Electronic Systems for Cancer Diagnosis

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Lecture – 41
ECG Signal Processing to calculate BPM (contd.)

Welcome to the module. In last module, we were discussing about ECG signal conditioning and signal processing using operational amplifiers. So, to continuation with our previous module, so in class module, we have also discussed about what are all the factors that influence our output ECG signal and what processing steps that we are doing in order to remove the unwanted signals those are available in the ECG. In this module, we will see the other type of filtering unit which is essential in order to remove unwanted signal in that.

So, last module, we have seen high pass filtering, low pass filtering. And what frequency to be used, we have discussed in the last module. In this module, we will see and notch filtering which is used to remove the power line interference. And we will be using a narrow band notch filter, the reason is that we require only to remove 50 Hertz signal and anyway the odd multiples of the power line interference was removed by using low pass filtering. So, our range of our the complete interest is in the range of removal of 50 Hertz signal that is due to our power line interference or the operating frequency of our systems or AC input signal.

So, since we are not interested in any other frequencies, if we can design, if we can design a notch filter with narrow band where the interest the removal interest is only 50 Hertz it will be really great. Even if it is not, as long as our QRS detection is able to do that as long as a design a filter which cannot remove, the actual requirement of our input signal our job is done. So now, we will see how do we do the notch filtering using operational amplifiers, how to verify the functionality of the system and what are all the connections that we are making it right.

And experimentally as well as simulation wise we will see the frequency response as well as in a time domain response to understand whether the notch filter is filtering at a 50 Hertz frequency or not ok. So, similar to that of a previous filtering modules, even in this case we will be using an active filters. The reason is because of very high input impedance due to the operational amplifiers, we really output impedance and the gain is easy to set using our operational amplifiers.

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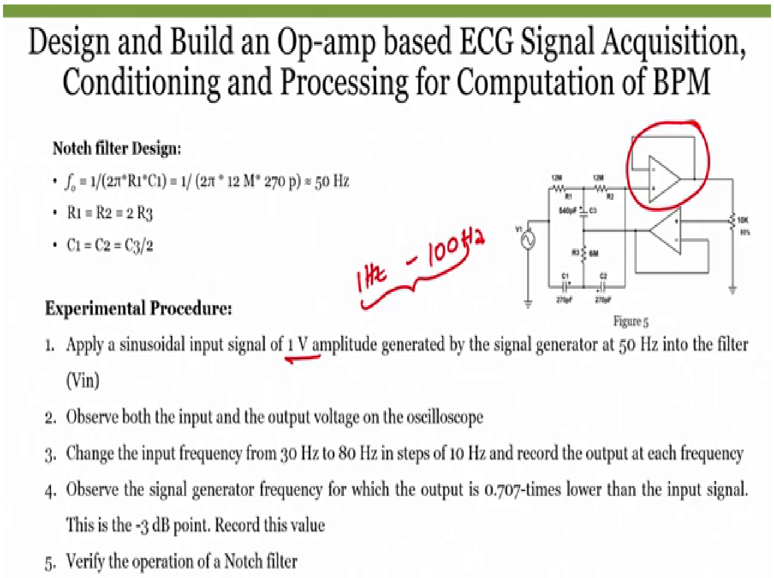

Now, now when we look into our experiment, the design to design and build an op amp based ECG signal acquisition, conditioning and processing of P, Q, R, S wave and complete BPM, we will see how to do the notch filtering using the operational amplifiers here. So, if we see as we know the how a you know the importance of a notch filtering and an application, if we see and we also know how to use a passive notch filtering circuit, it is similar to that of our passive notch filter.

So, we are using two different resistors which are 12 mega and 12 mega and capacitors C 1, C 2 which are all 270 picofarad and other resistor 6 mega and 540 picofarad. Now, what makes this to select these particular values? So, since our interest is completely on elimination of 50 Hertz signal, if we can calculate our cut of frequency as you already know, the way to calculate our cutoff frequency is 2 pi R 1 C 1.

So, when we substitute the value of the capacitor as well as a resistor, so we get approximately of 50 Hertz and. And the selection of R 2 and R 3, R 1, R 2, R 3 should be such a way that, so R 1 and R 2 should be same; we I followed R 1, R 2 to be same as well as C 1, C 2 be the same. Similarly, the relation between R 2 and R 2 and R 3 is R 3 value should be to double then that of our R 2 value as well as well as sorry R 2 value should be double than R 2 and R 1 values are doubled to that of our R 3 values.

