Analog Electronic Circuits
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Lecture – 93
Feedback System (Part-D)

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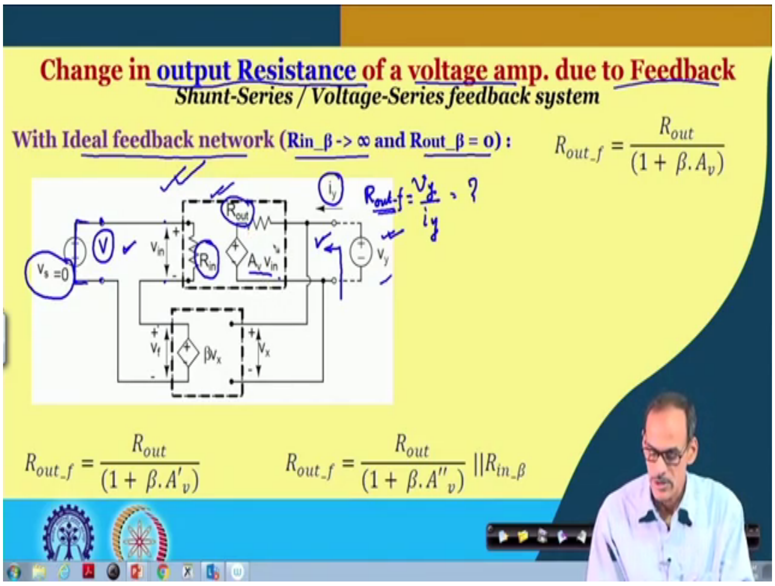

So, yeah dear students, so welcome back after the short break and before the break we are talking about the change of input resistance of the different configuration. And whereas, we are going to talk about change in output resistance to start with let we consider it is a voltage amplifier and we want to see the change due to feedback connection.

And since it is voltage amplifier as we have discussed, the circuit is given here. The configuration here it is referred as shunt series feedback or voltage series Feedback circuit. And to start with let we consider the feedback network it is ideal namely its input resistance, it is infinite and the output resistance as it is producing voltage, output resistance it is 0. However, for the forward amplifier we are considering finite input resistance and finite output resistance.

We do have the voltage dependent voltage source A v into v in, v in it is appearing at the input of the forward amplifier. Now, to know the output resistance what we can do? We can stimulate this output port by say voltage source v y and then we observe the corresponding current say i y and the then port impedance or port resistance it is defined by v y by the corresponding i y. So, that is what we need to find which is R out of the feedback circuit called R out f.

So, while we are doing this exercise we have to keep the input port appropriate. So, that it will support the feedback connection, namely we in this case the signal here it is voltage and so, we do have the ideal signal voltage source connected. However, we have to keep its magnitude, signal magnitude should be 0. Which means that we are essentially shorting this input port while we are doing this exercise to find the output resistance. Now, that is the condition and let we derive the expression of this R out f in terms of R out and probably A v and beta. So, let me clear yeah.

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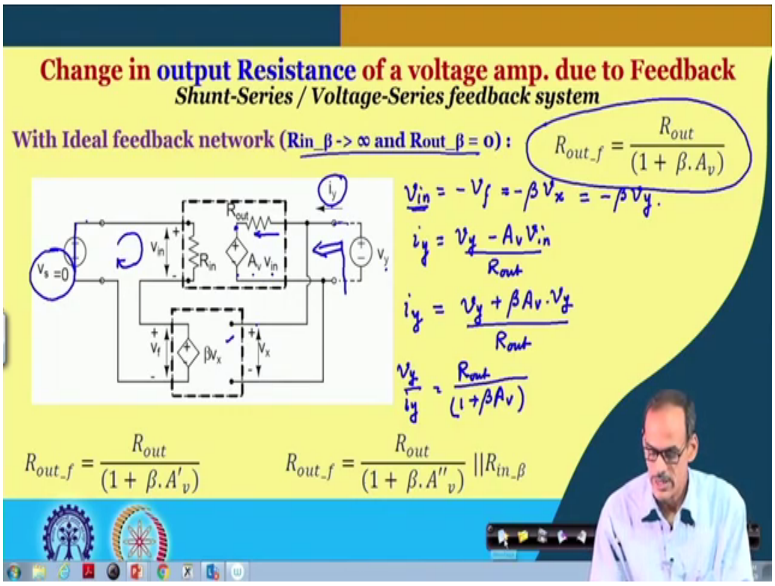

