Analog Circuits
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Week -01
Module -05
Inverting amplifier and Non-inverting amplifier

Welcome to another module of this course analog circuits. In the last module we had talked about the inverting amplifier and the summer inverter amplifier and then I had also introduced you to the formula for any general and inverting amplifier with general impedances.

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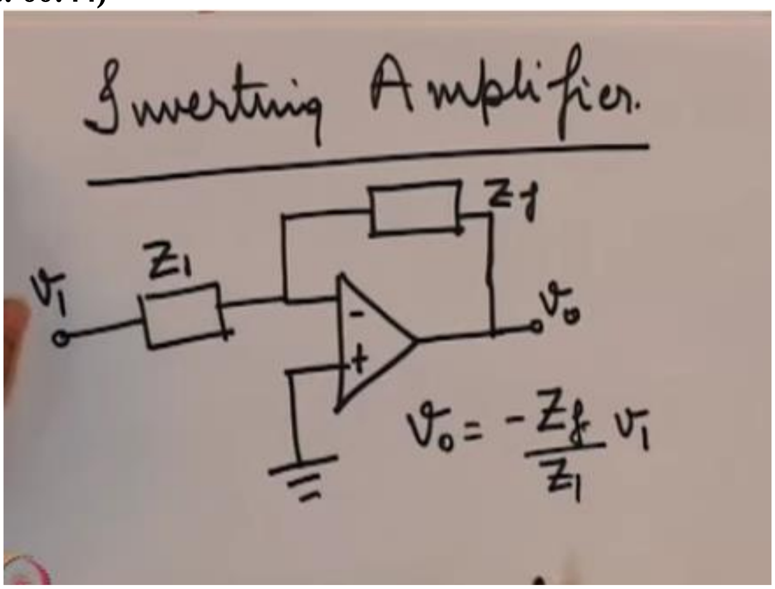

Here we shall be using that formula to further discuss some of the other circuits, so once again if we can write the formula for the general inverting amplifier with general impedances not just resistances, so this is the formulary letting the output voltage v0 to v1 suppose our Z1 and Zf are like this.

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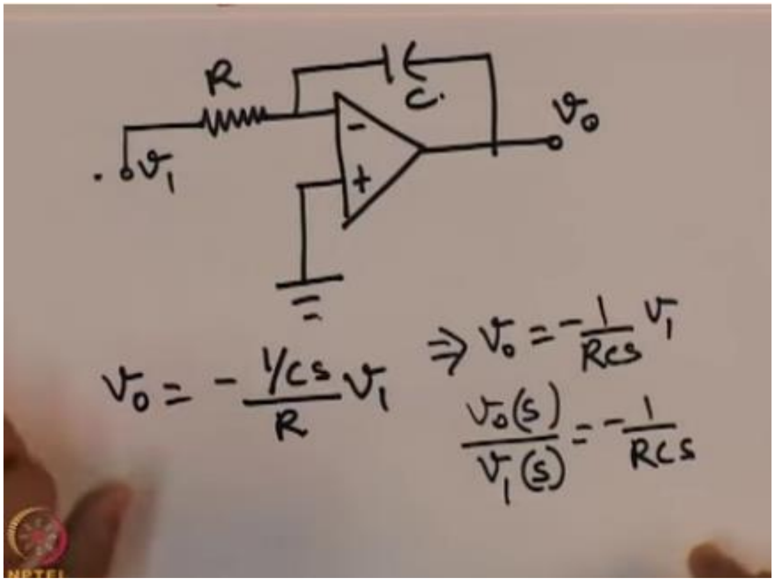

Of course, we can simply analyze this as v0 is equal to -1 upon CS upon R v1 which implies v0 is equal to 1 upon Rcx v1 now this is a low pass transfer function, if we can write a transfer function of the system it is v0 upon vs 1 upon Rcx, as we can see this is a low pass transfer function, because as s tends to infinity the value of the magnitude of this transfer function keeps decreasing, but in order to also see the time domain response let us try to write the time domain equations.