So, that is a reasons since we are selecting R 1 and R 2 as 12 omega. So, R 3 should be of 6 mega and similarly C 3 value should be double than C 1 and C 2 values. So, we are taking C 3 capacitors are somewhere around 540 picofarads, right. Now, how do we test the circuit? So, similar to that of our previous thing, we will connect our input from the signal generator which is of an amplitude of 1 volt and since if you observe here op amps are just used to provide some buffering or some impedance matching.

So, we are not using any kind of a gain in this case. So, when you apply a input signal of 1 volt, we get an output also as 1 volt. So, when you keep on change our input signal from 1 Hertz to somewhere around 100 Hertz. Why do we not to go with below one Hertz and why do we not to worry about more than 100 Hertz? The reason is that we have already this particular stage of filtering is comes after passing through high pass filtering and low pass filtering and we already know that the high pass filtering the cutoff frequency somewhere around close to 1 Hertz and low pass filtering cutoff frequency somewhere around 100 Hertz.

Even though when you are looking for the frequencies lower than that as well as higher than that which is which are not in our interest, we do not have to even test our circuit in that operation in. So, the complete area of interest a complete frequency of our interest is between 1 Hertz to 100 Hertz frequency. And this particular circuit is designed to remove the narrow band of 50 Hertz. So, since 50 Hertz is also between this particular frequency the purpose and the requirement can be completely monitored using this particular range of frequency.

And when we apply a input, we will slowly change different frequencies from 10, 1 Hertz to 100 Hertz with a factor of 10 Hertz in steps and we will see observe at what particular frequency, the output amplitude is 0.707 times lower than that of the input signal. That 0.707 times is because of our minus 3 dB point. So, if we can calculate the minus 3 dB point or if we can know at what frequency that the output is smaller than point 707 milli times smaller than that of the input, that particular frequency gives us the information of our cutoff frequency of our notch filter right.

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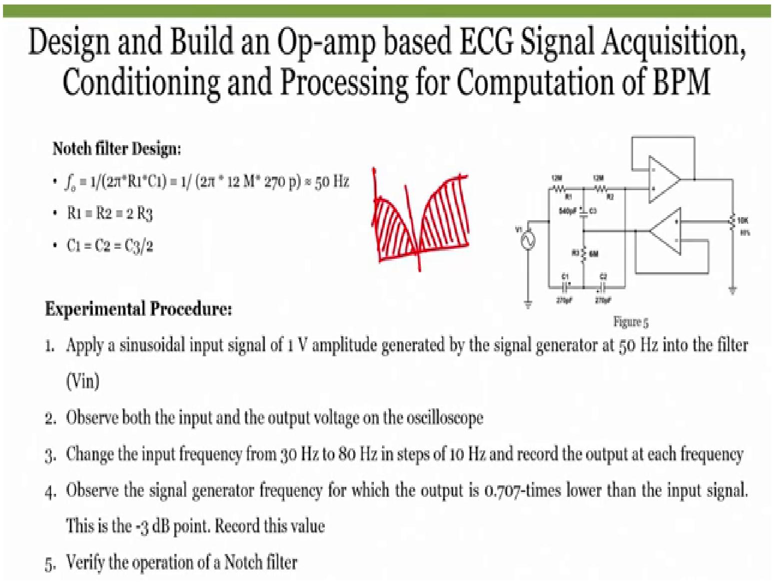

Why this is called notch filter? The reason as we know that when we see the frequencies, this is out the representation of our notch filter. This particular frequency is will be completely allowed as you already seen in our in our other modules and this particular frequency is also completely allowed but this particular frequency which is not about the centre frequency or this particular band our frequencies will not be allowed. That is a reason it is called notch that particular notch that particular band is not allowed.

And other than that particular band, all other frequencies are allowed. Not allowed in the sense, it is nothing but attenuated we cannot say completely remove, we can say attenuated. Now, we will see the simulation of how exactly the notch filter works by designing the same, the same filter right and output will be taken at this point. Now, if you see that has similar to that of our previous experiments, how we have done. So, we will go to multisim, we will try to design the same.

