Analog Electronic Circuits
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Lecture – 92
Feedback System (Part-C)

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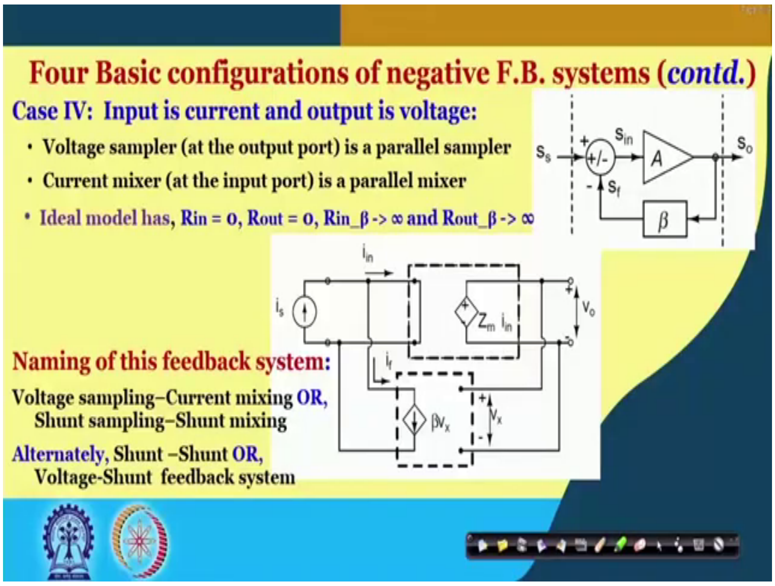

Yeah. So, dear students, so, welcome back after the break and before the break we were talking about four basic configurations of a negative feedback system and we have seen the change of the system gain due to the negative feedback and we have talked about the desensitization factor. Now we are going to talk about the effect of the feedback system on input resistance and output resistance as I have given a hint in the previous part of this lecture.

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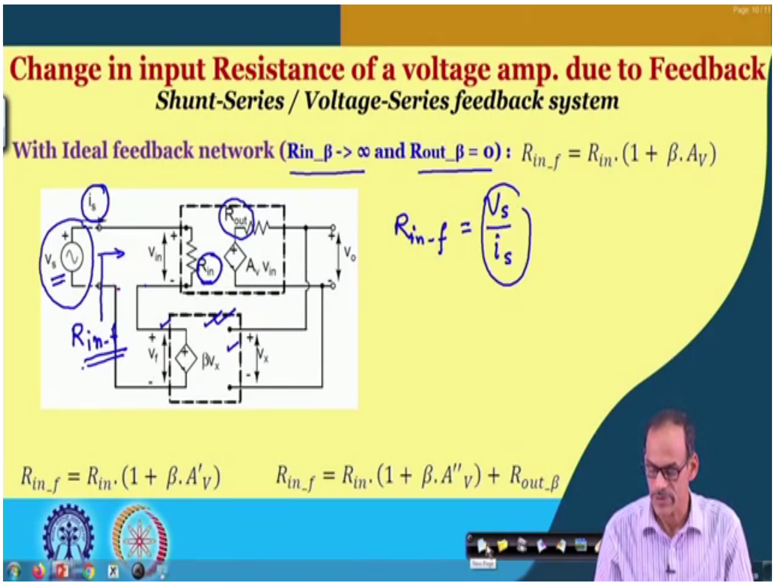

So, in the next slide we do have the corresponding circuit diagram here and to start with let we consider a voltage amplifier and its feedback connection it is shunt series or you can see voltage series feedback; which means that this port it is shunt and here we do have a series connection here.

So, if you see here at this port we do have the input port and a primary port and feedback port they are connected in series. So, here of course, while you like to see the change in input resistance and output resistance of the amplifier we have to keep this in mind that we have to consider finite value of this input resistance and the corresponding output resistance.

However, to start with for feedback network let we consider it is ideal situation namely; it is input resistance it is infinite and the corresponding output resistance here it is 0. So, here we do have open and here we do have 0 resistance and we will see that the input resistance of the feedback system initially it was R in and now due to this series connection of the feedback network we will see the corresponding change and we call the changed input resistance in R in f.

Now, to get this derivation of this input resistance of the feedback system let we consider that we are stimulating the circuit with a signal source called V s and we are observing the corresponding current entering into the port and let we call this as i s. And then the input resistance of the feedback system are in f it is defined by V s divided by the corresponding i s. To get this ratio let we consider the input port and then let we get the corresponding relationship.

