Electronics for Analog Signal Processing - II
Prof. K. Radhakrishna Rao
Department of Electrical Engineering
Indian Institute of Technology – Madras

Lecture - 6
g Feedback with MOSFET

Before we consider operational amplifier negative feedback circuit, let us complete the last example that we had considered under the feedback. That is, g feedback with MOSFETs. Purposely I am taking MOSFETs so as to illustrate the fact that the attacking of the problem remains the same as the bipolar structure.

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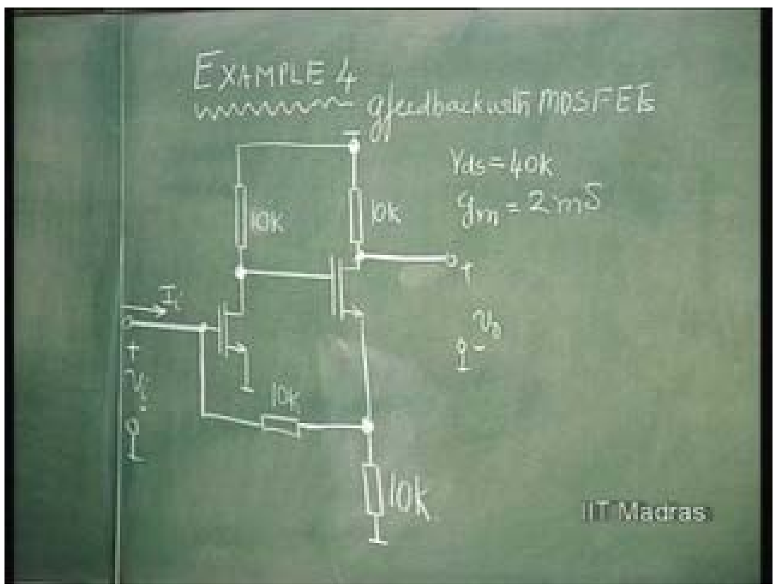

So, we have MOSFET T 1 amplifier cascaded to MOSFET T 2. Actually, this is, this was originally grounded and we wanted g feedback. So, we put the network shunt at the input and series at the output. So we connected it in series. So, this is the feedback network that comes into picture here; coming in series at the output and in shunt at the input.

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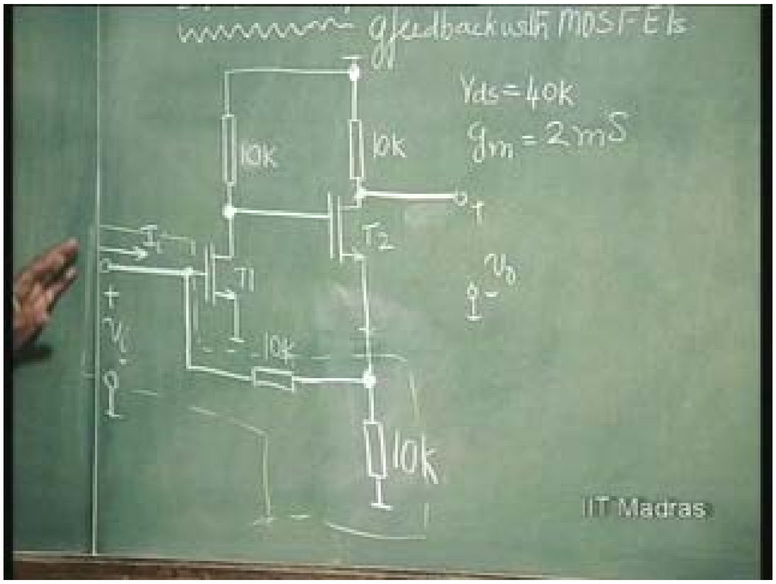

Now, this has been illustrated in shunt at the output. V i is common to both the feedback network as well as the amplifier. V naught is common; that is, I naught is common to the thing at the output. V naught is going to be shared between the amplifier and the feedback network.

Now, one thing you have to be extremely careful. Now, V naught is not common and therefore I naught is common. So, the load that you put must be put at this point so that this load comes in series with the amplifier as well as the feedback network.

So, this connection from here to ground is simply lifted and put here. So, this is considered as the load. In addition, actual load may be there.

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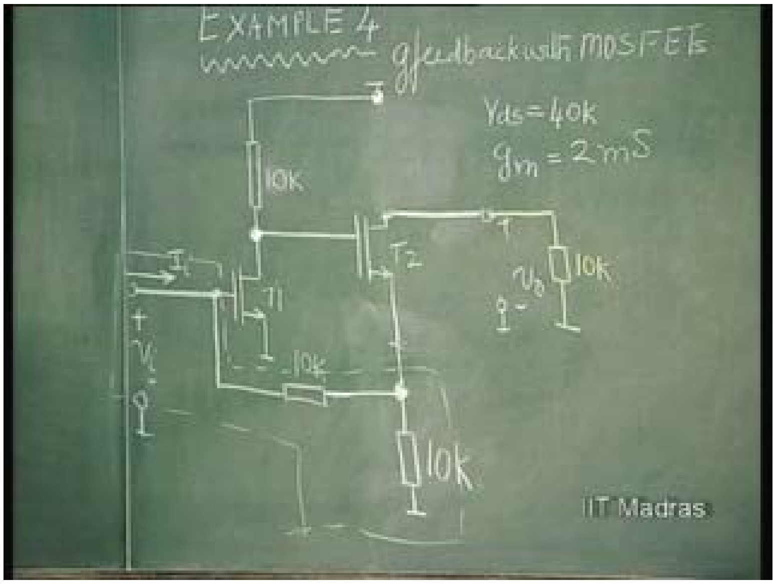

So, in this problem, the actual load is not given; just the R D 2 has been given as 10 K. That has been put here. So now, the current is common to the load, the amplifier and the feedback network. This is how it should look.

So, this is an important point that you should note. Same things should happen when we have things in series at the input. There should not be anything in shunt at the input. Things should be in series at the input for H feedback. There also, the amplifier should come in series with the feedback network and bias networks and all should be considered with the source impedance; not with the amplifier. Likewise, in the case of series arrangement at the output, the load resistance should always be considered outside. This is something that you have to bear in mind. Now, once you do that, this is going to be pretty simple problem here.

This 10 K, also is nothing but a 10 K connected like this; the same thing can be depicted as being connected like this. So, simple enough. Now, we have V i applied to this. This V i is same as this. So, we have here g m times V i; and if R D S is 40 K, we will put R D S also here, let us say, in the equivalent. This is 40 K. And please remember to put that R D S of 40 K here in the equivalent.

So here now, the current here is going to be g m times V i, V i being the gate to source voltage. The current here, if I call this as V i dash, is going to be g m times V i dash. That is the equivalent circuit, part of it. So, this much if you do, you have almost solved the problem.

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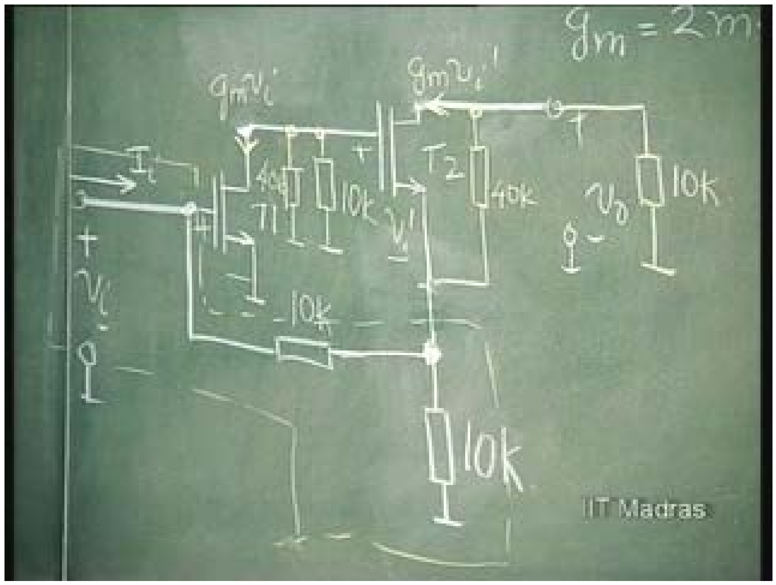

Now, we have to evaluate the composite g parameters for this. That means, first I open circuit the output. Remember. g parameter - the two input parameters g i and g f are defined for open circuit output; g r and g naught are defined for short circuit input.

So, when I open circuit, what happens? So, we want to evaluate, in this condition, g i which is V i by I i, under this situation. Now, as far as this amplifier is concerned, it is very convenient. There is no current drawn from this. The only current drawn is by this. And this current is zero. If this current is zero, this current is going to be zero. This current is zero; therefore, this current is zero. In this network, this is open because this is a MOSFET here. So, this is open. This current is zero; this current is zero, automatically.

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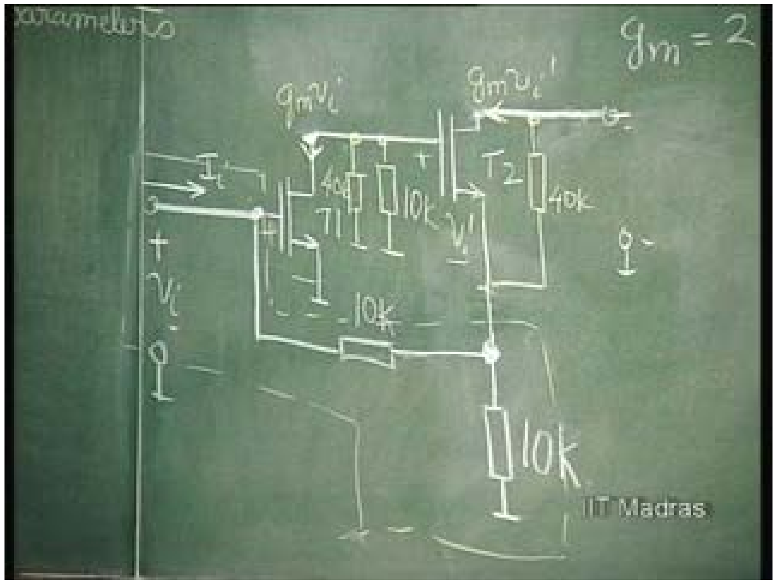

So, this resistance that comes is simply equal to… g i is equal to 1 over 10 K plus 10 K. That is, 20 K, simply. That of the amplifier... g i amplifier is zero; the conductance, input conductance of the amplifier is zero; or input impedance is infinity, in the case of MOSFET. Otherwise, that would have been added to it.