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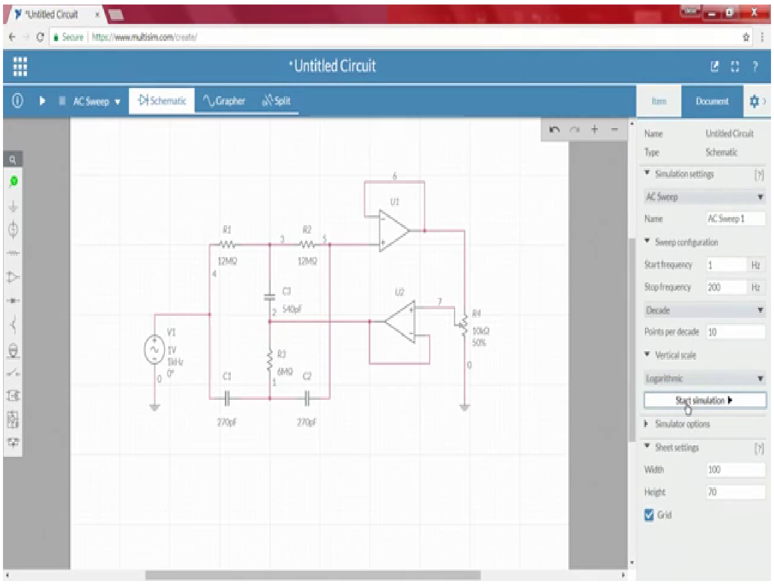

So, we will take three resistors and three capacitors. If you remember correct, R 1 and R 2 should be doubled then that of our R 3 values. So, what I will do is that I will take three resistors the value of this is 6 mega. So, I am replacing the resistance with the 6 mega and other resistor should also be 6 mega; sorry 12 mega 12 mega and one resistor should be 6 mega. So, this should be 6 mega resistor and let me delete this.

So, easy to create, then other one should be 6 mega R 3 resistance should be 6 mega. Now, now we also required three capacitances. So, capacitor 1 C 1, I am saying it as which is nothing but 270 picofarads, 270 pico. Then two capacitors and the value of capacitor should be half of that of our three C capacitor. So, C 3 capacitor is somewhere here right and the value of this should be double than that of our C 1 and C 2 capacitor which is 540 picofarad.

So, whatever the required resistors, capacitors we have arranged it here and only thing left is connections. So, the passive elements connections will do now, then we will go with our active elements required, right. So, which look similar to that of our circuit if you observe here, right. Now, the input should be connected at this point. So, what I will do is that, I will take AC voltage connected here and other terminal should be connected to the ground.

So, we are expect, we are thinking to take a resistance value sorry the voltage source with an amplitude of 1 volt peak value. So, peak to peak we selected as 2 volts to right.

So, it is easy to understand, relatively it is easy to understand outer output voltage. So, and we need two op amps. So, one op amp we are taking it here and as the purpose of this op amps are one is to provide and you know impedance mismatching; other one is to provide some offset to the system. So, what we do is that, we will flip the op amp. So, the op amps looks similar to that of our the connections. We look similar to that of our connection that we see in our circuit board, right.

And we will take one more op-amp, rotate it. So, this one should be connected to the a second point the junction of the C 3 capacitor and R 3 capacitor and one part we will take potentiometer. So, the output some percentage is passing through our input. So, this particular term has been connected here, right. So, you made the connections whatever we look. Now, we will test the functionality. So, as we are following the frequency analysis in order to see how exactly the frequency domain looks like. So, as remember the notch filter will pass a frequencies from 1 Hertz to somewhere around you know say you know like except the narrow band frequencies it will pass all other frequencies.

So, in order to verify we will go ac sweep we will keep some settings here, 1 Hertz and the stop frequencies we may not required up to 1 e power done. So, we will go off to somewhere around 200 Hertz and the decayed value, we will say points per decay ten points per decay, then logarithmic scale, then start simulation but in order to visualize we have to put our voltage points to one green indicates our input voltage and blue represents our output voltage.

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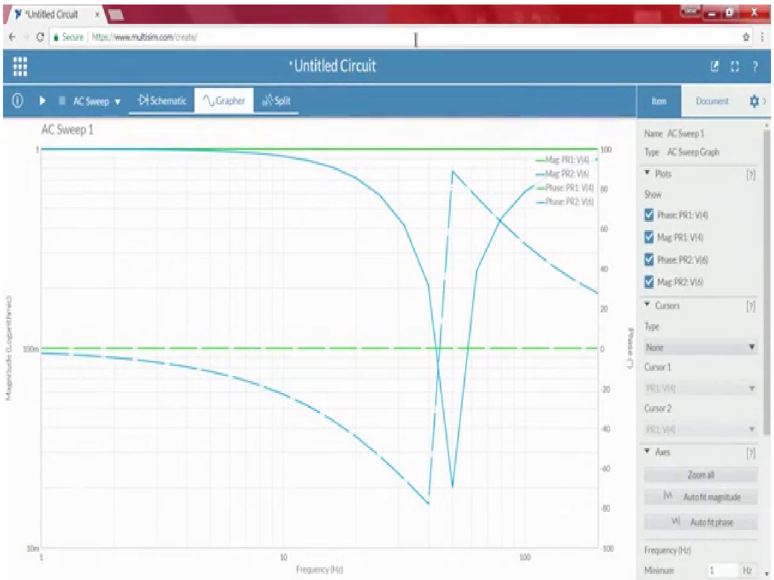