So, if you see if I consider this is short, then if I consider kcl in this in this mixer what we are getting it is v in, input voltage of the amplifier it is minus v f. But then v f it is same as beta into beta into v x; v x is the voltage appearing at the input port of the feedback circuit and v x in this case the moment we connect v y here it is v x it is same as v y. So, we can say that v in equals to minus beta into v y.

On the other hand if you want to know what will be the corresponding current here, if we know the internal voltage which is A v multiplied by v in and here we are applying V y and this is open. So, the i y it is essentially flowing through this R out.

So, we can say that i y equals to v y minus whatever the voltage we do have which is A v into v in divided by R out and v in in this case signal source it is 0 here. So, v in it is minus beta into v y. So, we can see that i y equals to v y plus beta into A v into v y divided by R out. So, that is the relationship between i y and v y, so from that we can see v y divided by i y equals to R out divided by 1 plus beta into A v.

So, this is what the expression of the output resistance of the feedback system due to the feedback connection. And this is what we have talked about it is the ideal condition. Let we consider non ideal situations to start with let we consider that we do have a source resistance called R s. So, let me create the space, let me erase it.

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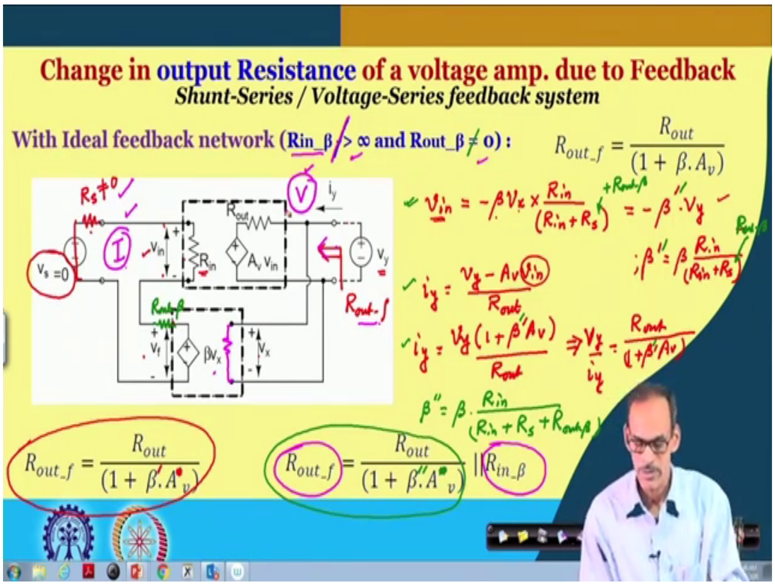

So, to get the output resistance; to get the output resistance R out f in presence of a series resistance called source series resistance called R s and of course, we have to keep the signal here it is 0, so; that means, it is getting shorted like this.

Now, in this condition; v in, the input voltage at this port it can be written in terms of beta into v x. In fact, it is minus beta into v x and then the voltage appearing here it is a part of this voltage and the fraction it is decided by the potential division getting created by R in and R s. So, we need to multiply this by R in divided by R in plus R s. So, V x again it is same as V y. So, we can replace this v x by v y and beta into this factor we may call it is a beta dashed.

So, beta dashed multiplied by v y, where beta dashed it is equal to beta into R in divided by R in plus R s. So, whatever the previous discussion we already have namely i y equals to v y minus A v into v in divided by R out that is valid in this case also and then if we replace this v in terms of beta dashed into v y from that we can get i y equals to v y into 1 plus beta dashed into A v divided by R out.

And that gives us v y divided by i y equals to R out divided by 1 plus beta dashed into A v. So, that is the output resistance under this condition, in presence of this R s, where beta dashed it is given. In fact, this is a typo so, it should be beta dashed not A dashed so, it is A v. So, we do have A v here. Now, if we also have to consider say finite value of a this resistance, so if I include say this resistance as well.