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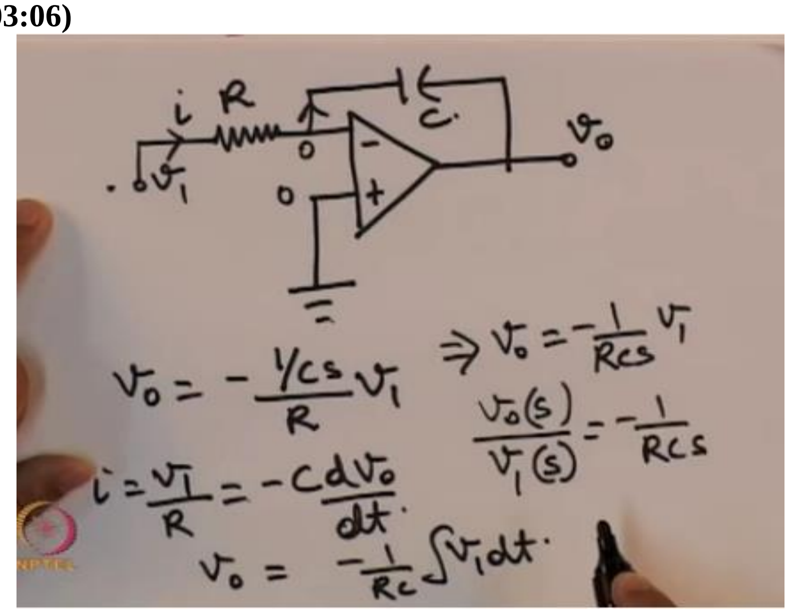

So once again you see that these 2 terminals are at 0 voltage is a virtual short between the inverting and non-inverting terminals and so I can write the current i is again flowing only through i R and C the current i flowing through R can be written as i is equal to v1 upon R and the current flowing through C is -C dvo upon dt.

So then v0 is equal to -1 upon RC v1dt so this is an integrator the circuit is an integrator which also matches with the transfer function because I mean the transfer function of an integrator is always a low pass filter prototype this is also an inverting integrator okay because there is this negative sign at the beginning if we in place just like the summer inverter or summer inverting amplifier if we have a series of in input voltages which are connected at the input not just one input then the circuit becomes something like this and my V0.

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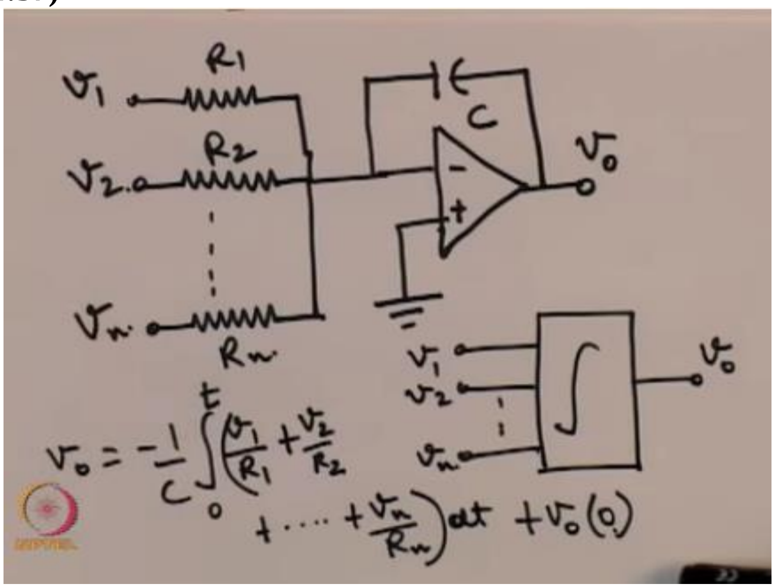

So this is the block diagram of this integrator or summer integrator and the output Voltage in time domain is given as you where this v0 at 0 is the initial condition so this is the formula for integrator now just like the non-inverting or the inverting amplifier we also have to take into account the currents that are flowing so just like the previous case suppose we have a limitation on the maximum current that can be supplied.

