Circuits for Analog System Design

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Lecture No. # 33

AC- applications of the Op-Amp and Lock in Amplifier Design

Today, we will discuss about A C application of the operational amplifier. So far, we have discussed about D C applications and then we calculated various errors associated with the D C amplifiers and so on.

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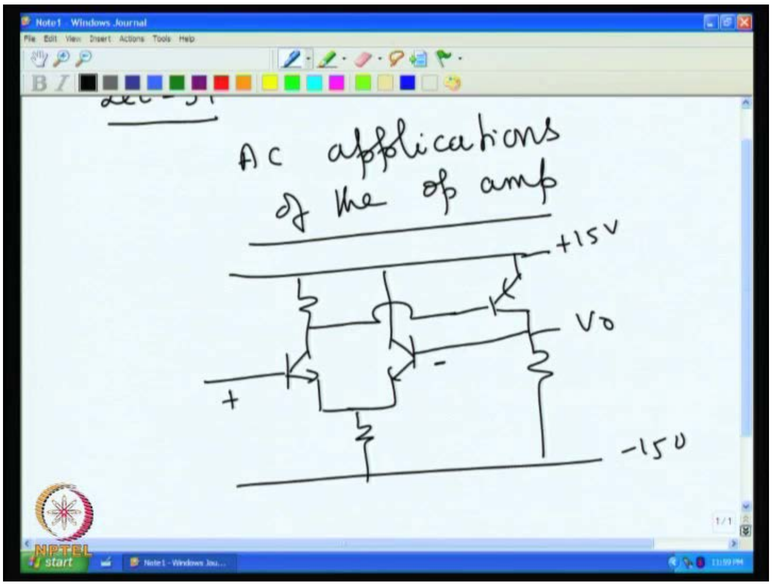

Now, we will discuss about A C applications of the operation amplifier.

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Now, if we look back what is the operation amplifier and so on that we are seen, that is the basic simple operation amplifier was looking like this. We had input stage difference amplifier, essentially that is count to minus 15 volt and then we are connected this. This acting as non inverting input and then the output was here and then the feedback was given to the minus terminal like this.

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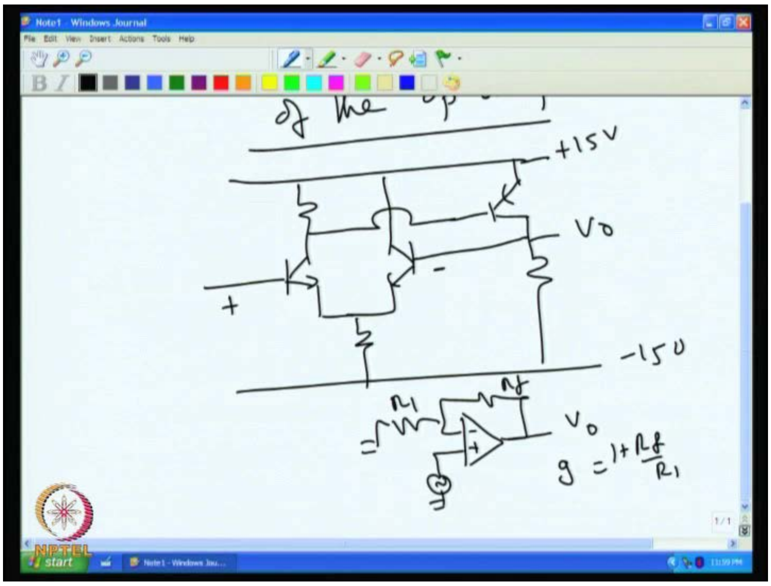

Now, this is the basic operation amplifier we are discussed initially. So, we will use the same model to see what is the problem in using op-amp for A C applications, because we may think that you know, we can have operation amplifier and then for example, we want amplify, the simplest thing would be similar to D C, we can have two gain setting resistors and give signal here and then you get the output voltage. Now, the gain actually is given by, R f by R 1 in this case is 1 plus R f by R 1, similar to D C that what we had discussed earlier.

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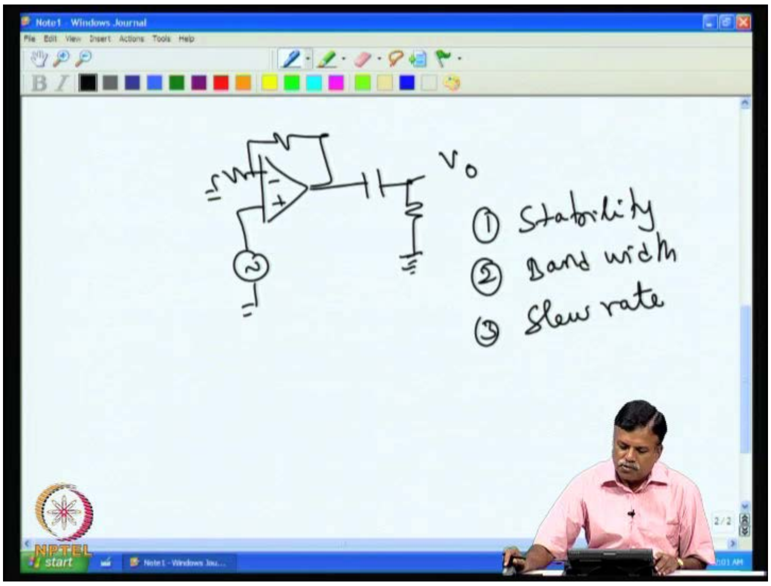

In A C applications of course, there are other advantages that need not worry about the D C voltage drift, because if I have amplifier then, I can always block the D C voltage and take only the A C voltage using a D coupling capacitor, so we can have a D coupling capacitor and then take the, we A C output. In that case, the offset voltage, bias current error, all these things goes up which looks to be much easier, because the lots of problem gets solved, because of this the because of the elimination of this D C problem. But nevertheless, there are issues involved in A C amplifier that is, what is the main worry is, that is stability at the amplifier. We are too worry and then the second one is band width, what is the band width and the third problem is slew rate related issue. So, these issues creates additional problem as per as A C amplifier is concerned. Now, what is the problem due to slew rate and then what is the problem due to the stability? Let us look at the stability problem, for that we go back to our operation amplifier circuit.

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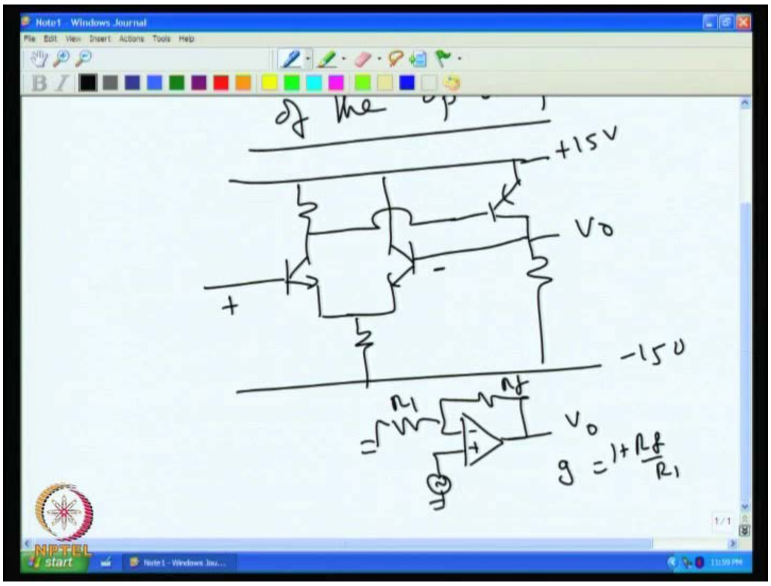

Now in this case, if I trying to amplify A C voltage for example, I apply A C voltage here and trying to get amplifier A C output, then we have issues mainly due to, there are capacitance between this, this call miller effect capacitance. Actually, this capacitor is coming due to the diffusion charges, because charge that is diffusing. It takes its own time so, that is represent as a equivalent capacitance here. This is the famous miller effect capacitance and similarly, we have capacitance here at the input.

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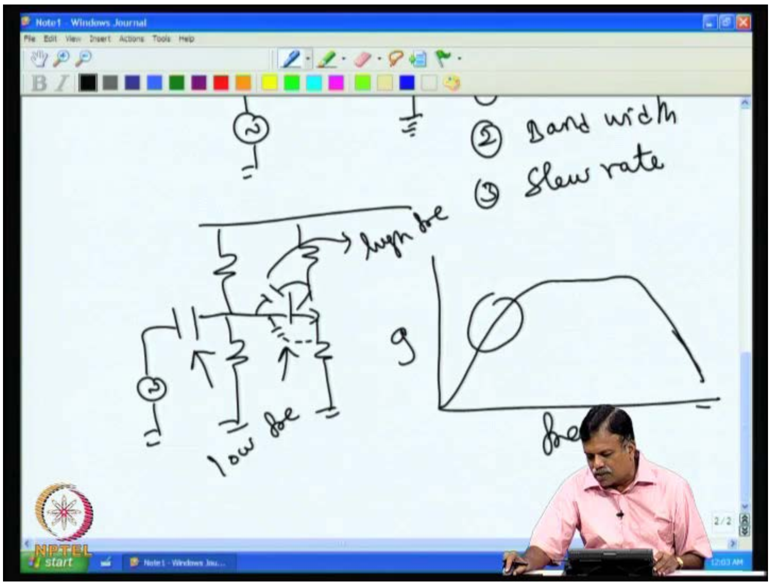

Now, this for a single stage amplifier like this, this capacitors create a problem because it has seen that in our original transistor amplifier that we were using in the conventional circuit that we have. If I take this transistor amplifier circuit, this single stage amplifier and we used to get a gain band width relation like this, that is gain versus frequency. If I plot that we used to get for example, curve like this so, this is actually low frequency region. Problem is coming because of this capacitor and then high frequency gain is reducing because of this miller's or called miller effect the capacitance, also we have capacitance here. So, this low frequency is limited by these two capacitance; low frequency effect low frequency, this actually creates problem in the high frequency. So, this problem is there in the operation amplifier as well, because after all operation amplifiers if we see carefully what is involved? There also you have a miller effect capacitor and then the input capacitance.

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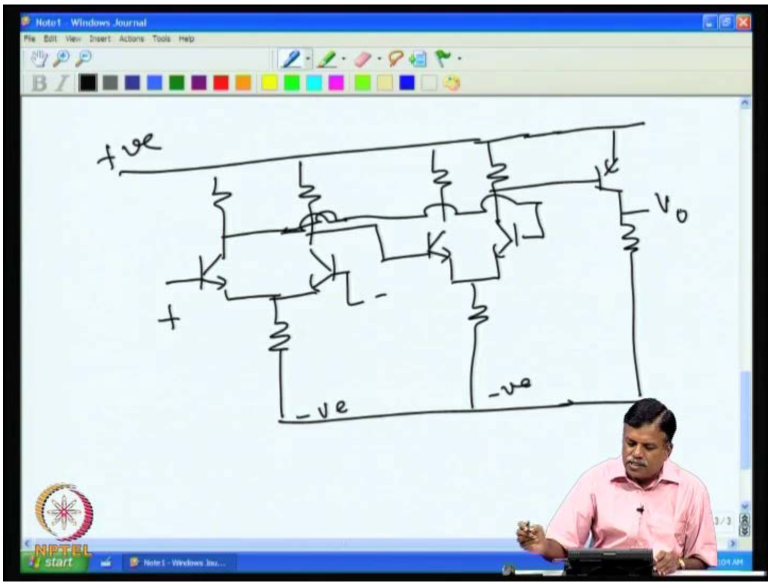

And the actual operation amplifier in the real work consists of several stages, it is a multistage amplifier. So essentially, if we see the operation amplifier simplified circuit, it looks like this. That you have the input stage where in, it is a different amplifier here, negative voltage and then this is connected to positive voltage. Then this output actually invariably applied to the one more stage of difference amplifier, again this is given to the minus supply and then this output is fit here, and then the other output also fit to the next stage. And then this output is actually given to the output stage which is similar to what we have discussed in the earlier stage. The output stage consists of some more amplifiers, that will see later the current limiting and so on. If we see this one, this is some minus input and this is a plus input and you get the output voltage. It is a multi stage transistor amplifier. So, what is the issue with multistage transistor amplifier?

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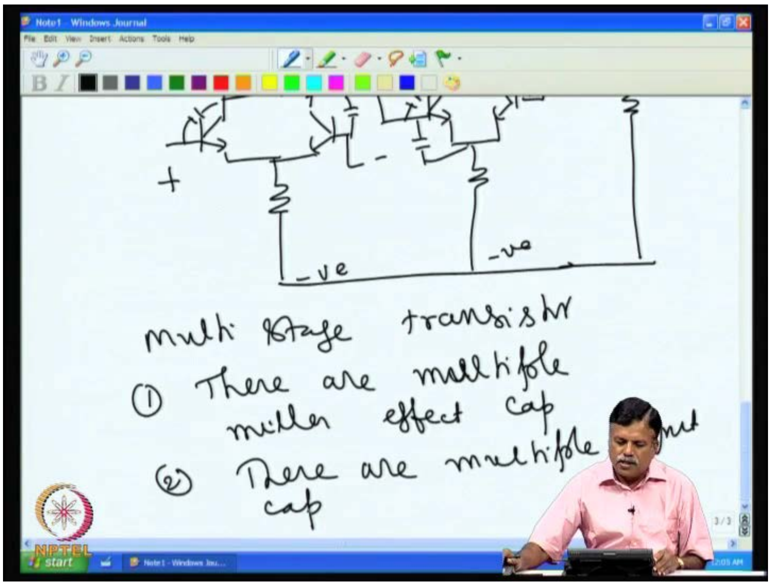

The multi stage transistor amplifier has multiple poles and zero that is the worry, because for example, if we take this, that we have a capacitor from here to here and then you also have a capacitor from here to here and so on, that all the stages have their own miller capacitances and then also you have this and then also the you have the input capacitances also there, which limits the low frequency performance.