Then we have g f. What is g f definition? When I apply I i here, I find out what? V naught is open circuit output voltage. So, if I find… apply I i and find out V naught, it is V naught divided by I i. That is defined as g f. That is, V naught divided by V i, that is defined as g f. So, we know that this voltage V i is going to appear here as V i and because of this g m times V i, the voltage developed at across this is going to be g m into V i into parallel combination of this 40 K parallel 20, 10 K. So, 4, 40 into 10 by 40 plus 10; and g m is already known to be 2 millisiemens. So, 2 into 10 to power minus 3 gets cancelled with 10 to power 3 here. So actually, the gain here of this single stage is going to be 16 times V i.

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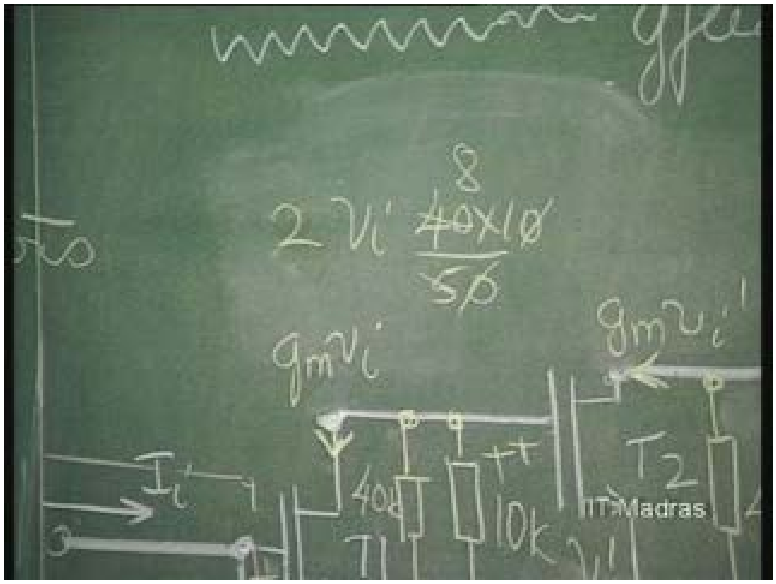

16 times V i and this end positive; and therefore, it will be minus 16 times V i. This voltage is going to be minus 16 times V i across this. Remember. So, across 10 K, it is minus 16 times V i coming here; and this V i is this minus 16 times V i minus this voltage. What is this voltage? If this is V i, half of V i comes here. If this is V i, half of V i comes here, because this is open. So, this is 10 K, 10 K. So, half of V i comes here. V i by 2. So, we have minus 16 times V i here. That is, plus here, minus here, 16 V i; and here we have plus here, minus here. So effectively, plus, minus, plus, minus; these voltages add. V i by 2 adds with plus minus 16 V i; or it is effectively having a V i dash which is minus 16 point 5 V i.

Once again, let us see this. This 10 K parallel 40 K is 8 K; and 8 into 2 millisiemens is 16. So, this is giving you minus, plus, minus, 16 V i, this. You have, plus, minus, V i by 2. So, this will add on to this and V i dash is going to be minus 16 point 5 V i.

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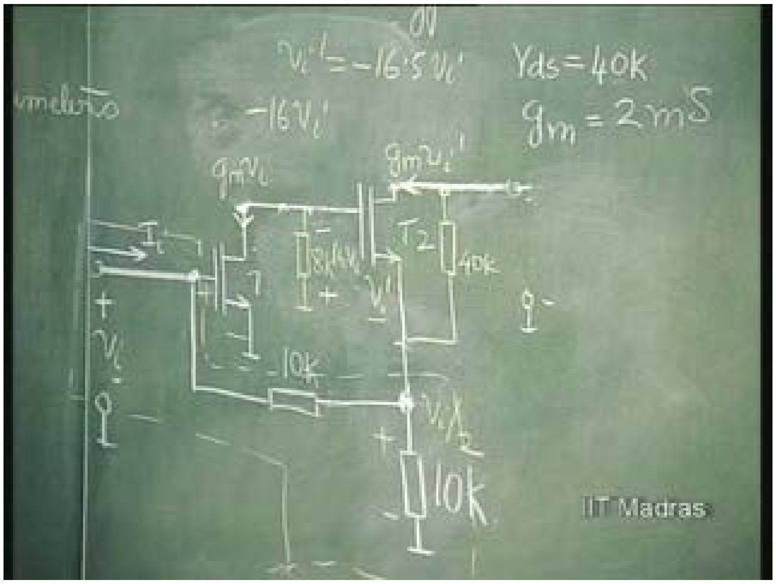

Now, that into g m is the current in this, in this direction. If it is minus 16 times...16 point 5 times V i, the current will be actually in this direction with 16 point 5 into 2. 16 point 5 into 2 - that is 33 times V i flowing in this direction, which will develop a voltage in this direction, which is 33 V i into 40 K. 33 into 16 point 5 V i into 2 millisiemens. So, 33 into 10 to power minus 3 into 40 K.

So basically, the voltage developed here is going to be 40 into 33 times V i, positive here and negative here. And there is V i by 2 getting added to it, plus if you want point 5 V i. So, that is really the gain. V naught over V i. V naught is, open circuit voltage is, from here to ground. So, we have 40 times 33 V i positive, negative, here and V i by 2 here. So, 40 into 33 plus point 5 V i is the total output voltage.

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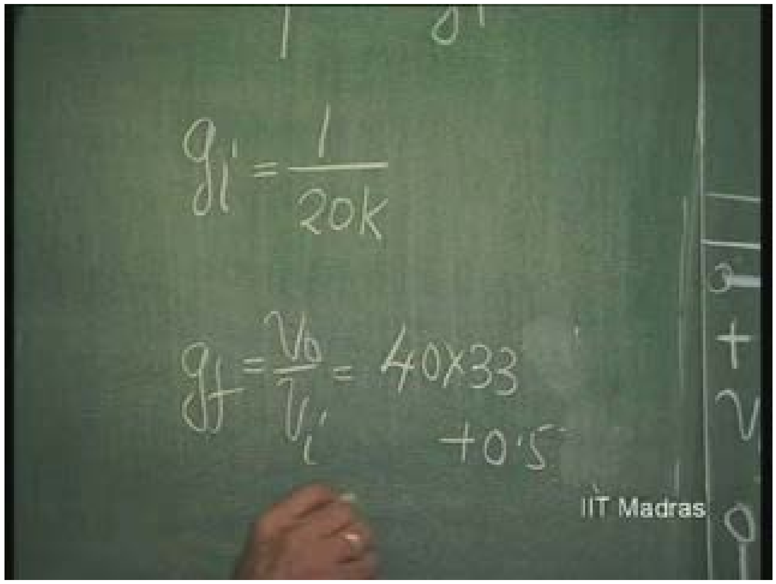

So basically, we can even ignore this because this is 1320 and the contribution due to this forward path is only point 5. So, we have now evaluated g f. So, 1320 point 5. This is the parameter g f; we have already evaluated g i. We now have to evaluate g r and g naught.

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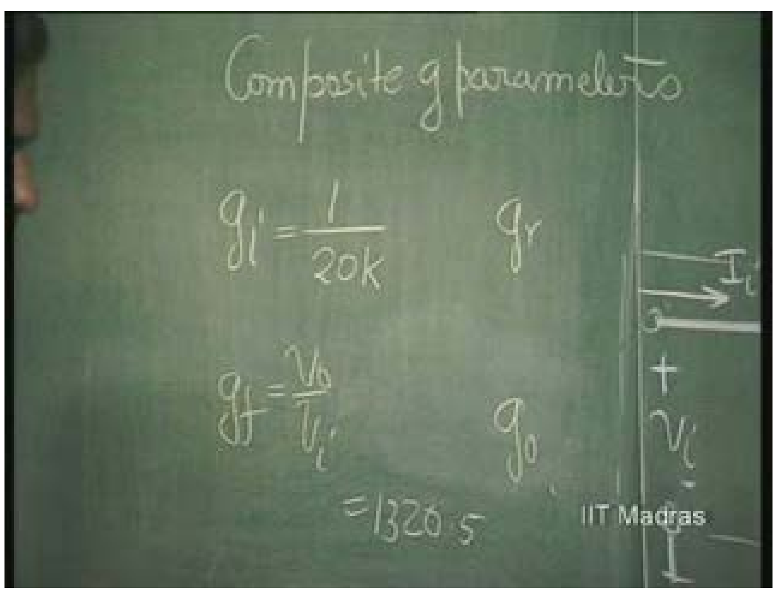

What are these parameters? Now I apply a voltage at this point which I call as… actually, I should apply a current here; I naught, we will call it; and short circuit this. So, it is a parameter with input shorted. Now, when I short this input, you will know that this 10 K come in parallel with this 10 K. I have shorted this. So, this 10 K will come in parallel with 10, 10 K.

I will remove all these values. So, we will redraw this. So, V i is zero. So, I have the circuit becoming like this. This is shorted; at input is shorted; and this 10 K comes in parallel with this 10 K. So effectively, we have a resistance of 5 K. So, please understand that that comes about because of the 10 K; and the input shorted 10 K coming here. So, that, you should remember. That is effectively 5 K.

