Analog Electronic Circuits

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Module No 01
Lecture 31: Analysis of Feedback Amplifiers

We are going to tackle the problem of analysis of feedback amplifiers.

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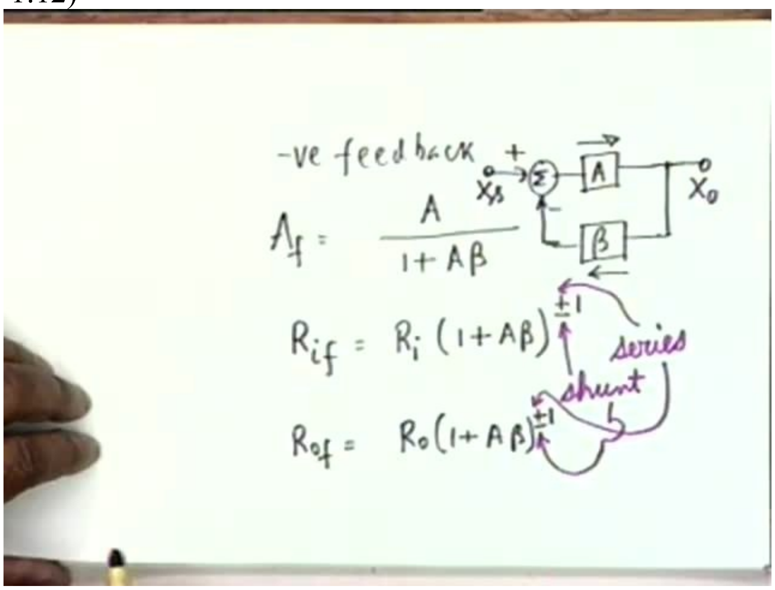

To recall what we did, we said that if there is negative feedbackthen the gain with feedback,Af would be given by the gain without feedback divided by 1 + A beta. This formula was derived by assuming that the forward transmittance is through the A network only and the reverse transmission is through thebeta network only. Then there was a feedback here with this polarity, negative feedback and the output was taken from here and this is the output. This is the input,Xs and this is the out putXo .

The assumption was that the forward transmission is through the A network only, reverse transmission is through the beta network only. In addition,A beta and the summing operation or the sampling operation do not affect the characteristics of A and beta networks. This is implied okay that any of these connections does not affect any other parameters all right. In other words for example, the input impedance of A would-be very high compared with the output of the summer okay. Or that this connection does not affect the A network or the beta network.

In practice, this is not the case and that is why the difficulty arises in the analysis of feedback amplifiers. We also saw that if there is negative feedback, then the output, well the input impedance Rif is equal to the impedance without feedback multiplied by 1 + A beta to the power +- 1 where the + sign arisesif the connection at the input is, the input impedance is increased if the connection at the input is series, that is correct. Series connection increases the impedance, shunt connection decreases the impedance for very obvious reasons.

So the - sign appears for the shunt connection. In a similar manner, the output impedance with the negative feedback Rof is also equal to R0 1 +A beta to the power +- 1. And once again, the + sign arises for series connection and the - sign arises for the shunt connection. All right. This is the basic, this is the summary of what we did. And then inthe last lecture we have taken an example of a feedback amplifier.I am tempted to take another example to showhownegative feedback occurs and how the ideal block diagram that we have drawn is never never obeyed in practice. And therefore the problem arises when you have to make some simplifying assumptions.

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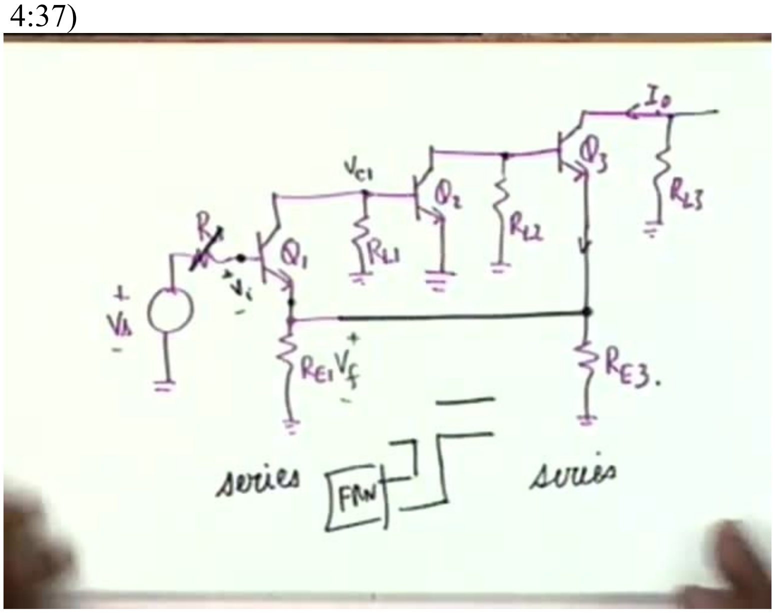

One example of negative feedback, then we shall identify the type of feedback. We have a Vs,Rs, a transistor Q1 which has a resistance, RE1 at its emitter. Feedback will be applied to this resistance. Then, I am not showing the biasing circuits. This is a load of RL1. The amplified voltage is applied to the base of the 2nd transistor Q2whose emitter is grounded, it is a common emitter. The load of the 2nd stage is RL2 and this voltage is used todrive the base of the 3rdtransistor Q3 and the current, there is a load RL3, the current is sampled by means of a small resistance at the base of Q3, we call this RE3.

This current if I had to sample the current, I should have taken from here but I do not because this will load the Q3 and therefore what I do is instead of taking it from here, I take an approximately equal current. You know that this current is I0 by alpha where alpha is very close to unity. Alpha is beta divided by beta + 1 and this current is sampled by RE3, a small voltage is developed and this current is fed here okay through this. And therefore, the current develops a voltage, you see at the input the connection is what kind of connection?

It is not exactly at the input. It is, the input voltage across the base emitter of Q1 is if RS is 0, VS - whatever voltage is developed here. And therefore it is a series connection. This is the feedback voltage and it is a negative feedback okay. VS yes VS suppose RS is 0, if RS is 0 then the voltage applied here, VI is equal to the source voltage VS - the voltage VF and therefore it is a series connection. Voltages are being combined and it is a negative feedback which can be very easily seen. This voltage, VC1 let us say is out of phase with VI, 180 degree phase shift. Therefore this voltage would be 360 degrees phase shift. Agreed? Which means that this voltage is in phase with VI and then this current shall be in phase with this voltage or out of phase?

Student: Out of phase.

Student: Out of phase.

Professor: oh, no.

Student: In phase.

Professor: In phase. The current is in phase, the voltage across this is out of phase.

The current is in phase and therefore this voltage is in phase with V sub I okay and therefore this voltage is in phase with V sub I and that is why it is negative feedback. The polarity of VF, if VI is of this polarity, then VF is of the same polarity which means that VI is equal to VS - VF and therefore it is negative feedback. And the connection is series and what are the output? What connection is it there at the output? Current is being sampled. So.

Student: (())(8:31)

Professor: no. It is a series. You have forgotten. The current sampling shall occur like this. This is what goes to the feedback network right?

So it is a seriesconnection. The input impedance would be increased, output impedance would also be increased okay. Right, this is another example. And it requires alittle bit of thinking and a little bit of intellectual exerciseto be able to identify what kind of feedback it is, what kind of architecture it is and once you identify the architecture and once you identify the A network, you see the A network is far from clear from here. It is a total feedback network. What is the A network and what is the beta network, is not very clear. How to determine capital N? How to determinebeta?

Student: Sir.

Professor: Yes.

Student: Why do we need an RE1 at all over here?