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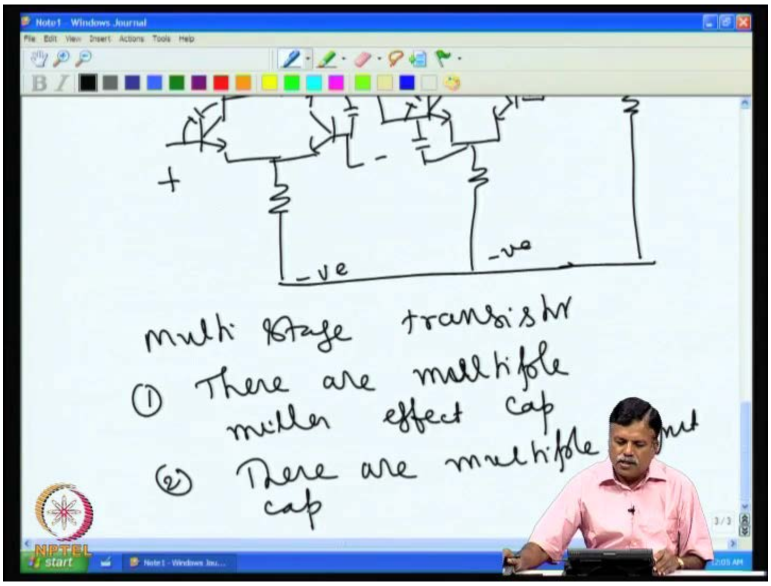

Now, that is there are multiple there are multiple multiple miller effect capacitors miller effect capacitors .Similarly, there are multiple input input capacitors input cap and the capacitor the performance of this stage, frequency response for components of this stage is actually related closely to how this is coupled to the next stage and the capacitor associated with this. Similarly, the performance of this stage, frequency response of this stage is actually coupled to the related to the next stage.

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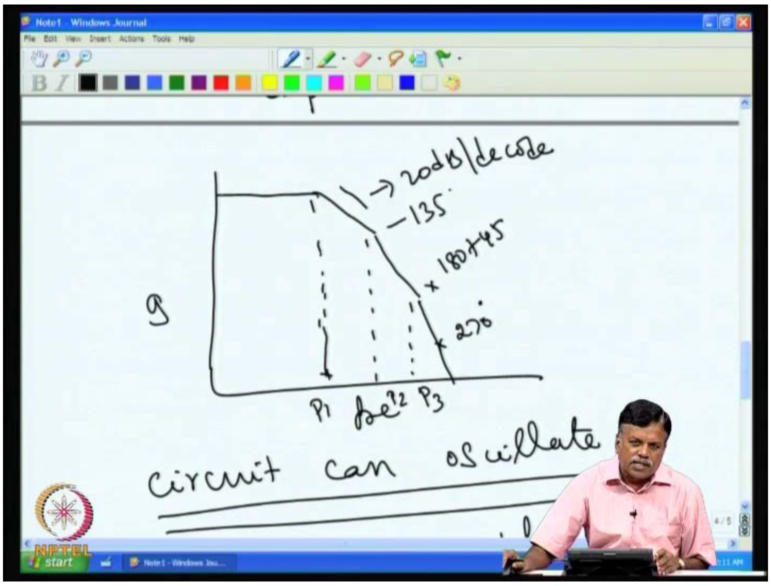

So net result is that, if we have several capacitors and if we try to plot the frequency response of this multistage amplifier, it looks like this. That is, if you plot frequency versus gain relation then, you have for example; many three different poles for example, you will be getting. So, you have a first pole here, and then the second pole in the second stage and third pole in the third stage. This is the frequency response of the multistage amplifier, similar to what we are discussing the op-amp circuit. Now, what is the issue with this multiple amplifier and then frequency response of this multistage amplifier. The problem is that the circuit can oscillate, that is the main issue actually. That is, instead of working as amplifier by putting the two resistance and now, we can we are shown that, it can be used for amplification, where actually instead of working as amplifier it can work as an oscillator. If the phase shift around the loop and then, the gain the around the loop are satisfied. It circuit can oscillate, this is the main issue that we have to worry instead of amplifier, it can act as an oscillator.

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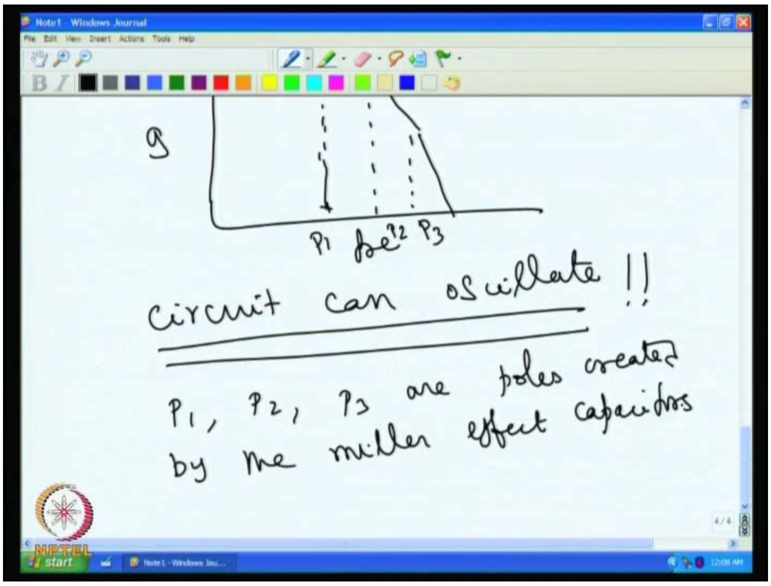

The reason is that, in the here is a pole, this is created by one R C component mostly it is actually, miller effect capacitor and the resistance also associated that. So, miller effect capacitor first stage and the resistance associated with the input can create a this pole one and then you have the second pole here, P 2 and third pole here, P 3 so, P 1, P 2, P 3 are poles created created by the miller effect capacitors. P 1, P 2, P 3 are poles created by the miller effect capacitors.

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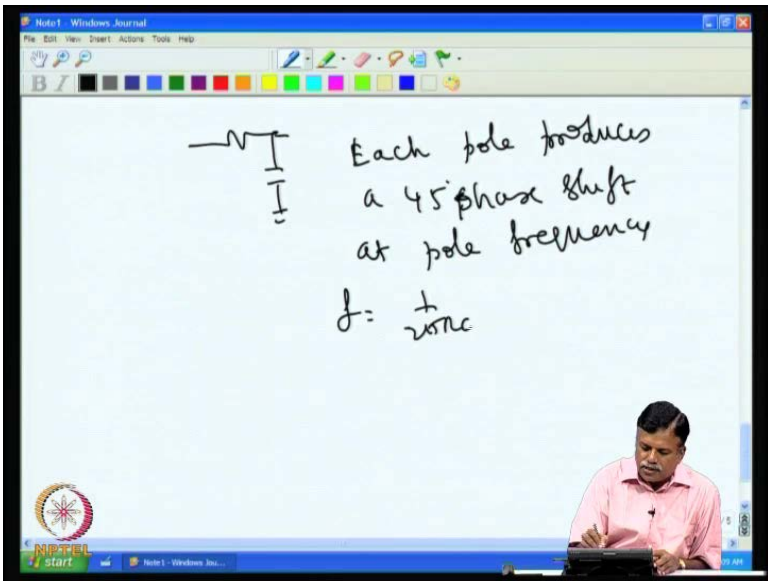

Now what is the form, which each pole we know the produce a 45 degree phase shift, because each one act as R C, each pole we have R C filter effect. So, each pole produces a 45 degree each pole produces a 45 degree phase shift 45 degree phase shift phase shift at pole frequency, pole frequency actually is given by, 1 by 2 pi R C now and…

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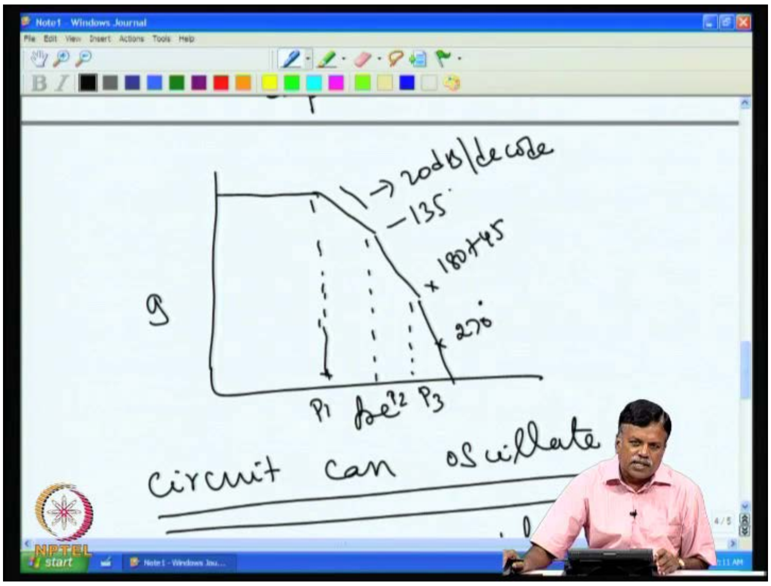

As we increase as increase the frequency, this has a 20 d B slope, 20 d B per decade slope.

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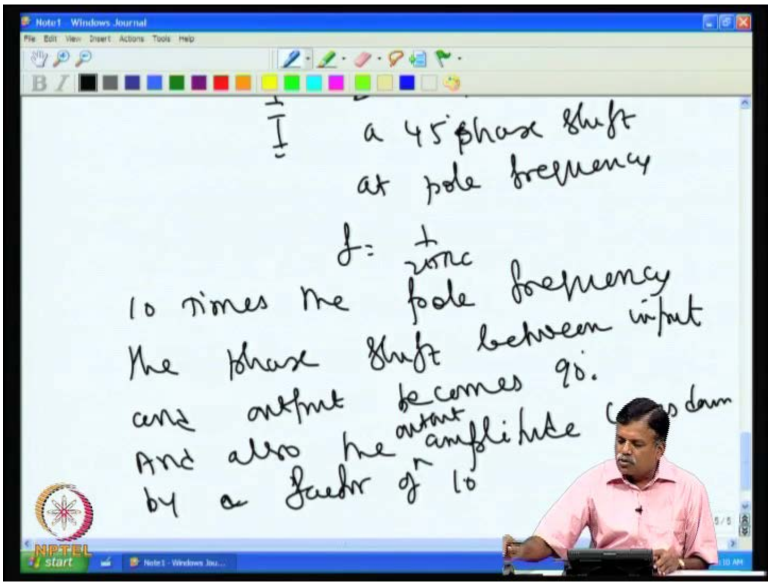

And then the phase actually, the phase shift continuously increases 10 times of pole frequency, phase shift becomes 90 degree. 10 times the pole frequency 10 times the 10 times the pole frequency pole frequency the phase shift the phase shift, this phase shift between input and output between input and output becomes 90 degree and also the amplitude reduces by effect of 10 and also the amplitude comes down by effect of 10. The output amplitude output amplitude comes down by a factor of 10.

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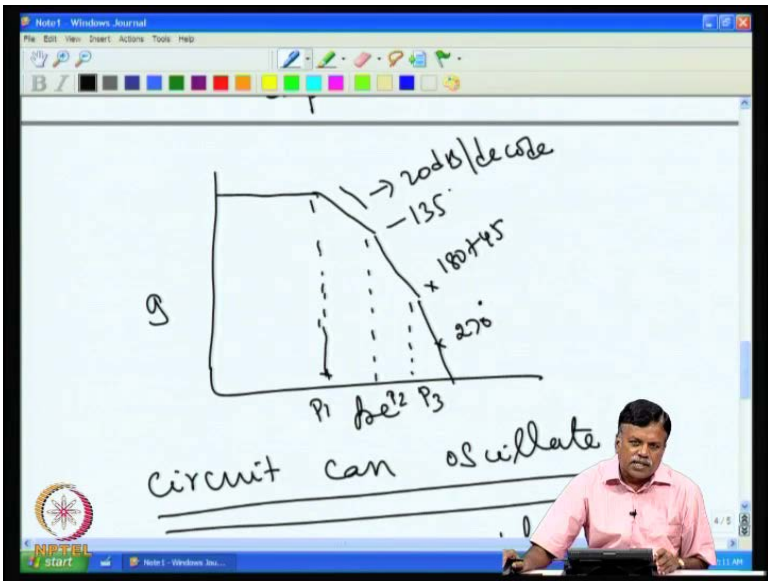

So, when we have multiple poles like this. Each pole produces 45 degree phase shift here and then, 10 times the pole frequency becomes 90 degree the next pole comes, again produces the 45 degree phase shift. So it is possible, at this point we can have 135 degree phase shift then, it at this point it can become 180 plus another 45 that it because, this phase shift slowly increases, because 180 and then, becomes another 45 degree phase shift. If you see that one, then another 10 times for frequency it can become 270 degree. When you have a multiple pole frequency that it is, we can have a phase shift of more than 180 degree and if the phase shift goes more than 180 degree and if in feedback, we are already giving 180 degree phase shift. The net result is the amplifier can oscillate at some frequency because of this multiple poles. This is one of the major problems in using the amplifier.