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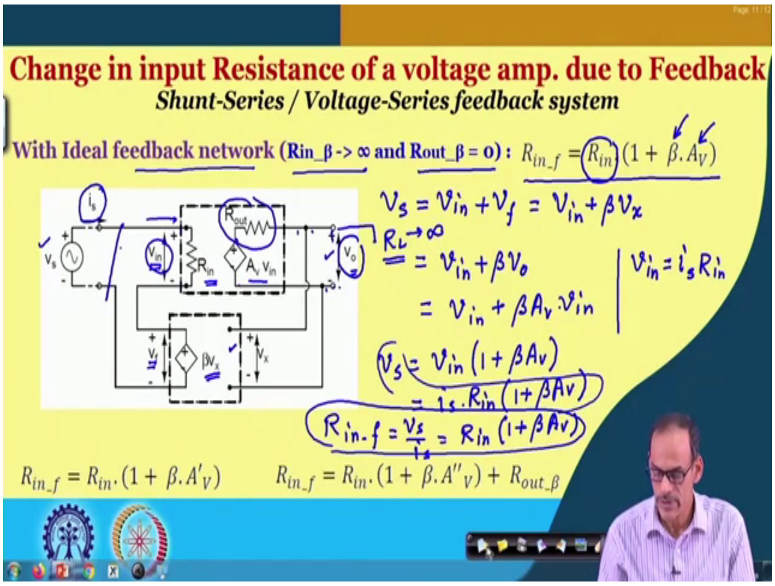

So, if you consider say this port and if we are applying say V s here and if you consider V s actually it is equal to summation of V in and then corresponding feedback voltage V f. So, we can say V s equals to V in plus V f which is of course, V in plus the internally developed voltage which is beta into V x. In fact, V x it is same as this voltage V o.

So, we can say this is V in plus beta into V o on the other hand if I consider that this port it is open and here also it is open then the voltage getting developed here V o even though we do have R out the voltage here it is same as internally developed voltage namely A v into V in. So, we can further consider this expression of V s as V in plus beta into A v times V in right.

On the other hand, if I say that i s current is flowing and it is entering to the circuit and we do have a resistance of R in and across this resistance R in we do have V in it is getting developed. So, we can say that V in equals to i s multiplied by R in. In other words we can say that V s equals to if I take V in common and then we do have one plus beta into A v and that is equal to i s into R in times 1 plus beta into A v.

And that gives us the feedback systems input resistance R in f equals to V s divided by i s and using this relationship we can see that this is R in multiplied by 1 plus beta into A v. So, that is why the feedback system input resistance it is having this expression in terms of the input resistance of the forward amplifier and also the corresponding voltage gain and also the transfer function of the feedback network. And of course, here we have assumed there the feedback circuit it is ideal one.

So, we have considered input resistance of the feedback network it is infinite, output resistance of the feedback network it is 0 and also it is load we considered this is infinite. So, we consider load of the circuit it is infinite.

Now, let we consider that in practical situation where definitely there may be a finite load R L and due to which the voltage available here at this port it may not be same as internally developed voltage and in that situation what maybe the corresponding change. So, to start with let we consider R L it is finite.

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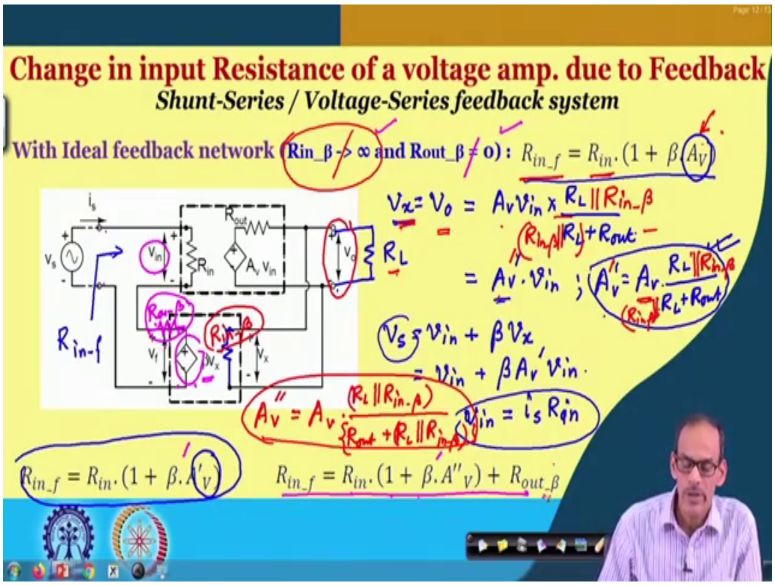

So, if we put say R L here and then the voltage here V o. In fact, this is same as V x also. So, V x is equal to V o equals to A v times V in multiplied by R L divided by R L plus R out right.

Or we can rearrange this equation and we may see that this is equal to A v dash multiplied by V in where A v dash is A v multiplied by R L divided by R L plus R out. Or we can say this is load affected gain of the amplifier A v and rest of the analysis it is remaining same namely, if you consider V s which is summation of V in plus V f which is beta times V x and then expression of the V x it is given here and from that we can see this is equal to V in plus beta into A v dashed into V in and of course, you know we also have relationship between V in and i s. So, V in equals to i s multiplied by R in.

So, using this relationship and this relationship we can find that the corresponding input resistance of this circuit we call the say R in f and. So, it is remaining very similar to this equation except this A v need to be changed by A v dashed. So, we can say that we are finding this new expression of the input resistance where A v dashed it is defined here.

So, likewise if I consider say resistance here also in case, if I consider finite resistance of the feedback network. So, if I say that this is having some finite value call R in beta then the corresponding voltage here getting developed here across this R L and R in beta they are coming in parallel.

So, then the voltage here instead of A v into V in into R L it will be R L coming in parallel with R in beta. So, likewise here also we will be having R in beta coming in parallel with R L and of course, we do have this R out in series. So, we may say that the corresponding expression of V x it will be say A v double dashed and the expression of A v double dashed as it is A v multiplied by R L coming in parallel with R in beta and in the denominator here also we do have R in beta coming in parallel with r l.

