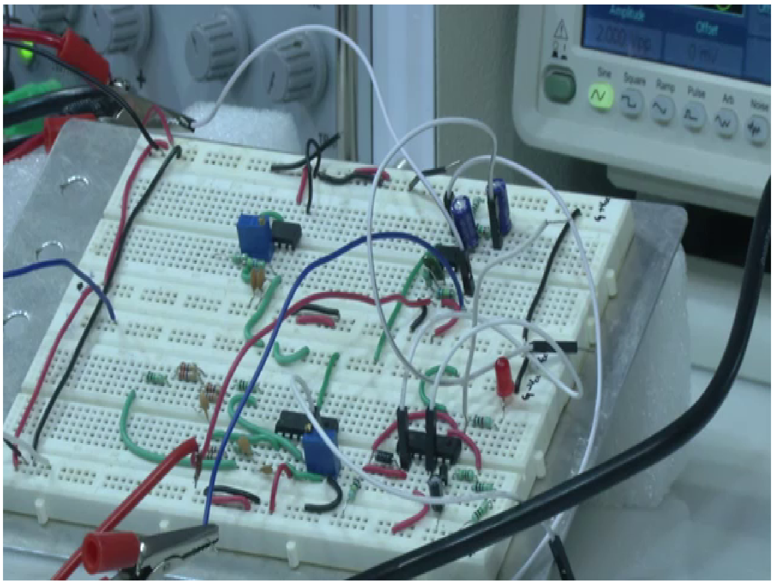

We have already done the same security using our breadboard. So, we use the other part of the T L 0 A 2. So, previously we have seen low pass filter; now we will see the high pass filter on the same op-amp just next to that, but we are using the first side of an op-amp in this case. Now, when we look into our TA board here, TA board here, so this part this part this part is completely high pass filter circuit.

So, this part is high pass filter, this side this side of an op-amp, this side is high pass filter circuit, this is a low pass filters, we can see two op-amps; sorry two capacitors here as well as different resistors 3 4 resistance 1, 2, 3 and one more here, 4. So, two resistors are for gain and two resistors are for the filtering thing. And the input is nothing but the input is input should be given to the C 1 and the output should be taken from op-amp output.

So, even in this case what we do is that, so the board is right now switched on. So, now, we will replace input from this, from here to the input side of capacitor. So, this is the input side of capacitor. We have connected to the capacitor right and output is 1 and this blue wire, we will connected to the same point. So, we can the input signal input frequency in a oscilloscope and output connecting it to the first one, the first one is here.

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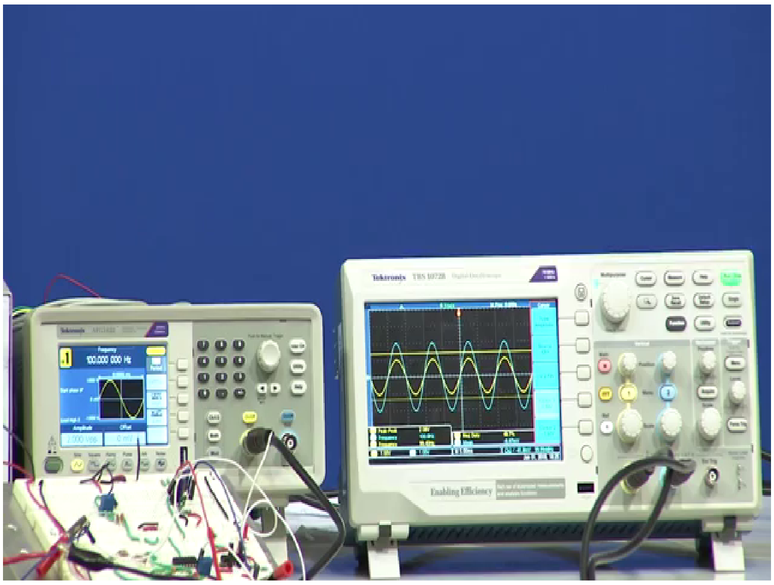

Now, when we look into the output, so right now the frequency that we have given as an input to the op-amp is 100 Hertz is the input frequency that we have given to this, then these output we got. So, I will put both the things to the same point. So, easy to understand right and even this two little up to the to 0, 0 position. So, both are right now at 0, 0 position. Now, the scale if I observe, this scale it at one volt whereas, this scale is a 2 volts. What I have to do is that I will increase I will put both scales at the same level.