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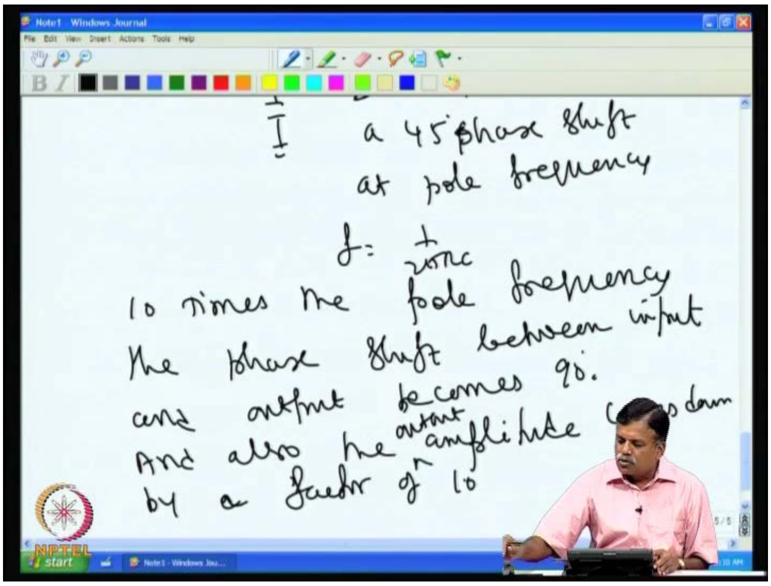

So, if you have to use the amplifier for practical use then one have to worry about this oscillation and we have to make our effort to stop these oscillations.

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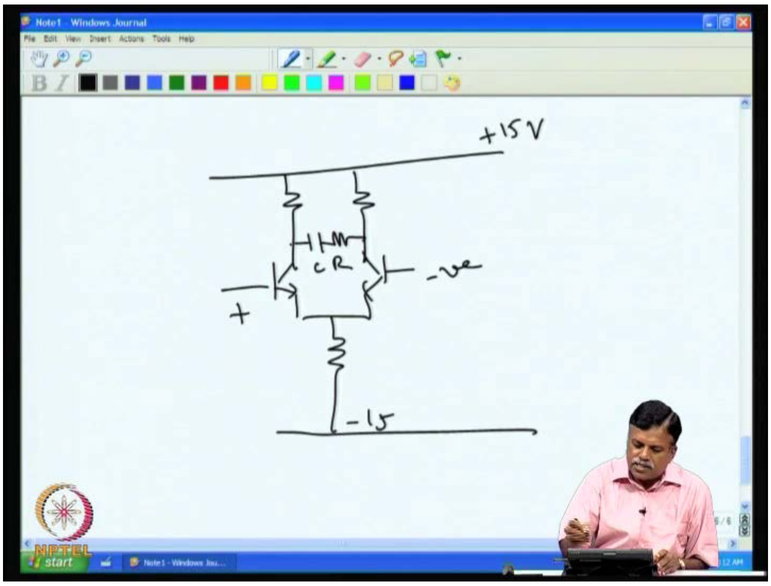

So normally, the manufacturers do the frequency compensation inside the operation amplifier itself so that, the amplifier is stable and then it works as a amplifier. That is done invariably in the first stage by adding a R C at this point, so we have plus here and then the minus input and the plus supply plus 15 volt supply here.

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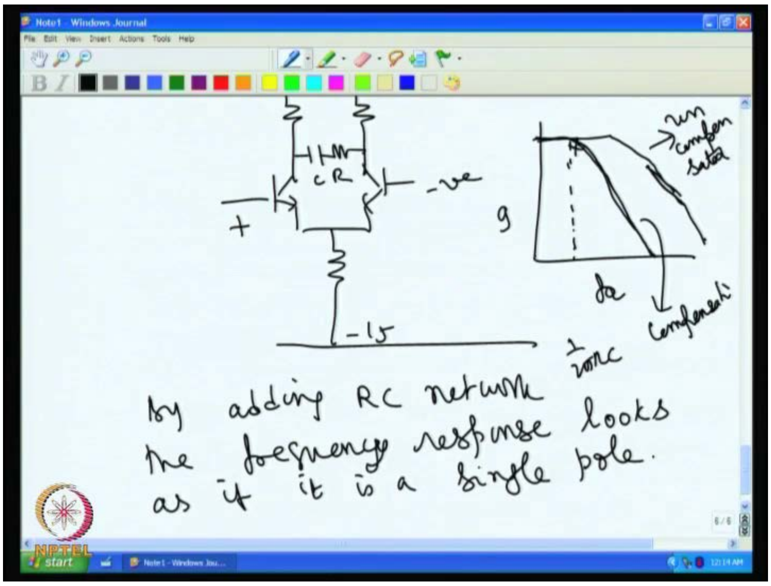

And the input stage if we see that, you add this R C so R C is added such that, you can save the open loop frequency response, because open loop frequency response which is like this, that we had shown the gain versus frequency curve the multiple poles. Now by, one can actually do this and bring down the frequency response is like this. If its single pole frequency response and the pole frequency now shifted to this, this is actually given by 1 by 2 pi R C and then one can bring down to a very low frequency and then, now this is a uncompensated amplifier this without this R C network the uncompensated op-amp, this is compensation. With compensation, it you can bring it down like this, with this the idea is that, we have here at this point 45 degree phase shift and then, the phase shift increases and then it can become maximum only 90 degree because, for R C network the phase shift cannot go more than 90 degree. So, acts as if it is the single pole amplifier.

So, by adding R C network, the frequency response looks, as if look looks as if frequency response frequency response looks as if it is it is a single pole amplifier a single pole amplifier.

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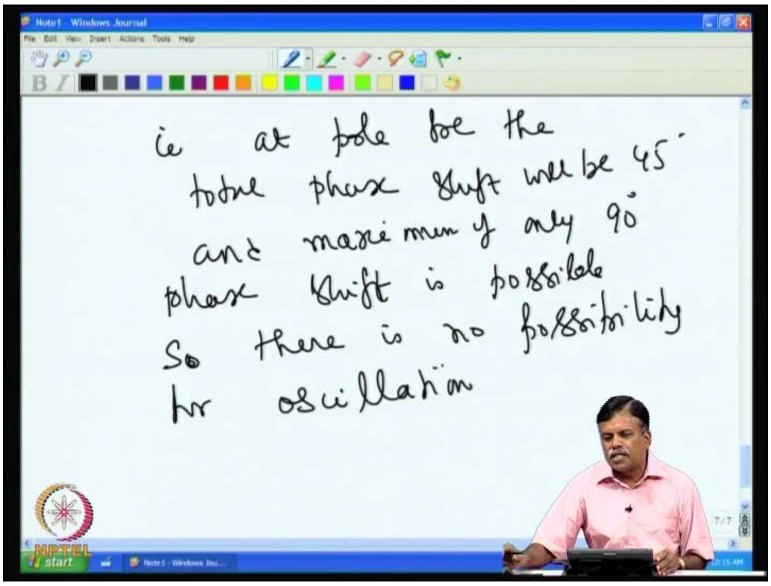

Now that is, at pole frequency now you can have at pole frequency see the total phase shift will be phase shift will be 45 degree and maximum of only 90 degree phase shift is possible phase shift is possible. The amplifier, so there is no amplifier there is no possibility for oscillation there is no possibility for oscillation.

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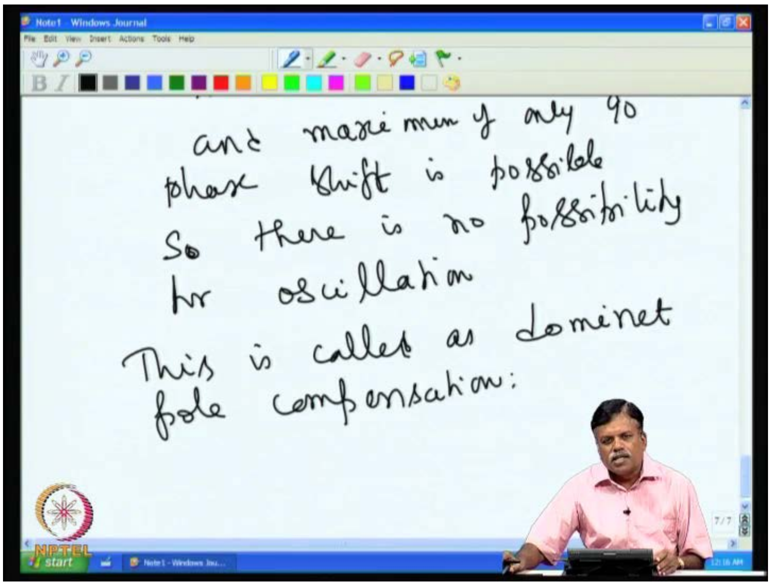

In fact, this is what you design in most of the operation amplifier. This is called as dominant pole compensation this is called as dominant pole compensation.

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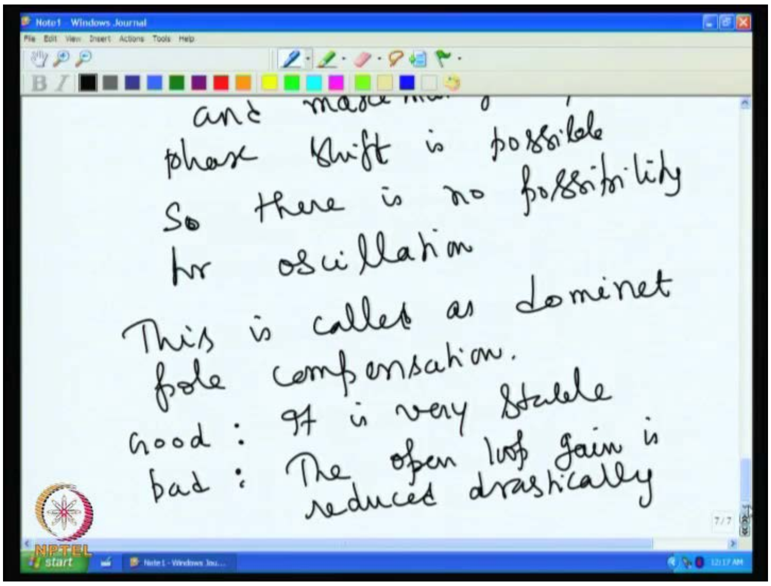

Now, the dominant pole compensation is good. It works always, there is no problem at all but, only drawback of this scheme is that…

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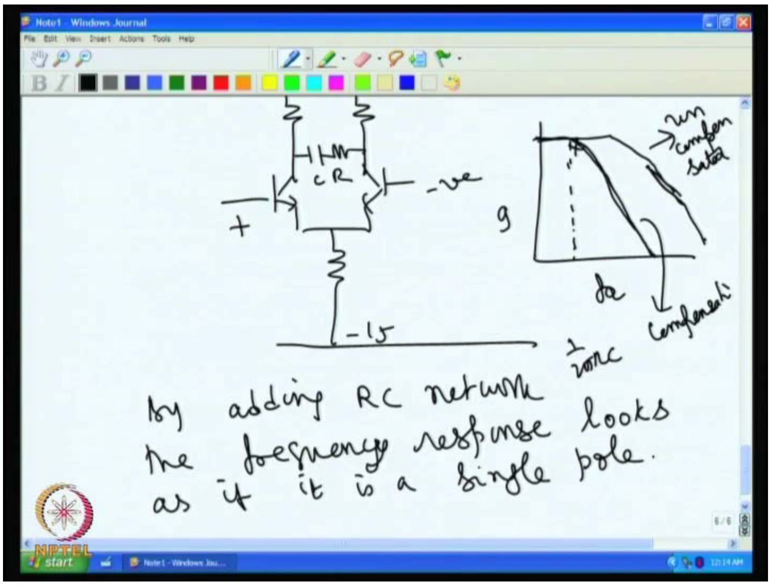

The open loop gain is drastically reduced, we are achieved this stability by drastically reducing the overall open loop gain of the amplifier. The dominant pole compensation is good, we look at the positive part of it.

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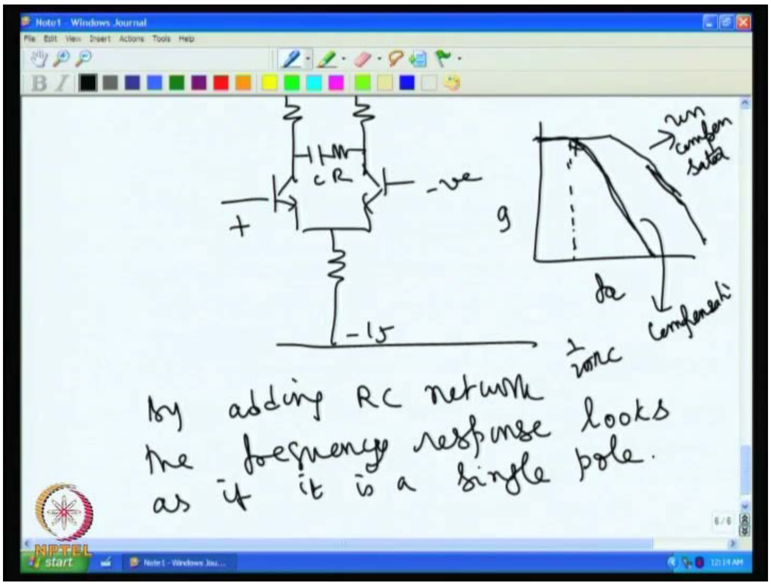

Is that, it is very stable. You can depend on this. It will never oscillate but, the bad part of if it is the open loop gain is drastically reduced, open loop gain is reduced drastically. So, the frequency open loop gain is drastically reduced except at, low frequency that, it all I if we look at high frequency, the gain is drastically reduced. This is the bad part of it nevertheless; most of the op-amp particularly general purpose, op-amp follow this rule that is, the do the dominant pole compensation, so that we can use the op-amp for variety of applications.