So, let me write the expression of A v dashed rather A v double dashed in presence of R in beta and R L it is equal to internal voltage gain A v multiplied by R L coming in parallel with R in beta divided by R out plus R L coming in parallel with R in beta. So, again the relationship here between input resistance of the feedback system and without feedback it is remaining similar except this A v need to be replaced by A v double dashed and its expression it is given here.

So, if I on the other hand if I consider the output resistance of the feedback network also namely, if I say that R out of beta network it is non zero. So, if I consider this resistance and if I say that this is R out beta in that case whatever the relationship we said here it will be very similar, but of course, then this R out it is coming into picture and the voltage coming here V in it will not be same as whatever the voltage you do have.

So, what we will be getting here it is this beta part beta part it is also getting a load affected. Namely, the voltage here it is not only say this voltage rather of course, this voltage will be there, but also we have to consider this drop. So, the beta is also getting affected and the corresponding beta need to be changed by considering this load and so then the corresponding beta here need to be a changed and. In fact, we also have this is coming in the series.

So, we have to consider this R out beta also in the series. So, if I consider both this and this are having say practical value then the expression of the input resistance of the feedback system it is coming in this form where it is the expression includes R in multiplied by one plus beta dashed and then A v double dashed then plus R in of the feedback network sorry R out of the feedback network.

so here what we have seen that the series connection the series connection it is making the input resistance getting increased by whatever the desensitization factor; either we consider in this case, or this case, or this case. And also you mean you might have observed that it is independent of this port situation.

So, in case if we have a circuit where see this part the mixer part it is series, but then if this port it is different namely series; that means, if it is current sampling and then series feedback then also we will be getting we are expecting that input resistance it will be increased by so called desensitivity factor. So, let us look into the corresponding circuit there ok.

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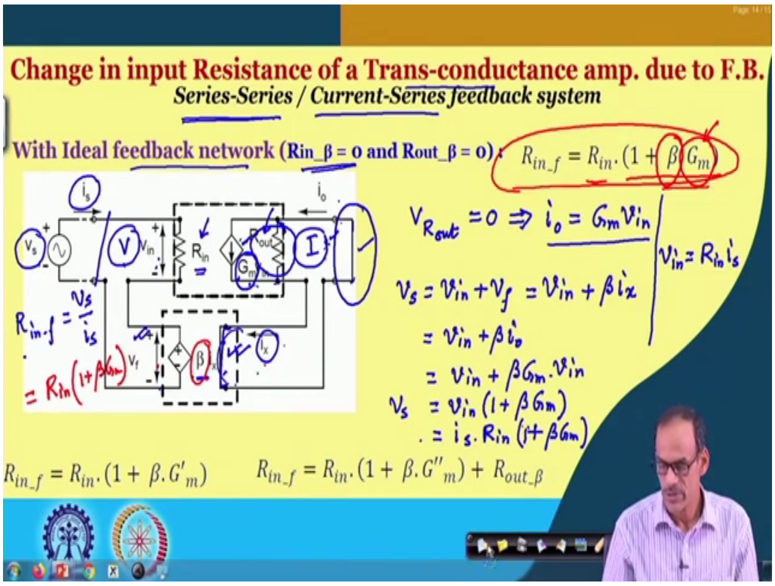

So, here we do have a trans conductance amplifier and what do we have what we have here it is input it is of course, in the form of voltage and since it is trans conductance here the signal output signal it is current. And of course, the amplifier gain need to be replaced by transconductance amplification and the feedback system of course, it should be appropriately modified signal here we are sensing is current and then here of course, mixing in series.

So, the feedback system it is current series feedback, or we can say it is series feedback. Here again to start with we consider practical value of R in and R out, but we are keeping the feedback network ports are I should say ideal namely the input resistance here it is 0 and the on the other hand output resistance it is also remaining 0.

And why it is this input port is 0, but that is because now the signal here it is in the form of current. So, to avoid loading effect namely to absorb the maximum current within this circuit to sense it we have to make the input resistance to be 0. Also you might have observed that since the signal here it is in the form of current and to avoid loading effect we are considering the output resistance it is 0.

So, if this is 0 resistance and this is also 0 resistance we can see that the whatever the current we do have internally developed current that is entirely flowing through this because the drop across this R out is a 0. So, if I say that drop across this R out since it is 0.

So, that gives us i out i equals to G m into V in. So, that you have to keep in mind. So, we are receiving the maximum current and hence we can see that this is providing unloaded situation. And then to start with to find the relationship between this V s and i s to give the expression of R in f the input resistance of the feedback system which is defined by V s by i s we start with this relationship of say V s equals to V in plus V m.

So, we can see V s equals to V in plus V f, but we do have the expression of V f which is equal to beta into i x. So, this is V in plus beta into i x. And in fact i x it is same as i o. So, we can see that this is V in plus beta into i o and the expression of i o in terms of V in it is G m into V in.

So, then V is equal to V in plus beta into G m into V in and. So, that gives us V s equals to V in multiplied by one plus beta into G m and if the V s it is flowing through this R in we have as we have done last time in the previous slide the V in equals to R in into i s.

