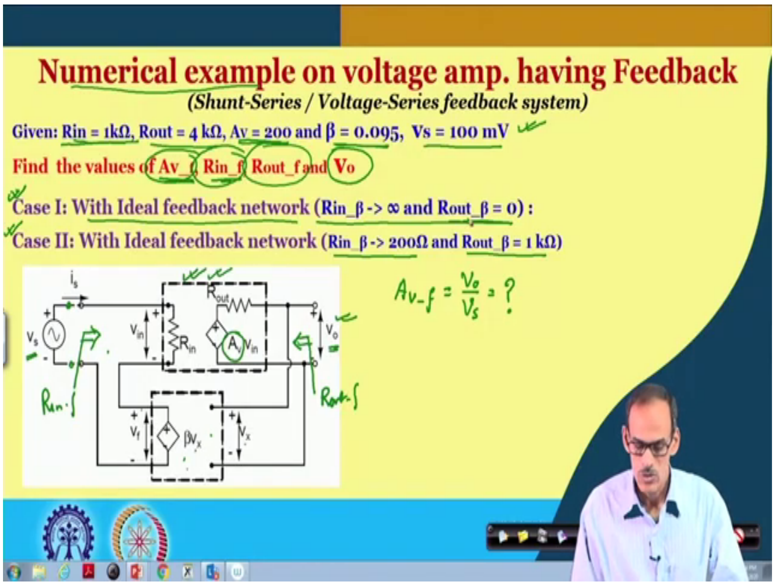
Analog Electronic Circuits
Prof. Pradip Mandal
Department of Electronics and Electrical Communication Engineering
Indian Institute of Technology, Kharagpur

Lecture - 94
Feedback System (Part- E)

(Refer Slide Time: 00:27)

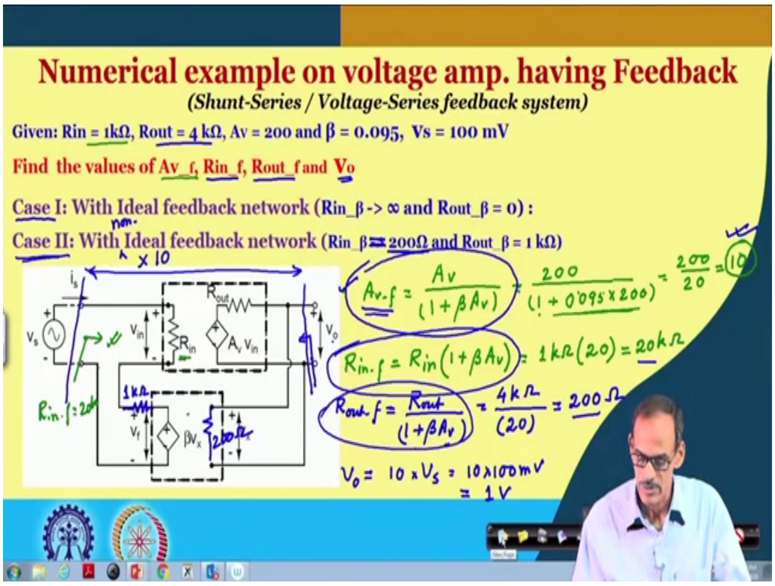


So, welcome back after the break. So here we do have numerical example and what is our objective here? It is that we need to find the voltage gain of the feedback system, input resistance, output resistance of the feedback system and the output voltage for an input voltage or the signal voltage of 100 millivolt.

And the parameters of the feedback systems are given here input resistance and output resistance of the forward amplifier and the gain of the forward amplifier it is 200 feedback network, the feedback factor it is 0.095. So to start with, let me consider this relatively simpler case, case 1 where we consider ideal feedback network having the input resistance it is infinite and its output resistance on the other hand it is 0 as we are generating voltage.

So 0 output resistance it creates the ideal Thevenin equivalent voltage. So let me clear the board, yes. So to start with, let we have the derivation of this Av rather Av dashed or rather Av of the feedback system Av-f.