So, if I consider R out of the beta network R out beta, then this relationship it will be getting changed and the change it will be R in it will be there and then R s and R out beta it will be coming in series. So, along with this we need to put plus R out of beta and the corresponding beta we can call it is beta double dash where beta double dashed expression it is beta into R in divided by R in plus R s plus R out beta.

And again this equation it is remaining same and this equation it becomes beta double dashed here and rest of the things it will be same. And here it will be double dash where beta double dashed it is beta into R in divided by R in plus R s plus R out of beta network.

So, that is what we will get the output resistance in this form again I made this typo typographic error, so double dash it will be on beta. Now in addition to that if we have this resistance it is also finite, so if I consider this is also finite. So, I need to put this resistance and if there is resistance it is say some R in beta, then the situation here it will be and the output resistance it will be, whatever the situation earlier it was there and then I have to consider this additional resistance there.

So, that resistance it is coming in parallel to whatever the resistance we just now we have considered. So, if we consider this is nonzero, this is finite, this is also nonzero, then the output resistance expression it is given here.

Now, this situation the expression of R out it will be similar for the configuration where the voltage here it is or the signal here it is voltage and in case this mixer this port it is getting changed to current then also the expression it will be similar., it will not be same, but it will be similar. And in that situation since the signal here it is voltage and here it is current of course, it will not be voltage gain amplifier, it will be rather the current is getting converted into voltage; that means, it will be trans impedance amplifier.

So, in the next slide we will be talking about change of output resistance of a trans conductance trans impedance amplifier due to the feedback connection.

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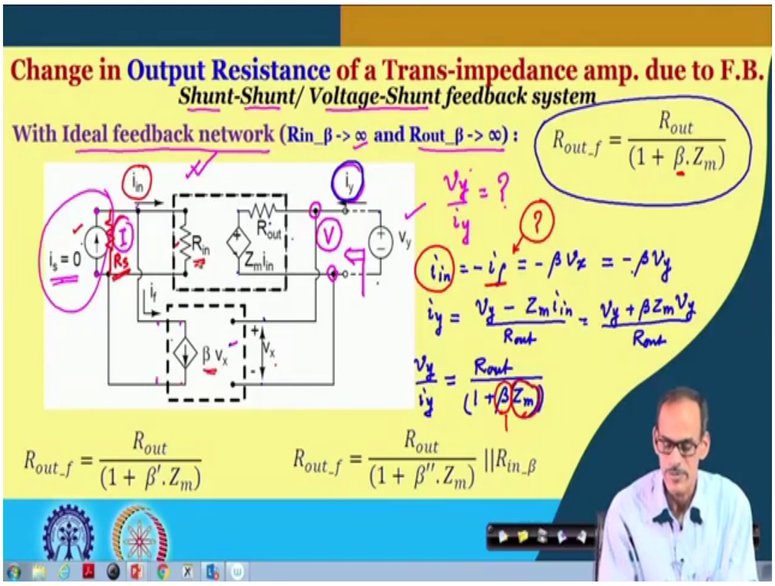

So, here we do have the circuit. So, the this configuration the configuration is given here, it is at the sample side we do have shunt connection and also at the mixer we do have shunt and hence it is called shunt feedback configuration or we may say that here we do have the signal in the form of voltage and the signal here it is in the form of current. So, we are having this voltage shunt-shunt feedback system.

Now, in this system to get the output resistance, the you know we are stimulating this output port by v y as we have done before and we like to observe the corresponding current entering to the circuit and then we have to take the ratio of this v y divided by the corresponding i y. But while we are doing this exercise we have to keep in mind that input port; input port should be supportive for this exercise namely we have to take the signal here it is 0 and in ideal condition it is it is having 0 conductance of this not on equivalent representation of the signal source.

So, if i s is equal to 0, here this port it is remaining open. So, with this condition we need to find what will be the expression here. Now, if you and also we to start with we are considering ideal feedback network, namely its input resistance it is infinite and since it is a current source. So, we are considering output conductance is 0 or output resistance it is infinite.