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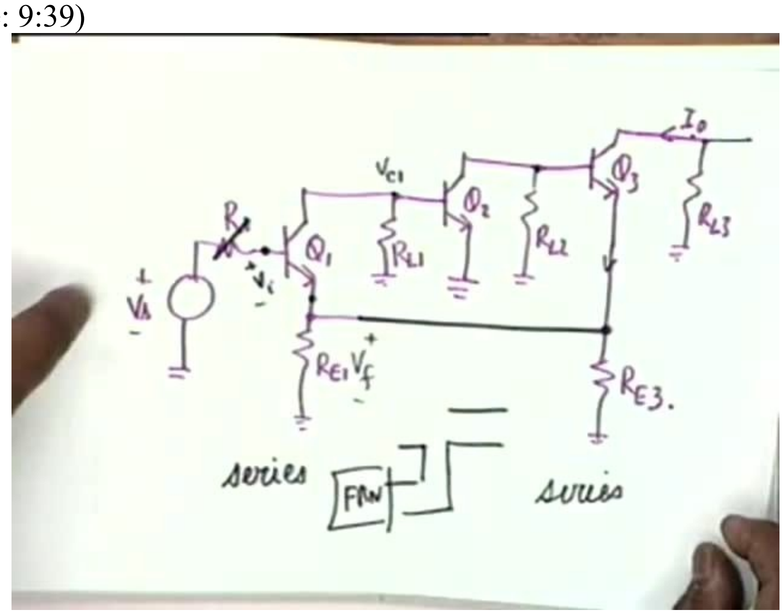

Professor: Why do we need an RE1? Otherwise, how would this voltage be dropped.

Student: That will drop across RE3.

Professor: Oh, across RE3. Well, we do not do this because then emitters of Q1 and Q3 shall be coupled by a small resistance. We might like to control the gain of Q1 by RE1 which shall not be possible if we have a single transistor here okay. It is actually the parallel combination of RE 1 and RE 2. We might like to control. You see if this feedback is cut off then we shall get the A circuit with some modification. The gain of the A circuit, I may want to control RE 1 as well as RE. Agreed? So we do not connect that directly.

Now before we go to the identification of the A circuit andbeta circuit, let us take, we shall take these 4 architectures one by one.

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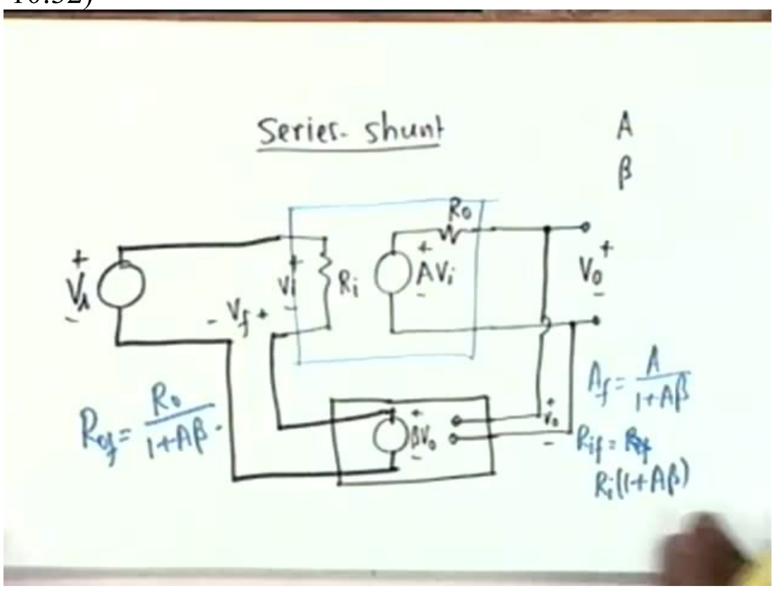

1st let us say series shunt. We will say about the ideal architecture is and what the practical architecture is and how the practical one can be modified to suit the ideal one for the identification of the A circuit and beta circuit. So in a analysis of feedback amplifier all that you have to do is to identify the A circuit and the beta circuit. Once we do that, the gain, the input impedance, the output impedance, everything would be found out. Let us consider the series shunt. If it is series shunt, then what kind of basic amplifier would be most suitable for this?

What kind of basic amplifier model? Series means voltages are being compared and shunt means voltage is sampled. And therefore voltage to voltage, in other words a voltage amplifier. Is the point clear? The model that will take is that of a voltage amplifier, that is RI, VI and AVI, then we might have a small output resistance, R0. This is the basic amplifier, then we apply the feedback. Now in the feedback we assume that the output is open, that is the ideal case.

Then the total voltage, AVI shall drop here okay and we are taking a shunt and therefore we go like this, series shunt, this is V0, this V0 comes here and we have the feedback network and the feedback network, the ideal case would be, if the feedback network does not load the input, that is V0 is applied here, V0 and the output, ideal case would be if I have a beta V0, this is the beta network, a fraction of the output voltage is fed to the input and let us say we make this a negative feedback connection, then VS and it is a series connection and therefore where would this go?

To the upper terminal or the lower terminal? We want negative feedback. To the upper or lower terminal? Upper one, obviously. Otherwise it wouldnot be negative feedback. Then VF is like this,+ and - okay. I have drawn a negative feedback connection. So VI is equal to VS - VF. Right? VI + VF is equal to VS and therefore I have made a negative current negative feedback. This is the ideal case in which the A circuit and the beta circuit are obvious all right and wehave seen that well can you tell me what would be the, the gain with feedback of course would be A by 1 + A beta.

There is no problem in identifying the A andbeta circuit. The RIF, would it be increased or decreased? Series connection. Therefore?

Student: increased.

Professor: increased. RI 1 +A beta and the output would be.

Student: decreased.

Professor: decreased. So R0 divided by 1 +A beta okay.

If the circuit is like this, it is wonderful. There is no effort needed but the practical circuit is quite different and that is why, the problem arises and I want you to be in tune with me, not out of phase okay. To be in phase.

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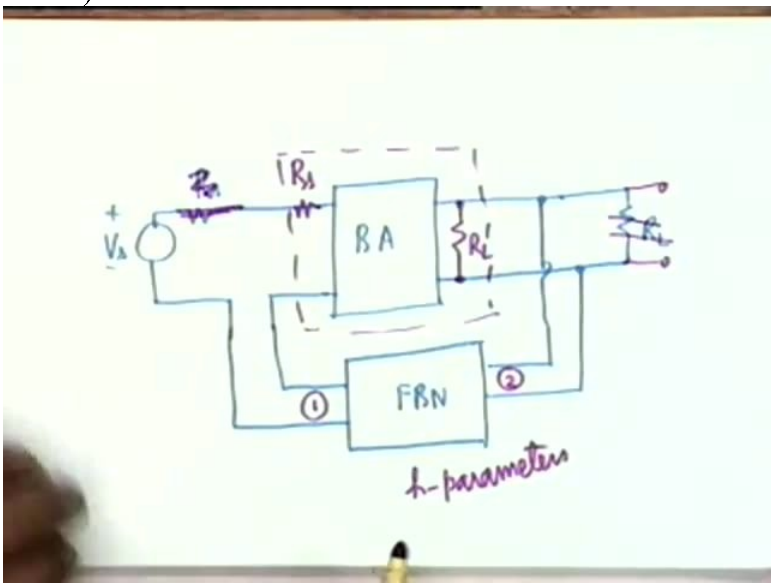

A practical circuit. In a practical circuit, you shall have a VS and a source resistance okay. I have a series feedback. The basic amplifier is this, basic amplifier which is not a voltage controlled voltage source, ideal voltage controlled voltage source. It has other imperfections. And then the output is not usually open circuited. There may be a load, R sub L. It is a series connection at input, shunt connection at output. So you have, this is the feedback network FBN and the output is connected like this.

The feedback network usually, to complicate matters usually is passive, usually is passive andmost of the times if it is an amplifier, then it would be a resistive network. And therefore in a resistive network, it shall load the output, it shall load the input and therefore the characteristics of the basic amplifier shall change and beta identification will also be difficult because RS also shall affect the feedback network. RS and the input impedance of BA, basic amplifier, they shall affect the input impedance of the feedback amplifier, output impedance of the feedback network, both shall be affected by this. And therefore the problem.

You see, one of the things that we can do is 1st, as a 1st step, we can include RS and RL inside the basic amplifier. Agreed? We can do that. If I do that, then what will happen is, this will become an open circuit. That was one of the requirements of the ideal amplifier and I shall bring RL here. Agreed? And instead of RS here, Iwill make this an ideal source by including RS inside the basic amplifier. So my modified basic amplifier would be this. This I can do by inspection.

The A circuit shall now include RS and RL. This is this but the story is not over here because the feedback network will also contribute to the characteristics, the change of characteristics of the basic amplifier and let us see how this can bethis can be done. The feedback network as I said is usually passive. Let us denote, it is a 2 port network, let us denote this as the 1st port and this as the 2nd port and the characterisation that we choose of the feedback network is that of H parameters.

Have you done H parameters?

Student: yes.