(Refer Slide Time: 02:04)



As we know that this Av-f it is the forward amplifier gain Av divided by 1 plus beta into Av. So the Av it is given 200 and on the other hand, feedback factor it is 0.095 and Av it is 200.

In fact, we have picked up these numbers such that we do have in the denominator this part it is becoming twin 19 and then we do have 1 here. So that is giving us in the denominator it is 20. So the gain of the feedback system it is 10. Now, to find the value of the input resistance

R in f. As you can now guess that since we do have series connection here R in f, it is getting amplified by the desensitization factor.

So that should be R in multiplied by 1 plus beta into Av. And R in it is 1 k multiplied by this factor it is similar to whatever the calculation we have done. So this part it will be 20 and that gives us 20 kilo ohms.

So note that just by this feedback network the input resistance it is getting increased by a factor of 20 which means that if the main amplifier input resistance it was 1 k, the feedback system input resistance it is becoming 20 k. R in f it is 20 k. So whenever for some application, we have to increase the input resistance we should consider the series mixer and then we can enhance the input resistance.

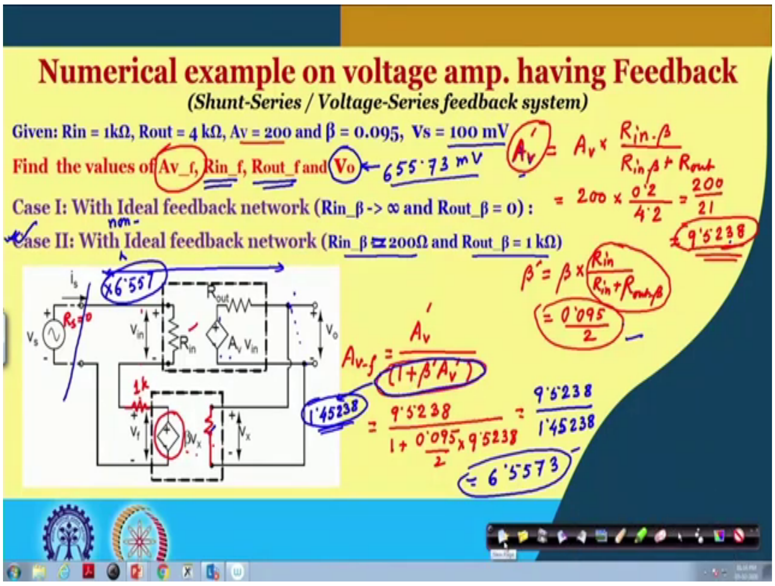
Now to calculate the output resistance R out f. So, now here we do have shunt connection. So the shunt connection it is reducing the resistance which means that the output resistance it will be R out divided by 1 plus beta into Av. And R out it is 4 k divided by this factor which is 20. So that is giving us 20 rather, 200 ohms.

So now we obtained input resistance of the feedback system, output resistance of the feedback system and next thing is that what is the output voltage? It is very straight forward. From here to here, the gain we obtain it is Av f. So, here to here the gain it is 10. So it is giving us very simple situation. So the output voltage V o it is 10 times V s. So that is giving us 10 into 100 millivolt. So that is equal to 1 volt.

So the case 1, it is relatively straightforward, we have used the whatever the formula we have obtained namely, the gain got decreased then and the voltage gain got decreased, input resistance got increased and then output resistance and got decreased. Now if I consider the IInd case, I should not say it is ideal. So this part may be ideal, but with finite resistance. In fact, we are considering relatively low input resistance.

So we are considering non-ideal rather non-ideal feedback, and input resistance it is 200 and output resistance coming in series. So, that is 1 kilo ohm. With that we need to find the corresponding feedback system gain input resistance and output resistance. It is very clumsy I should say, we need to be little careful.

(Refer Slide Time: 07:37)



So, before we start. So this should be non-ideal, I should have said it is non-ideal.

Before we start, let we consider since we do have since we do have finite input resistance and output resistance of the feedback network, the input resistance here it is affecting the output port. So the voltage will be getting here, it is not same as this internal voltage. Rather, we may say that load affected voltage, let me use different color here. So we need to be careful that Av it is giving us 200, but Av dashed it is different.