So, we can write this is as i s into R in multiplied by 1plus beta into G m. So, from that we can find the expression of input resistance of the feedback system. So, this is becoming R in multiplied by 1 plus beta into G m. So, that is the expression of the input resistance again input resistance it is getting amplified by this desentization factor. However, the difference here it is instead of A v we do have G m here and also we thought we are writing this is beta, but you have to be careful that or you should be aware that this beta converts got into voltage which means that this beta it is not unit less rather it is unit it is ohm.

And G m a unit of the G m is mho. So, these two together it is giving unit less factor ok. So, that is how here the input resistance it is getting amplified by this feedback mechanism. Now if I consider the these two are having some practical value then say for example, if I consider the we do have some resistance here and if I call this is R in beta and if I say this is non zero.

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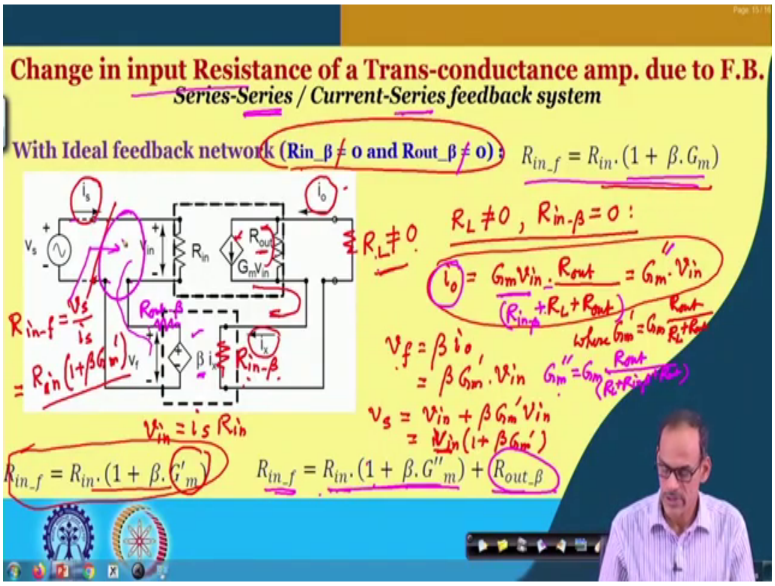

So, then it is expected that some part of this current internally developed current it will be flowing through this circuit and part of the current it will be flowing through this circuit. So, likewise in case if I consider R L here.

So, again part of the current. So, if this R L it is non zero. So, that will enforce some additional some current it will be flowing through this R out and only part of the current will be flowing through this the output port. So, just to start with if I consider say R L is non zero, but say R in of beta is 0 and then we will consider the other case. So, if I consider this case then i o i o it is G m into V in multiplied by R out divided by R L plus R out. And again you may say that this is equal to G m dashed load affected G m into V in where G m dashed equals to G m multiplied by R out divided by R L plus R out.

So now we are we are having this relationship between this i o and V in and we know that this i x it is same as this i o. So, we can say that V f equals to beta into i x and i x it is i o and that is equal to beta into G m dashed into V in. Now using this equation we can go back to this input port to get the expression of V s equals to V in plus V f and V f it is beta into G m dashed into V in. So, that gives us V s in terms of V in and 1 plus beta into G m dashed and also we know that i s equals to.

So, we know that i s rather i s multiplied by R in is equal to V in. So, V in is equals to i s into r in. So, if I put the expression of i in here and then you can find R in f which is defined by V s by i s and that is becoming R in multiplied by 1 plus beta into G m dashed.

So, if we have this load practical load then the corresponding input resistance it is also having the similar kind of expression as we have seen before only difference is that we have to consider load affected gain G m dashed. Now if we have say along with R L non zero, if you also have R in beta a non zero in that case you have to consider these two components together.

So, to find the i naught to find the i naught now instead of considering this i naught expression only R out and R L you also have to consider along with this R L you also want to have to consider R in beta in series right. And if I consider that; so since we do have some more modification. So, we can say that this is G m dashed where G m double dashed equals do G m multiplied by R out divided by R L plus R in beta plus R out right.

And then in the in the expression of R in f what we will be getting here it is R in multiplied by 1 plus beta into G m double dashed. Now if I consider that this is also non zero so; obviously, at the input port we do have some effect. So, the voltage coming here it will not be a really same as this voltage and this voltage we do have some drop across this R out beta also and if I consider that. So, either we may say that beta is getting affected or we may consider this is coming in series.

So, if i s is flowing. In fact, i s it is flowing through this also and then you may see that this R out beta it is coming in the series with whatever the resistance we do have right. So, that is giving us the change of input resistance and again since it is a series connection here; series connection of the feedbacks circuit at the in the mixer.

So, we may say there the input resistance it is getting increased by this factor desensitization factor now let me consider the other situation namely if the mixture it is having a parallel connection which means that signal here instead of voltage if it is current then we can see what kind of changes we do have. So, probably we can start with say current amplifier. So, in the next slide we can see the change of input resistance of a current amplifier having feedback.