Professor: Well, I have done it in this class. So you cannot say no. H parameters. Why H parameters shall be obvious once we draw the circuit.

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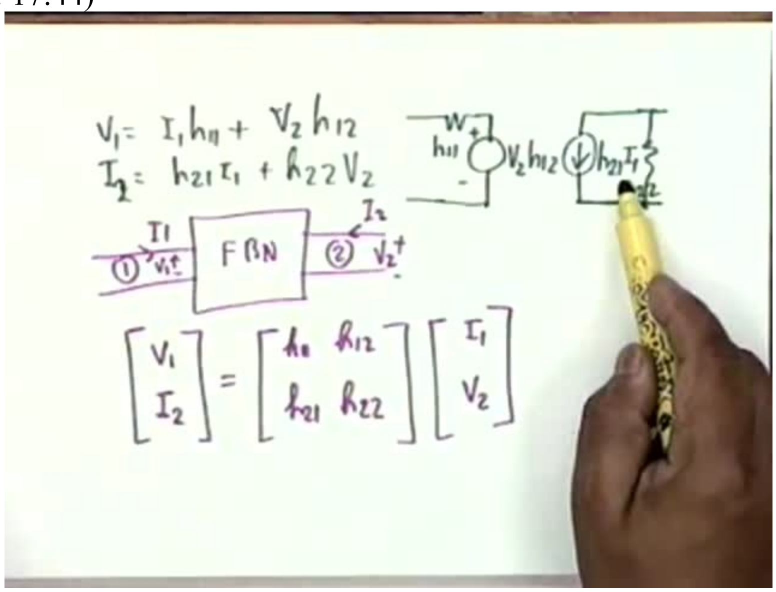

As you recall, if the feedback network is like this, this is port 1, port 2 which means that V1, I1, V2, I2 and what we do is V1 in the H parameters is a hybrid parameters, the input voltage and the output current. These are the signs of the input and output. The output currents, the current enter the network and the voltages are positiveat theupper terminal. You know the H parameters. Connect V1, I2 to I1 and V2. And these parameters are H11, H12, H21,H22 all right. This is the definition of the H parameters. If I write the corresponding equations, I have V1 equal to I1H11

+ V2H12 and I2 equals to H21I1 + H22V2 okay. Has 2 ports parameters been taught in circuit theory?

Student: Yes.

Professor: Oh, it has been taught, then I do not have to, my job is simpler. But nevertheless you recall that if I want to draw an equivalent circuit of this, the equivalent circuit would be something like this. You have an H11 then in series with a source V2H12 agreed? This describes the input.V1 equal to I1H11 + V2H12 and the output is output is I2 is equal to H21I1, then in shunt with a resistance of 1 by H22 but an admittance of H22. Let us recall let us keep this as H22. This is the equivalent circuit. Now one can understand why for the series shunt. Was it series shunt? Yes.

For the series shunt feedback amplifier, we used the H parameters because it offers a series circuit at its port 1 and you recall the connection at port 1 along with the basic amplifier is a series connection. So I have a series circuit replacement for the feedback network at port 1 and at what to, shunt connection, I have a shunt circuit at. This is the reason. All right? And therefore, myamplifier, nowone more point. You see, since H11 comes in series, I want you to bevery attentive at this point.

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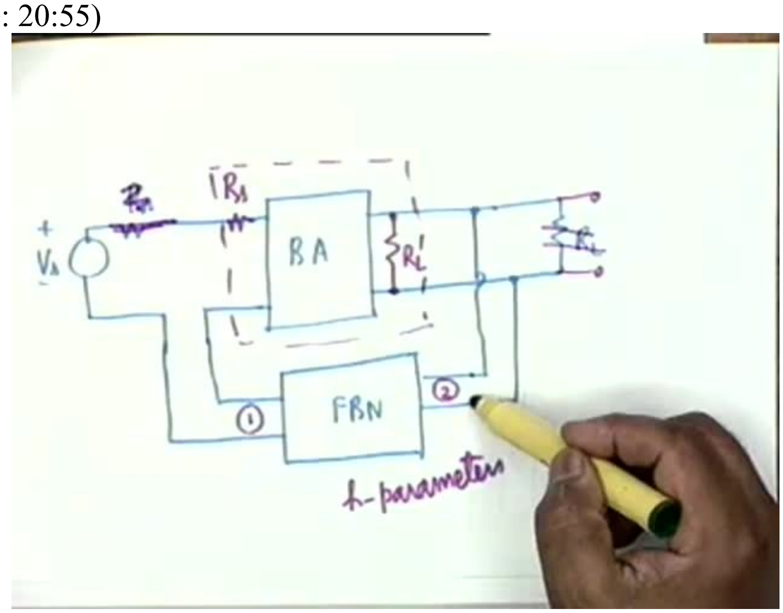

Since H11 comes in series, whether it is in series with this wire or here, does it matter? It does not matter. And therefore H11 can also be absorbed in the basic amplifier. In a similar manner, H22 occurs across port 2 and it does not matter whether it is here or here. Therefore H22 can also be absorbed in the basic amplifier. Is that clear?

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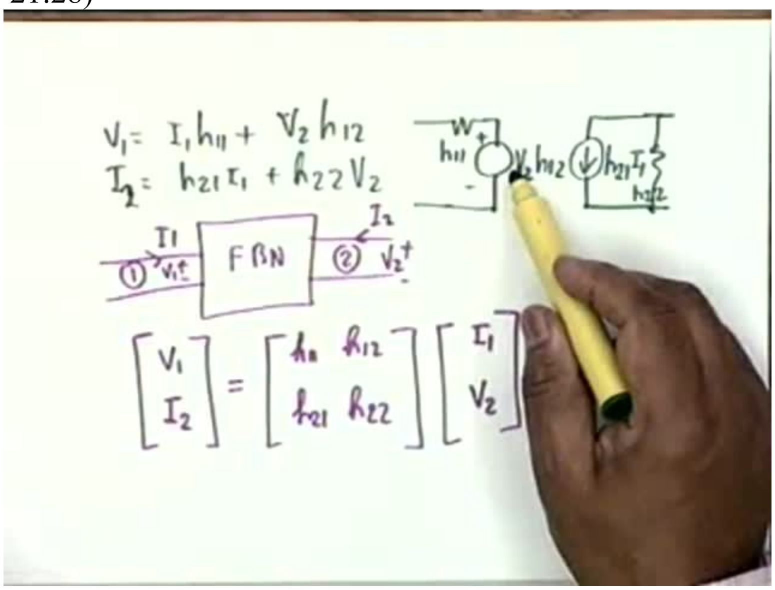

So we will be left with only 2 sources, one is a voltage source,a voltage controlled voltage source and the other is a current controlled current source. Now tell me what does H21 represent? H21, does it represent forward transmission or reverse transmission?

Student: Forward transmission.

Professor: Forward transmission because the current source is proportional to the input current whereas H12 represents reverse transmission.

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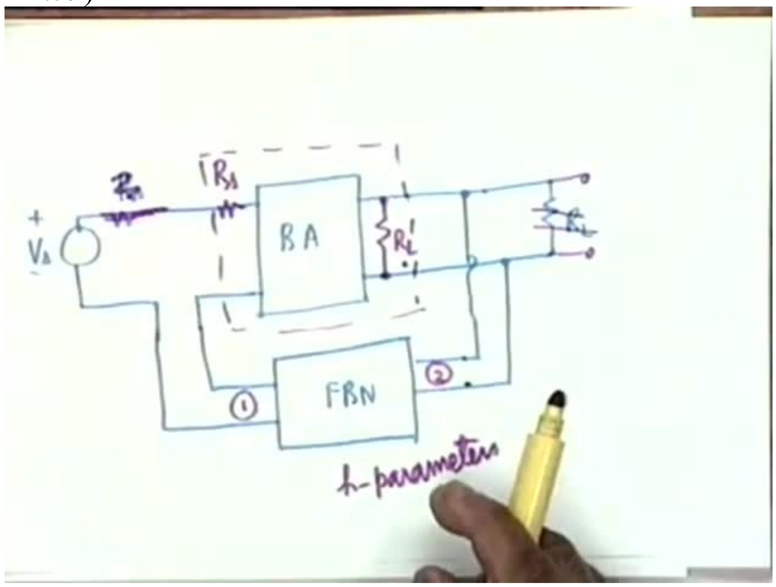

Nowlet me come back here. This explanation…

Student: Sir.