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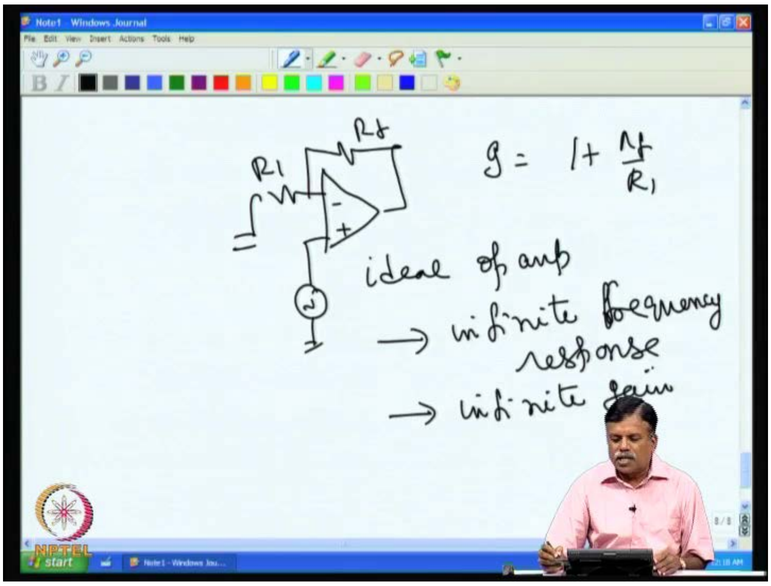

So, if I take the operation amplifier and then, look at the close loop gain then, if I put the two resistance for the example here, to get the give the signal here and then, this is R f and R 1 so that gain, is actually given by 1 plus R f by R 1. Now, this is the gain at low frequency now, what affect the gain has got, because of this finite close loop gain because, original amplifier, that original amplifier operation amplifier that we had looked at, to add a infinite gain and it has infinite frequency response that was a assumption, that we have made and then, derived this relationship. So, the ideal op-amp, if we take that, it has infinite frequency response infinite frequency response then, it has it had infinite frequency response then, infinite gain but then, both are not valid for the practical op-amp.

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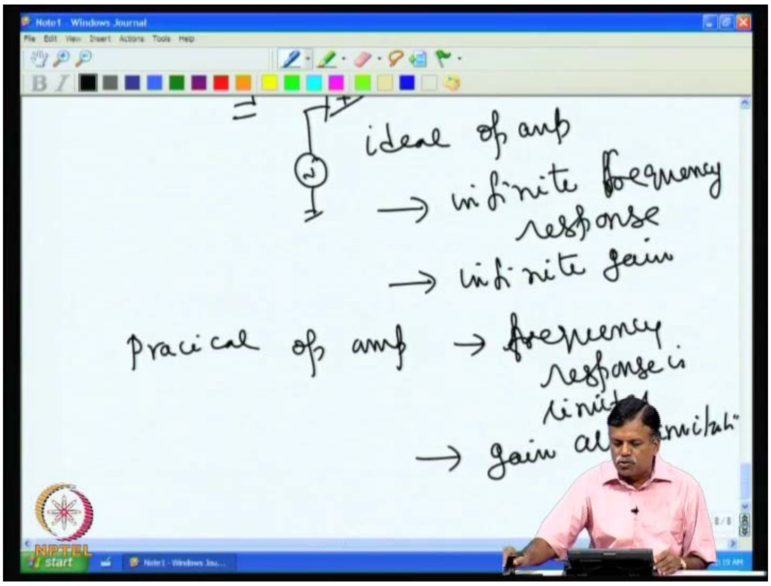

For practical op-amp practical op-amp, frequency response is limited frequency response is limited limited and second one, gain also limited.

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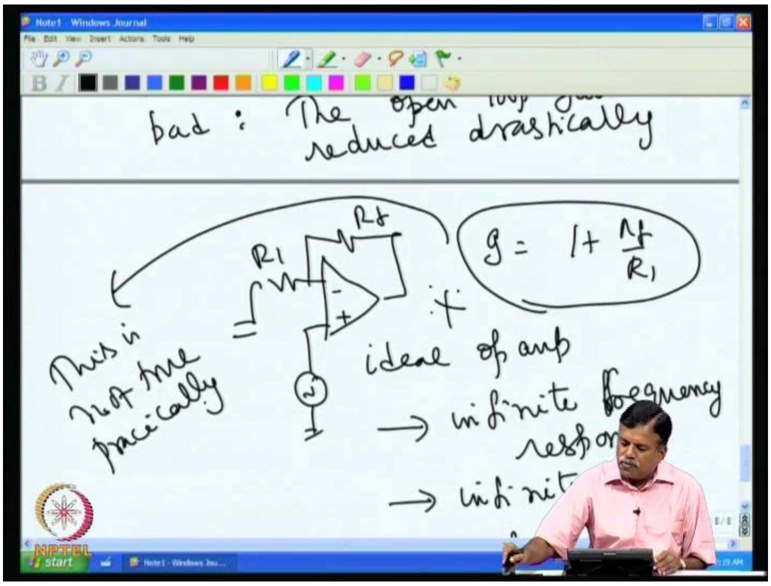

Now, considering these two limitations, now what is the close loop gain that you get? Is it true that gain is all the time 1 plus R f by R 1. Actually, it is not true that practically, this is not true.

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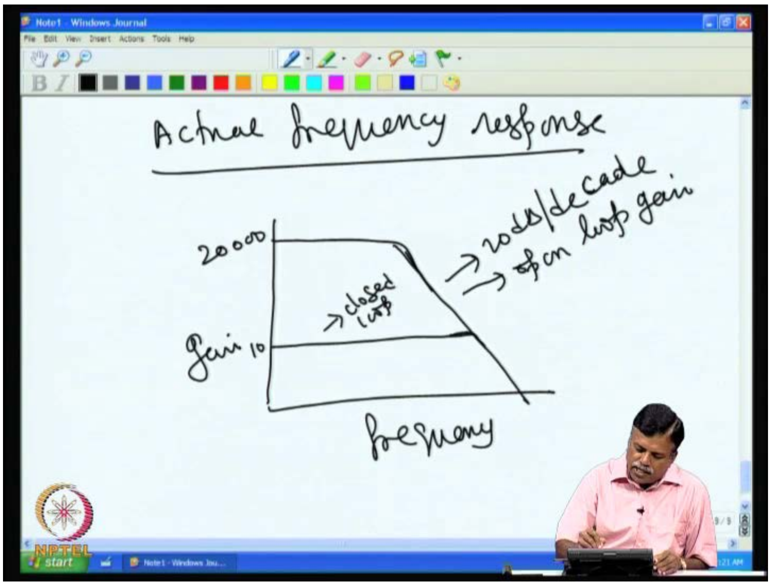

So, what is the new frequency response curve that you get? Considering this limitation the actual frequency response will be like this. If we look at the actual frequency response, it looks like this that you have for example, that you have open loop gain after compensation it comes like this, a single pole response frequency versus gain then, if I set the gain, this is the close loop gain. For example, if I want to gain 10, so I put this, this may be actually 20,000 for example, for 741, the D C gain would be around 20,000 minimum and then this is falling at the rate of 20 d B per decade and the close loop gain 10 at low frequency at low frequency, the gain is, a close loop gain is also 10 as increase then as increase the frequency at one point of time, it meets the open loop gain frequency response. This is an open loop gain and this is a close loop gain, it meets at one point and there on it follows the close loop gain.

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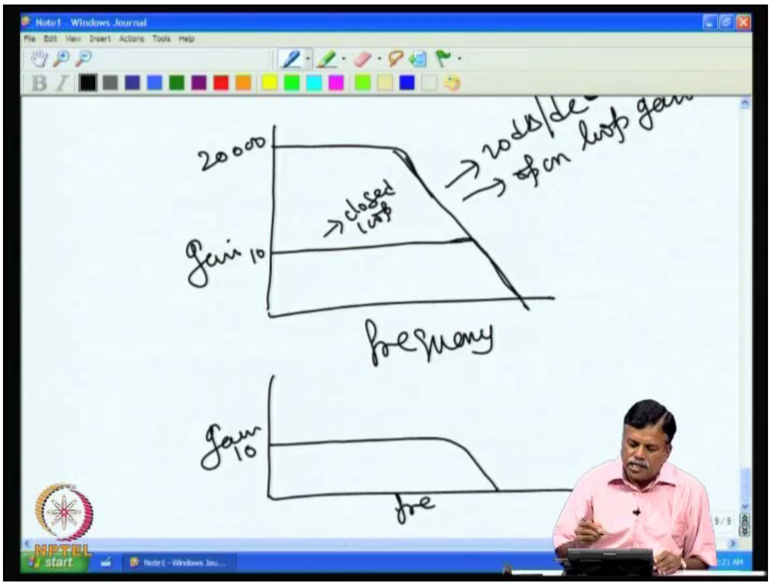

So the amplifiers, new amplifiers band width is like this; that is the gain. This is frequency if we plot; that you get that is the amplifiers band width that is, the D C is the gain 10.

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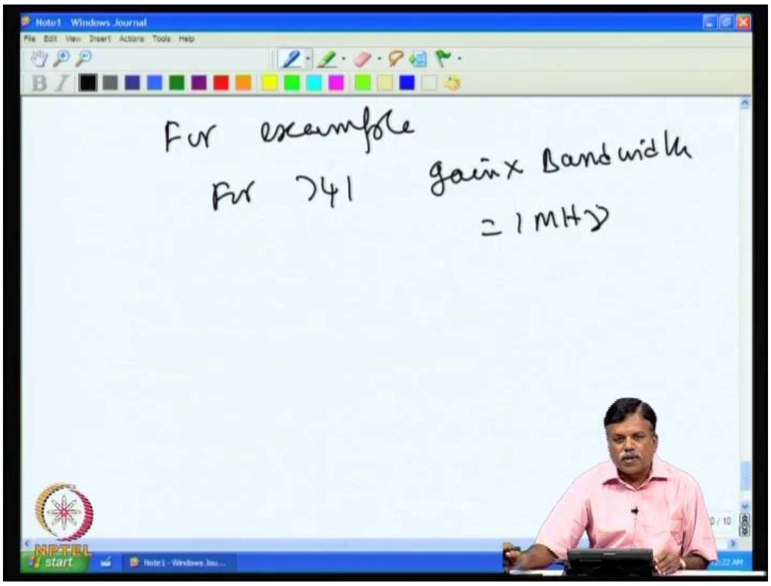

Suppose for 741, we have a gain band width product of 1 mega hertz for example, example for 741, gain into band width, it is equal to 1 mega hertz.

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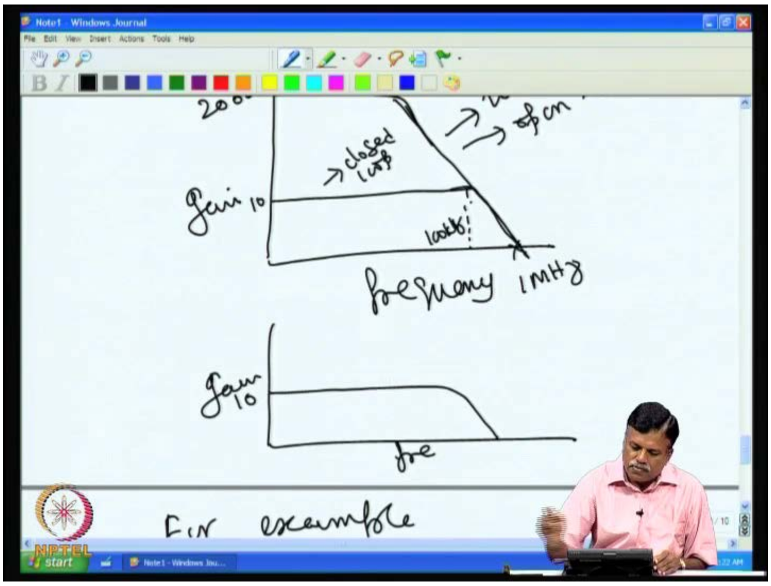

That means, and the gain is unity, the frequency is 1 megahertz for example, the at unity gain is 1 mega hertz.

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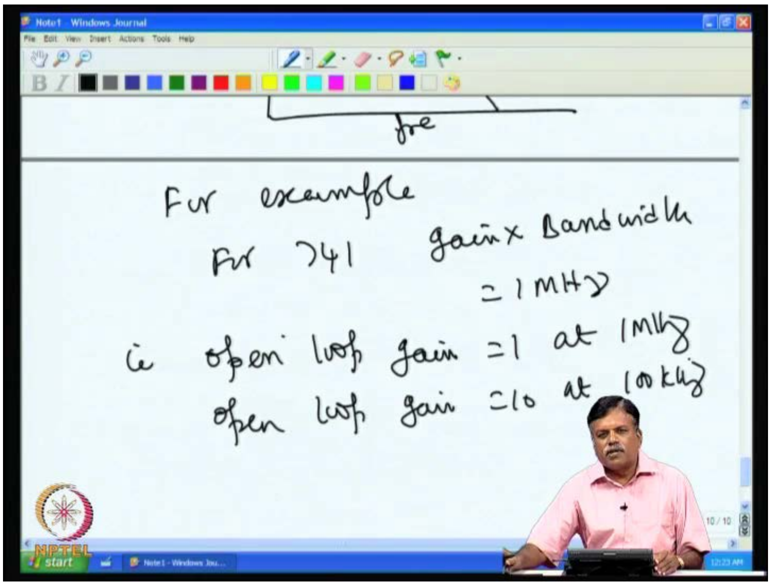

So when the gain becomes 10, this actually becomes 100 kilo hertz. So, if I have a, that means, that is gain is equal to 1. Close loop, open loop gain that is that is open loop gain is equal to 1, at 1 mega hertz, open loop gain is equal to 10, at 100 kilo hertz.