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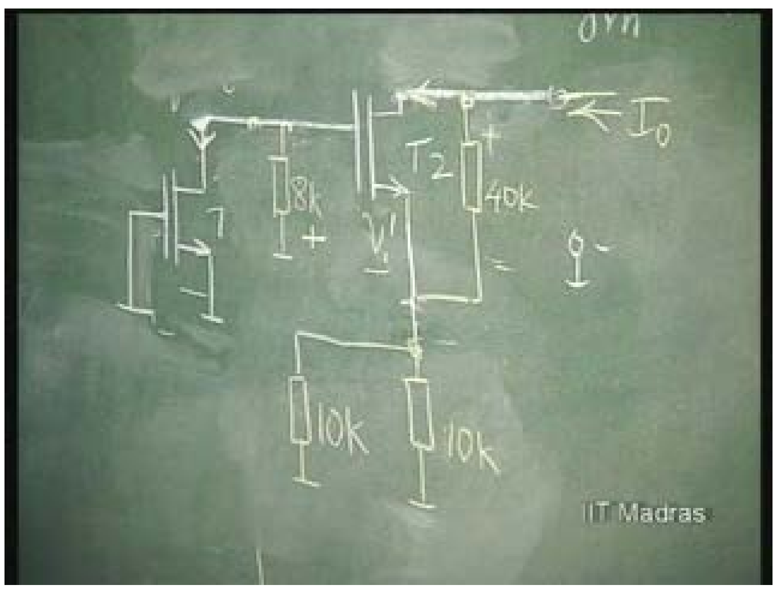

So, if I naught is this current here, whatever be the situation, I naught should be the current here, because this current is entering, this current should be leaving; this is open. So, I naught… What is the current that is going to fed back to the input? It is through this 10 K. So, half of I naught is going to be fed back. So, g r is equal to half. Out of the output current, half of it is fed back; and what is the direction? If this is entering, this will be leaving. So, minus. If this is entering, half of this current is fed back to the input. But if that is also going to leave the input port… So, half, minus half; if the current entering is positive; current leaving is negative; so, it is minus half.

What is g naught? g naught is... obviously, we have to evaluate V naught, when I naught is the pumped in current. If I naught is the pumped in current, this is I naught and the voltage across this is I naught into 5 K. This is the voltage across this. As far as this is concerned, this is useless. V i is zero. So, this current, source current is zero. So, circuit gets simplified very much.

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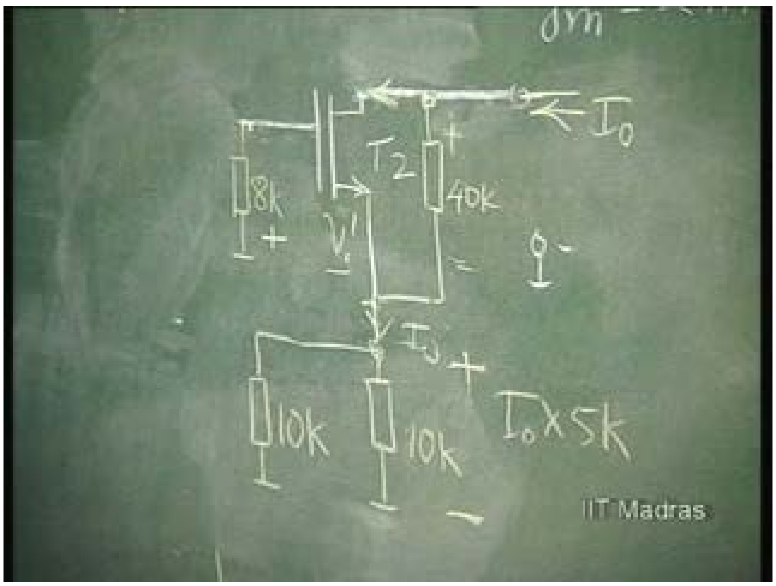

So, this has 5 times I naught into K as voltage across this; and that voltage will be coming with this end positive and this end negative. That means, this is negative. So, V i dash is equal to minus I naught into 5 K. That is because, this is at ground potential. So, from here to here, whatever voltage is occurring, is appearing as V i dash, but with negative sign. What it means is, g m times V i dash which is this value, will be flowing in this direction.

If I say that g m times I naught times 5 K is flowing, then this direction has to be changed because that minus says it is in the opposite direction to what we have assumed. In which case, I naught is flowing here. g m times I naught into 5 K is flowing there. What is g m? It is 2 millisiemens. So, this is 2 into 5, which is 10 times I naught; which means, here we have 10 I naught flowing; I naught flowing.

So, through the 40 K resistance, we have 11 times I naught flowing; which means, the drop across this is 11 times I naught times 40 K. That is in this direction. Already this is I naught times 5 K. So, the total voltage, V naught, total voltage V naught from here to ground. So, we have 40 into I naught times 11 K plus I naught into 5 K. That is all.

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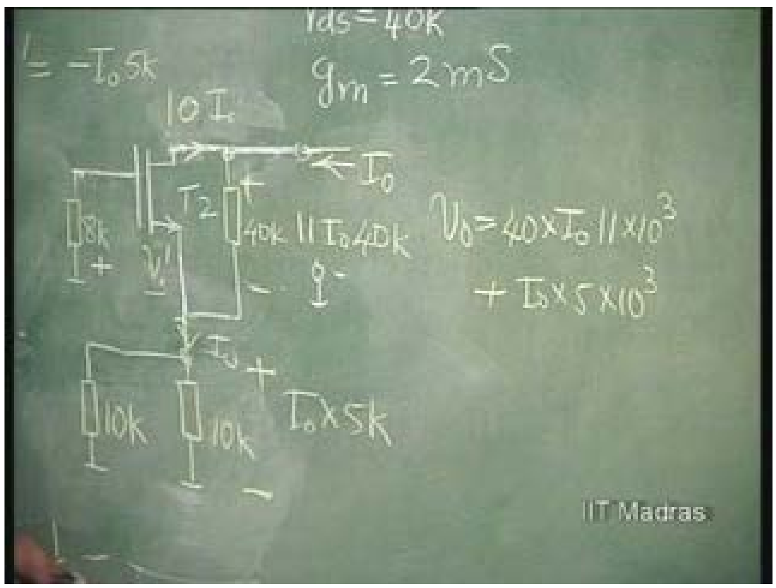

So, V naught over I naught which is the output resistance is nothing but 440 K plus 5 K which is 445 K. So, this is 445 K. So now, we have evaluated the composite g parameters completely.

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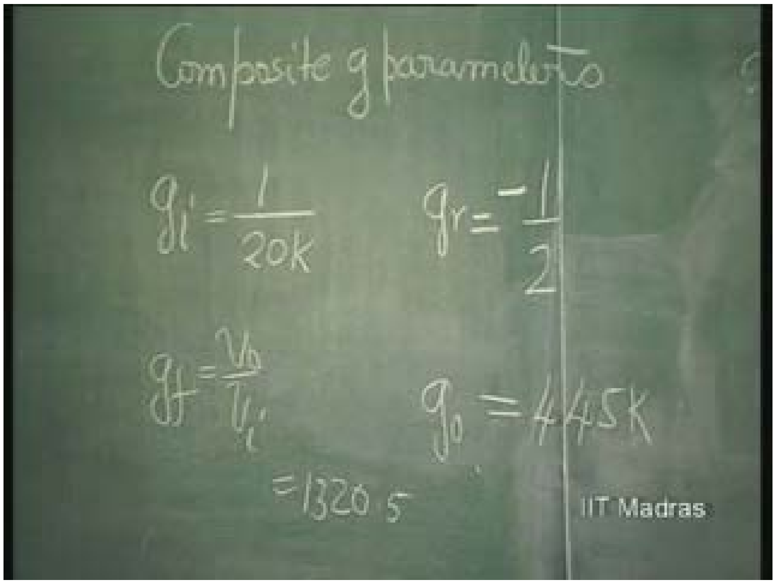

So, we have to now convert it into composite h parameters in order to find out what is the effect of negative feedback. That is g feedback.

So, composite h is what we have to convert. Before that, let us find out the loop gain. Loop gain is, once again, these things have become routine. You see, 1320 point 5 into half, minus… So minus, divided by this into this. 445 by 20. So, this is 22 point 25. So, you have the loop gain which is minus 660 point 25 divided by 22 point 25. If you neglect this point 25, it is simply… 22 goes 3 times. So, about 30. 30. So, if you ignore this… So, the loop gain is pretty high. So, minus 30 is the loop gain indicating that it is negative feedback.

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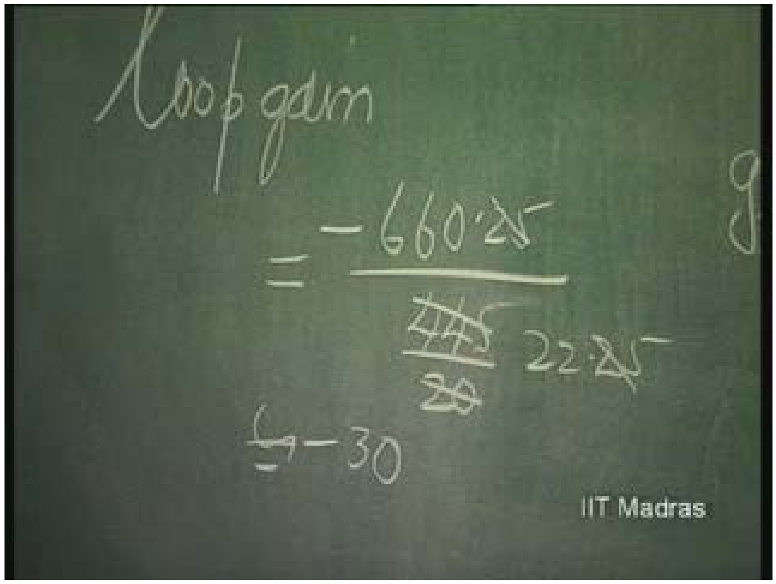

Now, we can go ahead with everything that we want to do. h parameter. So, h f first and foremost. Fine. So, once again, we can see here, Delta g is what is the modification factor. It involves loop gain. So, how much is this? This is 660 point 25 plus 22 point 25 which is point 5, 2, 8,... 682 point 5. That is Delta g.