When you start assimilation and we look into the graph, one thing is clear that if you clearly observe. So, it has two different frequencies sorry input phase as well as magnitude input output phase as well as magnet. Since we are not interested in the phase 2, you just look into the magnitude if you see that, the output as well as input right output and input are you know having the maximum amplitude magnitude as 1 right; that means, there is no gain acting in the system. Now, what we do is that we will see we will try to increase a frequencies to somewhere around 1000 Hertz so that even the output can go to the maximum right the gain and let me remove the phase values.

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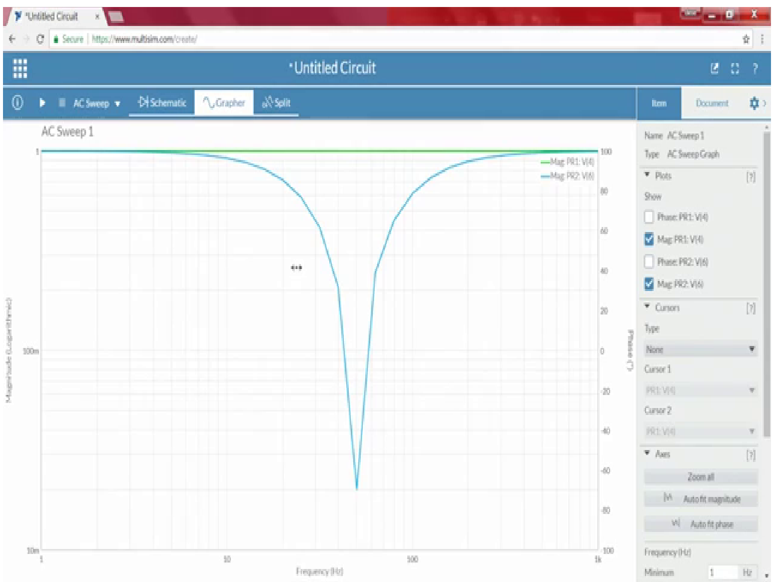

Now, if I if you clearly see that this is 10, it is in a frequency domain. So, if you recall how do we measure in a frequency domain. So, and that in a log scale basically 10, 20, 30 and 40 and 50, right, 60, 70, 80, 90 and 100. Now, when we see that we need to know 3 dB line the 1 2 3; this point right this particular frequency the frequency at this particular amplitude right is the cutoff frequency generally we do. But now if we see at a frequency of somewhere around 50 Hertz right, the magnitude is completely very very smaller right and again and again suddenly after you know just above 50 Hertzs, it started it started raising.

So, when you see the valley it is just like a narrow, that is why this is called narrowband filter 2. So, very narrowly we can sharp down we can cut down into one particular frequency. The reason is that we have we are we are looking to eliminate or to remove only the 50 Hertz noise and other things we are not we are we do not have to remove it. So, that is a reason rather than going with a long range of notch filtering, if you can go with a narrowband of narrow filtering narrow band of our you know narrow filtering it would be really advantage, so that it can only remove 50 Hertz frequency signal now.

So, this looks similar to that of our narrow band frequency. Now, how do we understand since most of the cases we may not have a function you may not have the frequency spectrum to visualize our filter. So, what we can do is that we can even analyze the cutoff frequency of the filter by looking into the time domain, that is what we are even visualizing in our previous experiments to. Now how do we do that? So, rather than going to ac sweep we will go to interact to and we will go we will try to change the frequencies slowly from 1 Hertz, 1 Hertz to up to 100 Hertz is more than enough and we will put it in a split mode.

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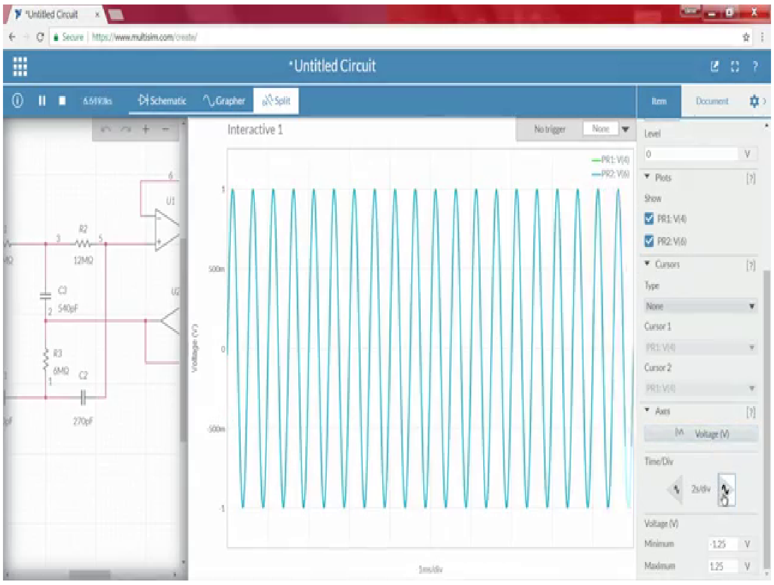