So, with this what we are having it is the expression of the current i in. So, i in, if you see here i in if this is 0 it will be equal to minus i f the feedback current and this feedback current it is beta into v x. So, i in equals to minus beta into v x and this v x it is incidentally same as v y. So, we can see this is equal to minus beta into v y and then also if I consider say this network to find the output current i y. We do have the voltage source here we do have internal voltage source here and then we do have the resistance R out; this circuit is open.

So, we can say i y equals to v y minus the internal voltage which is Z m into i in divided by the resistance R out. And i in its expression is given here. So, we can say this is v y minus and minus is getting plus. So, this is we do have v y plus beta into Z m into v y divided by R out. So, we can rearrange this equation to get the expression of v y by i y. So, that is equal to R out divided by 1 plus beta into Z m.

So, this is the expression of this R out, it is given here. So, you might have observed that the unit here it is ohm and though we are using the same notation beta here for the feedback network, but then it converts voltage into current. So, its unit it is 1 by ohm or mho. So, after making this multiplication this part it is it should be unit less. So, that is what we do have beta it is of course, it is having unit of 1 by ohm.

Now, let we consider non idealistic situation one at a time or let we introduce one by one. To start with if we consider that signal source it is having finite conductance; that means, if I consider say some finite R s. So, if I consider this is finite, then the whatever the current i in will be having it is not same as beta into v x, but it will be having a current division. Part of this current it is coming through this circuit and remaining part it is coming through this circuit.

So, we can say there is this i in, it is not entirely i f we need to have some whatever the fraction to be multiplied that fraction it is getting created by this R s and R in. So, to write that let me again clear the board.

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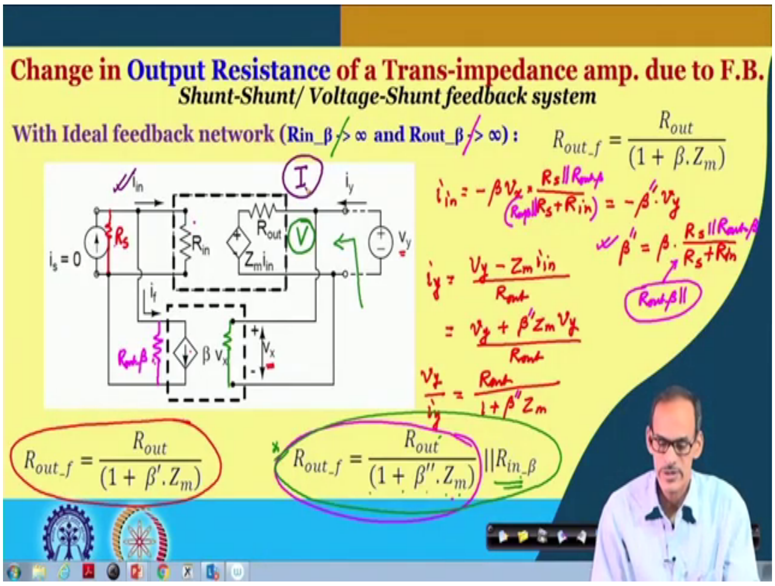

So, we can say that i in equals to i f which is of course, minus i f. So, minus beta into v x multiplied by if I am having say finite resistance R s then the current flow here it will be R s divided by R s plus R in, that we know from network theory. So, we can and v x incidentally it is same as v y. So, again we can say this is minus beta dash into v y, where beta dashed now this beta dash and the previous beta dashed they are different,this beta dash it is beta multiplied by r s divided by R s plus R in ah.

And on the other hand the expression of this current i y equals to v y minus Z m i in, that is valid for this case also divided by R out. So, this equation it becomes v y minus and minus is getting plus. So, we do have now beta dashed Z m into v y divided by R out. So, if we simplify it then we can get v y by i y equals to R out divided by 1 plus beta dashed into Z m. So, that is the expression it is given here.

Now, again in addition to this if I consider that this circuit is also having some finite conductance. So, if I consider this is a finite; that means, we do have R out beta. So, this current it will be having further division so, the current flowing through this one it will be further getting reduced. In fact, these two resistances they are coming in parallel. So, what we can say that this R s and R out of beta network it is coming in parallel. So, likewise here also R out beta network it is coming in parallel with this R s.