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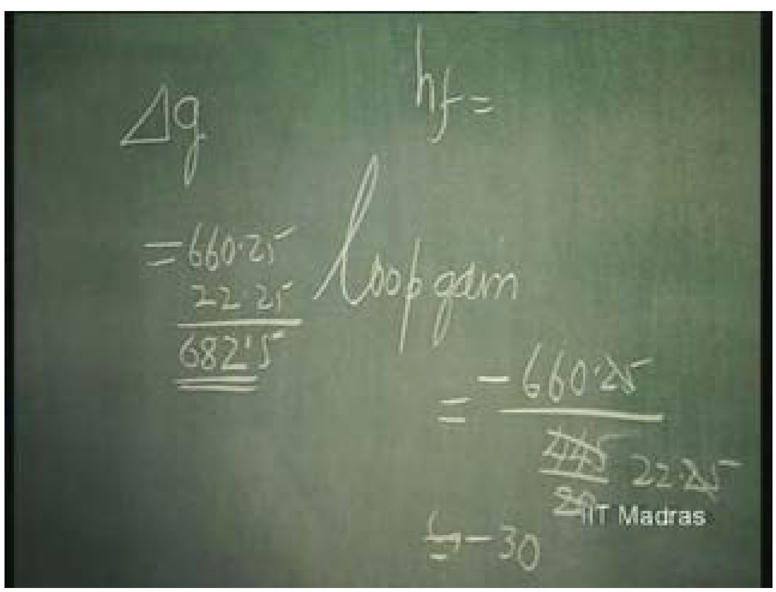

So, this gets modified as 1320 point 5 with minus sign. Minus. That divided by Delta g which is 682 point 5. You can see that this is very nearly equal to 2; slightly less than 2. So, this is very nearly equal to 2, minus 2. That is what it should be. It should be 1... minus 1 over g r, essentially. So, it is very nearly equal to 2.

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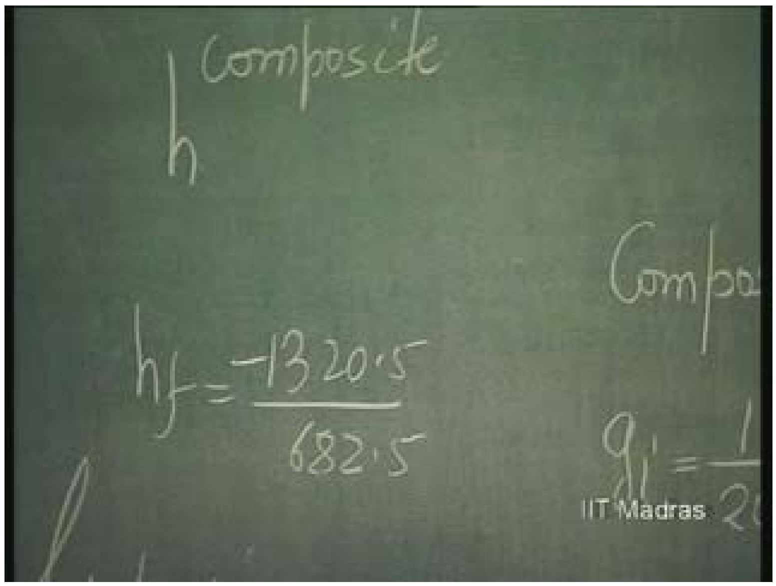

Next, let us find out h i. h i is this 445 K divided by 682 point 5; less than 1 Kilo ohm. This is going to be less than 1 Kilo ohm. So, the input resistance has come down drastically. It is becoming current controlled.

Output h naught, conductance, is going to be 1 over 20 K into 682 point 5.

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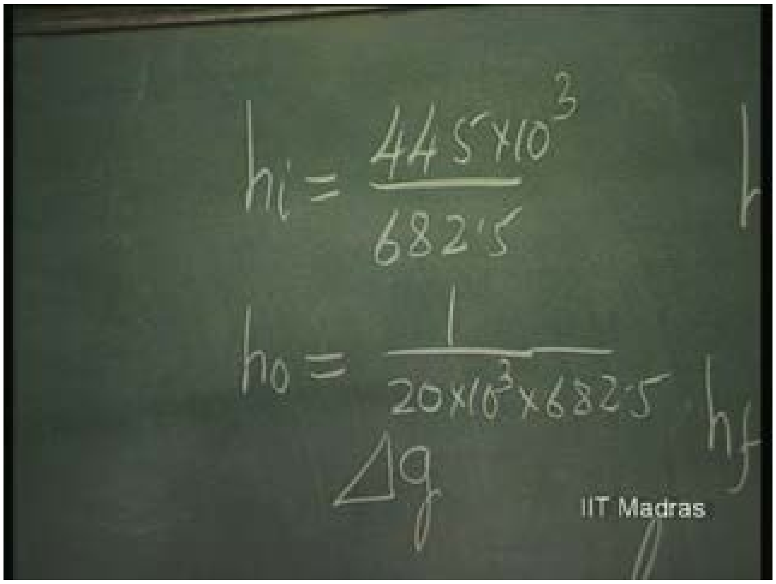

So, the output resistance, R out is going to be 20 into 682 point 5 K; or going… it is going to be of the order of mega ohms.

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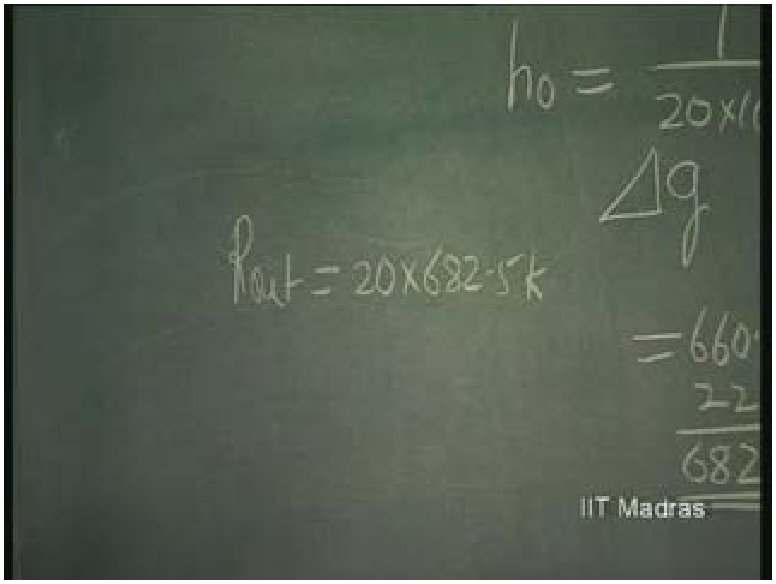

So, you can see that because of negative feedback, now, all these parameters have got modified. h i goes towards zero; h naught goes towards zero; h r also goes towards zero, which is, h r is going to be point 5 divided by 682 point 5 - goes towards zero.

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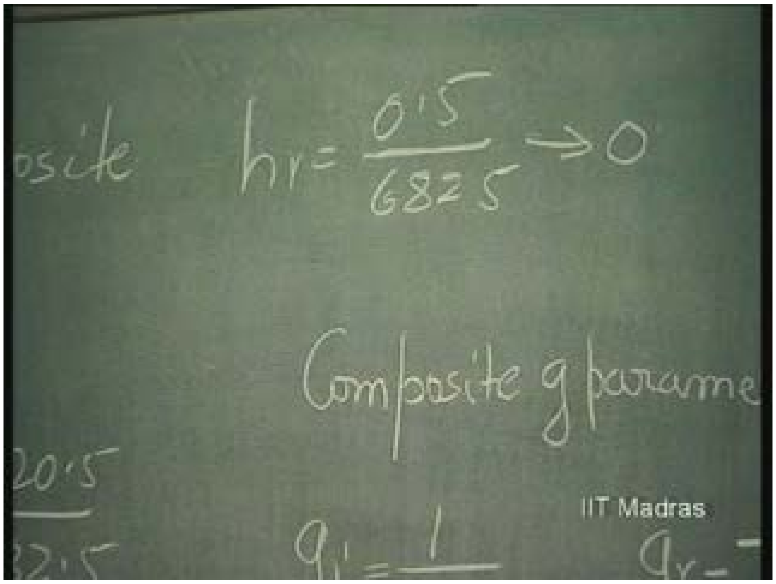

So, this is how we can analyze a given circuit with negative feedback and conclude very quickly without even doing any evaluation that the forward transfer parameter is very nearly equal to 1 over the reverse transfer parameter of the feedback network. So, input impedance decreases; output impedance increases.

This can also be done this way. The original input impedance was 20 K. The actual current input impedance is going to be reduced, by how much? 20 K divided by 1 plus loop gain. That means 20 K divided by 683. That is, loop gain is 20 K divided by 31. So, 20 K divided by 31 is going to be same as this. Similarly, the output resistance is going to increase. Original output resistance was about 440 K. What is the current output impedance? Everything is going to change by 1 plus loop gain. Loop gain is 30. So, 31. So, 445 into 31 is again this. 445 into 31. So, you will get this by the other method also.

So, input impedance increases by what factor? 1 plus loop gain. Original input impedance, if it is something, input impedance increases in the case of h feedback. In this case, it is decreasing by what factor? 1 plus loop gain. 20 K divided by 31. 445 K gets boosted up by 31. This particular thing, originally we had this feedback factor of half. So now, the forward transfer parameter is going to be very nearly equal to 2; 1 over the feedback factor. So, these are the modifications that take place in the case of feedback. Now we will come to an important topic.

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Operational amplifiers, which are amplifiers which have been designed in such a manner, that they are primarily used in negative feedback configuration. So, operational amplifiers with negative feedback - this is the topic that we are going to discuss. We had seen in our previous lectures how we can build operational amplifiers; saw the four types and out of these, for the present discussion, we will consider operational voltage amplifier which is nowadays commonly available; which means, basically it is an amplifier. Ideally speaking, operational voltage amplifier can be defined using only g parameters where g i is zero, g r is zero, g naught is zero and g forward is going to be infinity.

This is defined as… operational voltage amplifier; tends towards infinity.