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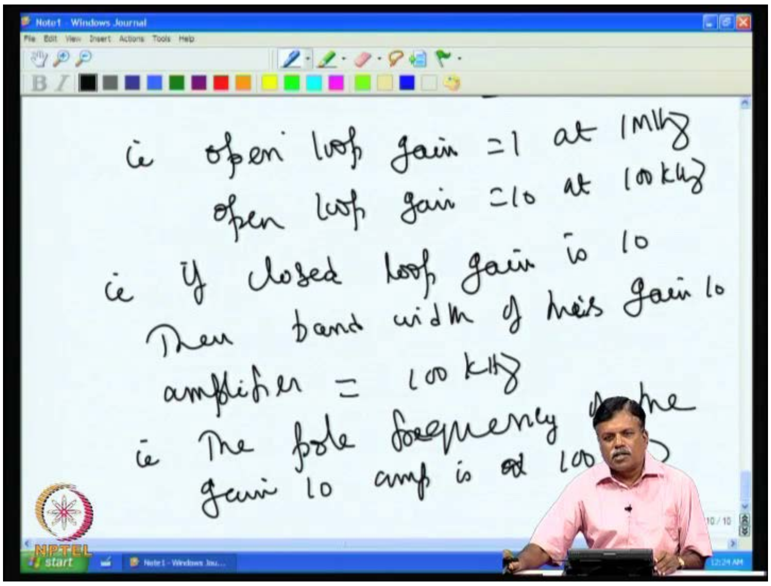

That means, if I have amplifier of gain 10 that is, close loop gain 10 then the its band width will be 100 kilo hertz that means, if close loop gain is one then, close loop gain is 10 gain then, bandwidth of this amplifier, this gain 10 amplifier, that is equal to 100 kilo hertz. So the gain band width, the new amplifiers gain is actually limited by this frequency response that is the, at 100 kilo hertz you find a gain is not 10, actually it will be only 7, because the pole frequency of this amplifier, new amplifier of gain 10 is 100 kilo hertz that is, the pole frequency of the gain 10 amplifier is at 100 kilo hertz. So, at 100 kilo hertz, this amplifier will have 45 degree phase shift.

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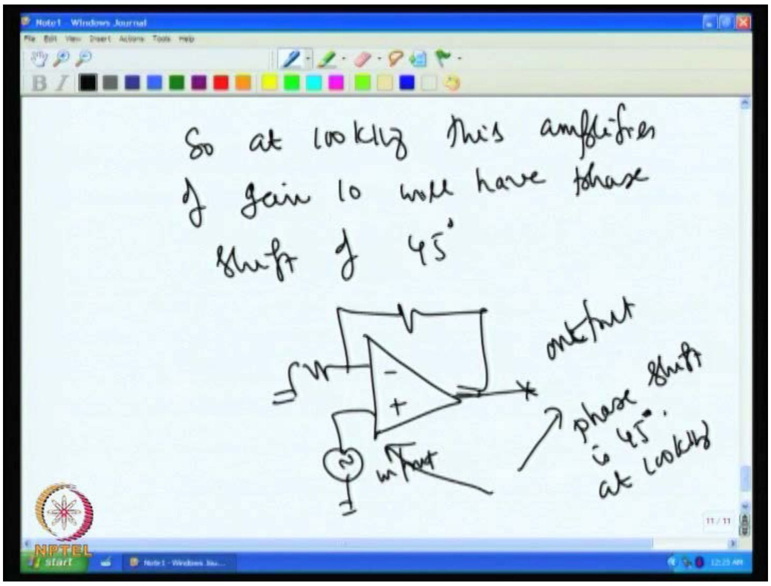

So at 100 kilo hertz, this amplifier will have amplifier of gain 10 at 100 kilo hertz this amplifier of gain 10 will have will have phase shift of 45 degree five degree that is the, if we look at the amplifier and then say a gain 10, if it is the 741 of gain band width product 1 mega hertz then, this is the input and then the output is here, the phase shift between this and this will be 45 degree. So, if you look at this and this the phase shift is 45degree here between input and output because at 100 kilo hertz.

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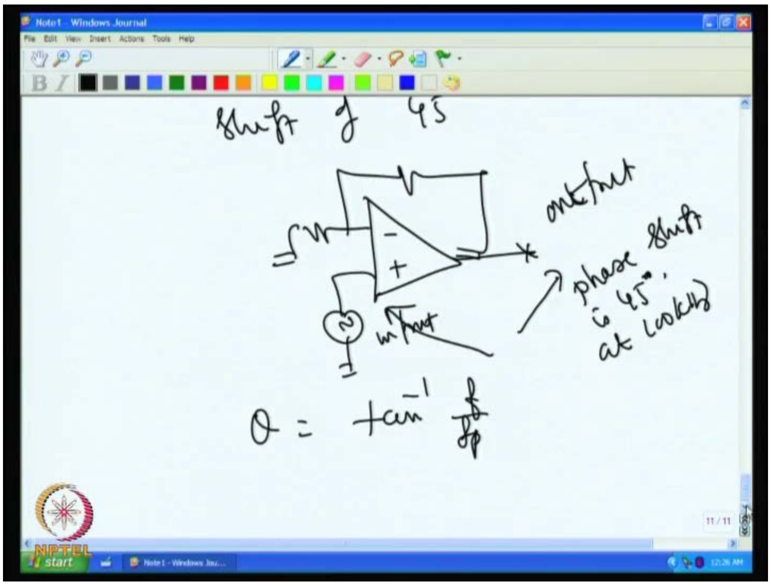

So basically, the phase shift is given by theta is given by, tan inverse of f by f p, f p is the pole frequency. So, once pole frequency is known and then, the applied frequency is known, one can find; what is the theta that one can get at any given operating frequency. This problem is understood, that one can use the amplifier properly in the actual application. Now let us see, one of the applications, A C amplifier application and see, what are the issues that one normally faces and then, we come back to this again and discuss about other issues like slew rate and so on.

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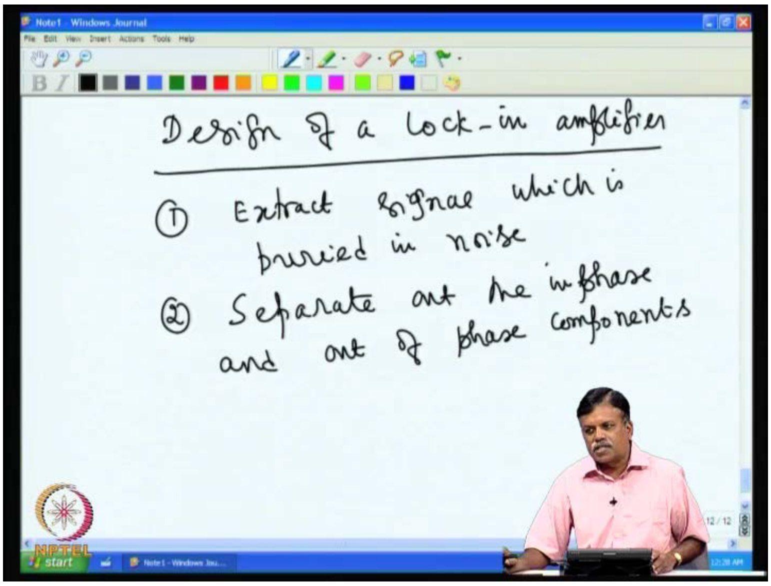

We will see one of the applications at this point of time. We apply this amplifier or we design amplifier now for the so called lock-in amplifier. So let us take, design of a lock-in amplifier.

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Now lock-in amplifier originally, was used only to extract the signal which is buried in the noise and also lock-in amplifier concept is used to, separate out in phase and out of phase components. Basically, lock-in amplifier is used to extract signal which is buried in noise. Typical example would be that, if the noise is 1000 times more than the signal and even we can extract the signal, without much difficulty for that purpose only the lock-in amplifier is used. Then the second is, separate out the in phase and out of phase component, separate out the in phase in phase and out of phase component like for example, if we have resistance and capacitor. The capacitor gives in phase component, the capacitor gives 90 degree out of phase component, and resistance gives in phase component. If I want find out, in phase resistance part of the signal and the capacitor part of the signal. One can use the lock-in amplifier and separate out this.

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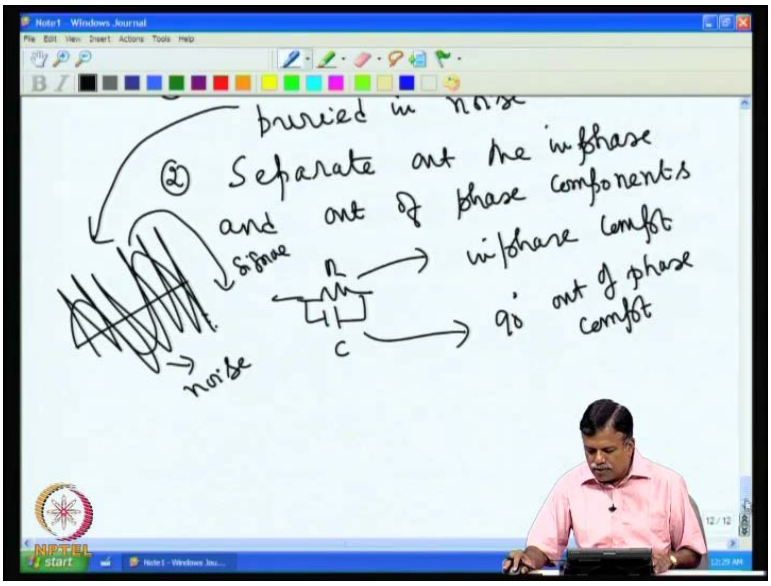

Example: say that is, if I have a resistance and capacitor together this gives you in phase component, this is 90 degree out of phase component out of phase to this. For example, the signal which is buried in noise is like this, if I have a signal and if it is buried in the noise then, the noise can be several times than this. It can extract this signal alone, signal alone can be extracted and the noise can be, for this purpose only lock-in amplifier is used.

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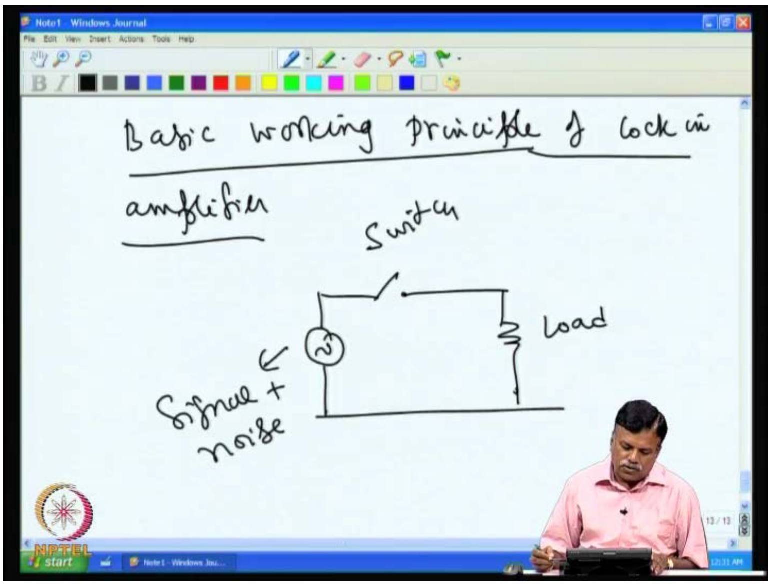

Let us see, how to design such a lock-in amplifier and how it is working so, what is the basic principle involved in the lock-in amplifier that is, extracting the signal which is buried in the noise. So, what is done is that, if I have a signal and noise basic principle involved, basic working principle. Now what is done is that, let us assume that, we have a signal source and then, the noise and then, I have a assume that, I have a signal and then, I pass through the switch and then, I have a load here. This is a load and then, we have a switch here, assume this signal plus noise signal plus noise is there.

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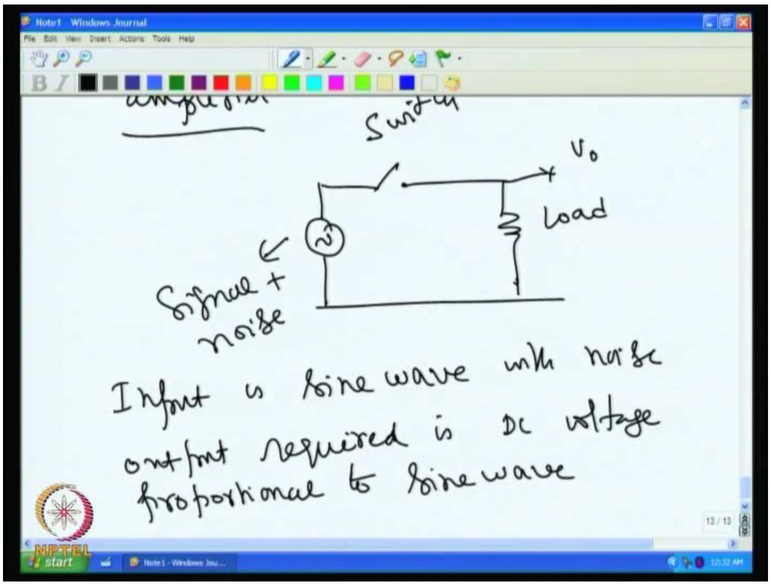

Now, we want to extract only the signal and we want get away you know form the noise. Take this example: Now assume that, it is a sine wave source so, I will take this input as a sine wave input is sine wave sine wave with noise output required is only required is D C voltage D C voltage D C voltage proportional to proportional to proportional to sine wave. We are not we are not looking for the exact sine wave to be reproduced at the output. We want here the D C voltage proportional to sine wave but, it should not depend on the noise, that is the noise will noise this output voltage will not have any component due to the noise, that is what we are looking for.