So, how do we find this Av dashed? So the way we define this Av dashed, it is Av multiplied by whatever the load we do have here, it may be external or it may be internal part of the feedback network. So in this case, R in beta it is loading. So, the loading factor it is R in beta divided by R in beta plus R out. In fact, this is 200 multiplied by this is 200 ohm. So, 0.2 k and then we do have this is 4 k. So, that is 4.2 and that gives us 200 divided by 21. In fact, that is becoming 9 point something.

So, I have some calculation for you. So this is 9.523 right. So we have to keep this in mind. Likewise, when we see the feedback network, since we do have output resistance of 1 k. So whatever the voltage we are developing here, beta into V x it is not directly coming there. In fact, if I consider R s equals to 0, the corresponding load affected beta called beta dashed is equal to beta multiplied by R in divided by R in plus R out of the feedback network. So this is 1 k this is also 1 k.

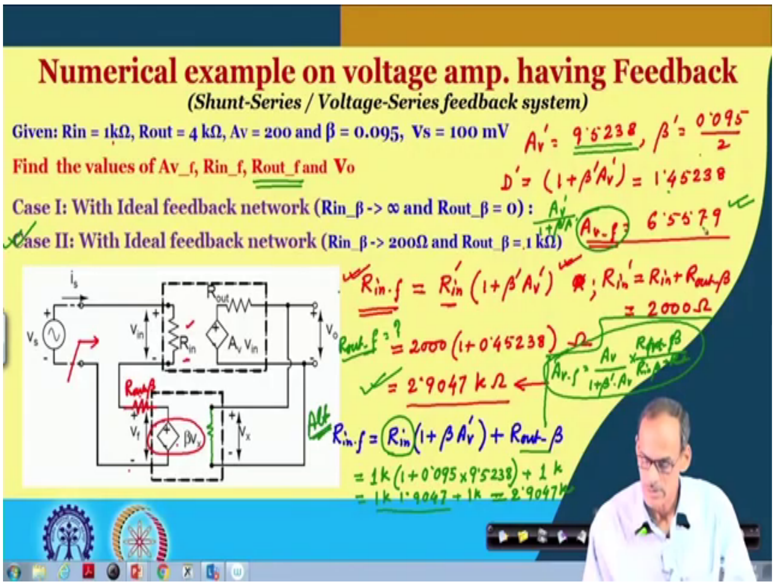
So, that gives us this part it is 0.5. So we can say this is equal to 0.095 by 2. So a priori we should keep these 2 parts, load affected A and load affected beta ready for our consideration. Now if we have to find what is the corresponding gain, voltage gain of the entire network. So, Av f we can say load affected Av divided by 1 plus load affected beta and then load affected Av.

So we do have here it is 9.5238 here divided by 1 plus 0.95 by 2 into 9.5238. In fact, again I have done this calculation. In fact, in this case the desensitization factor this part it has drastically changed. So if you consider its value here and here the value here it is 1.45238. So the value here for this Av f it is 9.5238 divided by 1.45238. And that is becoming 6.5573. So earlier the gain from here to here the gain it was 10 now it is 6 6.55.

So if we are applying say there is 100 millivolt. So what we are expecting this voltage the corresponding voltage here it will be 655.73 millivolt. As the gain of this entire circuit for this case it is 6.557. So, this is also obtained. So next thing it is that, what is the input resistance and output resistance of the feedback system? Again we have to keep this in mind that Av dashed it is 9.5238 and beta dashed it is this one and the desensitization factor corresponding desensitization factor is given there.

So to start with let you consider input resistance, let me clear the board again.

(Refer Slide Time: 14:21)



Let me also keep Av dashed which just now we have obtained it is 9.5238 and beta dashed it is 0.095 by 2 and also 1 plus beta dashed and Av dashed it is what we say, it is desensitization factor it was 1.45238. So, we need to find what will be the R in f. So we are knowing that the input resistance it will be getting increased. But should we consider R in multiplied by 1 plus beta dashed Av dashed? Should I be getting this value correct?