Professor: Yes.

Student: In this case the input is port 2.

Professor: Fine, but I am taking this as port 1 and this as port 2. And this I am calling forward transmission and this I am calling reverse transmission.

Okay, for the total network and for this one also, okay. Now the forward transmission parameter for this which is H21. Of the 2 networks, which one shall dominate in forward transmission? Obviously, the basic amplifier. And therefore, compared to the basic amplifier forward transmission, a forward transmission for the feedback network can be ignored. In a similar manner, the reverse transmission is desired to be through the feedback network and therefore, we must design our feedback network such that the reverse transmission through the feedback network is much greater than the reverse transmission through the basic amplifier all right which we make by using active devices whose reverse transmission is negligible.

You recall, H12 for a BJT is of the order of 10 to the - 4 agreed? WhereasH21 is of the order of how much? H21 for a common emitter amplifier? Come on, H21 is the same as

Student: R0.

Professor: what?

Student: 1 by R0.

Professor: H21.

Student: beta.

Professor: It is beta. It is of the order of 100. And therefore , right from here, with the help of the H parameter circuit, we can ignore H21I1 for the feedback network and retain only H12V0. If I do that, let us see what the circuit becomes.

Student: Sir will you please show that?

Professor: Show what?

Student: The right-hand side, the top right.

Professor: Oh, this circuit?

Student: Yes.

Professor: This is H2.

Student: Sir actually 1 upon H2.

Professor: Hmm okay. We areretaining the admittance for bringing variety into life. We should be able to identify that H22 is not a resistance.

Student: It is a conductor.

Professor:It is a conductor..Okay. Wherever H22 is there, to complicate life, we should be able to get out of it by remembering what it is okay. All right.

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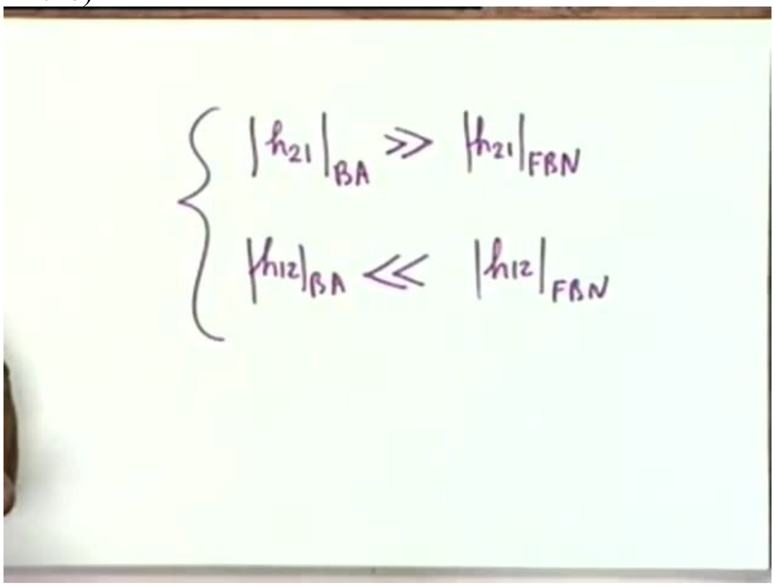

So our basic assumption is that H 21 of the basic amplifier and H21 of the feedback network, I am taking magnitudes because they may be complex quantities, they may be positive or negative, does not matter but H21 of the basic amplifier must be much greater than H21 of the feedback network and H12 of the basic amplifier must be far less compared to H12 of the feedback network. Once these 2 assumptions are justified or are valid, the circuit becomes very easy as you shall see now. We will draw the equivalent circuit. The basic points are that H21I1 is ignored, H12 V2 is retained,H11 is absorbed in the basic amplifier and H22 is absorbed in the basic amplifier at its output port.

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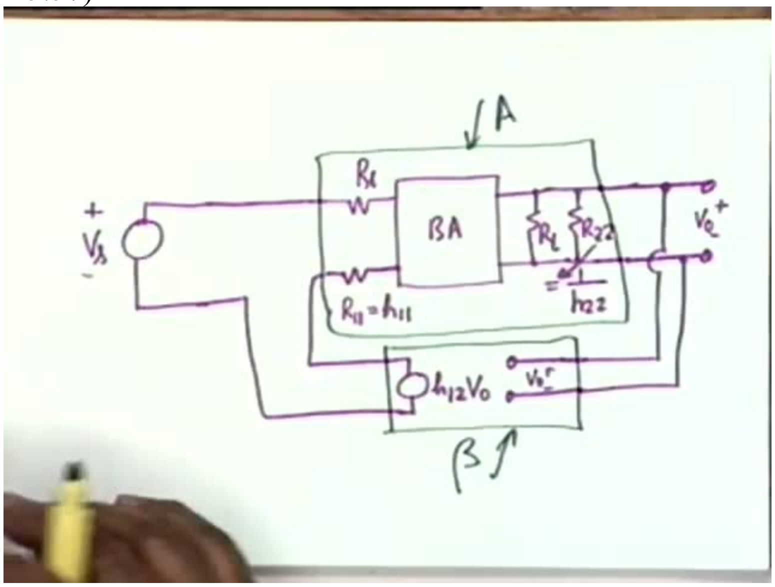

If we do that, then our circuit becomes the following. VS. No RS. RS has gone into the basic amplifier. And in addition, another resistance has come here. What is this resistance? We call this R11. We modify the terminology which is simply equal to H 11 of the feedback network, then the basic amplifier, this is the basic amplifier. The basic amplifier now has 2 resistances in parallel, one is RL and the other is R22 which is equal to now we shall identify 1 over H22 okay. So this is what this is the modification. Then the output as we required is open circuited and there is a series connection now and in this, what we have retained is H12V0, if this is V0 and what have we retained here?

Student: H22.

Professor: Not even H22. H22 has been taken care of here. Nothing. It is an open circuit. Nothing else because the current source has been ignored,H21 I1 has been ignored. It being small compared to the forward transmission through the basic amplifier.

Now you see, if we identify this as our A circuit, this green contoured one as our A circuit and this ass the beta circuit, our job is done. It is in fact identical to the ideal series shunt diagram, ideal series shunt architecture. So in the identification of the A circuit in a practical case, these are the steps to be done. This is not an exact equivalent. Why not? Because we have assumed this and this to be unilateral. We have ignored the reverse transmission through the basic amplifier and we have ignored the forward transmission through the beta circuit.

So it is not identical but this is very nearly the same.

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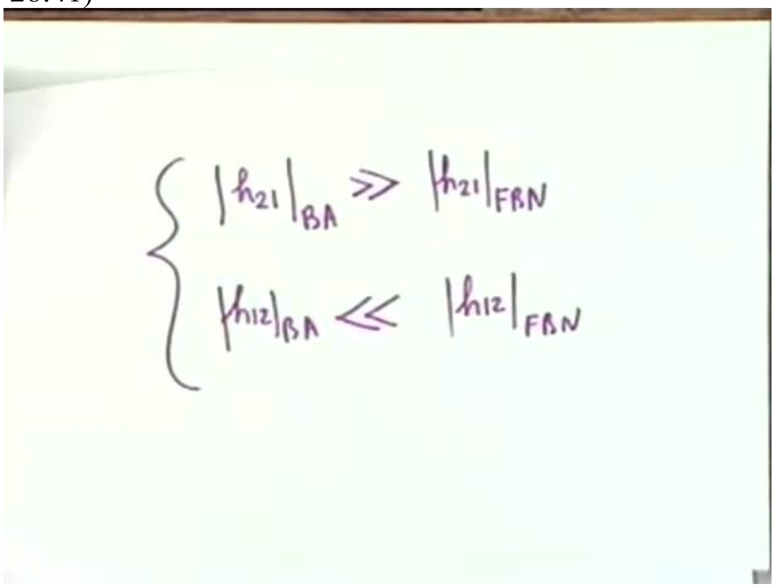

That is, the approximation is of a higher order provided the only thing that is to be obeyed are these, these 2 conditions.