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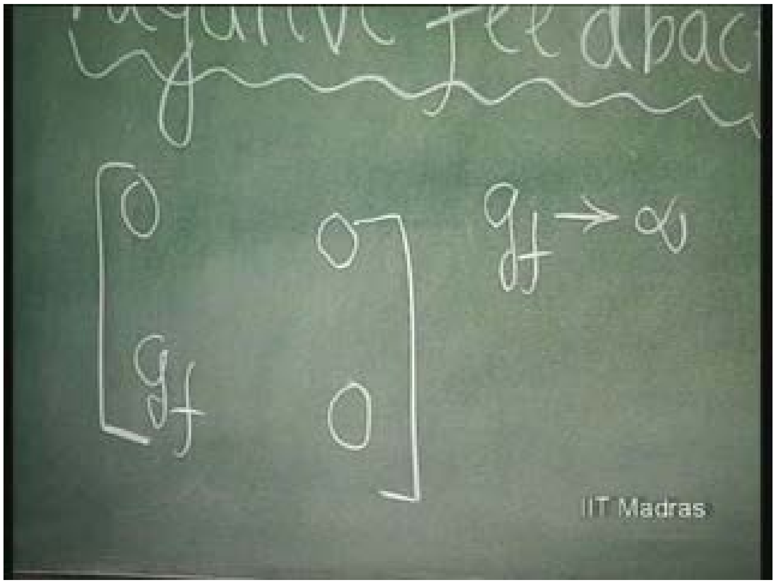

g i zero means it is voltage controlled; the input conductance is zero; therefore, input impedance is infinity. g naught zero means output impedance is zero. g r zero; no negative, no feedback, negative or positive. So, zero feedback. So, feed forward is very high. If we do that, obviously, the most popular one is the differential input. Single ended output op amp which may be designed by cascading several differential amplifiers together.

Now, in practice obviously, because of cascading, the forward transfer parameter keeps on increasing; the reverse transfer parameter keeps on decreasing. That we have also seen. The input impedance mainly depends upon the input amplifier circuit; output impedance depend upon the output amplifier circuit.

So, in a cascaded version, please remember; this is the multiplication of the forward transfer parameters of the individual stages. So, it improves drastically. This keeps on coming down; feedback. This is due to the input stage; this is due to the output stage. Anyway, we can design these things so that these represent operational voltage amplifier.

That means, input impedance is made very high; output impedance is made very low; and it is a cascaded stage. When you do that, let us see what happens.

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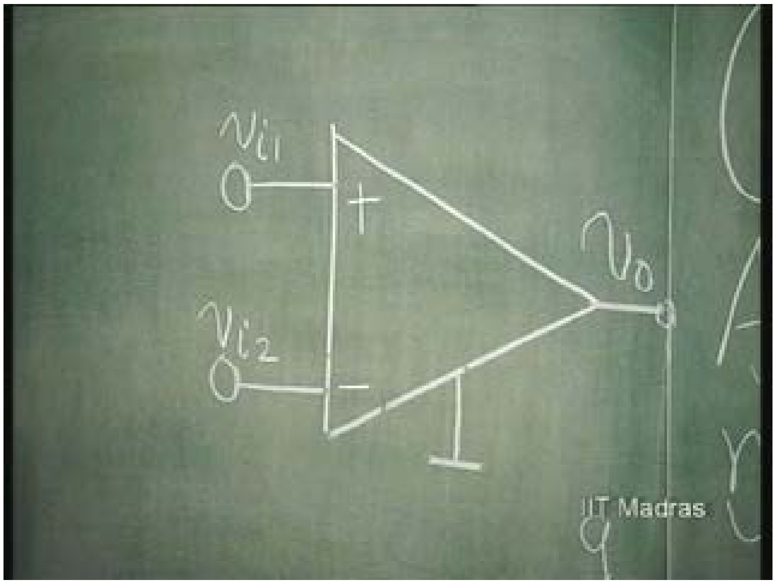

V naught is… let us consider only the g f. g f in this case, we will take as A. This is called open loop gain of the op amp. Typically, the D C gain; it is frequency dependent; the D C gain is of the order of 10 to power 5 to 10 to power 6; which means, it is of the order of 100 to 120 decibels. That is the kind of gain we are talking about. It is made, it is made very very high.

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So, V naught is going to be A times… this is called non-inverting amplifier terminal; this is called inverting terminal. So, V i 1 minus V i 2; it is always referred to single ended output. That means, one is… one end of the source is grounded; other end is giving you an output V naught equal to A times V i 1 minus V i 2. So, differential input, single ended output, we are talking of.

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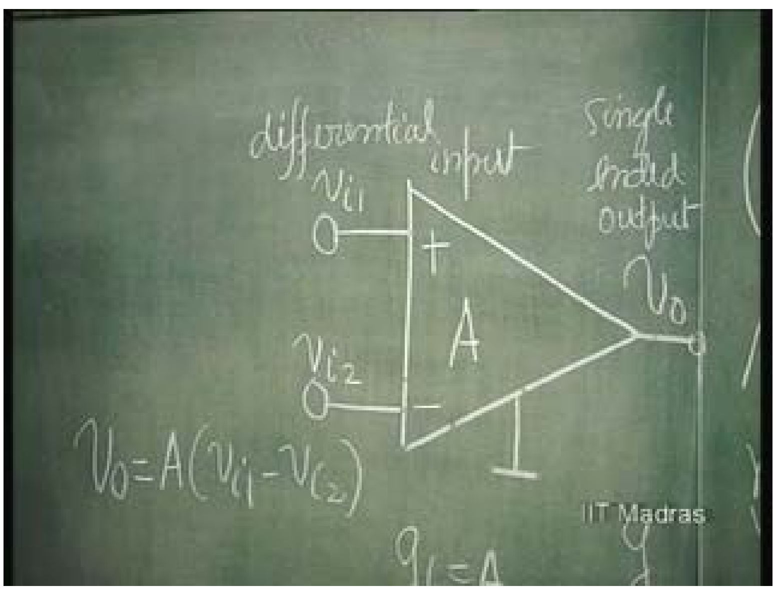

So, if you consider first that only the forward transfer parameter is con … high, rest of the things are all going to be zero, zero, zero, then, we can indicate that V i 1 minus V i 2 always becomes equal to V naught by A. This is an important principle I am trying to discuss. A is tending towards infinity; which means in an op amp, we can pronounce a statement which is always valid.

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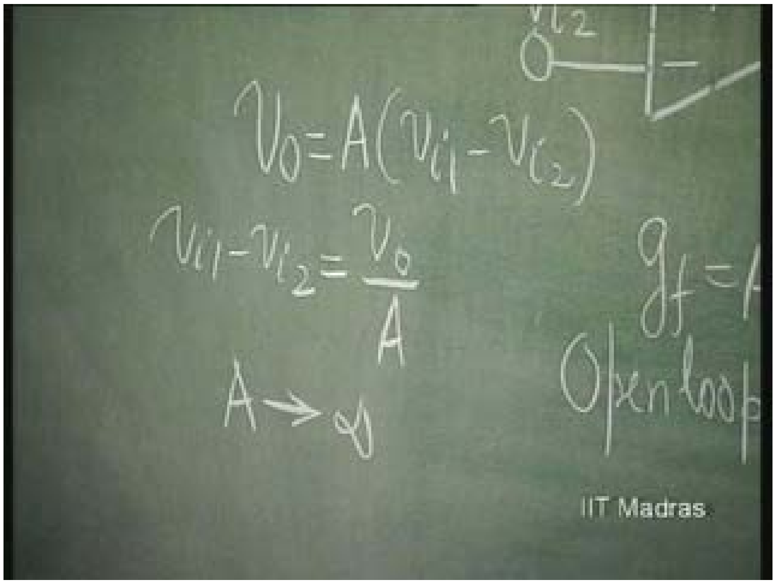

If A tends towards infinity, V i 1 minus V i 2 tends towards zero because A is coming in the denominator. V i is...or, V i 1 minus V i 2 becomes zero; or V i 1 becomes equal to V i 2. This error that sustains finite output is zero. That means, in this case, V naught should be finite. This is important. As long as V naught is finite, V i 1 is very nearly equal to V i 2 in all operational amplifier circuits.

If V naught is infinity, then V i 1 can be different from V i 2; or in practice, what is infinity? If this V naught goes to such a value in an op amp circuit that it is going towards power supply, or the amplifier gets saturated; positive power supply or negative supply, that is called infinity, practically. So, our amplifier reaches saturation. Then, V i 1 can be different from V i 2. But, if amplifier does not reach saturation, then V i 1 has to be always equal to V i 2.

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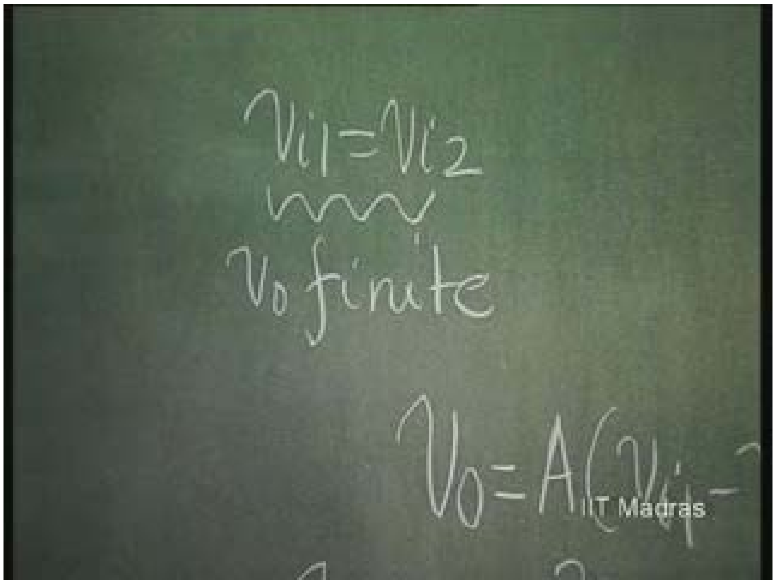

This is an important principle that is used in diagnosing any fault associated with an operational amplifier. That, what it means is, this voltage is same as this voltage. That means this voltage difference is zero; or, this circuit is not drawing any current.

So, I is equal to zero and V i equal to zero; or, this is a nullor. This we had earlier also considered. This input of an op amp is nothing but a nullor. So, this is called 1, let us say; this is called 2. Within 1 and 2, ideally speaking, you have a nullor.