So, that means, one box even for the input as a first channel as well as the second channel is one box equal to 1 volt. Now, if I observe that right here we can see 1, 1 volt and 1 volt. So, what we can understand? So, we can see yellow is nothing but our input and blue is nothing but our output. So, what we can understand from the output? We can see that the input and output are following each other; that means, that there is no phase shift between your input and output.

That is because of we are using second order low high pass butter worth filter right. The input is connected to the positive terminal and the because of that because of the input is connected to the non-inverting non inverting configuration, we do not see any phase shift. Other one is the gain since R 1 and R 2 resistors that we chooses of same value the gain is 1 plus R 1 by R 2 which is nothing but sorry R 2 by R 1 which is nothing but 2. So, we can see the amplitude change of double, double the amplitude of none of your input. Now, what we have to observe, we have to find out the cutoff frequency. See in order to observe or cutoff frequency, what I do is that I will create a cursor at a point of 1.414 right, so 707 into 2.

So, 1.414 because we have to create a 3 dB line for our output voltage, output magnitude is 2, right. For 1 volt, it is 0.707; for 2 volts, it is a 1.414. So, I will go with a cursor, I will go as type amplitude right and let me put the cursor to 1.414. So, if I observe here, this is right now at 1.4. So, I will try to see whether it is possible to change it to 1.41; unfortunately this not show what I will do is that I will fixed at 1.4. I will slowly decrease, right now the frequencies at under Hertz right. So, I will slowly decrease at a units of 20, 20 Hertz, till we are a 20 Hertz. After that, we will decrease to 10 Hertz, then from 10 Hertz slowly one by one, one by one will increase till we see the frequency at what at what frequency the input voltage is lower than that cut off point that we said.

So, I will say to 80 right now, what I will do is that go to frequency point and make it as 80, 80 Hertz; any change in the output when you look into the oscilloscope right, there is no change in the output. Then I will go to 60, even now no change in the output; 40, even same right, even the same; decreases to 20 same; 10 same. Now, I will slowly decrease 9, but in a simulation we have observed that when the input frequency is getting close to 1

Hertz, we have also observed the output voltage is increased. We will also see whether a practical it is it is that we can visualize or not right 7, 6, 5, 4 3, yes observe still let us 2.

We are going to 2 Hertz, now yes. Here if you have observe, so, what I will do is that I will go to measure, I will create channel 2 peak to peak value. So, from the peak to peak value, we can easily understand sorry this is unable to measure, but that is fine, but we can see that the output value the blue colour one is slightly higher than this second box right. So that means, right we can see here it is slightly higher than this second box; that means, again it is increasing. Now, I am coming to 1.

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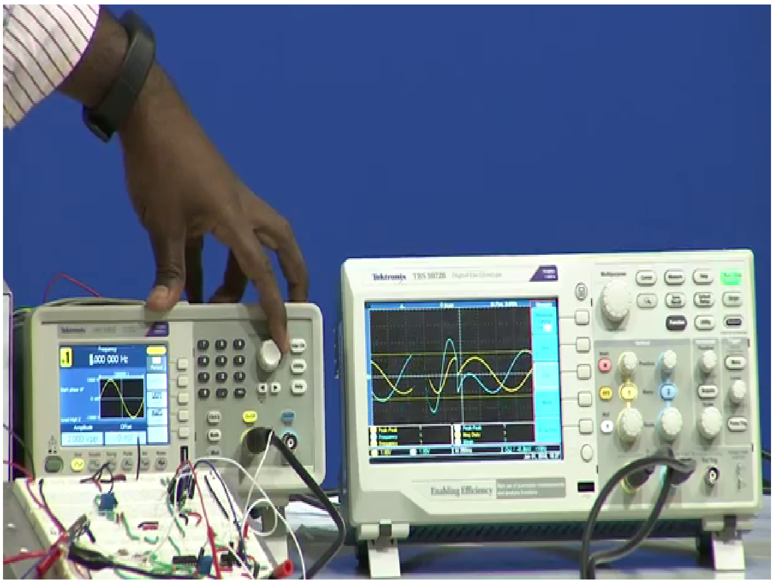