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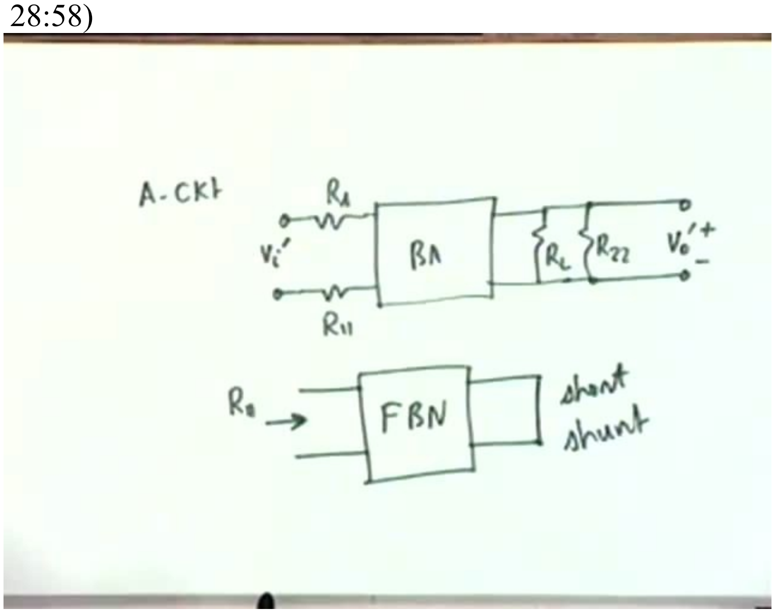

We will take an example to illustratehow to do it in practice but you notice that if I summarise theA circuit, I am repeating. A circuit includes RS, includes R11, basic amplifier okay, the input is to be applied here. Let us call this input as VI prime okay and the output shall have an RL, an R22, then this voltage let us say V0 prime, this is the A circuit, no feedback. Okay, this is the A circuit.The gain A shall be V0 prime divided by VI prime. Do you understand why primes have been used?

Okay, because this circuit is the inner circuit of the feedback amplifier. This voltage is not the same as the voltage output of the feedback amplifier. This is the amplifier without feedback where R11, how do you measure R11? It is the input impedance of the feedback network with the output shorted. The short will always occur, I beg your pardon whenever there is a shunt connection, short will come from shunt. SH comes as short. This is true for all the architectures. So this is R11.

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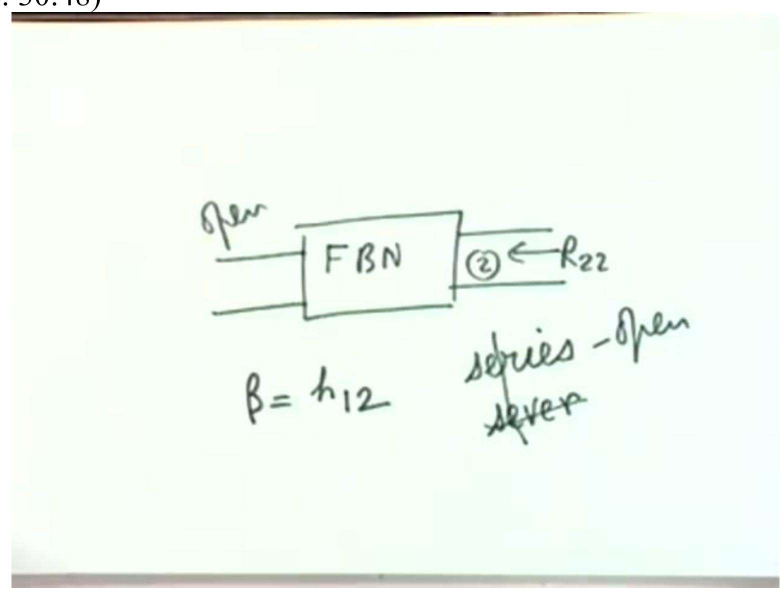

How do you measure R22? You have the feedback network. What do you do here at the output? Pardon me.

Student:(())(30:57)

Professor: This is open. You have to measure R22. R22 is the resistance if impedance looking at Port number 2 with port 1 open. Now port 1 open means it destroys the feedback.

Similarly, port 2 short also means it destroys the feedback. Butthe rule that you will see is, in series connection, the corresponding procedure would be to S E V E R, sever the connection. SE for SE okay. This isa medicine for remembering but series is open circuit. You have to open it and if the shunt connection then you have to short it. You will see that this is true for all the architectures. Finally, the beta network. How do you find the beta network? Beta network. What is identification of beta in this case? Beta is the same as H12.

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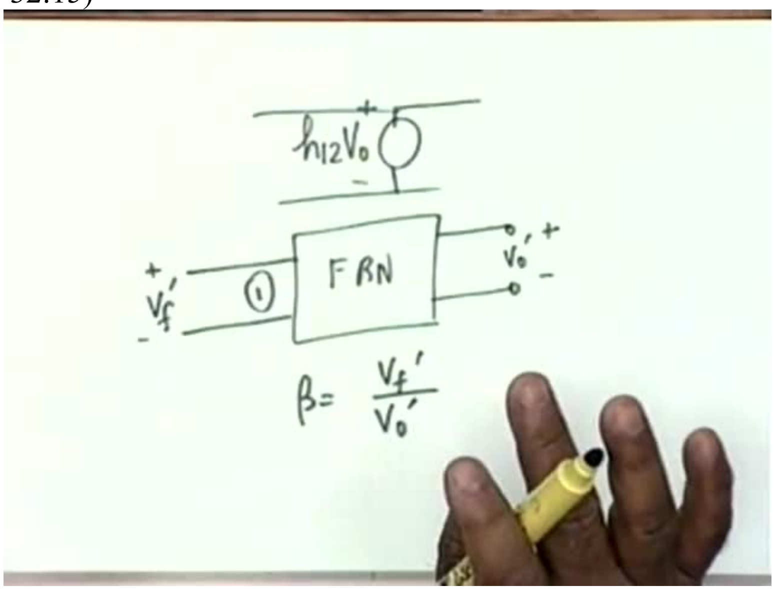

Beta is the same as H12 which meansthat the feedback network, you have to apply a voltage or a current? Voltage. You apply a voltage V0 prime, some voltage V0 prime and then would you keep this open or short?

Student: Open.

Professor:Open. And measure what?

Student: The VF voltage.

Professor: The voltage. We call this VF prime.

Student:H12 beta or H21 beta?

Professor: H12 is beta. You recall that our circuit was H12 V0.

Student: This is for reverse transmission.

Professor: That is right. This is the reverse transmission. Do not confuse this with beta for transistor. That is a different story. This is beta, a fraction of the output voltage that is fed to the input okay. So beta is equal to VF prime divided by V0 prime by keeping port 1 open. Open, that is right, by keeping port 1 open.

And this is the story in all the architectures. Whenever there is a series connection, to find out the beta network or to find out R22, you have to keep it open. If it is a shunt connection, then you short it. Ifthe input was short, then you will see that you will have to measure the current for beta network okay. But let us go ahead with this series shunt connection. We takean example to illustrate this. Is there any question at this point of time? Any question? What we do is, we let me summarise.

We absorb RS and RL and H11 and H22, inside the basic amplifier. That leads a skeleton into feedback network. That skeleton is an open circuit voltage, an open voltage V0 and an output voltage beta times or H12 times V0 okay. Therefore A circuit and beta circuit are identified and we can then find out the feedback gain, the input impedance with feedback and the output impedance with feedback. Let us see a very simple amplifier.

Professor: Yes?

Student: Why have not you considered the loading of the basic amplifier on the feedback amplifier?

Professor: Why did not I consider the loading of the…?

Student: Basic amplifier on the feedback network.

Professor: Oh, we have. Let us go back. Okay. What would you like me to consider?

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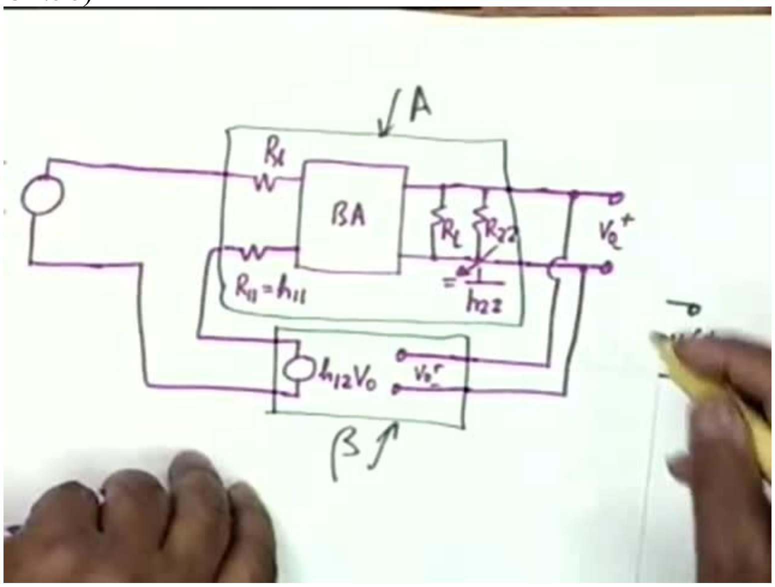

It is this voltage which appears. It is this voltage which appears which is fed to the feedback network and this voltage is V0. So all this loading is there. V0 occurs, the voltage here the voltage at the output of the beta, BA network, basic amplifier, is AVI agreed? Through R0 it becomes dropped in RL and R22 and this is V0. So I have already considered the effect of loading by the basic amplifier on the feedback network. But for convenience of analysis, I have considered all this loading to be inside the basic amplifier and absorbed it.