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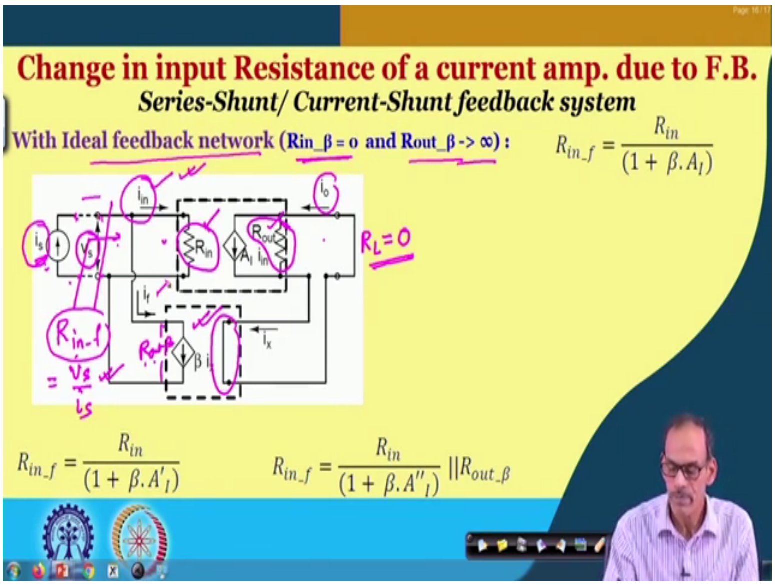

So, yeah. So, we do have a current amplifier and again we are we have to see what is the corresponding resistance here called R in f and in the amplifier you can see that input resistance it is having finite value output conductance it is having finite resistance. So, we are of course, here the signal it is current and here also the signal it is current. So, the feedback network on the other hand to start with we are considering ideal one. So, if it is current here signal it is current here to have 0 loading effect we want the input resistance should be 0.

Of course the load resistance to start with without having any loading effect we consider R L also equal to 0 and here the signal it is current. So, we are considering 0 conductance or we can say that the output resistance of the feedback network R out beta it is infinite. So, what I like to say here to summarize that we are considering R in and R out of the forward amplifier, but we are still keeping the feedback network in ideal situation and to start with we are also considering load resistance equals to 0.

Now to find the in input resistance probably we can stimulate this port by voltage, but it is since we are considering this is ideal a source we need to stimulate this port by say current; or I should say it is rather more convenient to get the derivation. If you want you can stimulate this input port by a voltage source and then you can observe the corresponding current as you have done for the previous two examples, but i think this may be having a relatively simpler derivation.

So, at the input port we are stimulating this port by i s and we are observing the corresponding developed voltage called V s and then the input resistance of the feedback system it is the developed voltage divided by the stimulating current i s. Now to find this ratio we need to find the corresponding relationship and again what we will be considering here it is you consider the voltage here and then we can see the voltage here it is a summation of these two or we can say that i s it is summation of this current and this current ok.

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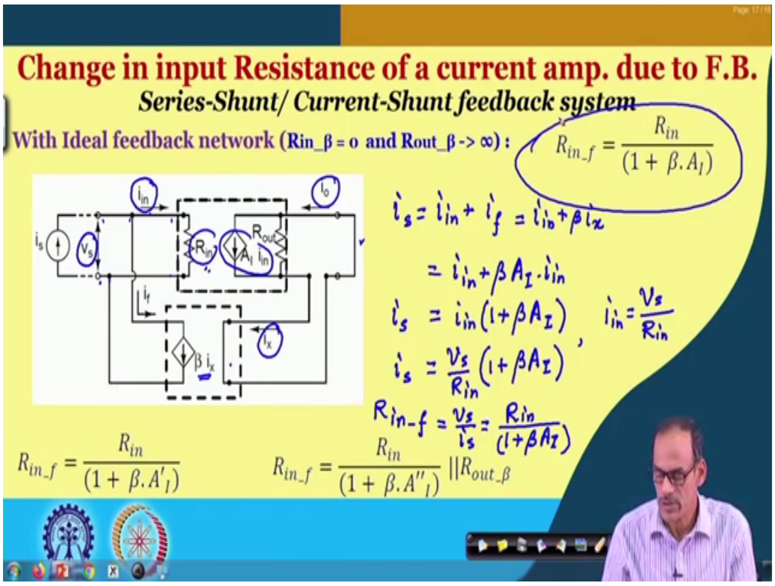

So, either way it is possible, but let me just start with say i s equals to i in plus this i f the feedback current and that feedback current it is beta into i x. So, we can see this is i in plus beta into i x and i x it is same as whatever the current we do have because we do not have any resistance here and we do not have any resistance here. In fact, both of them are equal to internally developed current.

So, i x equals to So, i in plus beta into i x it is A I the current gain of the current amplifier multiplied by i in. So, that is giving us i s equals to i in multiplied by 1 plus beta into A I. Now if you see the voltage V s and this i in and r in. So, since it is a parallel connection the voltage getting developed across this R in it is the as this V s. So, we can see that this V s equals to i in multiplied by R in or we may say that i n equals to V s divided by r in.

So, then i s equals to V s divided by R in multiplied by 1 plus beta into A I. In fact, from here we can get the feedback system resistance which is defined by V s divided by i s and that is equal to R in divided by 1 plus beta into A I. So, that is the expression of the input resistance of the feedback system.