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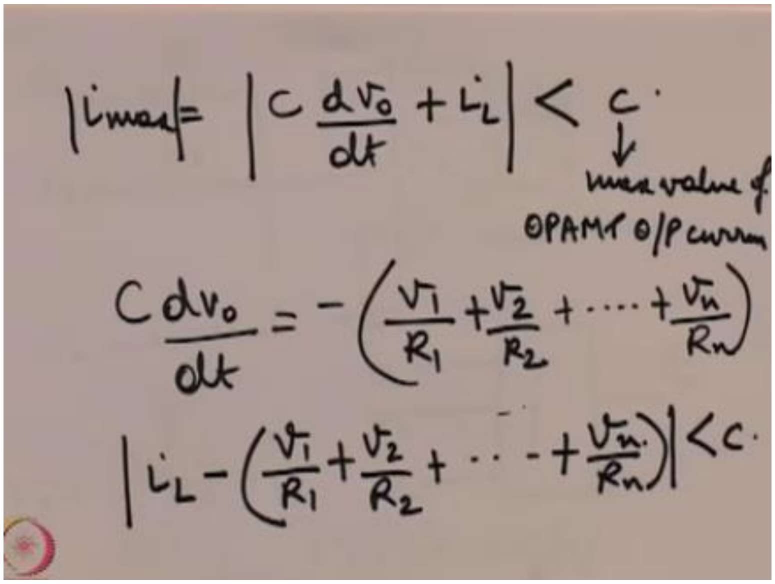

So suppose if we go back to this inverter itself and suppose the maximum current that can be supplied and the output is Imax was the current going to the load is IL, then what is the current flowing through this capacitor a current flowing through this capacitor is simply given by C dv0 upon dt in this direction, if you consider the current flowing in this direction then of course it will be there will be a negative sign.

So this current is CDV0 upon Dt okay the current flowing through the load is IL so Imax is equal to C DV0 upon Dt+IL and this whole thing should be lesser than some value C maximum value of opamp output curved so using this equation, we can find out a value of IL or the maximum current or the minimum current that can be always supplied by.

So what we do is we can find out what is the worst value of the C DV0 upon Dt and based on that we can find out the minimum Il that will always be supplied instead of attempting to calculate the Cdv both 0 upon dt we note that C dv0 upon dt is equal to - of v1 upon R1+v2 upon R2+vn upon Rn. For this formula, can be reduced as okay next we go on to the other opamp configuration which is called the non-inverting configuration.

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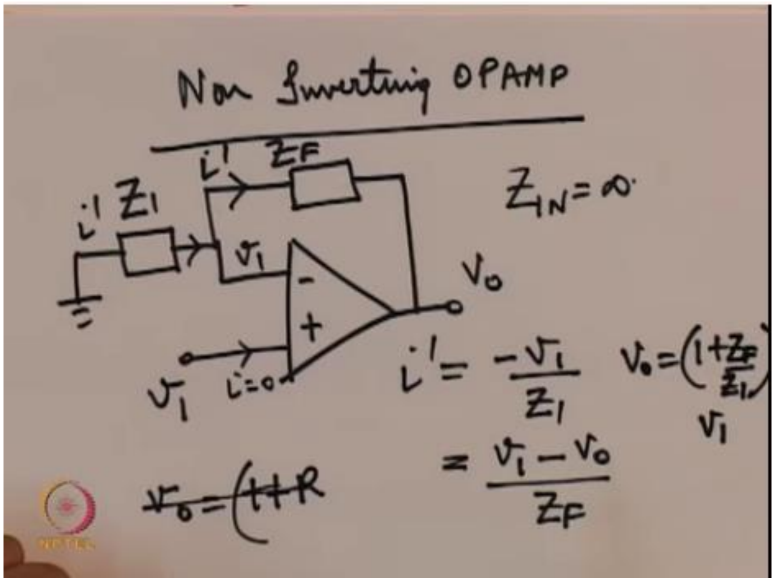

So we had an inverting configuration now we have a non-inverting configuration so the non-inverting configuration so the non-inverting opamp, now let us try to derive the relationship between v1 and v0 again we note that the current flowing in the non-inverting terminal will be 0 because the input impedance of the opamp is very high therefore for a non-inverting opamp Zin will be equal to infinity.

Next let us try to see the relationship between v0 and v1, now since this 2 terminals non-inverting and non-inverting terminals are at virtual shot and since the non-inverting terminal is connected to v1 and we can say that because of this virtual shot the inverting terminal will also be at V1, then what is the current flowing to the through this Z1.

So we can say suppose I call that i dash you can say i dash is equal to -v1 upon z1 and since no component of i dash will flow inside the inverting terminal all i dash will flow through ZF, therefore I can also write this i dash in terms of ZF as v1-v0 upon ZF now equating the 2 we will see that V0 will be given by 1+R or sorry let me V0 is equal to 1+ZF upon Z1 times V1.