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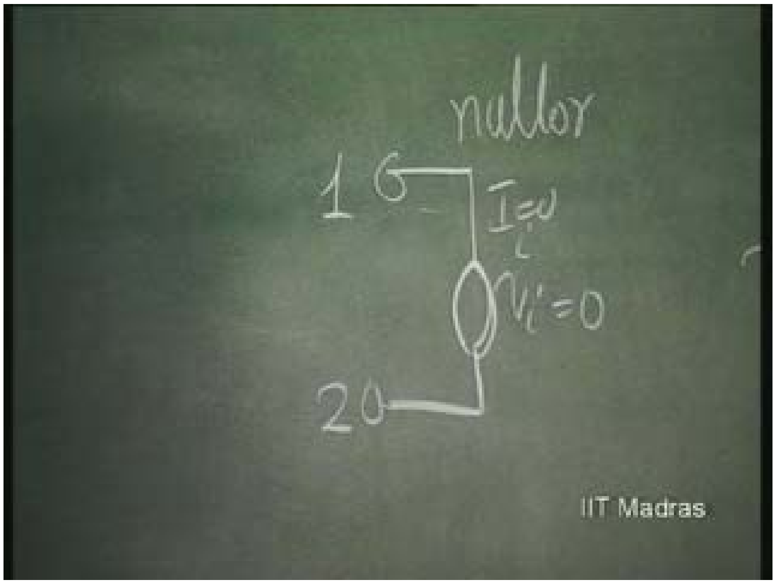

And, of course, at the output… output can be anything finite. So, it can have any voltage and any current. So, this is a norator. So this is the simplest equivalent circuit in terms of nullator-norator, for an operational amplifier of this type. We have already discussed this nullator-norator concept earlier in equivalent circuit.

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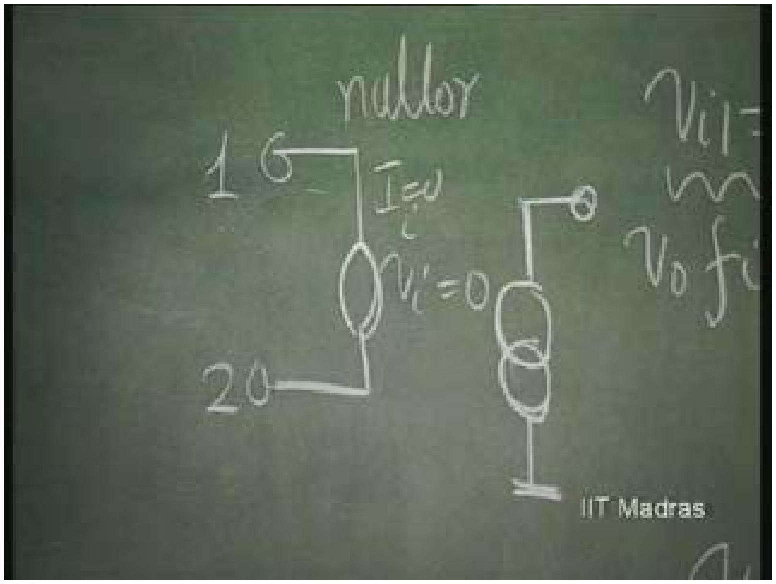

So therefore, these nullators and norators will always occur in pairs. That is… Why is that this nullor has zero voltage and zero current? It is because of the existence of norator, which is capable of giving any voltage or any current, finite. So, this equivalent circuit can be used for most of the operational amplifier circuits and you can understand this very well.

Otherwise, obviously, the equivalent circuit is going to be between 1 and 2. We will always have an impedance which is called R in of the amplifier source; and this is going to be having an output V naught. But there will be output impedance of the amplifier and this will be A times... This, if you call it as V 1, this as V 2, V i 1, Vi 2, this is going to be V i one minus Vi 2. This is the equivalent circuit which we had again discussed long ago when we discussed about amplifiers; input impedance, output impedance and open circuit voltage gain.

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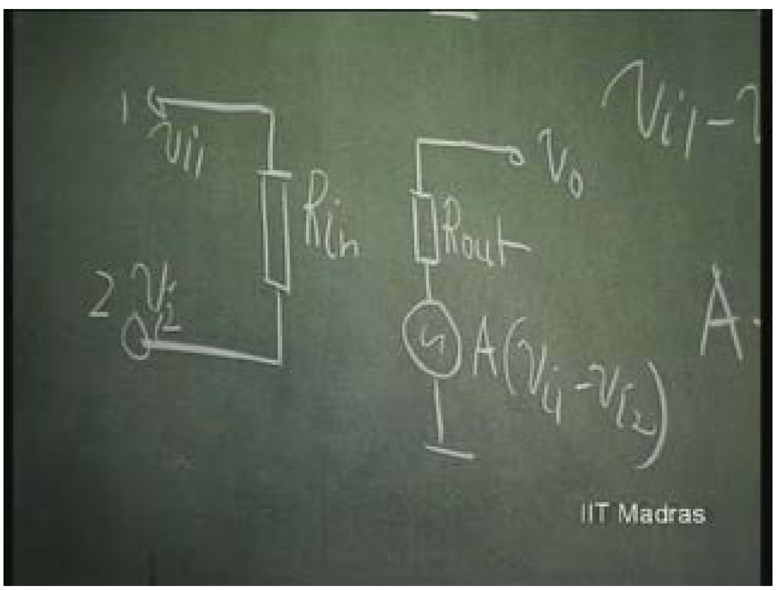

So, this is the equivalent circuit of the operational amplifier. Normally, the order of input impedance for typical operational amplifiers, which are general purpose operation… For example, popular one is 741 or 747 op amp. R in is of the order of 1 mega ohm. R out is of the order of about say, 50 ohms. A naught, that is D C gain here, is of the order of 10 to power 5 to 10 to power 6. This is what is commercially available as general purpose operational amplifier, to be used for a variety of useful applications.

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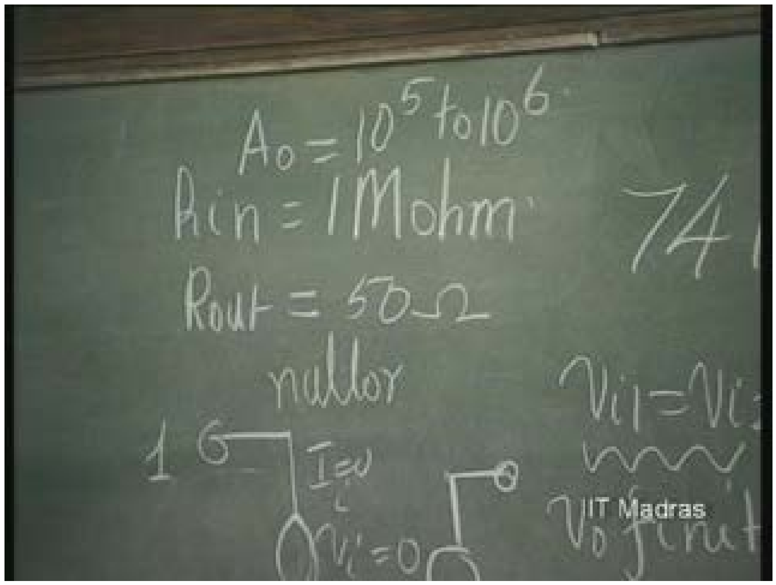

So, you should roughly have this idea about the order of magnitude involved. If you are asked to design such op amp, you will obviously cascade one amplifier with another. You might get gains of the order of 10 to power 4 to 10 to power 5; and this impedance also, you can get. This output impedance can be easily got.

So, even if it is a question of your designing an op amp, you can also get this kind of parameters for the op amp. Now, how do we use this in the negative feedback configuration? First, of all, let us try to see the forward characteristics of the op amp. If you try to plot, what will you see?

If we ground this and try to apply voltage here, since by definition, this is going to work in the active range only in a situation when V i 1 close to V i 2. So, until V i 2 becomes equal to zero, because we had maintained V i 2 at zero; until V i 1 comes close to zero, this op amp will be in saturation. That will be in positive saturation because we are applying it to the non-inverting terminal.

So, if I apply a positive voltage here, this will go to positive saturation. If I apply a negative voltage here, it will go to negative saturation. So, the characteristic of this amplifier will be looking like this. If I apply negative voltage, it will go to negative saturation. So, this is V naught versus V i. These have been, let us say, plotted in terms of volts. So, almost up to this point, it will be in the saturation region.

This is minus, let us say, V supply. Then, at this point, when V i is exactly equal to zero, it is going to change state and go to plus V s. This is almost vertical. Why do I say almost vertical? If I really see… if the gain is taken as 10 to power 6, you can say that this is about 10 volts supply voltage. 10 volts divided by…even for the maximum output, 10 volts divided by 10 to power 6 is going to be, 10 micro volts.

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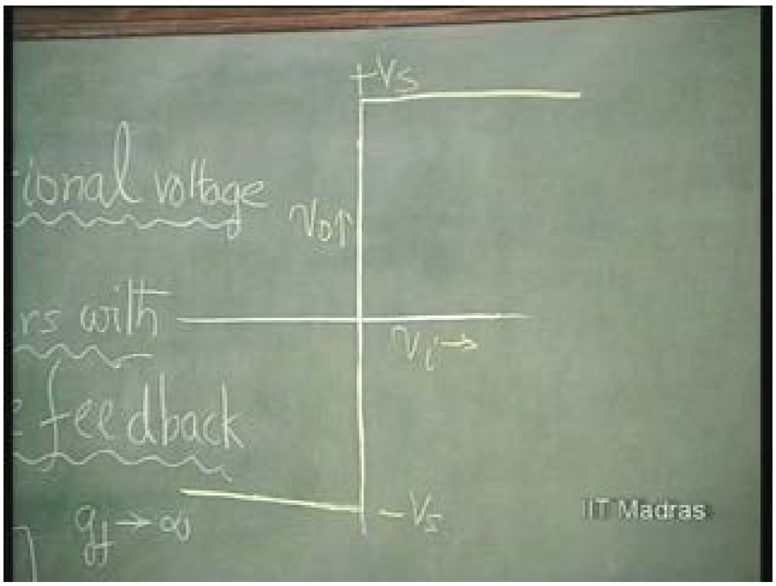

In a voltage scale, in a range of volts scale, this is not at all visible. So, the region where it is going to have high gain… if you expand this, it will be having a slope, of course, which is equal to one of… That is A. The slope of this is equal to A. If A is going towards infinity, this is almost vertical. Obviously, for the same reason that this is almost vertical, it can be also used as a voltage comparator. Just telling us in this mode, it can be used as a voltage comparator or zero crossing detector. So, it tell us for a great degree of accuracy when exactly the input voltage crosses zero. Where do we use this zero crossing detector? Normally, when we design electronic switches, these electronic switches tend to operate… Power line is being switched, let us say. When the power line is being switched, we would like to switch this exactly when the voltage is crossing zero.