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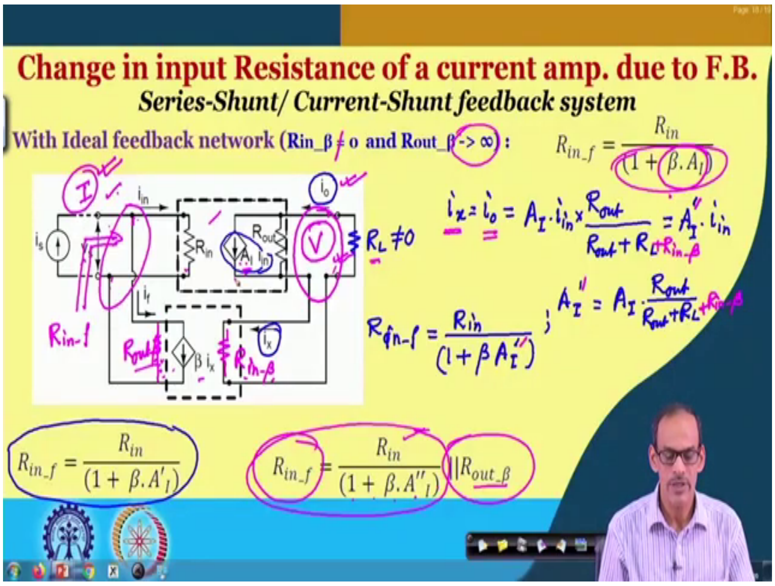

Now, a similar to the previous example you let you consider the loading effect and to start with if I consider we do have R L here, if I say that this is non zero. So, naturally the i o and i x both i x equals to i o both of them it will be A I reduced version of the internally developed current i A I multiplied by i in multiplied by R out divided by R out plus R in.

So, similar to the previous case here let we consider this factor it is part of the load affected current gain A I dashed multiplied by i in. Where A I dashed equals A I to the internal current gain multiplied by the attenuation factor R out divided by R out plus R in. Now following the same procedure we can get the expression of R in f in terms of R in and the desensitization factor. So, R in divided by 1 plus beta into A I dashed where A I dashed it is given here.

So, in case if we have R L it is non zero. So, that is the expression of the input resistance we will be getting. Now if I consider say this input resistance of the feedback network it is non zero and if i see this is R in beta which is non zero then the current here current expression of i x and io it will be similar only thing is that along with R L I have to consider this R in beta also because that is coming in series with R L. So, I have to consider this R in of beta and let me call them this is A I double dashed. Where the expression of A I double dashed it is A I multiplied by R out divided by R out plus R L plus R in beta; and so that is how the expression of the whole system it is getting changed so you can get this expression.

Now if I consider this part it is finite which means that if I consider it as having some finite resistance getting connected. So, what will be its consequence that the this resistance it is coming in parallel. So, we can say that input resistance here, it is whatever the resistance it was there and then we do have this resistance coming in parallel.

So, if I call this is R out beta then the complete resistance R in f it will be a R in divided by 1 plus beta into a double dashed A I double dashed in parallel with in parallel with R out beta. So, again for this case you might have observed that because of the shunt connection the input resistance input resistance got decreased and the decreased the factor it is this desensitization factor 1 plus beta into a whether we call A or A dashed or A double dashed and also in case if you have R out beta then also you have to consider that as well.

Now, here the signal it is of course, it is in the form of current the situation it will be very similar in case if we have the signal here it is voltage and of course, if it is voltage and then if the input signal it is remaining current then the corresponding amplifier it will be different, then feedback connection it will be different. But there also we will see that input resistance it will be getting decreased by desensitization factor because of the parallel connection.

However, the corresponding loop gain it will be different its expression it will be different. Note that both A I in this case in the present case where signal here and signal here both are current both A I and beta they are unit less once we go to the other amplifier where input is current and output it is voltage; obviously, then the amplifier gain which is converting current into voltage it is essentially trans impedance.

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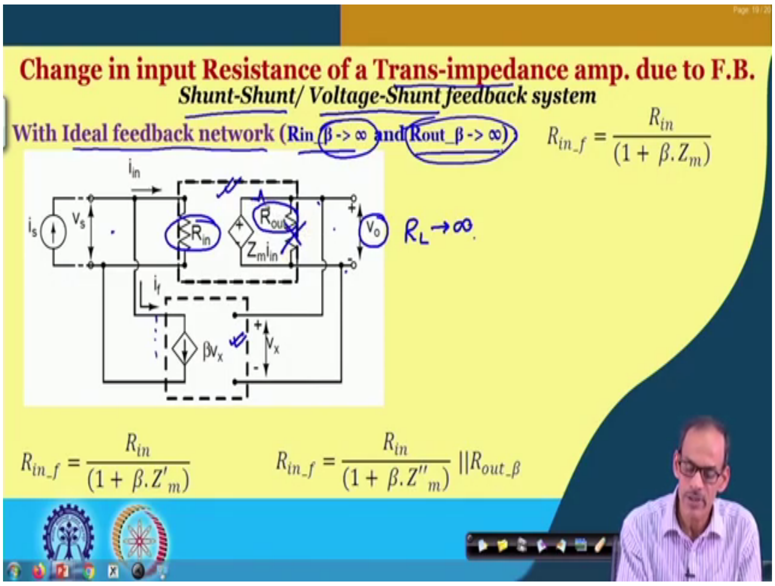

So, the corresponding circuit it is given in the next slide. So, here we do have the trans impedance amplifier. So, in the circuit. So, this is a trans impedance amplifier and it is corresponding feedback it is of course, it is sampling voltage and then mixing in the form of current.