I leave the calculation for the output impedance of this configuration as an exercise for you let us see whether we can obtain a similar summing configuration like we obtained for the inverting of them for this non-inverting case also we need a circuit for non-inverting summing amplifier.

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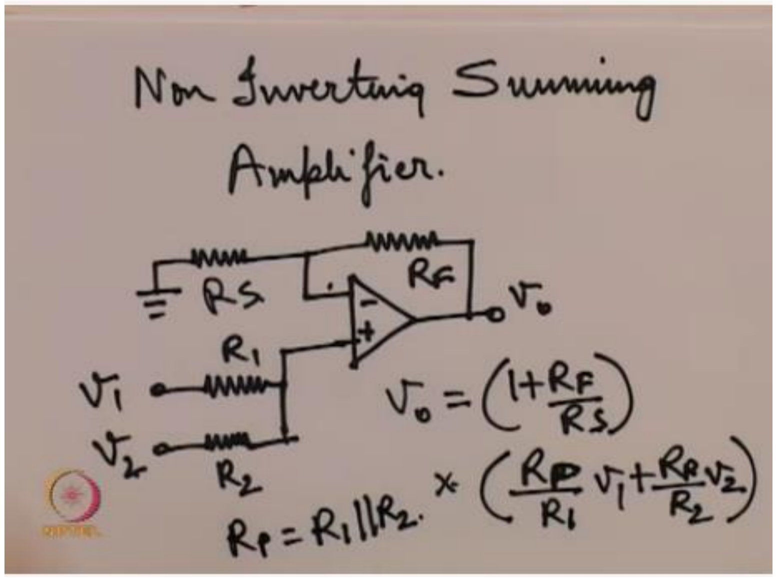

So, we have suppose we have 2 inputs like this we can show that this output V0 will equal to 1+ RF upon RS times R it will be RP this is RP upon R1 times v1+RP upon R2 times V2 where this RP is equal to R1 parallel to R2 in fact for a number of such sources when in here we have considered only 2 inputs.

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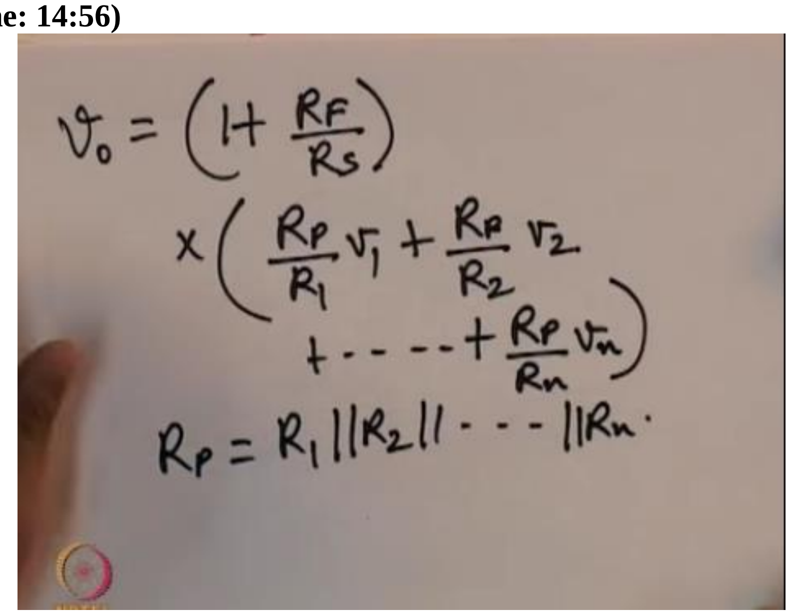

But suppose we have more than 2 input then this V0 is given by 1+RF upon RS multiplied by RP times R1 v1+RP times R2 v2 till RP times Rn vn where this RP is equal to R1 parallel to R2 till Rn, now taking this concept or rather combining both the inverting and non-inverting configurations in the same circuit we obtain what is known as a differential amplifier.