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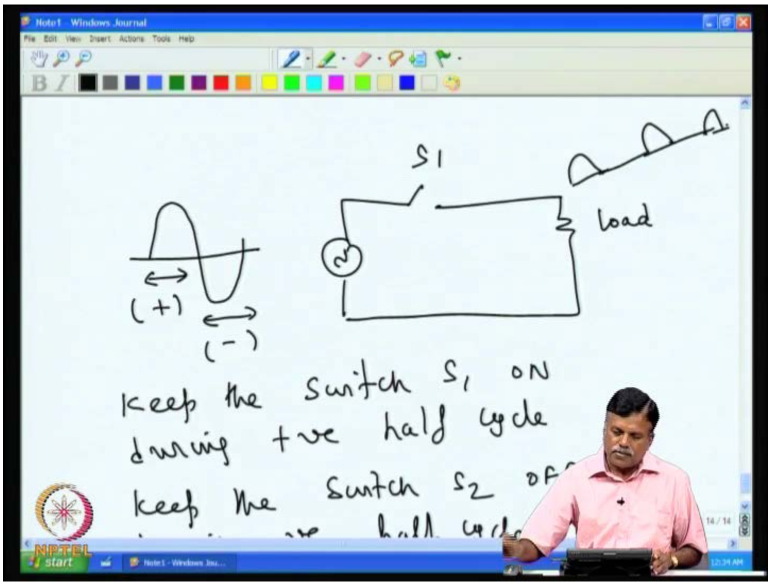

Now, how will you achieve this? Now, one can do this in the following manner; assume that we have a sine wave that is we have input sine wave like this. Then, we will have switch here, then I operate the switch. Switch is on, that is this is positive half cycle, we have positive half cycle and this is a negative half cycle so, this is a positive and this a negative half cycle. Keep the switch on that is, keep the switch on switch S 1 on during positive half cycle.

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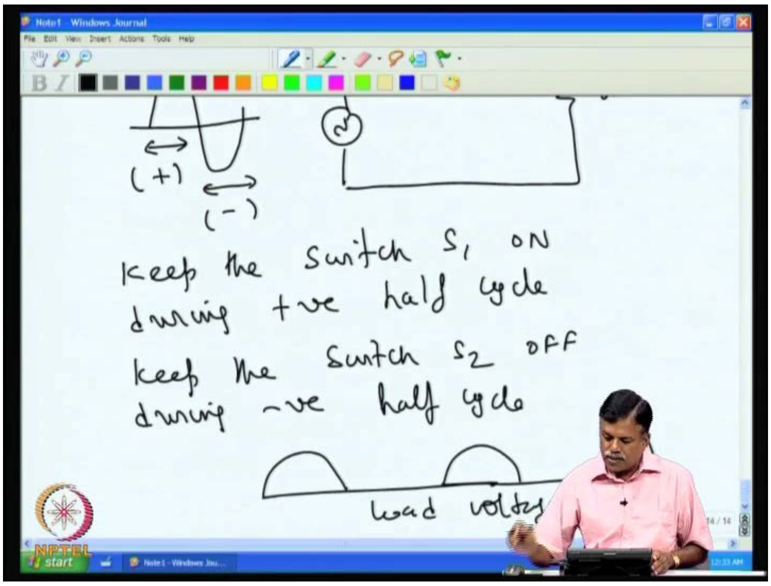

And keep the switch S 2 off during negative half cycle and at the load, you will get only positive half cycles. So the load at the load point, if you see you will get a signal positive and the negative is not appearing you will get this, this is a load voltage. Assume this ideal switch, and then I will switch on only when the signal is positive. I will switch it on and the signal is negative, that is when the signal is positive I switch it on. When the signal is negative, I switch it off, then I will get here only the positive half cycle at this point. So, you will get only the positive half cycles at this point.

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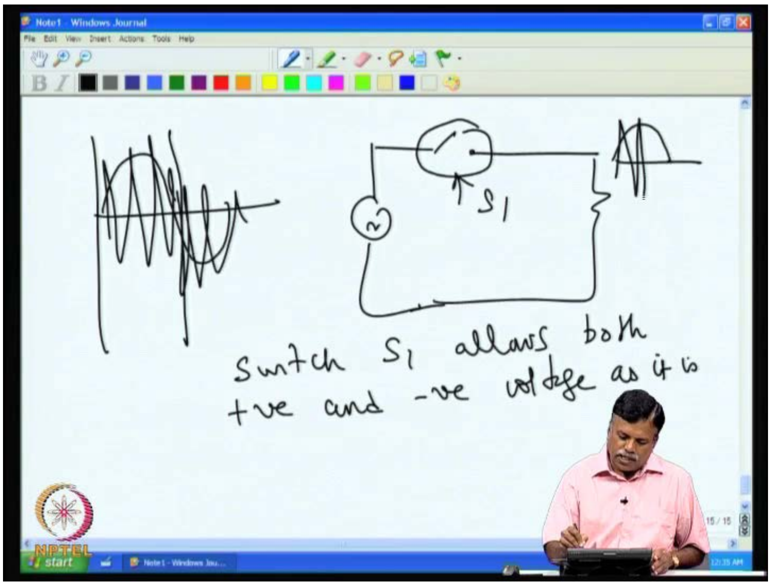

Now, what is that we are to trying to achieve by this? Assume that we have signal, which consists of signal plus noise. Then, I will draw that I will have a signal, which actually has a noise continuously. Now when the switch is on, then if I look at the load side I will get during this time whatever was there. This is not a diode, it is a switch, it allows both positive and negative during the on time, so switch is a bilateral switch. Switch S 1 allows both positive and negative voltage as it is, that means at the across the load, I will get a signal which is I switched on with respect to signal.

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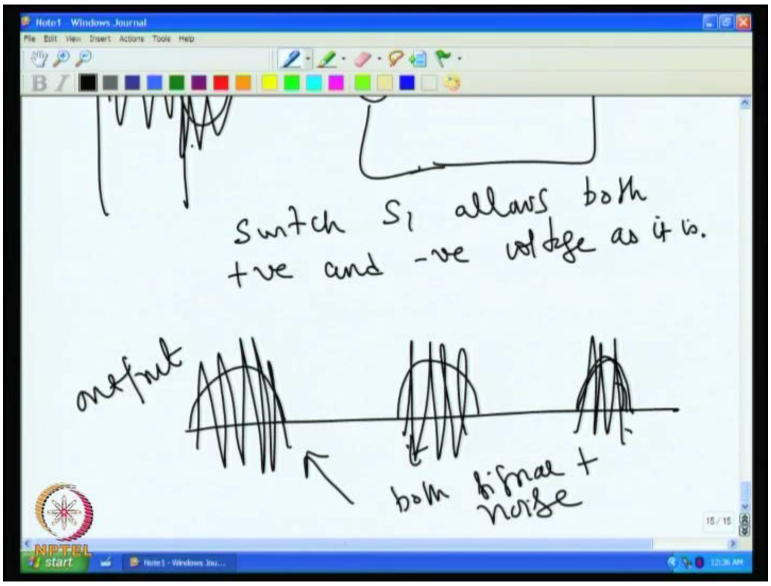

I am switching with respect to the signal so, you will get at the output, positive half cycles of course, with a noise. Noise may go positive and as well as negative. So, if you look at the signal now that is, time versus voltage if I plot, I will have this and there is no voltage comes here, no voltage comes here. Then during this time whatever signal noise is there, that also will come along with the signal. So, both signal and noise coming here, both signal plus noise is the output, this is a output voltage. Both signal as well as noise is appearing at the output.

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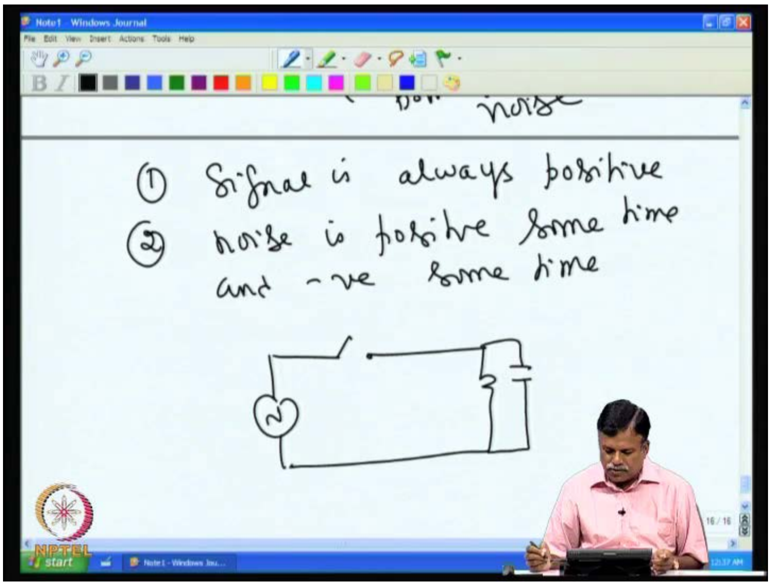

Now, but negative is not coming, but signal is always positive, will see this signal is always positive. Here, signal is always positive, signal is always but the second point is, noise is positive sometime and negative some time. So, if I average the signal at the output then, I will get the signal is continuously adding because, signal is positive so what can be done is that, I will have a signal and the switch is like this and then I have this. Then, I will keep the capacitor here such that, I can also do the filtering in the following manner that is because; I want to store the average, the signal plus noise.

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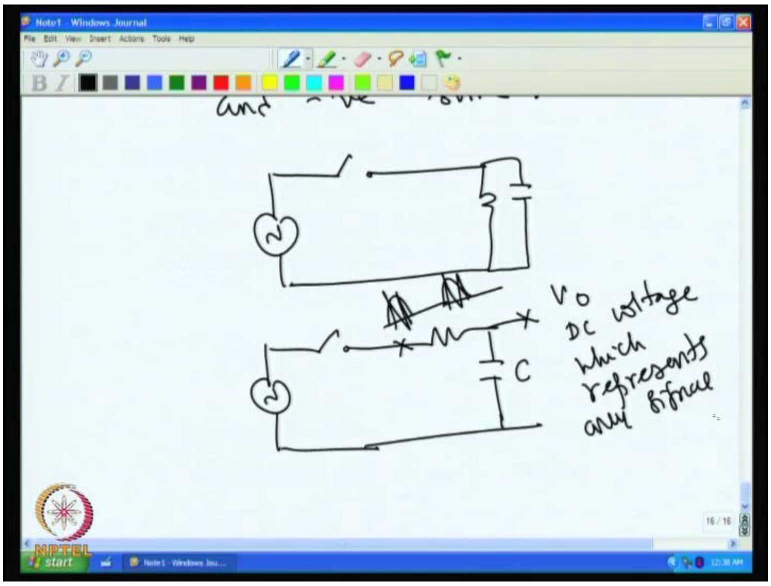

So, I can do in the following manner, instead of having the load like this. I can have a switch, then I can put one R C like this. Now at this point, you will have signal plus noise that is coming here. At this point, if I see that is v 0 then, this is a capacitor use to average out, at this point I will have D C voltage which represent only signal.

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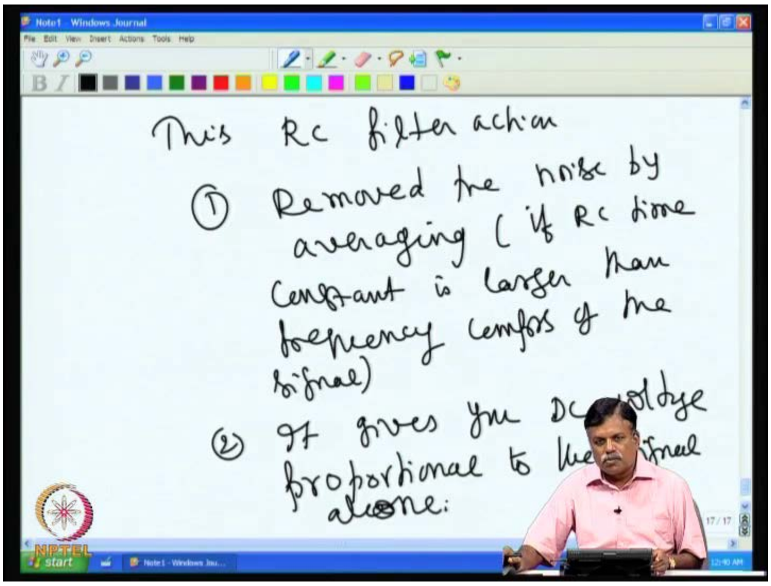

What happened to the noise? Actually, noise got averaged by itself because, noise is positive sometime and negative sometime. So, the by R C filter action this R C filtering action this R C filter action actually, removed the noise removed the noise by averaging. Of course, the time consent of R C so, it will be much larger than the frequency components of the noise then only averaging is possible. So, we assume that our R C component is very large; the noise by averaging this is, if R C time constant, larger than frequency components of the signal. So, one can the noise get averaged out and the it gives you it gives you D C voltage proportional to the signal alone proportional to the signal alone.