So, this feedback system it is voltages and feedback or we may say this shunt feedback in this case again to start with we consider in input resistance and output resistance of the trans conductance amplifier. However, we are starting with ideal feedback network namely its input condition and output port condition it is avoiding helping to avoid loading effect.

Namely, the input resistance it is in finite and the output conductance is 0 or output resistance is infinite. And here of course, since the signal it is in the form of voltage to avoid loading affect we consider R L it is in finite.

So, if I consider this R L it is infinite then at this port whatever the voltage you will be getting. Sorry I will I will make a correction here I have committed a mistake since this is Thevinin equivalent model please consider this resistance coming in series with this.

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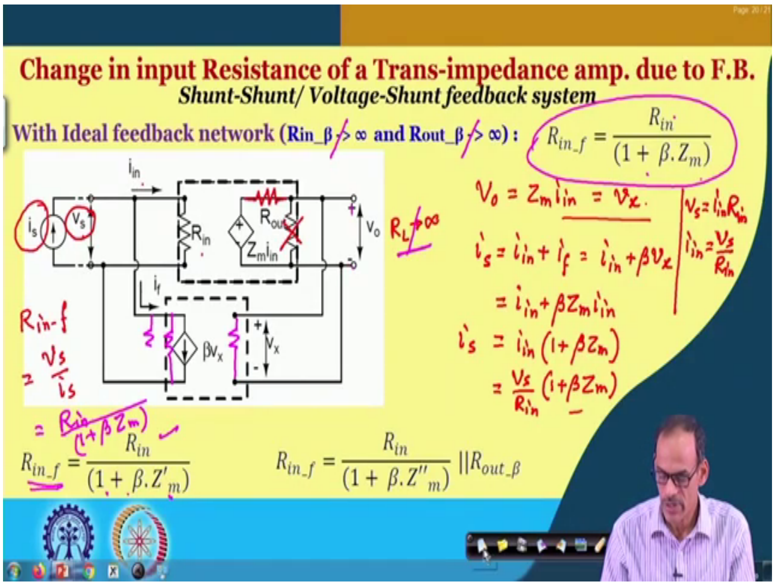

So, let me correct it instead of having this resistance what I mean it is the resistance it is here R out ok. So, since I consider R L it is infinite. So, we can see that V o it is same as internally developed voltage namely, Z m into i in and that is also equal to V x and if I consider on the other side the input port to get the expression this current the total current i s is equal to i in plus i f and are i f it is equals to beta into V x i in plus beta into V x and expression of V x it is given there.

So, we can see this is i in plus beta into Z m trans impedance gain into i in. So, i s equals to i in multiplied by 1 plus beta into Z m. On the other hand, here relationship among V s R in and i in it is given by; let me write here V s equals to i in multiplied by R in or r i in equals to V s divided by r in. So, this is V s by R in multiplied by 1 plus beta into Z m.

Now again the definition of the input resistance of the feedback system it is ratio of V s divided by i s and from here we can say this is equal to R in divided by 1 plus beta into Z m. So, this is what we have written that the input resistance of the feedback system it is R in divided by beta into Z m and similar to the previous case if we start considering the loading affect namely, if I consider this R L it is finite.

And then if I consider this resistance also and then if I consider the internal conductance here namely both of them are finite R L it is also finite then we can get the derivation of input resistance going to R in divided by 1 plus beta into Z m. Where, Z m it is taking care of the loading affect due to R L finite R L. So, let me consider that the expression of ok.

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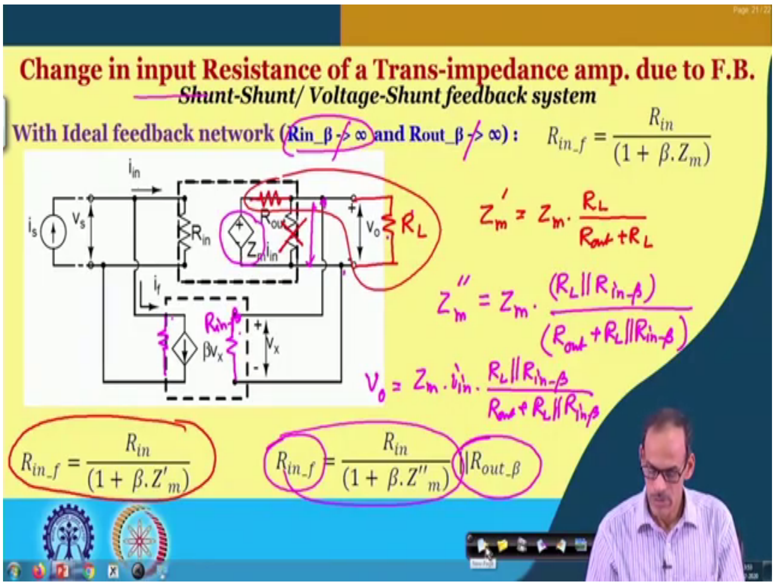

Again I have to make this correction and then if I consider this R L it is finite. Then the input resistance of the feedback system it will be given by this where Z m dashed it is load affected trans impedance and look when I say load affected it is basically whatever the attenuation factor we do have here that we need to consider along with the original Z m.