This is for convenience in analysis.

Student: Sir, why we are using VF prime in the last one?

Professor: Because this may not be exactly equal to VF. It is the feedback voltage. Okay. The feedback voltage is the voltage that is developed here if you make a series connection here. H11 should have been included here okay but for convenience in analysis, I had absorbed it in basic amplifier many circuit and I am considering this as my beta network. I have to bring it to to become similar to the ideal architecture. All right? So this is how I identify. Let me take an example, things would be more clear hopefully.

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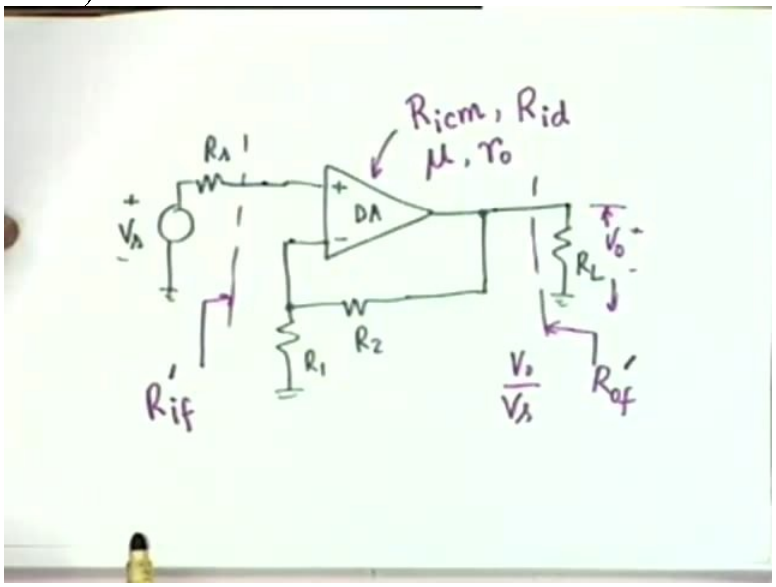

The example is that of a differential amplifier. A differential amplifier, as you know it has two inputs , inverting and non-inverting corresponding to the 2 bases of the emitter coupled pair and the input is connected to VS, RS, the noninverting terminal and the inverting terminal is connected to a resistance R1 and a resistance R2, obviously this is feedback. And the output, to the output and the output is connected to a load RL. Okay. Thequantities that are required to be found out are if we call this as V0, we want to find out V0 by VS okay.

V0 by VS, that is the gain of the amplifier, we want to find out what impedance source sees,Ri, obviously this is with feedback. So let us call this as RIF prime. You will understand why I am saying prime now. I am not saying this is AF. I am simply saying, I require V0 by VS because I shall have to identify what is A, only then I will be able to find out AF. And AF may not be V0 by VS. It may be something else as we will see in a minute. One has to be very careful about notations and one has to follow strict discipline. Even then you get approximate results. But the discipline, if you do not obey the discipline, then of course you are gone.

And then I also want to find out what the impedance RL sees. I will call this also ROF prime. You will see why I am calling ROF prime later. The differential amplifier, it is given that the differential mode input resistance is RICM and that, I am sorry, the common mode input resistance is RICM and the differential mode input resistance is RID. It is given okay. It is also given that the open circuit voltage gain, differential mode gain is mew, that is A sub D is equal to mew and that the output resistance of the differential amplifier is small R0. Capital R I shall using for the basic amplifier, for the feedback amplifier and so on.

So I use this symbol small r. I also do not use capital A for obvious reasons right? Because I do not want to confuse. These are the parameters of the basic amplifier. Basic amplifier is a differential amplifier. Now to solve this problem, you see this is a series shunt because I am sampling a current. I am sampling the output current, it is a shunt connection. And there is a series because the the voltage that is applied between these 2 is the input voltage - the voltage that appears across the inverting terminal. So it is a series shunt connection.

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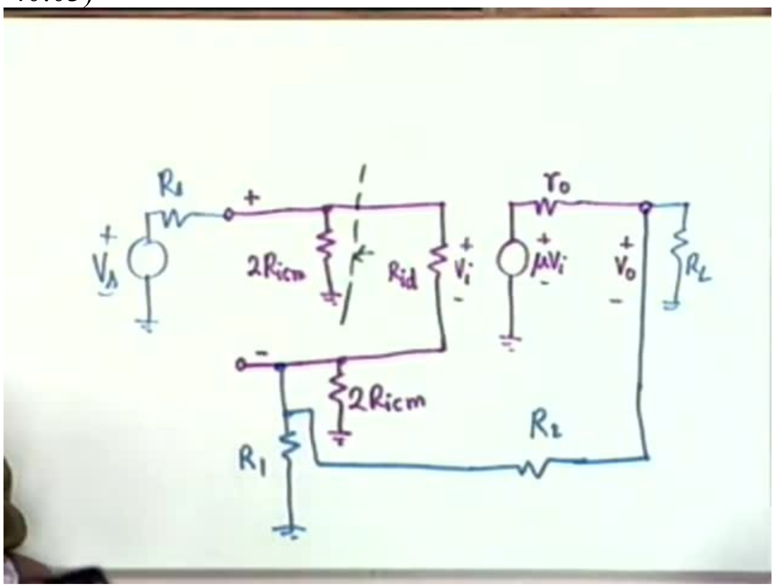

Now the differential amplifier can be modelled like this. PleaseI have not discussed this earlier. I thought this would be an appropriate occasion. Differential amplifier can be modelled like this. A resistance from here, this is thenoninverting terminal. Then the inverting terminal, a resistance from here to ground, thenbetween these 2 obviously I shall have the common mode I am sorry, differential mode input resistance. That is, this will be RID. And the voltage here is V sub I. Can you tell about these resistances would be? RICM, common mode. No. This would be.

Student: RC.

Professor: yes?

Student: RC.

Professor: No.

Student: Twice RICM.

Professor: Twice RICM, wonderful. Why twice? Because when I short these 2, the resistance should be RICM. Okay. You understand this?

Student: yes.

Professor: And these 2 terminals are exactly identical. There is nothing to this comment and therefore we divide them equally. Then the output circuit will be mew VI. Okay, this is the differential mode gain and R0, this is my output voltage V0 okay.

Let us use a prime because this is onlywe will come back. The circuit that we have now, this is a differential amplifier. The circuit that we have now is thatfrom here 1st we have connected to a load RL. Then we have made a connection from here through a resistance R2 to this terminal which is where have I taken? Here. This resistance is R1 all right. And I applied the source RS, VS here. That completes my model? Agreed? Is the point clear? Now that it is not quite similar to the even the equivalent circuit that we have drawn because that is a shunt resistance here.

Agreed? If it was not there, then RS + RID, I could have absorbed the basic amplifier. But it is not too difficult. What we do is we apply Thevenin's theorem to the left of this. Then we have also was in series with a resistance. All right? And I combine R1 and twice RICM. Let us see what happens. You also note that RL has to be absorbed inside the amplifier, inside the basic amplifier.