Now, when it comes to one here we can observe that. So, I will decrease the scale right from when we look in when we zoom the input signal towards the CRO, here we can observe that the output is very close to that the cursor right, but still it is a higher right. It is very close to the cursor this cursor point is 1.4 right. So, when you look into the cursor, the cursor oh it has been change it would be 1.4, all right. So, it is very close to the cursor value. Now, I will slowly increase, let me see what will be the change 1.4 Hertz right now, 1.5. Now, when it is at 1.5 Hertz the gain, when you zoom into that the gain is higher than 2 right.

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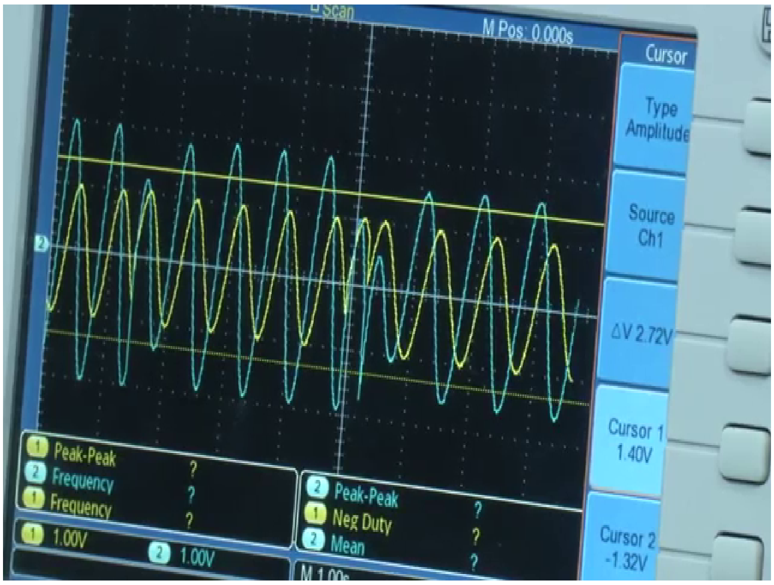

That is what even we have observed in our simulation 2, increase 6 even higher right, 7 higher and 8 even higher. So, what I will do is that I will slowly decrease value now you will have observe at what frequency right now it is 1.3, right now I am sitting at 1.1. So, even at 1.1 Hertz, the input value is higher than the cut off the cut like what we call that the cutoff value which cursor point which is at 1.4. Slowly, I will decrease to 1 Hertz. Now, suddenly it has move to 70 1.4 volts 3 dB line. Now, I will slowly decrease we can see, the output is below that cut off right.

When I zoom into the oscilloscope, we can observe that the output is below the cutoff which means that 1 Hertz. Theoretically, when I see sorry a theoretically we have seen that it is at 1 Hertz even if the practical, we can observe that it is at 1 Hertz itself right. But when I slowly decrease it, it is going below the below that cut off value even if I go even beyond lower value below that. So that means, one thing we can clear that for a high pass filter, below the cutoff frequency the phase sorry the amplitude will be attenuating. It will not be completely removed, but amplitude will be attenuated from the cutoff frequency.

And here we can clearly one more thing we can understand that since it is second order filter, we can see the drastic change from 1 Hertz to you know when we are decreasing from 1 Hertz right. So, I hope this is clear about our high pass filtering and the high pass filter is also working as per our as per our expectations, right. Now, we will stop at this point. We will see other filters in the next module.

Thank you.