So, let we call this is beta double dashed. So, beta double dashed is equal to R s in parallel with R out beta and here we have to write R out beta in parallel with; in parallel with R s and then of course, we do have this R in. Rest of the derivation it will be same except this beta dash need to be changed to beta double dashed and expression of beta double dashed it is given.

So, come end of it the output resistance it is getting changed to R out divided by 1 plus beta double dashed into Z m and where beta double dashed expression it is given here. Now, if I also consider that input resistance, this is also finite. So, if I consider some finite resistance here, then we have to consider that resistance effect also. So, whatever the previous R out was there. So, we can consider this is also coming in parallel.

So, the net resistance here it will be if I consider all the three non ideal factors, then I will be getting the R out f it is having expression of R out divided by 1 plus beta double dashed into Z m in parallel with R in of the beta network. So, that is the change of the output resistance particularly when output port it is having signal in the form of voltage. Now, if we consider other two configurations where the signal at the output port it may be current whereas, at the input port the signal may be current or voltage.

So, we can think of either it will be current amplifier or it will be trans conductance amplifier. So, in the next slide we will be talking about R out f, output resistance of the feedback circuit for the current amplifier and trans conductance amplifier.

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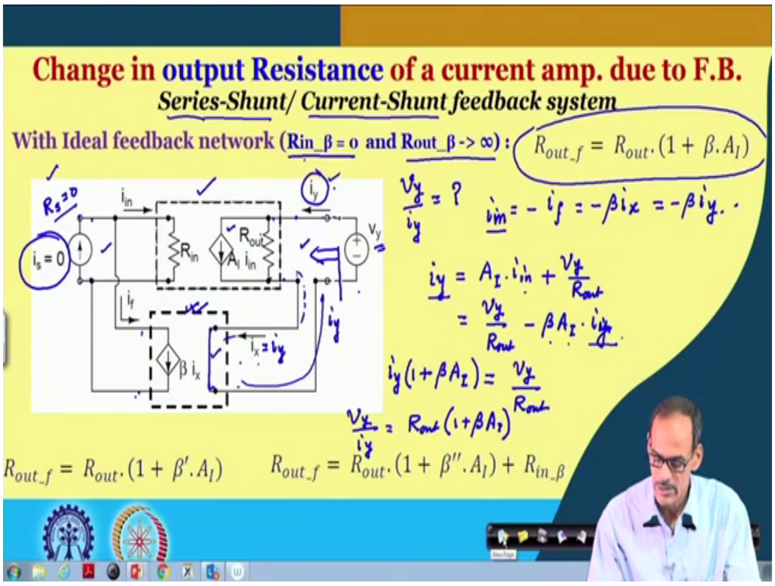

So, we do have on this current amplifier it is given here. So, we do have current amplifier along with its feedback and here as we have discussed the sampler it is series and mixer it is shunt. So, the feedback it is series shunt or I can say current sample and shunt feedback. So, it is current shunt feedback.

And to get the output resistance, to get the output resistance again we are stimulating the output port by a voltage source and we are observing the corresponding current. In fact, we can do it to the other way also, we can stimulate this output port by a current source and then we can observe the corresponding developed voltage. And while we are doing this exercise, we have to keep in mind that the signal here we have to make it 0, but then port we have to keep it in such a way, so that it is supports whatever the feedback connection we are making.

So, in ideal situation if I consider it is having 0 conductance or say source resistance it is 0 and if I consider the feedback network it is also ideal namely its input resistance it is 0 and so, this is 0, so that it will not create any problem while the current it is getting sense and at the output conductance it is 0. So, the this conductance it is 0 means the output resistance of the feedback network it is infinite.

So, with this condition, we need to find what will be the expression of v y by i y right. And to get that again we can start from here and we can see the i y or other i in equals to minus of i f and this is equal to minus beta into i x and this i x it is incidentally equal to i y. Because, whatever the i y it is this current is flowing whether through the internal current source or through this resistance finally, they are combined, getting combined together and the return current should be consistent way this i y. So, which means that i x it is also equal to i y.