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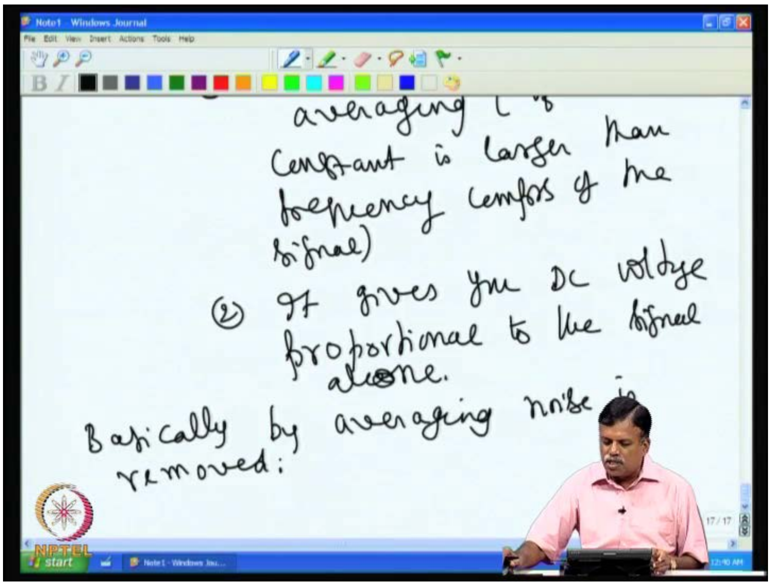

So, the by averaging technique, one can remove the noise. Basically, lock-in amplifier works by averaging that noise is removed. So, basically by averaging noise is removed. So, this is a basic working principle of the lock-in amplifier.

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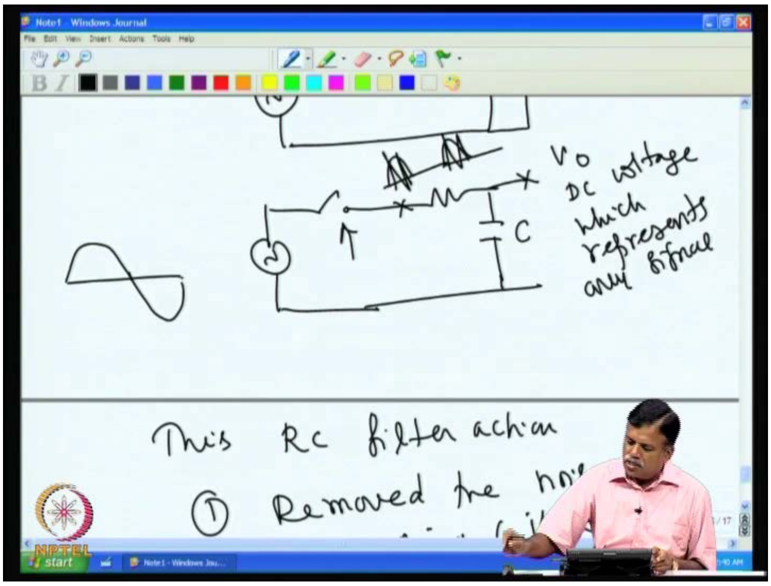

So, this noise ejection happens, only if the switching is done correctly, because this should be on during the positive half cycle and it should be off during the negative off cycle then, the averaging can take then only averaging can take place. One should find out what is the trues zero crossing point for the signal. So, for lock-in action to take place then, one had find that true zero crossing points of the signal.

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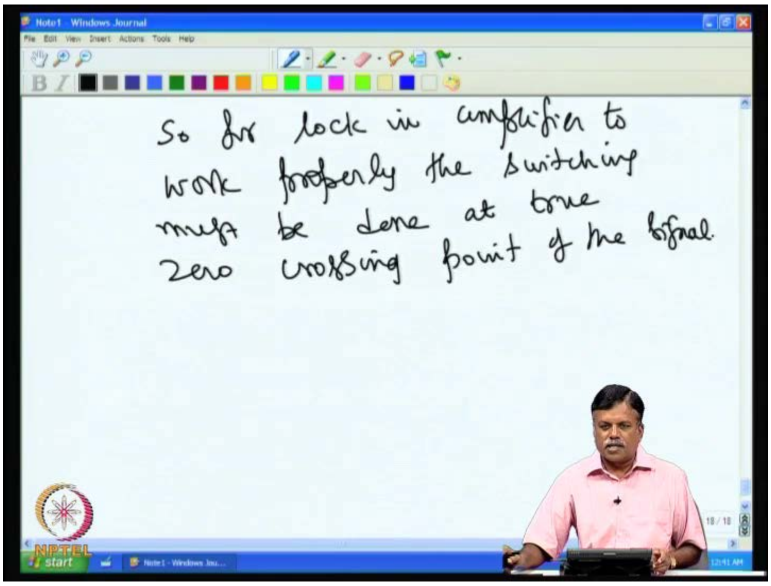

So, for lock-in action to take place, for lock-in amplifier to work properly work properly, the switching must be done at true zero crossing point of the signal then only lock-in amplifier can be useful. Now, of course we set here only, one half cycle switching that is, positive half cycle alone we are switching, negative half cycle we are not switching. We can also do it in both cycles plus and minus and reverse the signal and put it in both side so that, still average can be done for both positive and negative.

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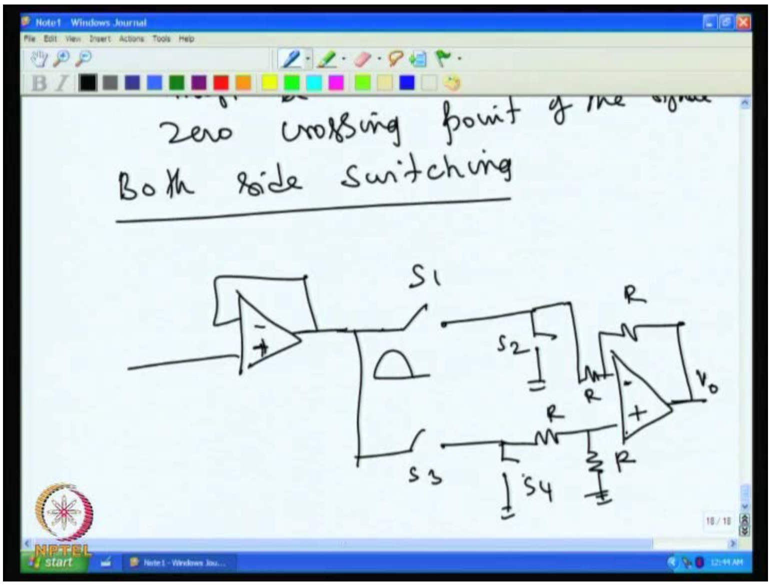

So, we can do that in the following manner. We can say that, how to do the both side switching. So, both side switching example I can show you now, what can be done is, for example if the signal is coming out from the operation amplifier for example, if I have a signal that is a A C signal coming out from here, then I can do the switching in the following manner for example, I can have switch S 1 and then, here S 2, have S 1, S 2 then, this I can take here then put S 3 then, also I can put one more switch S 4. This assume that, I give it to the operation amplifier so, I give it to a difference amplifier for example, I give this, give this then, minus keep this then here, I put this, this take it as output, I have R and R so for example, if it is positive half cycle then for example, it is a positive half cycle, I switch on S 3 and then S 4 is off, so I will do like this.

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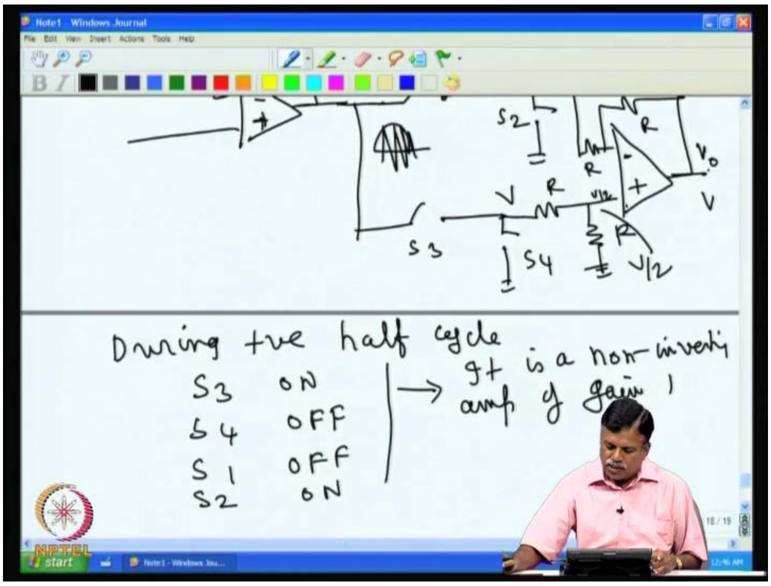

That is, during positive half cycle, I will switch S 3 on, S 4 off then S 2, S 1 off S 2 on that is during positive half cycle, what I do is, I will switch on this and switch off this. So, the signal can come here and half of the signal will appear here so, you will get whatever voltage there, half the voltage will be appearing at this point. So, V by 2 you will get and then, this switch is open at that time and this is on that means now it is acting as a non-inverting amplifier. So, if we have V here at this point, at this point V by 2 you will get and then, that is multiplied by 2, because if I make this also equal to R, this resistance also equal to R then, whatever voltage V here and that becomes V by 2 multiplied by 2 that gives you V here. So, here that means this action makes it is a non-inverting amplifier non-inverting inverting amplifier of gain 1 means, the whatever input voltage is there that will appear as it is at the output.

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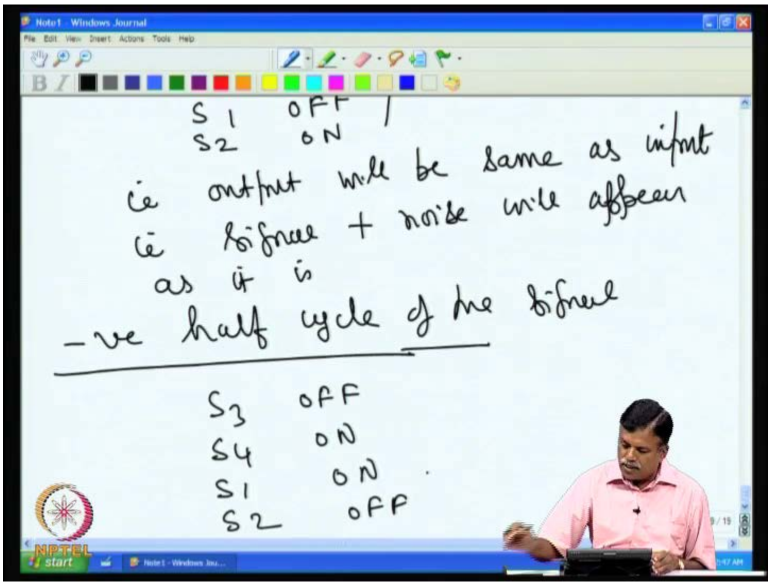

So, if this has noise plus signal plus noise, during that time whatever was that the same thing will appear at the output. So, non-inverting amplifier of gain 1, that is output will be output will be same as input, a signal plus noise will appear as it is. That is, signal plus noise plus noise will appear as it is. Now, during the negative half cycle so during the negative half cycle we will discuss, negative half cycle negative half cycle of the signal, what you do is we will reverse the action that is, I will keep S 3 off, S 4 on, S 1 on, S 2 off.

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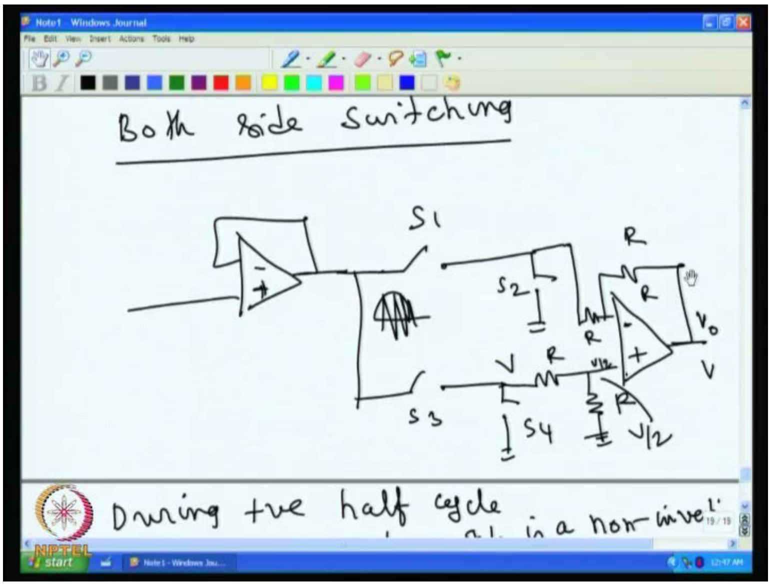

That is, what we do is, in the negative half cycle in the negative half cycle, I will keep this open and this is closed, so that you know the plus input is grounded, now S 3 is open. No signal is coming here and then, S 1 is on so, whatever signal is negative, signal is there to come here and S 2 is open, so that signal will be applied here and this is acting as a inverting amplifier.