Now, if we observe, let me run right now it is 1 volt 1 Hertz, let me change the settings of our time domain of our signal right. So, we have both the signals if you carefully observe right, the reason the reason why we are showing only one is because one is ahead of other I mean the back the green is on the background of the blue colour ok. We slowly change our signal frequency at an intervals at the steps of 10 Hertz.

So, now, we will go with a 10 Hertz. Now, if you observe, let me change our time divisions right. Here, we can clearly see that this is our input green colour and this is our output. Now, how do you understand this is that particular point that we have to consider it. So, in order to make our self easy, let us let me create a cursor for us.

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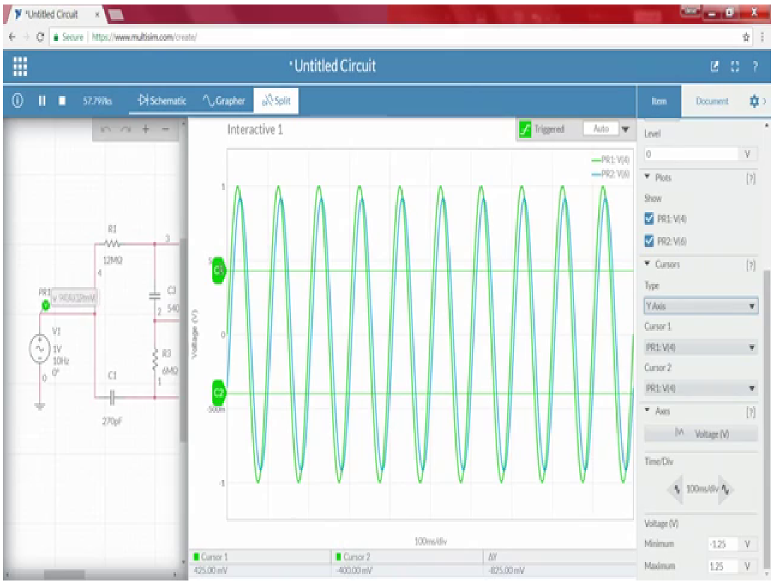

So, the cursor point should be somewhere around 707 milli volt. So, let me move very close to if you observe here at this point, so I just keep the cursor at 707. So, this is nothing but our 3 dB line. What we do is that when our output voltage is lower than this particular 707 or at 707, that is nothing but our cut off frequencies generally we consider in our in our frequency domain.

Now, the input output is greater than that particular cursor point. So, that means, this is not our cut off frequency, let me increase to 20 Hertz, we increase almost close to but not exactly right.

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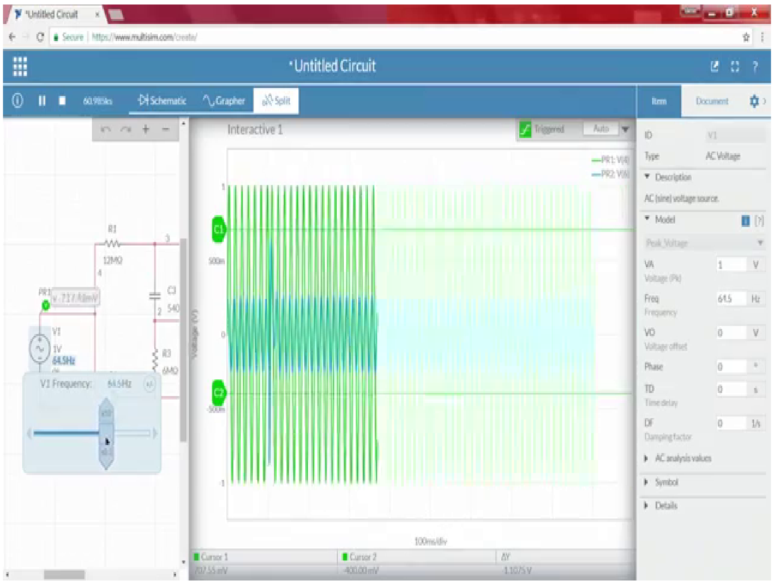

Then, 30 Hertz see below that, below that 40, very very small signal, 50. So that means, if you have observe that there is a drastic change for every 10 Hertz increment right, that is why this is called a narrow band, a very drastic change right. Now, if I known increase, the input frequency, even you can observe the drastic change in our output signal too, right.