So, this ix is equal to i y, so that gives us the expression of i in equals to minus beta into i y. On the other hand, if I want to know what will be the corresponding current i y here, we do have two current components. One is internal current A I multiplied by i in and then current flow through this resistance R out and the voltage drop across this resistance is V y. So, since here we do have short circuit.

So, we can see entire V y it is appearing across R out. So, the corresponding current it is v y divided by R out. And expression of i in it is already given here so, we can say this is v y divided by R out minus beta into A I into i in. And this i in sorry, this in it is actually beta into i y, so rather beta into A I into i y. So, left side we do have i y and right side we do have this term. So, we can bring them together to get i y plus this term.

So, we can take this i y common to get i y into 1 plus beta into A I. So, that is equal to v y divided by R out. And from that we can get v y by i y equals to R out multiplied by 1 plus beta into A I. So, this is the expression of the output resistance of this system and this is of course, under ideal condition. Ideal condition means the source resistance it is 0 and then feedback networks impedances are supporting the ideal condition.

Now, again similar to the previous exercise, let we consider those non ideal factors one introduce those non ideal factors one at a time and let us see the corresponding cumulative effect. So, let me clear again clear the board and let we continue the discussion.

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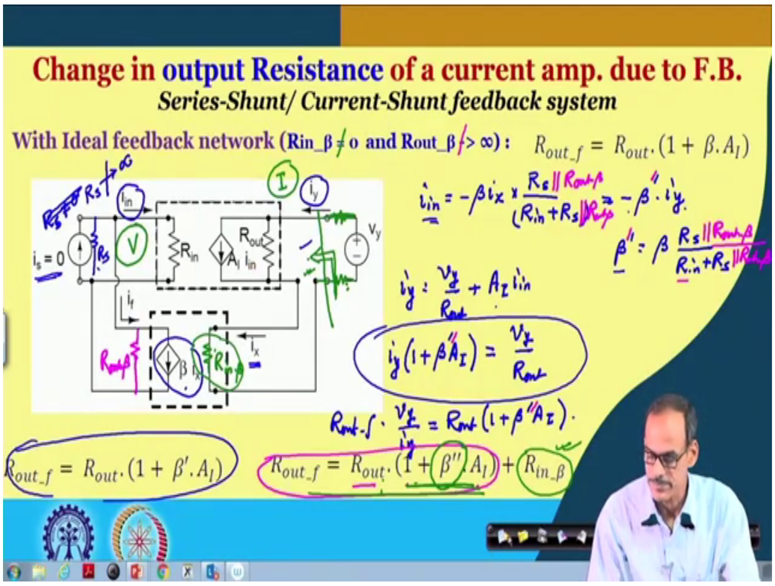

So, here what we said is ah, let we consider r s equals to is nonzero. So, the i in equals to minus beta into i x multiplied by this so, sorry, this will not be what I want to say it is finite R s is finite, it is non infinite. So, it is we do have some finite resistance R s. So, the current going through this main input port of the forward amplifier i in is a fraction of this current in absence of the signal source, it will be this current multiplied by the fraction getting created by R s and R in. And this fraction it is from the current division we can get R s divided by R in plus R s alright.

And this i x it is incidentally same as i y. So, we can say this is equal to minus beta dashed into i y where beta dashed is equal to beta into R s divided by R in plus R s. And the other equation at the output port it is remaining same namely i y equals to v y divided by R out plus A I into i in and i in it is beta dashed into i y with a minus sign, so that, we can take at the left side.

So, again we are getting the relationship between iy and v y in this form iy multiplied by 1 plus beta into A I equals to v y divided by R out. Again sorry, this is beta dashed the beta dashed is given here and again by considering this equation we can get v y by i y which is given here. So, that is the R out f. So, that is equal to R out multiplied by one plus beta dashed into A I.

So, likewise, if we consider finite conductance here as well, namely, R out of feedback network beta. So, then the derivation it will be very similar except this R s it is coming in parallel with R out beta. So, we do have R out beta here and then we call this is beta double dashed and its expression it is beta into R s in parallel with R out beta divided by R in plus R s in parallel with R out beta.