Now this R in, it is representing only this resistance. In fact, there it is having 2 alternate approaches. So definitely this is not correct. We should consider what is the corresponding R in dashed. And what do we mean by R in dashed? It is we have to consider this R out beta also along with this R in. So the R in dashed. In fact, this R in dashed, if I put R in dashed then it is of course, it is correct. Where these R in dashed is equal to the input resistance of this circuit in absence of this feedback signal.

So if I say this signal it is 0, the input resistance it is R in and R beta R out beta is in series. So, R in dashed is equal to R in plus R out beta. So that is equal to 200, sorry 2 kilo. So, we do have 1 k here and another k here. So it is basically 2000 ohms. So the input resistance it will be 2000 here multiplied by 1 plus beta dashed.

So, we do have this number 0.45238 and that is giving us a value which is 2.904 around 4, 7 kilo ohm. So earlier the input resistance it was 2 20 kilo ohm. Now that got drastically reduced to 2.9 only. In fact, whenever and also we already have obtained Av f. So, its value it was 6.5579.

So, for both this R in f and Av f it is having alternate way of calculating say to explain say this part, the let me use the alternate expression R in f can also be considered as a R in multiplied by 1 plus beta into Av dashed in series with R out beta. So you might have seen here what are the things sorry Av dashed what are the things we do have different terms in this expression and this expression.

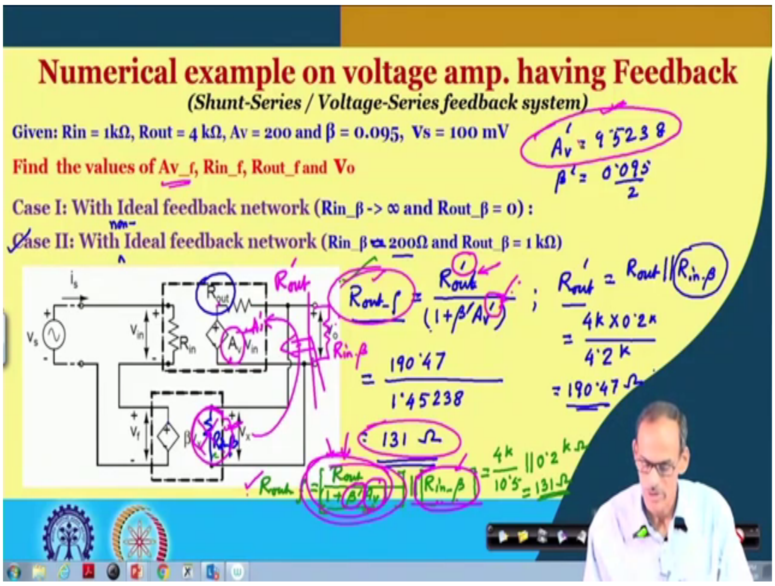
In fact, both of them are same first of all here we consider R in only without dashed. So, here we do have 1 k and then here we do not have beta dashed. So we do have one plus 0.095 only, but then A already got affected by whatever the resistance we do have. So that is Av dashed we have to consider Av dashed. So that is multiplied by 9.5238 in series with 1 k. So if you calculate here, what we will be getting it is this part it is coming 1 k multiplied by 1 point.

In fact, I do have the calculation for you. This will be 1.9047 plus this 1 k. In fact, this part it is becoming 1.9047 k and this is 1 k. So that gives us 2.9047 k. It is same as whatever you do have. So we do have this alternate approach. In fact, same way you can find for this Av f also. In fact, we have used this expression of Av f where we considered A v dash divided by 1 plus beta dash Av dash.

So the alternate approach to calculate this Av let me use this space it is we can consider Av f equals to Av divided by 1 plus beta dashed into A v multiplied by R out if, I should consider not R out f rather R in. R in of the feedback network divided by R in of the feedback network plus R out f ok.

So, this calculation I will be showing you once we get this R out f. So let me find this R out f first and then we will be discussing about the alternate approach of finding this Av f. Similar to R in f. So to, now next thing is that we are going to calculate R out f for this case. But before that, let me clear the board. Please keep the information in mind that Av dashed and beta dashed and and those things.