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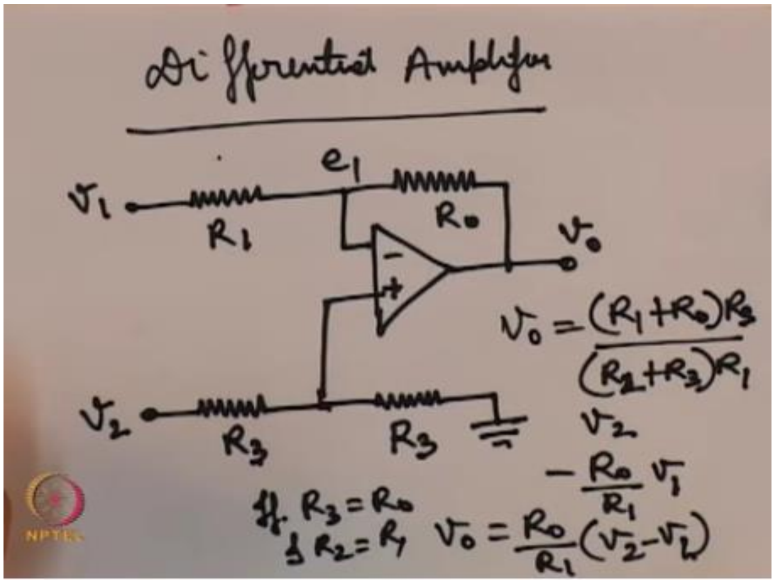

So here this is a combination of both the inverting and non-inverting opamp, if only v1 is present and v2 is not present then by virtue of this short this point will also be shortened, which basically means that there is this R3 plays no role because the current here is 0.

So in that case the output will simply be equal to an non-inverting, the whole opamp will act like and inverting opamp and if only v2 is present and v1 is not present then it has it acts like a non-inverting opamp, now you can prove that (()) (17:47) overall impact of this whole circuit will be something like a differential amplifier and actually the output will be given by this formula if R3 is equal to R0 and R2 is equal to R1 then v0 will be equal to R0 upon R1 times v2-v1, now here what you see is that this output is directly proportional to the difference between v1 v2 and v1 so that is why this term it is called a differential amplifier.

It produces an output which is proportional to the difference between the 2 inputs only unlike the previous cases for the non-inverting and inverting cases where only the input v1 and v2 were individually amplified for a differential amplifier, the output is proportional to the difference between the 2 and then one other use of an opamp is implementation of a transfer function, so this we have already seen briefly.

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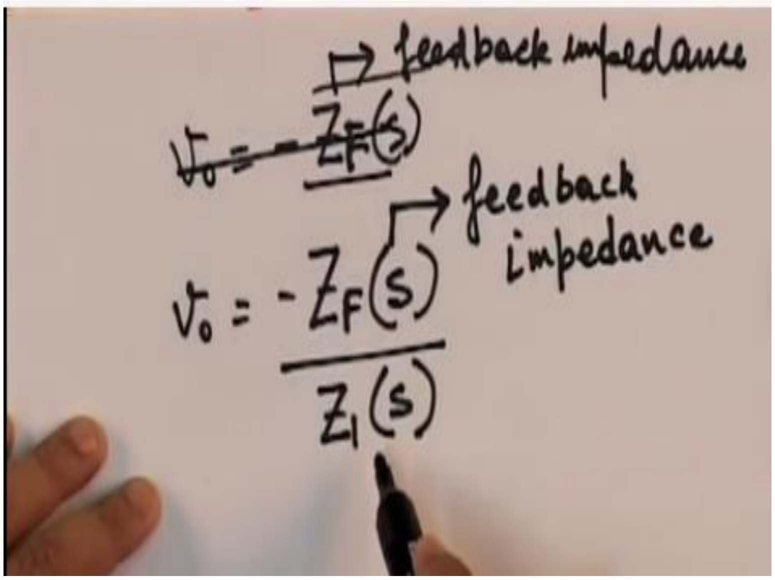

Because for an opamp V0 is given by -ZF this ZF is also known as the feedback impedance by the feedback impedance that is why we use the subscript F, let me write it correctly now depending what we choose as ZF+Z1 we can implement the appropriate transfer function one other circuit that we can also implement using a opamp and which follows naturally from an integrator is the differentiator if we can implement and integrate a non opamp then we should also be able to implement a differentiator.