So, this derivation it is remaining same except this beta dashed it is getting replaced by beta double dashed and then the output resistance it is finally, it is coming like R out multiplied by 1 plus beta double dashed into A I. Now, the last item it is if we consider this is also finite. So, if we have some finite resistance here. So, what will be having it is that, that will be contributing to this output resistance and its contribution it is that this R in beta it is coming in series with whatever the previous resistance it was there. So, we can say this resistance it is coming in series with that.

So, you might have observed that the this element, presence of this element it is really not disturbing. In fact, you can whenever you are putting this resistance we can think of that we do have a series resistance getting added here. So, this resistance probably either you can shift it here or here.

So, up to this one whatever the resistance you are getting it is given here and then we do have this resistance coming here that is how we can visualize. And also we have seen that the input resistor the output resistance it is getting increased because of this series connection here and the increased it is essentially this desensitization factor it is helping us to increase this output resistance or we can say that output conductance it is getting reduced by this factor. And we need to be very careful while we are considering this load affected beta.

So, the fourth configuration where the signal here it is current and on the other hand signal here it is voltage namely, the trans conductance amplifier. So, we are going to discuss about the output resistance change in trans conductance amplifier in the next slide yeah. So, here we do have the circuit, so, the, we do have the sorry yeah.

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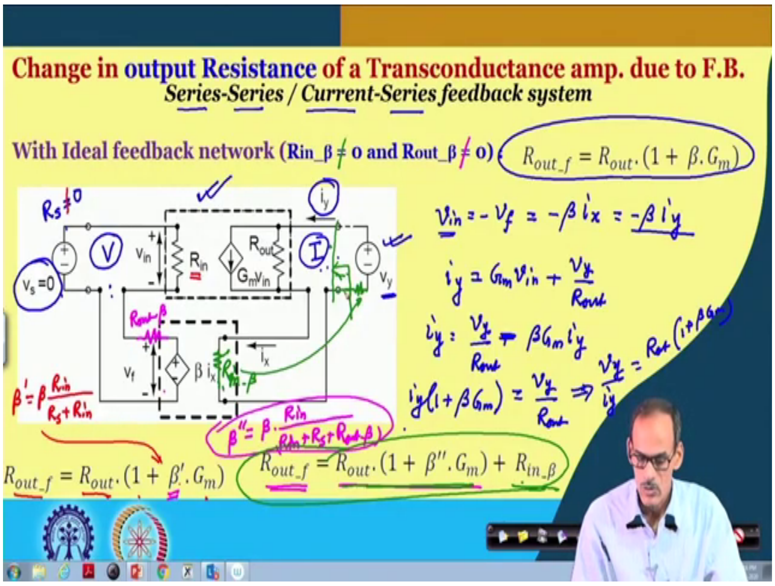

So, we do have the trans conductance amplifier here and the forward amplifier it is you can see here the signal it is current and the signal here it is voltage. So, the mixing here it is series and sampling here it is also series. So, this is series connection or current sampling series mixing feedback network.

Here also it will be very similar to our previous discussion as we said that to get the output resistance. So, we need to stimulate this circuit by one voltage source and then we can observe the corresponding current here. Keeping the input port condition it is supporting the feedback network namely we are keeping the source with a source signal of 0 and for ideal condition to start with we are considering source term in equivalence equivalent source resistance equals to 0. So, from that we can say v in equals to minus v f.

So, we have analysed lot of similar kind of circuit, almost similar kind of circuit probably you yourself can now be comfortable to derive that v in equals to minus v f which is equal to minus beta into ix and this ix it is incidentally equal to i y. So, this is minus beta into i y and at the output port we can get the expression of a i y equals to G m into v in and yeah. So, v in we do have in terms of i y ok.

So, we also have one more component plus v y divided by R out or we can say that i y equals to v y divided by R out plus gm into v in which is we can say minus beta into G m into i y. And from that we can get i y multiplied by 1 plus beta into G m equals to v y by R out and from that we can get the output resistance of the feedback network defined by v y by iy is equal to this one, R out multiplied by 1 plus beta into G m.