If we do not switch this this way, then the voltage suddenly rises at that point and it causes lot of high frequency to be generated. This causes lot of interference. This noise generates lot of interference all around. In order to suppress this electromagnetic interference, we would like to operate every switch when the voltage is crossing through zero. Now, for that purpose, the electronic device needs a zero crossing detector to tell us exactly when a given voltage is crossing zero. Such ICs are available and such ICs also use a high gain op amp for the purpose of detecting this zero.

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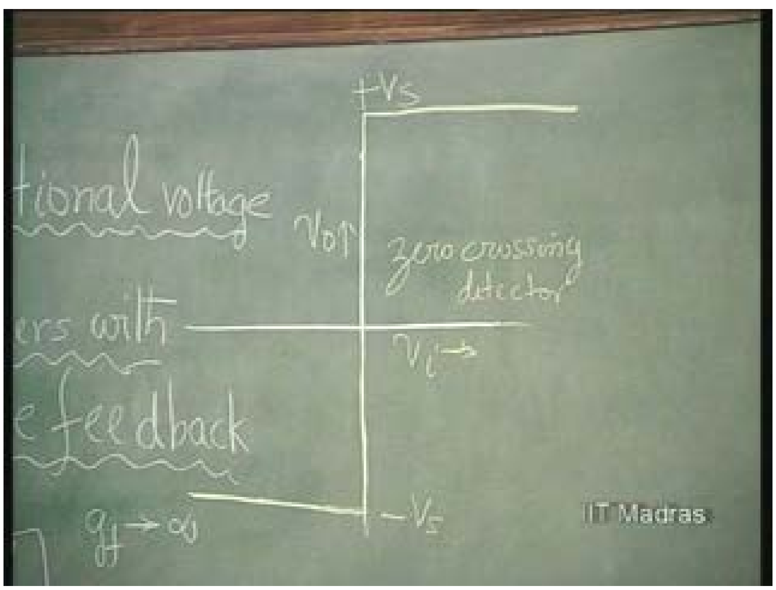

Now, in our application here, is not for this. We would like to operate this amplifier in this range between these voltages, output voltages. So, and under this situation, obviously, the active region is going to be extremely small here; range, as far as the input voltage is concerned. But, as far as the output is concerned, it is extending all the way from plus V S to minus V S. The moment output voltage reaches V S, it has ceased to be an operational amplifier and V i 1 can be different from V i 2. That is what is explained by the characteristics shown here.

So, we have also understood how the equivalent circuit can be taken. The simplest equivalent circuit is this. We will use this, as well as this, for our analysis of operational amplifier negative feedback. Now, what are the possible negative feedback circuits possible with this operational voltage amplifier? The output is always taken as a voltage. So, I can only sample output voltage, let us say; in which case, the arrangement at the output is always shunt. At the input, it can be in series or shunt. So, the only positive, that is negative feedback configurations possible here will be output always in shunt; input either in series or in shunt.

That means, you have y feedback possible and you have h feedback possible. With this operational amplifier, you have y feedback possible and h feedback possible. Since we are not able to sample the current here, the current feedback is not possible. That is why the z feedback and the g feedback, these are left out here.

So, let us therefore discuss y feedback amplifiers and h feedback amplifiers using operational amplifiers. Consider, this operational amplifier. We will apply h feedback to this; output voltage is sensed. Now I am going to feedback the complete output voltage to the input. So, V naught is…by making this V naught connection here, I am making the fed back voltage to one of the inverting terminals saying that it is negative feedback. So, if this is V naught, this is made forcibly equal to V naught. This is the feedback connection. So, this is V i and this is V naught. So, we have V i 1 equal to V i, V i 2 equal to V naught.

V i… this was V i 2 and V naught was equal to A times V i 1 minus V i 2, according to our definition.

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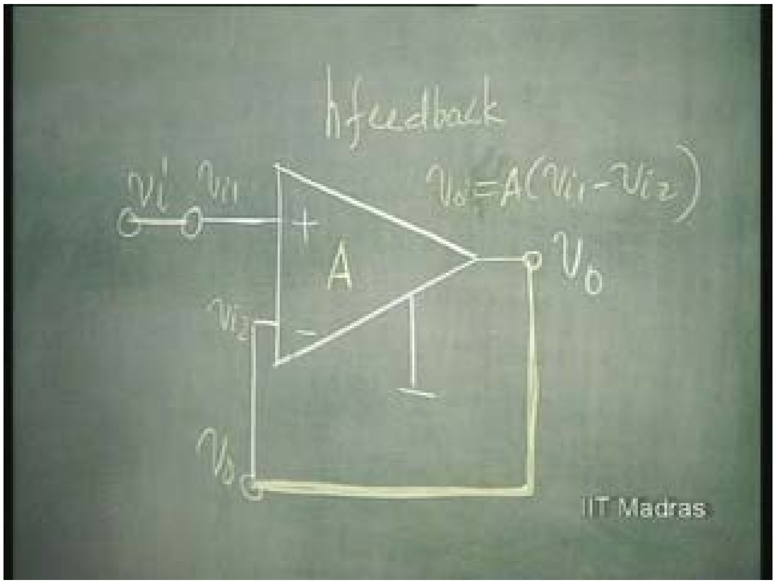

So, what did we do? We made V i 2 equal to V naught. That means, in this expression, V naught equals A times… V i 1 is V i; V i 2 is V naught. So, V naught into 1 plus A equal to A times V i; or, V naught over V i which is called the transfer function of this network is A by 1 plus A.

This you remember. We started discussing about negative feedback and saw that if I completely feedback X naught as… I mean at the input, then the error voltage is X i minus X naught; and the output will follow the input. We call it voltage follower or current follower or phase follower depending upon the parameter. Here, it is called voltage follower circuit because if A is as large as that, A 10 to power 6 or so, this is definitely very close to 1, for A much greater than 1.

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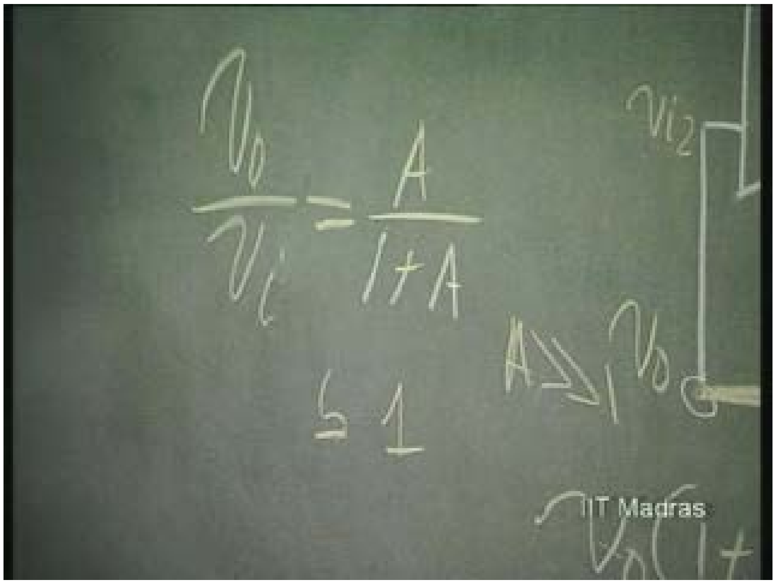

So, voltage, output voltage, will be following input voltage irrespective of the load. Whatever I connect here, it does not matter. So, if I have a source here R s and then V s, we can see that there is no current drawn here and therefore V i is going to be same as V s, irrespective of the value of R s because there is no current in R s; and V naught is going to be same as V i. Therefore, V naught is going to be same as V s. So, this is called a buffer stage.

It is going to be introduced between, let us say, high impedance source and load. Otherwise, obviously, if I directly connect the load here, the voltage will be attenuated by R l by R l plus R s. Therefore, if I introduce a buffer stage like this, whatever source voltage is available; here, it is going to be open circuit voltage that is available here; will be available at the load as V s. So, that is why this is normally used as a buffer stage between the transducer which has, may be, high impedance and the load which may be pretty low value.

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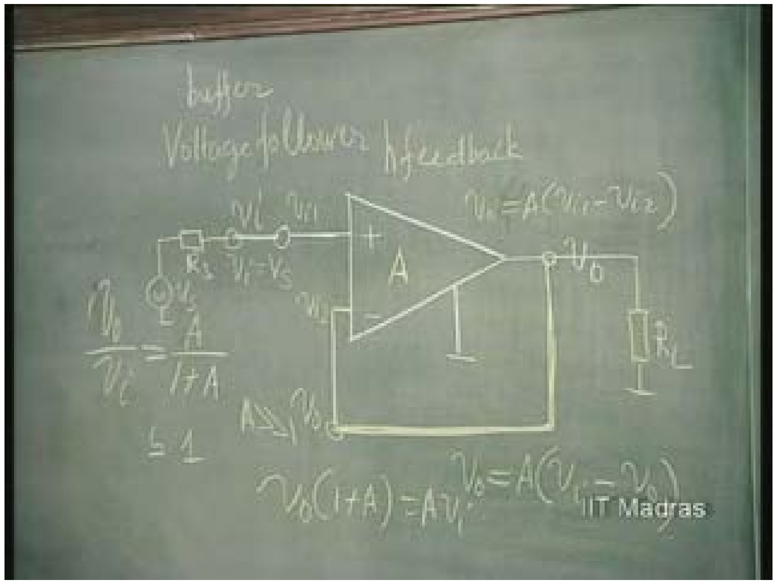

So, this is an important application of voltage follower which is also called buffer stage. Now, if you use the nullator-norator concept, then we do not have to go through this. A is definitely infinity and it is to be indicated very clearly that all this thing is irrelevant, if output is finite; then, this should be equal to this. So, this is already equal to V i. So, V naught is equal to V i; that can be concluded without any problem at all.