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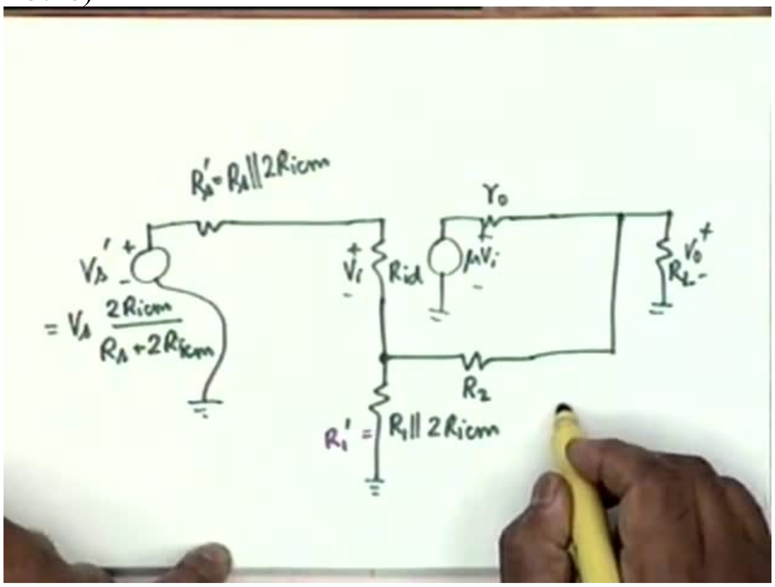

So my equivalent circuit would be VS prime which is equal to VS multiplied by twice RICM divided by RS + twice RICM agreed? This is aThevenin equivalent source. How do I connect it to ground? Okay. VS prime, then in series with RS prime. RS prime is the parallel combination of RS and twice RICM. Then I have the RID, VI and this goes to ground via a resistance, a single resistance which is R1 parallel twice RICM. Agreed? That connects to the output through a resistance R2 and here I have mew VI, a resistance R0, then all right let me draw the total circuit, then I shall identify the A and the B circuits.

This is A and this is B0. You see, this circuit has killed VS. Is not that right? Has killed VS and RS because VS has now been modified by the internal parameter of the differential amplifier, RICM. RS has been combined with twice RICM but there is no other way. We have to identify the basic amplifier in terms of this. In other words, for the basic amplifier, for the A circuit now, our input would be VS prime, not VS and this effective source resistance is this. So I have to include this inside the A circuit.

I have to include RL inside the A circuit and in addition, I have to include two resistances, R11 and R2. What will be R11? If I call this as R1 prime, R11 would be the resistance measured from here with the output, this is the feedback network with the output shorted. Therefore it will be R1 prime parallel R2. On the other hand R22 would be the resistance measured here with this open and therefore it would be R2 + R1 prime. Is the point clear? Let us look at this.

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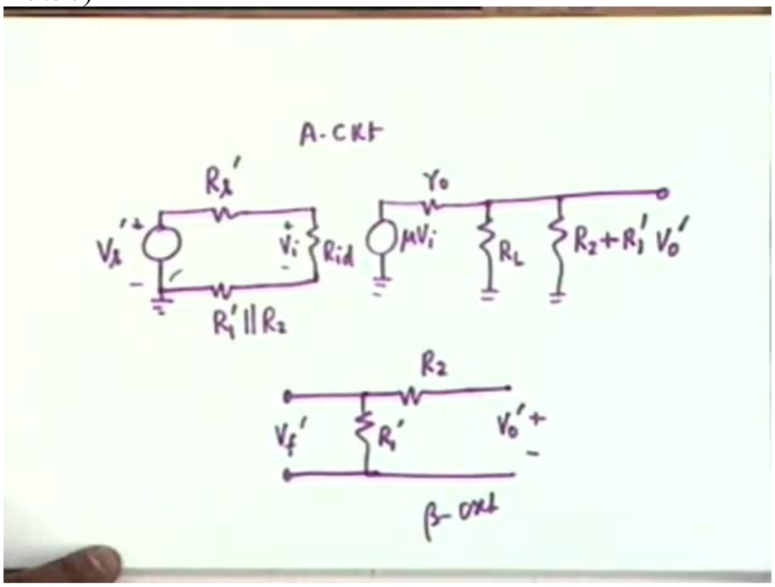

So the basic, the Acircuit would be VS prime, RS prime. No, I made a mistake. All right. RS prime, then RID, then what then? Another resistance which is R1 prime parallel R2 and this is VI. Then we have mew VI in series with small R0, then parallel connection of RL and R22 which is R2 + R1 prime, not parallel. And this is my output voltage and we call it V0 prime okay. Input can remain the same, the output is different. This is my A circuit. Is this clear? We have found out by inspection, the A circuit. And the beta circuit now. For the beta circuit, what is our beta circuit? R2, you have to apply a V0 prime here and you have to measure the voltage across here with these terminals open or short?

Student: Open.

Professor: Open and therefore this is VS prime. This is the beta circuit. Agreed?

We had to do some manipulation to be able to identify the A circuit and the beta circuit. Now what we will have to do is to analyse this for A and analyse this for beta. Obviously, beta is,what is beta? R1 prime divided by R1 prime + R2. A also can be written down by inspection. What is A? Let us see if we can write down by inspection.

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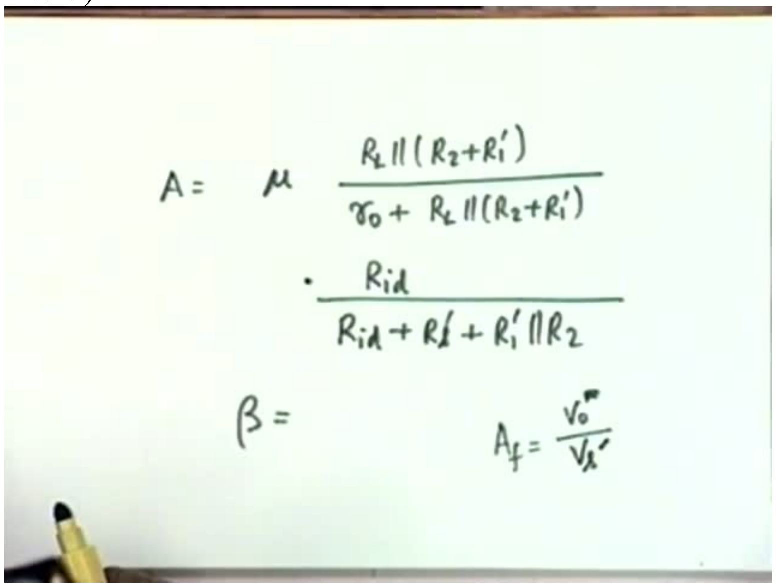

A is, sorry this is mew here. A is mew VI, we shall substitute for VI later. Mew times RL parallel R2 + R1 prime divided by R0 + RL parallel R2 + R1 prime. Is that okay? This is new times this multiplied by VI. But what is VI? VI is RID divided by RID + RS prime + R1 prime parallel R2. So we know A, we know beta and everything else about this circuit is known.agreed? The problem is what we have found out, if we find AF now, what is AF? AF is V0 prime divided by V0 divided by VS prime, not VS. Agreed?

Once we identify this as our A network and this as our beta network, we have found out V0 prime or V0. V0 divided by VS prime that VS prime is different from VS. You recall, there was a Thevenin equivalence but nevertheless, VS prime is very simply related to VS.

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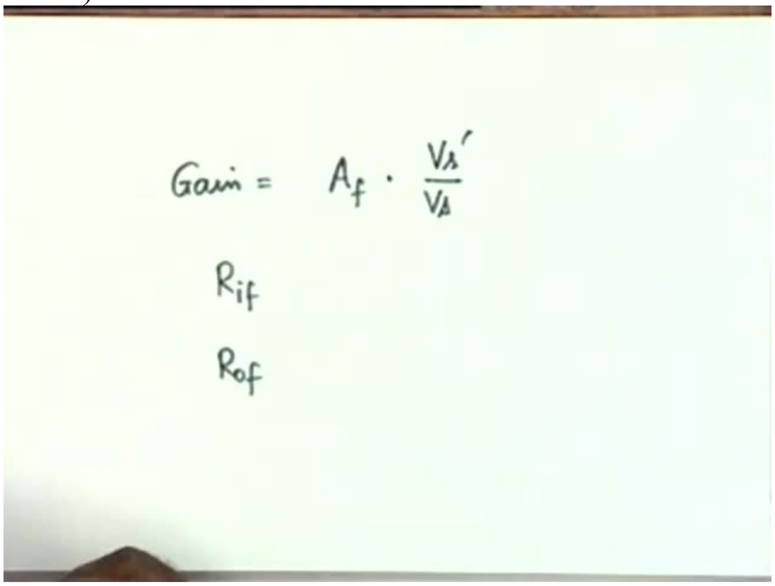

And thereforethe desired quantity, gain of the feedback amplifier would be AF multiplied by yes VS prime divided by VS, which you know, is twice RICM divided by RS + twice RICM okay. Thething is not so easy in terms of RIF and ROF. What is RIF?