Now, again similar to the previous case, if we consider non ideal factors namely if I consider this is nonzero, then I have to consider the corresponding beta dash. And the expression of the final output resistance as we have discussed earlier which it will be R out multiplied by 1 plus beta dashed load affected beta dashed and multiplied by G m where this beta dashed in presence of this resistance it is coming due to the potential division happening between this R in and R s.

So, we can say beta dashed is equal to beta multiplied by R in divided by R s plus R in, rest of the things it will be very similar. And now in addition to that if I consider if I consider the output resistance of the feedback network, namely if I consider this is nonzero R out in beta. So, if I consider R out beta then I need to consider different node affected beta called say beta double dashed and its expression it is given by beta double dashed is equal to beta into R in divided by R in plus R s plus R out of the beta network.

So, with this expression of this beta double dash, the output resistance it becomes R out into 1 plus beta double dashed into G m and then, the last non ideal item if we considered it is having some input resistance which is nonzero say R in of beta network and if I consider this circuit again this resistance contribution of this resistance it is simply getting added. In fact, this resistance as I was discuss in previously we can think of it is getting shifted here without hampering any arrangement here.

So, the resistance here it will be whatever the resistance we do have without considering this resistance in series with this resistance. So, that is why you can think of the total resistance, it will be the main feedback circuit resistance in series with the input resistance of the feedback network, that completes all the four possible configuration. Now whatever the discussion we do have related to change in gain input resistance and output resistance probably that will be clearer if we consider some numerical examples.

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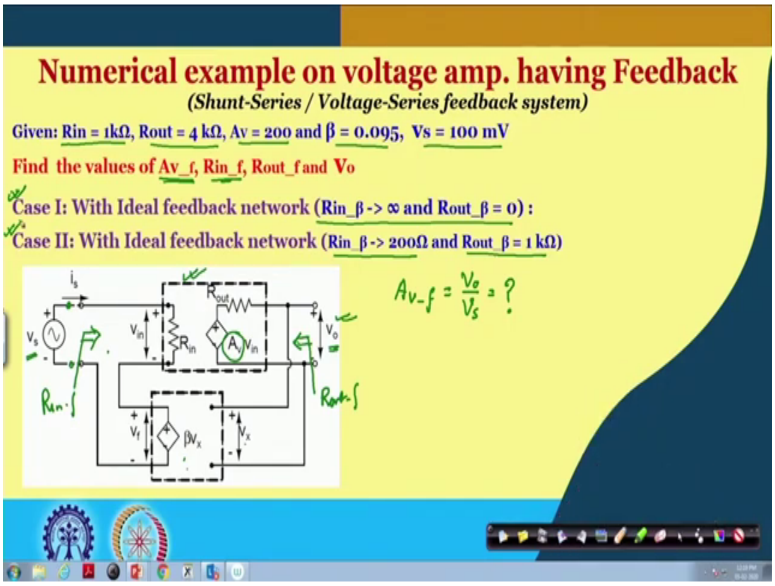

So, we do have some interesting numerical examples also to have see starting example it is a voltage amplifier, we do have a voltage amplifier here. So, this is the forward amplifier and the feedback along with its feedback connection of course, the feedback it is shunt here and series here; that means, voltage series feedback connection.

The given parameters are here, input resistance it is 1 k output resistance it is 4 k A v, the gain of the forward amplifier in ideal condition it is 200. On the other hand for the feedback circuit the beta is given equal to 0.095 of course, this is converting voltage to voltage. So, it is unit less.

And also we do have say signal source V s having say 0 source resistance and V s equals to 100 milli volt. We need to find the value of the voltage gain from the primary input to the primary output defined as denoted by A v f and defined by v o divided by v s. So, we need to find what will be this ratio. We also need to find what is the input resistance of the feedback network and also we need to find what will be the corresponding output resistance of the and the circuit and R in f here.

And also what may be the corresponding voltage and that we need to find for two cases. Case I; when you consider feedback network it is ideal one and case II where feedback network it is having finite input resistance and also it is having finite output resistance. So, rather nonzero output resistance. So, this part probably it will be straightforward, but this part it is very tricky. So, before we go into that let me take a short break and then we will come back.