(Refer Slide Time: 22:55)



So to get the to get the R out f what is the formula we can use? There are 2 formulas, one is we can consider R out dashed divided by 1 plus beta dashed and Av dashed all are load affected. So, where this R out dashed R out dashed it is the R out here and if we have this R in beta whatever the net output resistance we will be getting without considering this feedback network. So that is the R out.

And if I consider this R out dashed, it is essentially R out coming in parallel with R in beta and this is equal to 4 k in parallel with 0.2 k. S, this multiplied by 0.2 k divided by 4.2 k right. And again for this also, I have some calculation for you, I was having 190.47 ohms only. As you can see that this resistance it is quite small. So that is dominating and so, this resistance it is very small.

So, the beta dashed and Av dashed we already have calculated before. So Av dashed it is 9.5238 and beta dashed it is 0.095 by 2 and this factor it is 1.4 something right 4 5. So that gives us R out f equals to 190.47 divided by 1.45238. In fact, this is equal to around 131 ohms only. So similar to R in f for R out also we do have alternate expression. So what is the corresponding expression? This R out f we can say this is R out divided by 1 plus beta dashed, but Av ok. So this is without considering this resistance.

Now all of a sudden if we say that this is appearing. So we need to consider then R in beta in series but while you are doing this, you need to be careful that not only this R out we are considering the inherent R out there. But also this Av it is not load affected ok. and in fact, it can be shown that this is this part it is coming 10.5. So, this is R out it is 4 k divided by this is 10.5 because the Av it is 200 so that is why it is 10.5. This is in parallel with 0.2 k and in fact, this is also becoming 131 ohms.

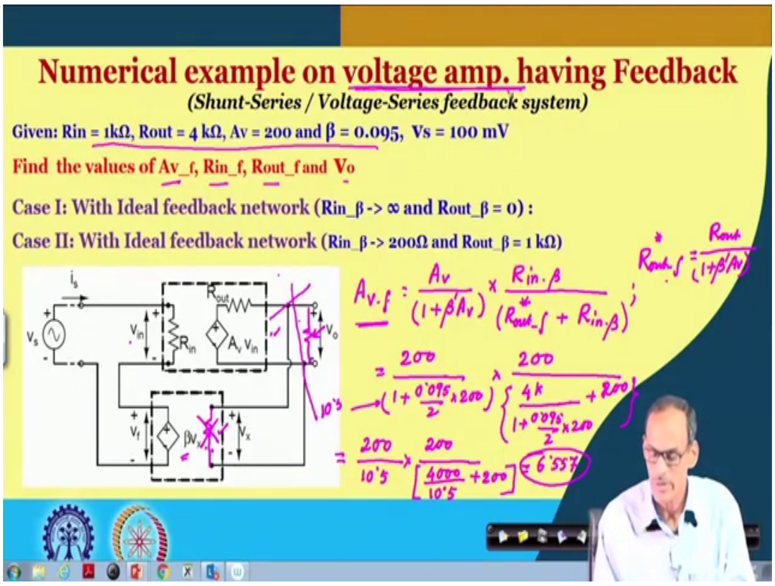
So we do have this equation, this equation as well as this equation. Again, I like to; I like to suggest you that these 2 expression difference are here we do have R dashed, but here we do not have any R dashed. Also here, we do have Av dashed, but this Av is not having any dashed this is R in beta is already it has been captured here and here. So, we do not consider this R in beta here, but in this case on the other hand R in beta it was completely ignored, now we can incorporate that.

But while we are doing this exercise the beta however, it is remaining load affected. So when the conclusion is that whenever we are trying to see the output resistance, either we can incorporate this resistance as part integral part of the amplifier and accordingly, we modify this R out to R out dashed and also this Av to Av dashed and then you can use this equation. Or the alternate approach is that we can keep this part aside thinking that this resistance it is here and here the resistance it is infinite it has been shifted there.