Now, what is the purpose offs the op amp that we have seen here? If you observe, so what we do is that to understand that op amp will slow, we will keep to one particular value yeah, we will consider this one.

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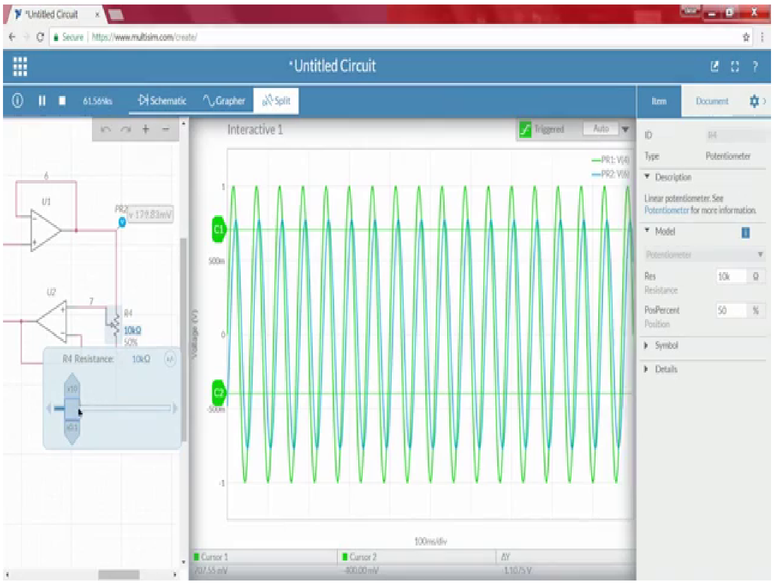

Now, we will change this particular resistance, sorry this should be 10 kilo and let me change this value. We observe right now the how much band, how much narrow band that we require, we can select by using this particular part. Now, we will slowly change once again 17, 25, 26, 30, 33 right. At this particular frequency somewhere around 34 right, somewhere around 33.5 if you observe here, it is very close very close to our C 1. So, what if I increase it?

So, if I see that, till that particular frequency 39, now it has increase to 39, so that means, we can see at what frequency that we require to have you know the proper cutoff right. Now, if I slowly increase right 44 point 45 let me see take 45, see there is a drastic change from 44.5 to 45 itself. And since our was interested somewhere around 50 Hertz within the range of plus or minus 5 Hertz frequency, from 45 Hertz to 55 Hertz frequency I am completely eliminating. Even if it is not even required, what we can do is that even we can change this R 4 resistant to some other value.

So, we can see we can see very drastic change narrow banding of the frequency everything. But, but the problem with this thing is that we can up when we closely look into the graph, there is some shift there is some shift in our output signal 2. So, to understand let me zoom little bit right. So, as long as if we keep on change our now the potentiometer value, it causes to create some kind of a shift in our output signal. So, if that is that is fine, if not try to set our you know op amp the resister to one particular value and change our resistance values. So, but if we are really you know interested in our narrow band of frequencies, one good way is changing the resistance value and we can observe that causes drastic change from 44 Hertz to 45 Hertz itself and below that particular value it is completely, it will be completely below the setoff. And if you see even that go to split and if I slowly increase input frequency 45.5 right, right at 59, 49 Hertz almost nothing.

If it is 50, again started increasing whatever about C 2 right, but as a frequency is you know greater than the value again, it follows the input right. So, this we can clearly understand whether whatever the filter that we have designed can cut off very close to the 50 Hertz frequency or not right. Now, we will how do we perform an experimental thing.