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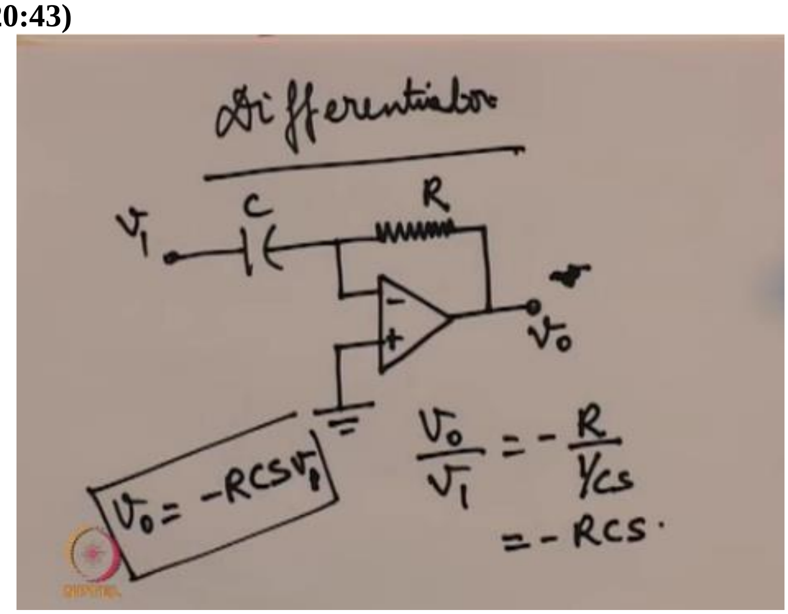

So in all this differentiator so in all these discussions that we had so far you see that we are using the opamp for various operations like summing than integration difference differential operation then finally differentiation so a simple way of implementing a differentiator might be this you know just the reverse of what we did for an invert integrator the problem with this kind of implementation is that when the input is or the frequency is 0.

Let us see what happens so we have v0 is equal to -RCS v1 at S equal to 0 the magnitude of the transfer function becomes 0 and therefore that becomes a problem, so this is a differentiator circuit whose transfer function is given by this equation, now here we see that as the frequency increases that is as the value of S increases the output keeps on blowing up or it becomes very high and that is not really desirable.

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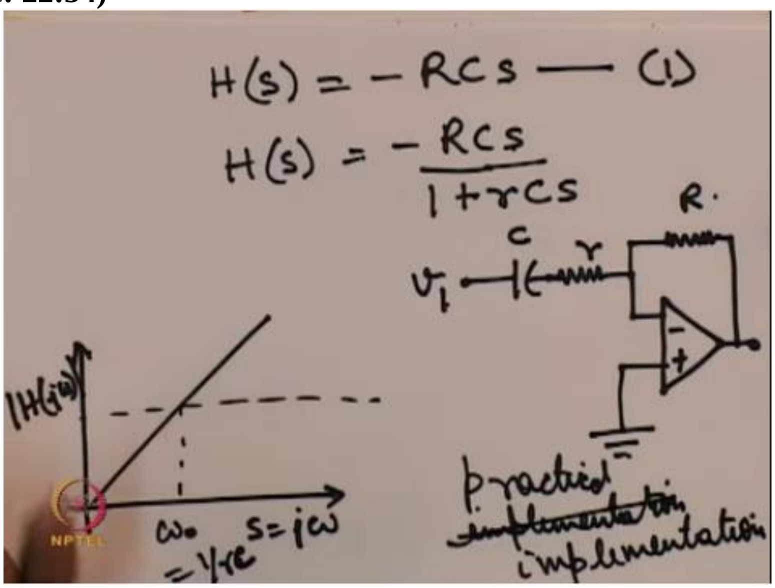

So instead of that, if we have a implementation with a transfer function like this HS, so in this case if I write in our case HS is or the transfer function is equal to Rcs let us label it as equation 1 and if we try to plot this magnitude of HS with omega or we take S equal to J omega and this as H of J omega

Then we see that when our transfer function is like this then it simply blows up like this so instead of this if we have a transfer function which does not blow up at infinity at S equal to infinity but is something like this so in this case what we get is the circuit for implementing such a transfer function will be like this ok.

So we purposely introduced a resistance small resistance are in series which will create instead of this transfer function blowing up, if we plot the asymptotic plot of H of J omega then at a certain frequency omega 0 given by 1 upon rC small R capital C at this frequency instead of the transfer function going on along a straight line it will asymptotically the transfer function will become flat, so this is a more practical implementation.