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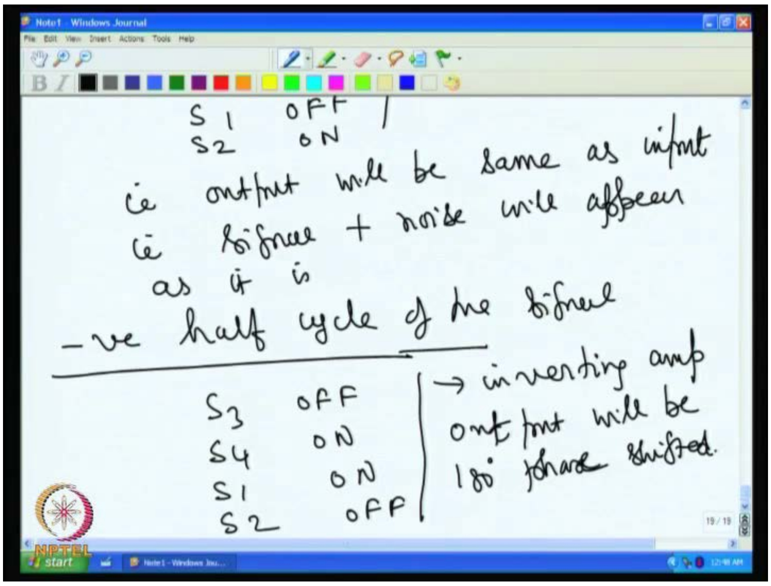

This action gives, it becomes inverting amplifier, it becomes a inverting amplifier amplifier now, output will be 180 degree phase shifted.

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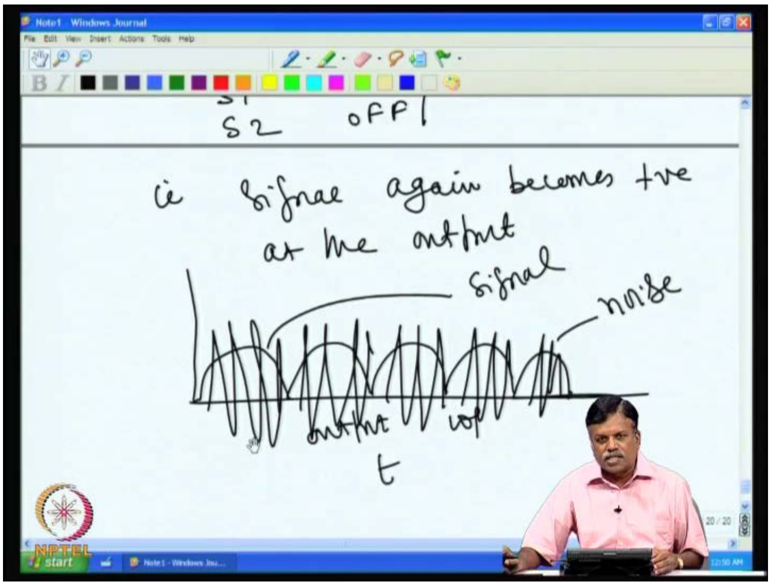

That is, minus signal will become plus that is, signal become that is signal again becomes positive at the output.

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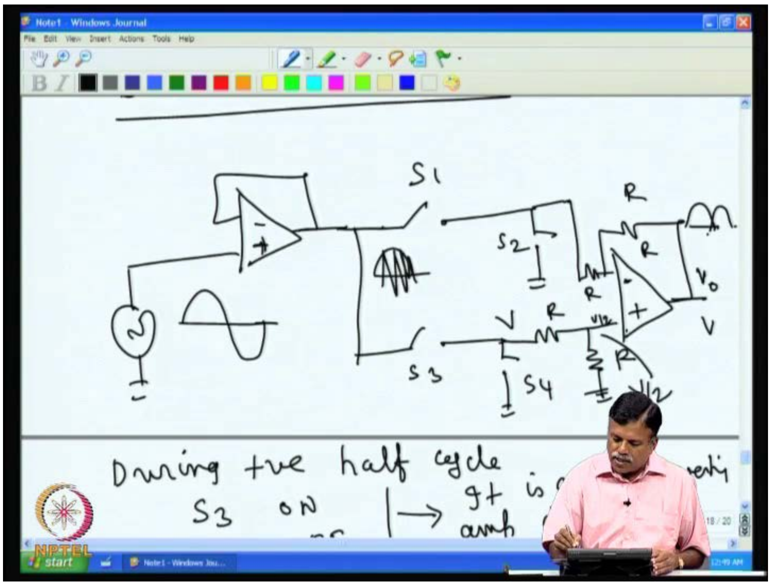

So, net result is that, if I look at the output V naught, we look at the output V naught here. You will have, if the switches are switched correctly that is, during positive half cycle of the signal that is, if I have signal here I have signal here which is positive or negative, during the positive half cycle assume that, you have signal during positive half cycle we will get the positive signal as it is, during the negative half cycle during the negative half cycle of this then, since the signal is going now through this route and get inverted and comes the in minus signal get inverted you come plus again. So, again you will get the signal like this.

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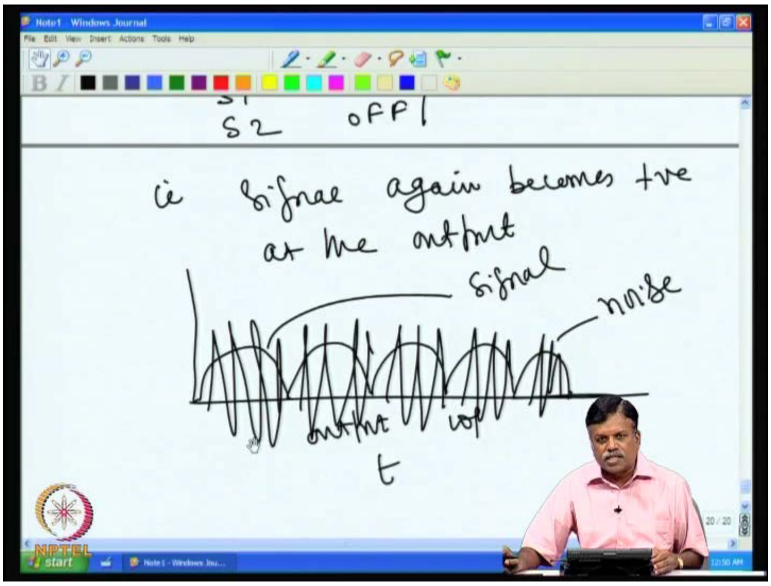

So, if we plot, if you look at the output voltage V naught that looks like this, so the output voltage V naught, that is output voltage. So, time versus voltage if I plot that, it looks like this, because whatever noise is there that will be the plus and minus, that will be going both plus and minus so you get, this is signal and that is the noise, that is coming here. Now we got, it is not a rectifier you know rectifier, you will never get this minus voltage and minus voltage. If we put a diode then, I will get signal positive, noise of positive alone will come, noise of negative will not come, if noise of negative is not coming then, there is no question of any signal averaging.

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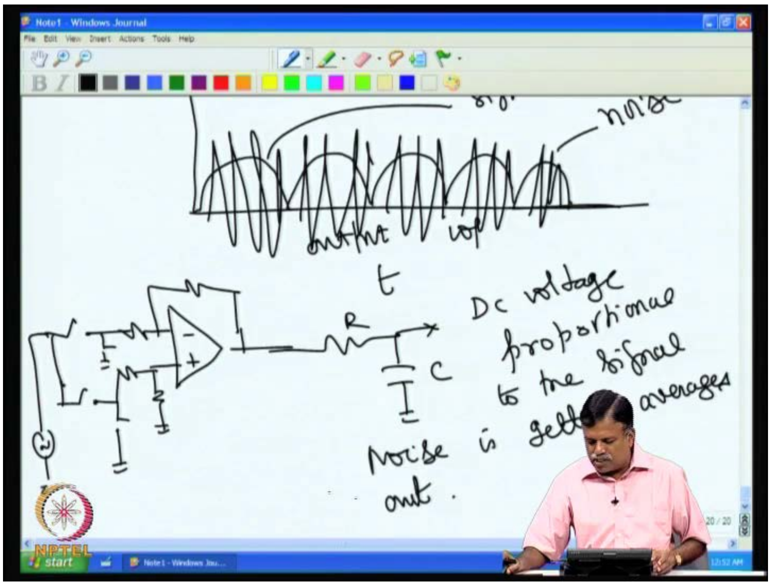

It is a switch which allows both positive and negative, but we are switching on at appropriate time with respect to signal so, taking signal as a reference we are switching that is, the clutch of lock-in amplifier working. If I now filter this that is, whatever the noise voltage that we have got at the output, now if I pass through the R C filter, this is the output of the amplifier that we have got here, we have these switches and then, this is the difference amplifier, we had these switches here and then, we have so this is the input signal. Now, we will have this averaging R C, the term consisting of R C much larger than the noise frequency, then you will get here D C voltage to here, voltage proportional to the proportional to the signal. Noise is actually, getting averaged by themselves noise is getting averaged out noise is getting averaged out. This is a wonderful technique to reject the noise and extract the signal. This was essentially used in electronics, wherever we are processing the signal. So, the lock-in amplifier technique by averaging means, we can extract the signal which is buried in the noise. Now in the beginning, we said that lock-in amplifier used for two proposes; one is, for extracting the frequency buried in the noise, other one is, to separate out in phase and out of phase component.

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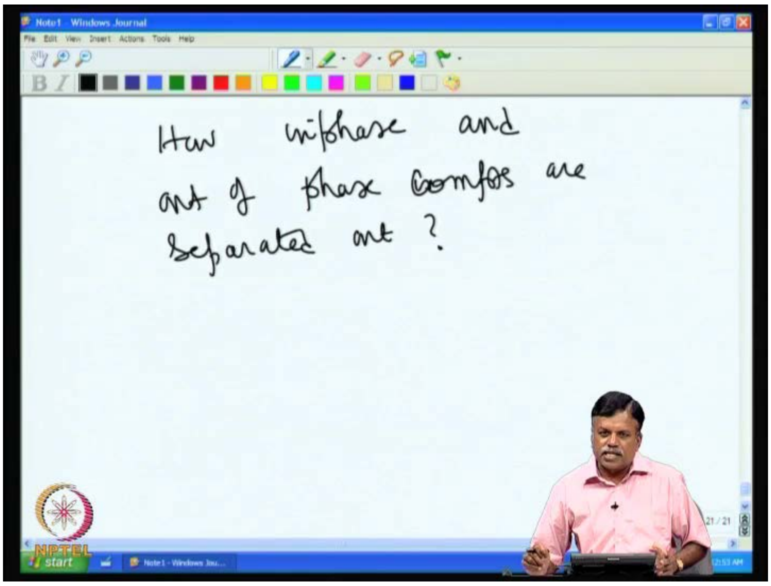

So, how in phase and out of phase component is separate out? How in phase and out of phase component is separate out?

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Because, this also required at many places for example, if we take induction motor; the in phase component is actually produce the magnetic field and then in phase component produce a load current, load current is actually in phase and the magnetic field the torque producing component is out of phase, 90 degree out of phase component. Similarly, inductor and capacitor if I take, the capacitor current is 90 degree out of phase component with respect to resistance or with respect to applied voltage. Similarly, if I take inductor, that inductor current is 90 degree phase shift at with respect to applied voltage. So, many times you want to separate out resistance with capacitor or resistance with the inductor or capacitor and inductor to be separate out. In that case, it is essential that we separate out in phase and out of phase component.

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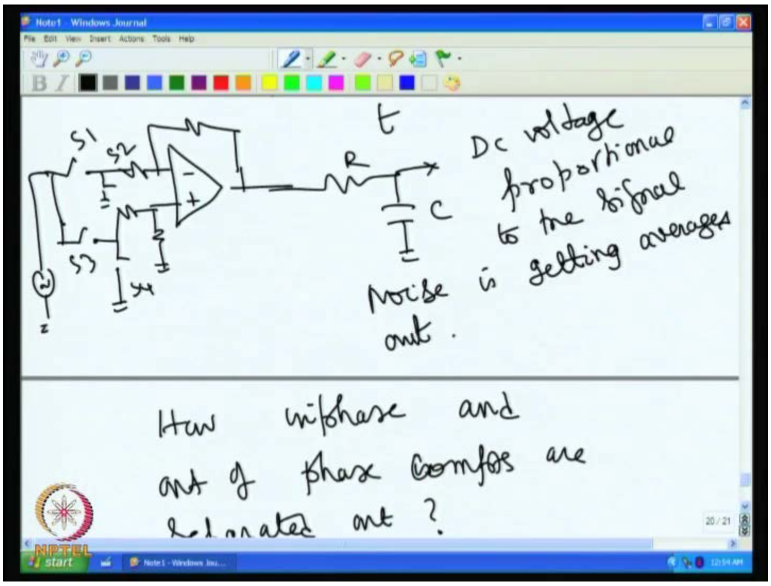

This also can be done using a lock-in amplifier, only thing is, we need to switch them correctly, these switches S 1, S 2, S 3, S 4 are to be switched correctly such that they can be, these components can be separated out, because once you separate in phase and out of phase components, they can be used for many purpose. For example, if I want to control the induction motor, if I want to vary the… For example: speed, I can I had find out the in phase component then, I can control what is the flux level the, I can control the out of phase component so that, I can control the flux level in the motor. Similarly, if I know the in phase component the, I know the load level of the motor so that way you know, they called as a vector control of the induction motor. We like that many applications are there, this we see in the next class; how to separate out these components and how to design a lock-in amplifier in detail, so we will see in the next class, how to design the lock-in amplifier. I stop today with this. Thank you.