And then we do calculate the whatever the resistance we do have by this formula where both R out it is inherent R out Av it is also inherent Av and then we consider this R in beta into consideration by considering its parallel connection. So now we do have the value of this R out if whether we do have this equation or this equation. In fact, if you consider this part this part without considering this we obtain.

So, we may say that this is also some form of the R out f without considering R in beta. So, as I was telling that Av Av f it is having two approaches one approach you already have discussed by considering this Av dashed and beta dashed together. The second approach now we are going to talk it is the following.

(Refer Slide Time: 30:18)



So, if we have say, we need to find what will be the Av f? What we can say that let we postpone the effect of R in beta. So this effect of this R in beta will be postponing. So instead of putting it here, if we connect it here and first we calculate what is the corresponding Av here and then we can consider this part.

So to do. So the without considering this the Av internal Av it is or internal Av f or intermediate Av f it is Av divided by 1 plus beta into beta dashed into Av multiplied by whatever the loading effect it will coming due to this beta in R in beta sorry R in beta. So, that is that factor it is R in beta divided by R out of this intermediate resistance. So let me call this is say R out f star plus R in beta where R out f star is essentially R out divided by 1 plus beta dashed into Av.

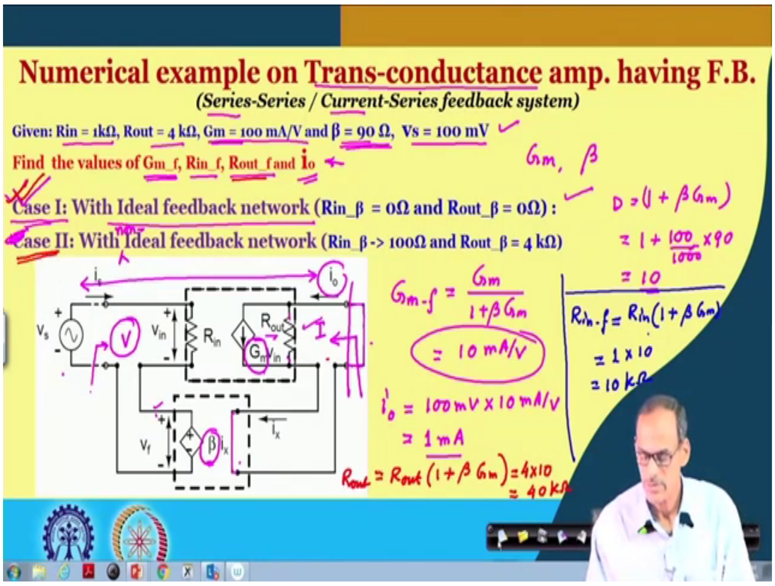
So that means, the whatever the in output resistance we are having without considering this R in beta. And if you do the calculation here Av of course, we do have 200 and this is 1 plus so, this is getting 0.095 by 2 into 200. And then we do have this resistance it is 200 ohms divided by this resistance which is 4 k divided by 1 plus 0.9 0.095 by 2 into 200 right.

So this is this resistance plus R in beta that is 200. In fact, this part it is 10.5. So that gives us 200 here divided by 10.5 multiplied by 200 ohms here divided by 4 k 4000 divided by 10.5 plus 200. In fact, this is also coming equal to 6.557. In fact, this is same as whatever earlier we obtained the value of this Av f.

So, we do have alternate approaches to find this Av. So either we consider this resistance as internal part of it or we can postpone its consideration. But of course, we have to keep in mind that beta we need to consider here. So that is how we can get the value of this the voltage gain input resistance output resistance and output voltage in terms of whatever the forward amplifier parameters and feedback networks parameters are given to you.

So similar kind of exercise you can do for other configurations. So right now it is voltage amplifier and the in the next slide we do have another numerical examples.

(Refer Slide Time: 35:04)



It is very similar. However, in this case, the circuit is trans-conductance amplifier and so the signal here it is current. So, the sampler it is series and it is sampling current and the mixer it is series as the signal here it is voltage. So here again, the gain of this circuit it is Gm it is given to us which is 100 milli ampere per volt, input resistance remains 1 k output resistance here. Of course, this is in the form of conductance. So, that resistance it is coming it is 4 k. Beta on the other hand it is 90 ohms.