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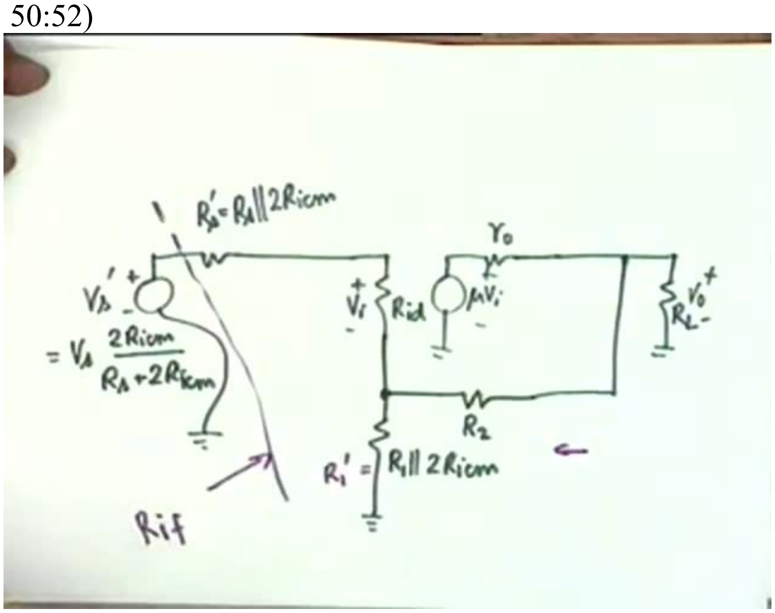

Let us go back. RIF obviously, please do concentrate on this. RIF obviously, let me use a different colour, RIF would be this right? That is, the resistance seen by VS prime in which VS has been killed, RIF has been killed. So I can find out RIF from what is RI?

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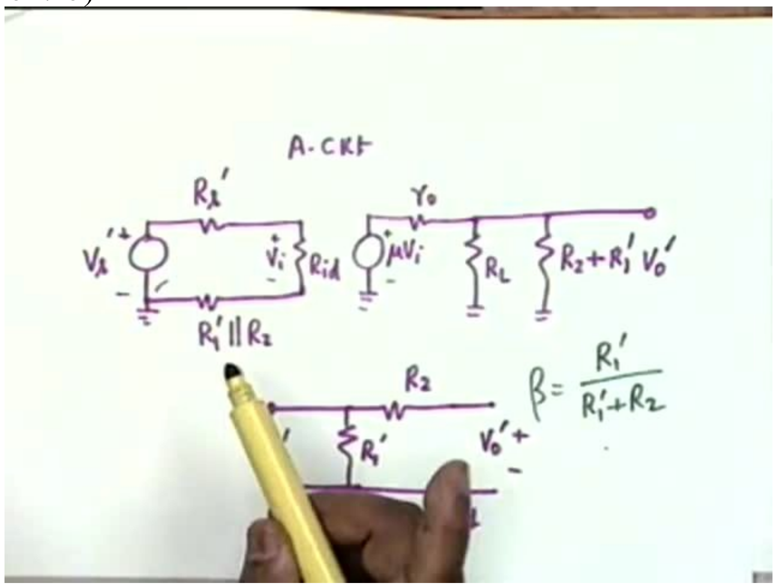

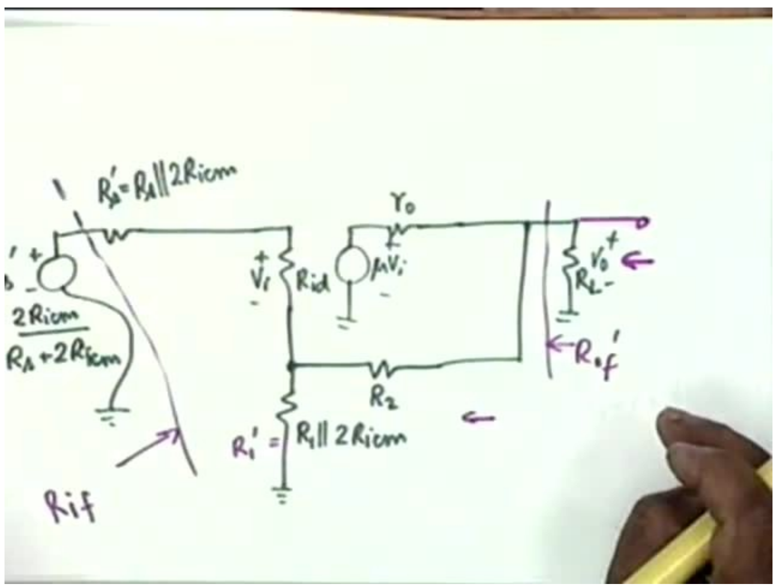

RI, I can see from here as RS prime + RID + R1 prime parallel R2. So I know RI, I know beta, I know A and therefore I can find RIF. I can also findROF. Now what will be ROF now? This is my basic amplifier, this is my basic the A circuit and therefore RIF would include RL. Is the point clear?

Student: (())(51:57)

Professor: yes, ROF. ROF therefore shall be this right.

And if you want to find ROF prime which is seen by the load, obviously you will have to manipulateROF would be ROF prime parallel RL and therefore you will have to find out ROF prime. And this is the reason why I used a prime here. All right. What about RIF? What is the resistance that is seen by the source VS? How do I find that out? So that is also not difficult.

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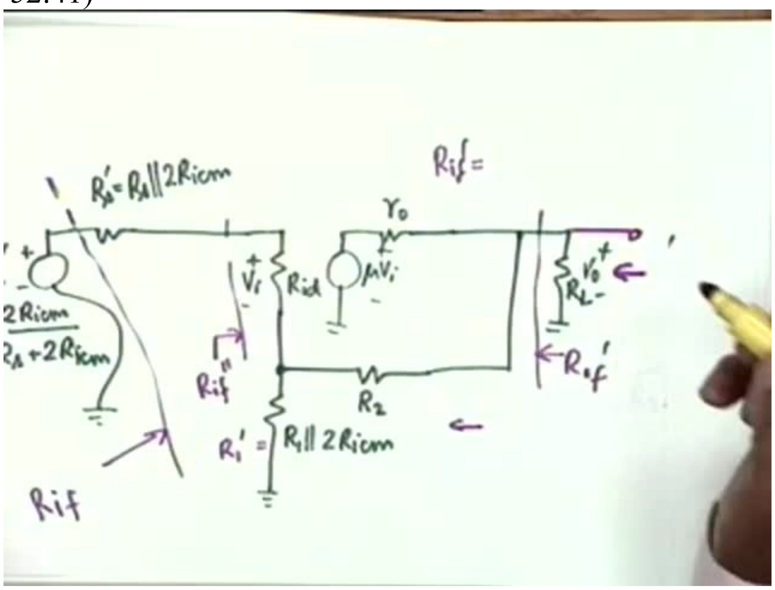

Can you find this out? This impedance, you see RIF would be this + this impedance. Therefore it is possible to find this impedance. Let us call this RIF double prime. Then what is RIF prime? What is the resistance that is seen by VS, VS RS? It would be this in parallel with?

Student: (())(53:08)

Professor: No nono. What was this? What was this? This was VS, RS, then in shunt with twice RICM. Agreed? So what does VS, RS see? It sees twice RICM in parallel with?

Student:(())(53:26)

Professor: Therefore if you can find outROF and RIF for the identified capital a circuit and the beta circuit, you can find out all the quantities that are required. Simple manipulations are required.

But one has to follow a discipline, one has to recognise that A circuit is a manipulated circuit, the beta circuit is a manipulated circuit. The input impedances and output impedances of the A beta circuit that we have manipulated are not necessarily the same as those of the original circuit. You have to go back to the original circuit in a careful manner. And this is the discipline, a strict discipline that must be followed in the analysis of feedback amplifiers. You must also realise that whatever we do, human beings, we can only obtain only approximate results because of that assumption to start with. Feedback amplifiers have posed difficulties in the past for analysis but I think this is a systematic procedure and we shall see many other examples by taking many other examples. Tomorrow we will consider another architecture.