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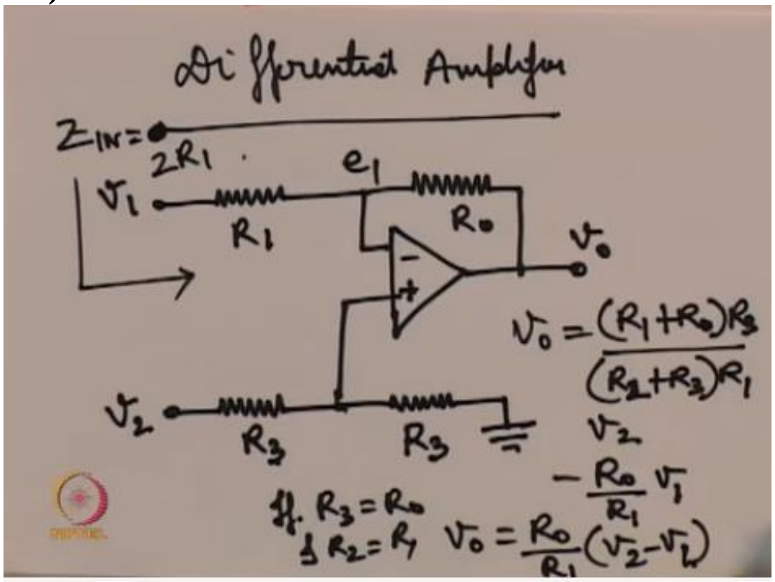

So one problem with the differential amplifier is that the input impedance Zin is equal to 2R1, it can be you know you can find it out you can calculate this and find out that the Zin is indeed equal to 2R1, now for many applications we need a high input impedance as we had discussed earlier for a Voltage amplifier the input impedance should be always very high, but in this case it is not so high and that is disadvantage so in place of a differential amplifier we sometimes use what is known as an instrumentation amplifier.

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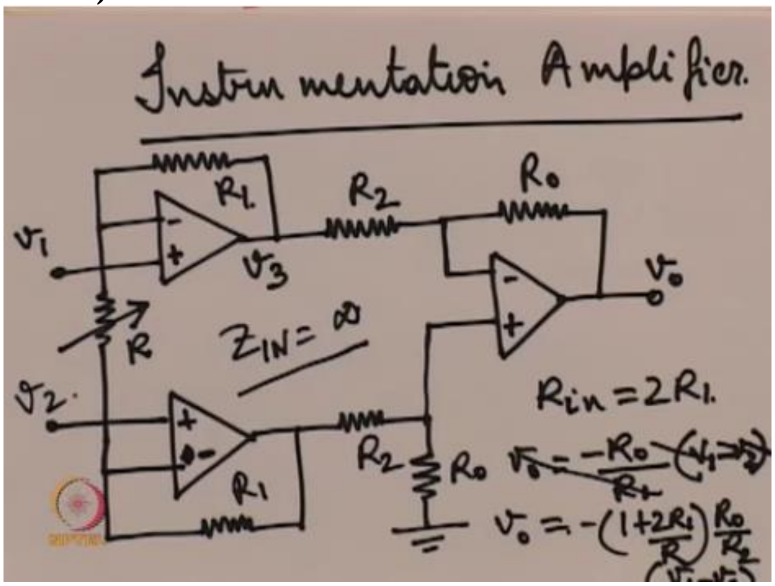

So an instrumentation amplifier has a circuit like this, now since in this case the V1 and V2 are supplied directly to the non-inverting terminal of 2 opamps the input impedance is equal to infinity and the output Voltage is given by this equation, it is still the output is still proportional to the difference between the inputs but the only difference is not the only difference of course the circuit is now consumes has more number of components more number of opamps and therefore it consumes more power.

But still the main advantage of this instrumentation amplifier is the input impedance which is now very high and necessary for a Voltage amplifier. So with this we covered most of the topics that were there with an opamp we have covered the basics of the inverting opamp the basics of the non-inverting opamp and we shall still be covering as we proceed along this course a wide variety of opamp circuits.

But in the next lecture or the next module, we shall be introducing some concepts of non idealities that are present in an opamp and how they are characterized and how they affect the performance of the circuit and how they can be reminded, thank you.