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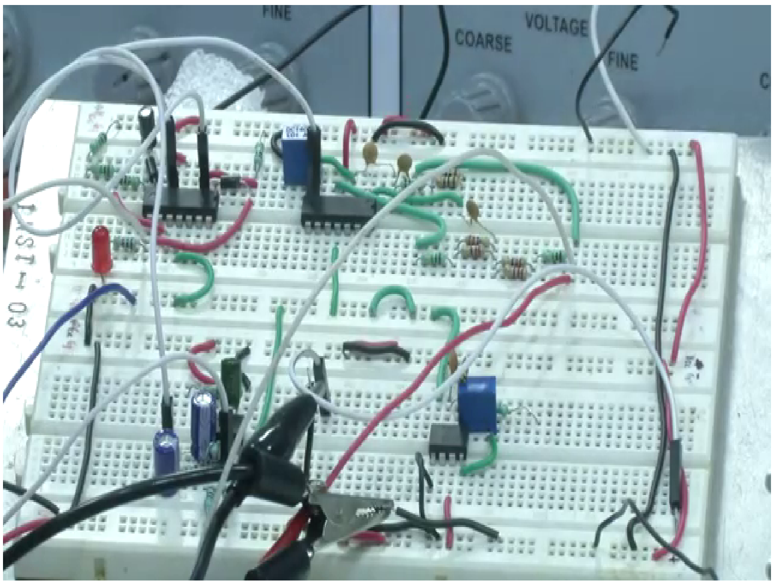

When we look into our board, if you recall, this particular portion, this particular portion we have use for both low pass and a high pass filtering right. So, this portion is for low pass filtering right and this portion is for high pass filtering, that we have use. Now, the other part that we are using is notch filter notch filtering and the 250 Hertz notch filtering.

So, if we call our resistance value that we have use the time, so somewhere around 12 mega 12 mega and 6 mega resistor 270 picofarad and 540 picofarad right. So, since 12 mega getting a 12 mega resistor is really harder in the market so, but we can get 10 mega resistances. So, either you can go with a 10 mega plus 2 mega, so that is a one way or you can use some other combinations in order to get 10 mega value sorry 12 mega value. So, in this case, we have used somewhere around 20 mega and 20 mega connected in parallel and we have connected it.

And 6 mega also, so we have we adjusted the resistance value such a way that to get the 6 mega resistance and apart from this everything as per the circuit. So, so, so that if you observe this point we have a different resistors connected in parallel right and connected in series right series, parallel again parallel and series and the capacitor right and both the op amps we are using from TL 084. So, TL 0484 is a quad op amp. So, it has a four op amps inside. So, we are using only two op amps in this point. And this is a another part where we have seen even in the simulation where we are changing the shifting or you know the phase value or shifting the narrowband and everything here right.

So, now let me implement the circuit so that we will see how exactly it is working. So, input at this point is the junction of both 12 mega and capacitor. So, when we see that, so, this particular point is the input to our system and the output is the seven th pin, this pin is the output for us. Now, what I will do is that I will take cro I will take function generator, I will connect input from the function generator right. If you remember, we are going to is a function generator starting from frequency of 1 Hertz to a frequency value of 100 Hertz. If we slowly increase our frequency at one particular point, we can see 707 degrees in our lesser than 707 or milli volt output voltage. That frequency at what at that frequency it is nothing, but a 3 dB line. So, I am connecting the input here and changing the input frequency to somewhere around 1 Hertz and. So, I will take CRO.

So, one terminal connecting it to the ground other terminal I will be connecting at the same input point so that we can see what input that we are connecting it to the system right. So, I have taken CRO, one CRO probe connected the same point right, another CRO probe let me connected to the output. So, this should be our ground, this is the ground and this should be our output the seventh pin is our output and connecting it to the output terminal. Alright, so let me switch on the circuit, let me switch on the input signal 2 associated.

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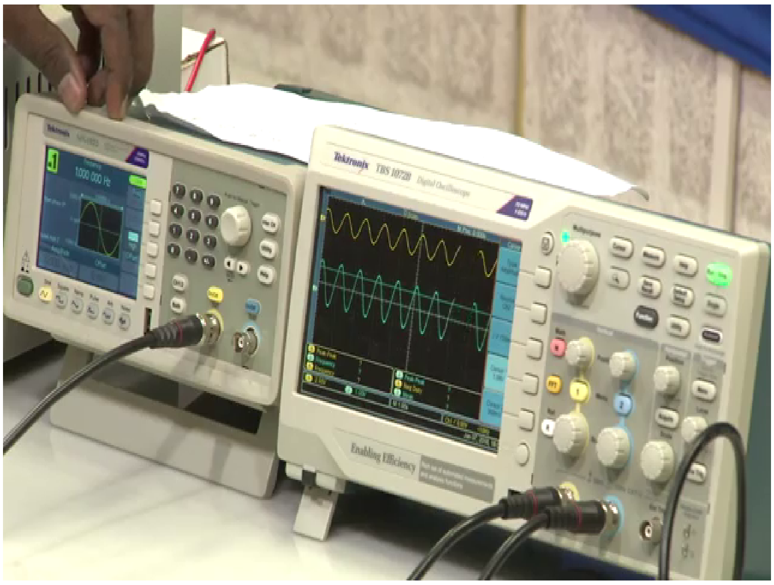

So, when we look into CRO right, so this is nothing but our input, the yellow color line and the blue color line is our output. So, just to understand, what I will do is that I will keep both the signals to the same point at this particular point so that it is easy for us to compare. Now, 5 volts, so let me change my amplitude to 1 volte, so I am setting the amplitude to 2 volts peak to peak. So, that is nothing but 1 volt peak. Now, I will zoom this particular. So, if you see one box in this case represents 5 volts right, even in this case one box represent 5 volts. So, let me increase the value one box to one volt and even here ok.