So, Z m dashed it will be Z m multiplied by R L divided by R out plus R L. On the other hand, if I consider if I consider this resistance also it is finite. So, if I consider that then the corresponding Z m need to be replaced by Z m double dashed and its expression it is Z m multiplied by this R L coming in parallel with R in beta divided by R out plus R L coming in parallel with R in beta.

So, why we have to consider these are in parallel that is because this resistance and this resistance they are coming in parallel. So, the voltage getting developed here which is V o which is of course, reduced version of internally developed voltage. So, the V o it is Z m multiplied by i in multiplied by parallel connection of R L and R in beta.

So, this is R in beta and divided by of course, R out plus R L in parallel with R in beta and the corresponding input resistance it will be this one. Now if I consider this also which means if I consider this resistance also then that resistance also coming in parallel. So, I think that is how we can calculate the corresponding input resistance of the feedback system. So, if we consider the previous cases probably I yeah, I can see one small mistake I have done.

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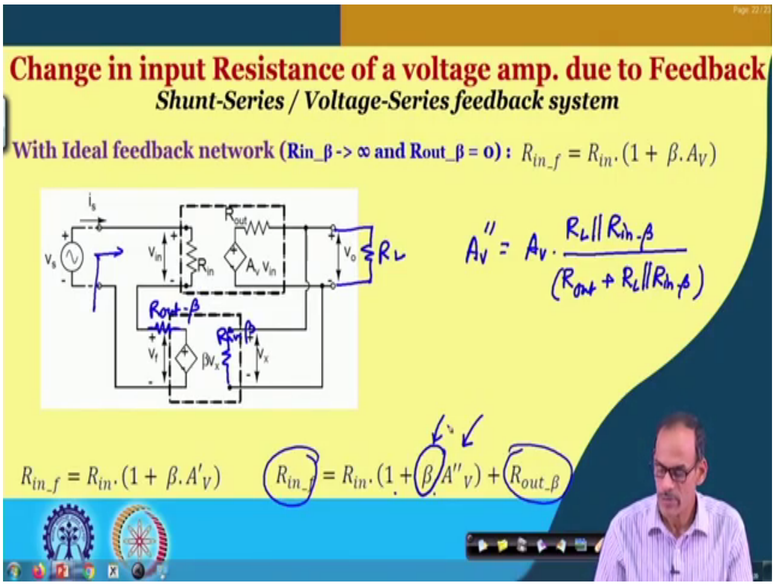

Yeah in this case when I explained that the we do have R L here we do have this resistance and this resistance then the input resistance of the feedback system it is 1 plus beta into A v double dashed plus this R o R out of beta this beta of course, it is remain should remain unchanged it should not be beta dashed because effect of this one I am I have I have already considered here.

On the other hand, affect of R in beta and these R L they are considered in this A v double dashed where A v double dashed it is A v multiplied by R L in parallel with R in beta as it has been discussed divided by R out plus R L in parallel with R in beta yeah the mistake I have committed before it is that I said it is beta dashed, but actually it is not beta dashed.

I think that is all we have to discuss, but of course then we have to consider the other feedback rather all this feedback circuit to find what will be the consequences in the output resistance. So, so far we are talking about input resistance, now we can also see the change in the output resistance before we go into this please let me take a break and then we will see how to derive the corresponding output resistance.

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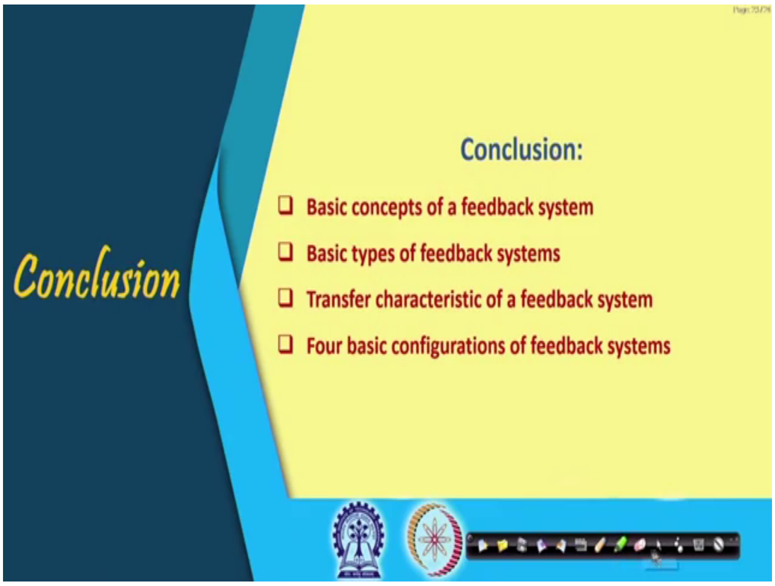

And sorry I do not want to conclude I let me cover that and then we will conclude. So, we will cover we will discuss this one and then we will conclude.

Thank you.