So, in the model that we have, we have said this voltage is equal to this voltage, for all practical purposes. So, if this is V i, this has to be equal to V i.

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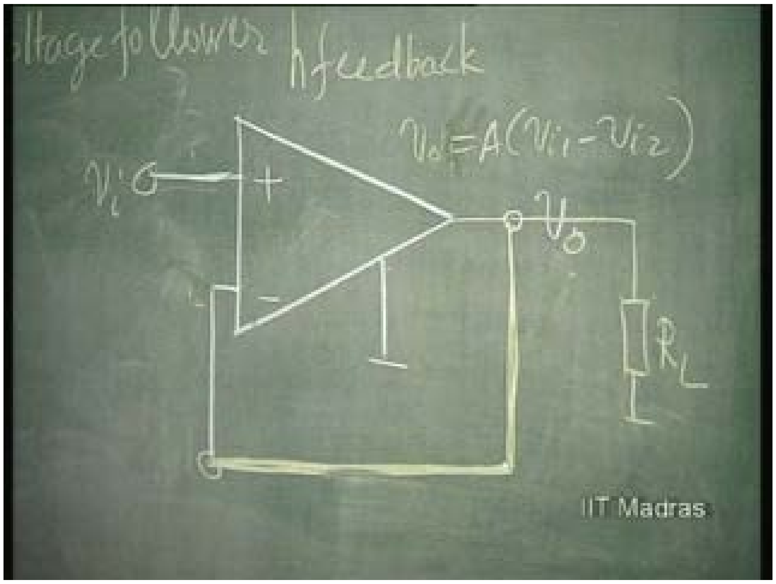

If I now, instead of giving the full output voltage, give portion of the output voltage; instead of giving the full output voltage as feedback, I take V naught and attenuate it by a network. So here, it will be V naught into R 1 by R 1 plus R 2. So, what happens? As far as the op amp is concerned, it does not really bother what you do; as long as you are connecting input to output by some means such that it is negative feedback; it will make this voltage equal to this voltage.

What it means is V i now equals V naught into R 1 by R 1 plus R 2 or V naught over V i now becomes equal to 1 plus R 2 over R 1.

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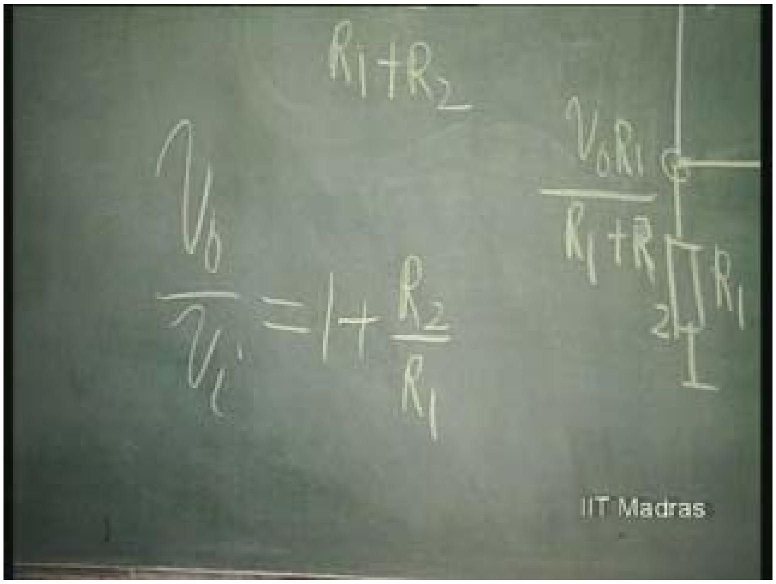

That means this is called an amplifier, non-inverting. Non-inverting because if this is sinusoidally changing this way, you will have this also having the same phase as this. So, this will be sinusoidal, let us say. This also will be sinusoidal but amplified. This input and this output - they will be in phase. That is what is meant by non-inverting amplifier Amplifier. The amplification factor is 1 plus R 2 over R 1. If R 2 is made equal to, let us say, 10 K and R 1 is equal to 1 K, for example, you have now designed an amplifier with gain equal to 11, very easily.

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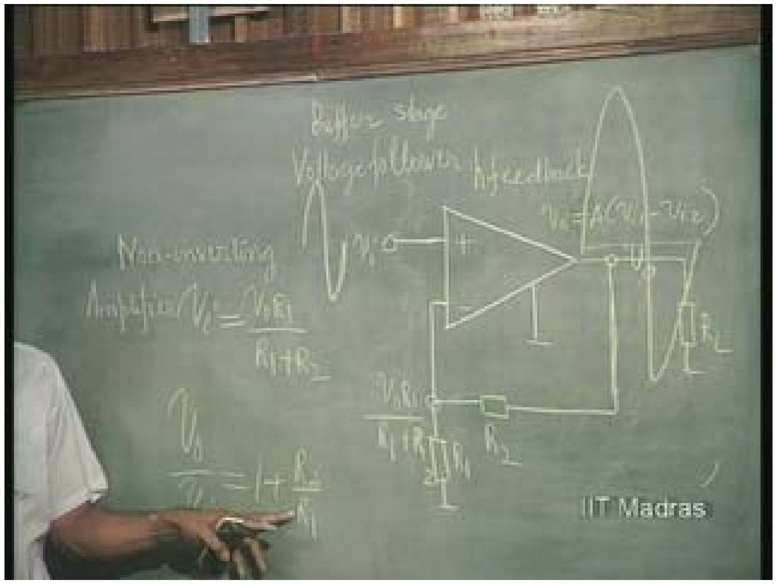

The biasing, etcetera, these are automatically taken care of. If you bias it plus V s and minus V s, the person in…who has designed this op amp has taken care that it is biased properly. The output is zero when the input is zero; no offset or very low offset.

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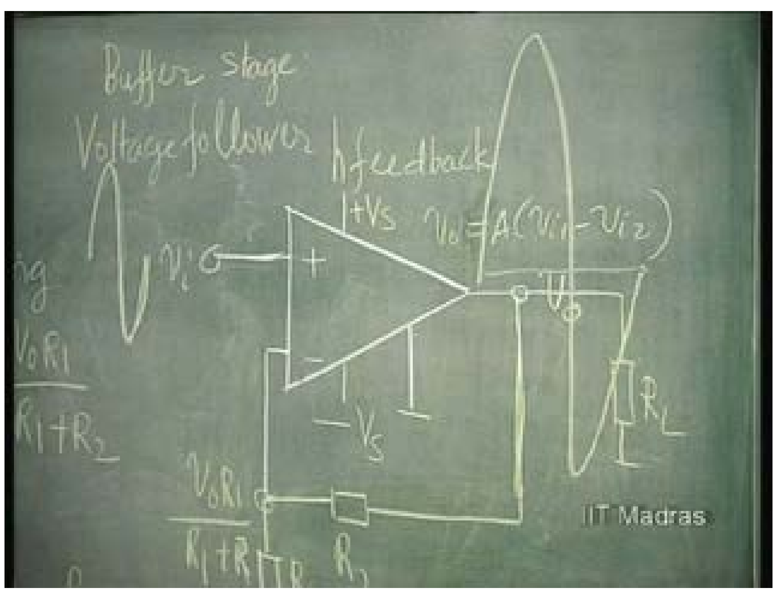

So, you do not have to bother about how to bias it, etcetera. It is enough if we simply design the external circuitry here. R 1 is equal to, let us say, some resistance; R 2 is equal to some resistance; so that the ratio of R 2 over R 1 is the one what fixes the K here.

If you consider A is not infinity, then what will you get? That also we can evaluate. Then we get V i 1 as V i minus V naught into R 1 by R 1 plus R 2. Now, A is not infinity. So, times A is equal to V naught. So, V naught over V i now becomes equal to A divided by 1 plus A into R 1 by R 1plus R 2.

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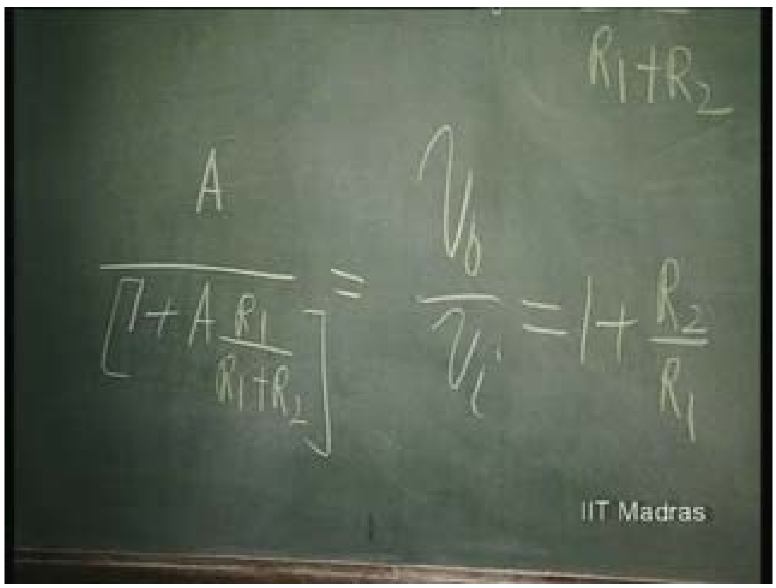

So, A was the amplified gain before feedback. Open loop gain it is called. The gain with feedback is therefore… gain with feedback is going to be A by 1 plus A into R 1 by R 1 plus R 2. This you can notice… If I ground this from here to here, the amplifier gain is A; and from here to here if I break this loop, this is a loop, feedback loop. So, from here to here, the gain is A; from here to here, attenuation is R 1 by R 1 plus R 2. So, this is the loop gain. This is what we talked earlier also as loop gain. A into R 1 by R 1 plus R 2. This is the loop gain. So, 1 plus loop gain is the factor by which everything gets modified. That is what we have concluded earlier in the feedback.

So, A gets modified to A by 1 plus loop gain. If this is very high, this will come out to be 1 plus R 2 over R 1. That means, A into R 1 by R 1 plus R 2 should be much greater than 1, then this is going to be the .. We will discuss about other configurations in the next class.