So, there is slightly shift of our output, so that we can adjust by using by changing the pot right. So, let me change the pot value. When we look into CRO, we can see we are getting both the input and output signal. Now, what we have to do we have to see whether this whether, but this particular circuit is filtering out the 50 Hertz component and other frequencies are passing or not. So, for that we have to change our input frequency and we have to see at what particular frequency the output is below 707 milli volt. So, in order to set 707 milli volts, I will use a cursor. So, I will go with a cursor and I will make it as an amplitude cursor.

For channel 2, so I will go for channel 2 and sorry, so I will change the cursor one value 2 oh where is at. So, the peak value when you take, so, this is a value and another channel I am moving it somewhere it below. So, the peak to peak value NIC delta v it is

2 volts that is cool now. So, this is our ground terminal and this is 720 milli. So, right channel cursor 1 is that the difference between both the cursor 1 and cursor 2 is somewhere around 720 milli volts.

So, now what I will do is that when we look into the function generator, I will slowly change at a frequency of 20 Hertz. So, now, it is at one Hertz frequency I will change it to 20 ok. So, 210 first, 210 Hertz, now when we see right, so I do not see any difference in below that particular value. So, let me change 220 Hertz even the resulted the same 30, even higher than that of the cursor value 40, slightly higher than that from here I will slowly increase 40, 1, 4, 2, 3, 4 5 right 6, 7, 8 48, 49 right. When we observe that, somewhere near to 49, somewhere near to 50 Hertz, so, when we see this CRO value 50 Hertz that is the output is almost below the cursor value right.

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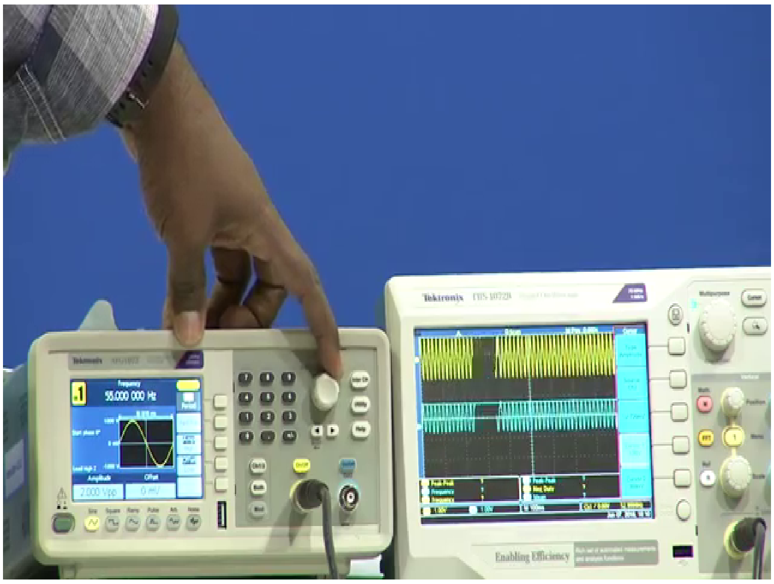

When I slowly increase here and there, now amplitude will be the peak to peak amplitude, we can see it is completely decreasing it right and if it is increasing again the peak to peak amplitude if you observe starts increasing now. So, in order to make it narrow band or something what we have to do, we also have to change the resistance value.

So, I slightly change the resistance value 2 because we narrow band. So, that is a reason by adjusting your resistance value we can easily see whether it is creating an arrow or little wider band right. So, that is a reason I change the resistance value, I am decreasing somewhere to 53, 52 Hertz, 50 Hertz and 49 if it is higher. So, there was no much.

In fact, now, so, if we recall our the pot resistance value that we have chosen, so, if that same resistance value if I measure and select it right we can see some adjust in the resistor. So, we can see it has come down right. Whereas, if I change the resistance value the pot the peak to peak voltage value will change it, we can easily see the CRO right. So, depends upon whether we require arrow or wideband. So, this despot the pot that we are using decides it right. So, this way, we can even you know change there is the notch filtering to be narrowband or little wider band and everything.