You might have observed that since this Gm its unit it is 1 by ohm the expected unit of beta it is it should be ohm and the value here it is 90, the input voltage we are feeding here it is 100 millivolt and you need to find what will be the output current? Also you need to find what will be the overall transfer function? Namely, overall Trans-conductance Gm of the feedback system Gm f.

Then input resistance of this circuit and then the and the output resistance particularly, whatever the output conductance we will see. So whatever the output conductance we will see that is 1 by R out f. So that also you can find. Now, to start with, we can consider the ideal feedback network and then after that we can consider non-ideal situation. So in the ideal situation of course, it is pretty straight forward. So both a or I should say Gm and beta they are not affected by load.

So to avoid the loading effect, we do have 0 load resistance. Here, the resistance is 0 and here the resistance 0. So, there is no loading effect. So directly we can use this Gm and this beta. So the desensitization factor it is equals to 1 plus beta into Gm and here it is 1 plus Gm, it is 100 and 100 milli.

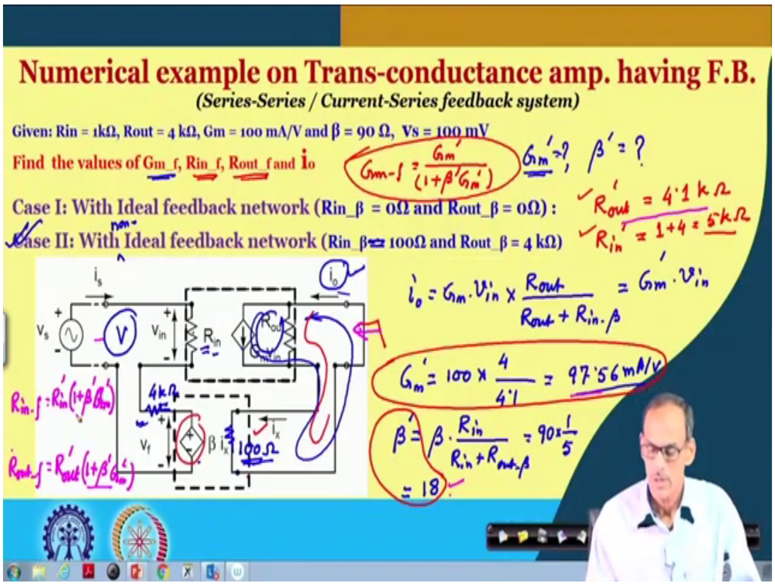
So, I should say this divided by 1000 and beta is 90. So what we have here it is desensitization factor it is 10. So for this case this case at least we can say. So, right now we are considering the first case Gm f. So, Gm f equals to this Gm divided by 1 plus beta into Gm. So that is equal to 10 milli ampere per volt. In fact, from that directly you can say that this i naught it will be 100 millivolt multiplied by 10 milli ampere per volt. So, that gives us 1000 micro or 1 milli ampere for this signal.

So likewise, we can calculate the input resistance. So, R in f as you can anticipate the input resistance it will be increased. So, original input resistance R in it is 1 k multiplied by the desensitization factor 1 plus beta into Gm.

So, this is we do have 1 k multiplied by 10. So, that is equal to 10 kilo ohm. Similarly, if I consider output resistance R out, here also since it is series connection. So we are expecting that R out will also be getting increased by this desensitization factor namely, 1 plus beta into Gm.

So we do have original resistance for the forward amplifier it is 4 k multiplied by desensitization factor of 10. So that gives us 40 kilo ohm. So, that is how we can calculate for the case 1. So likewise, you can make an attempt to consider the second part.

(Refer Slide Time: 40:59)



So, I may not be going all the solution for that, but I am going to give you hint for this non-ideal situation, where the input resistance it is 100 ohms and the output resistance of this circuit it is say 4 kilo ohm. So to start with, we need to find what is the corresponding Gm dashed and beta dashed.

So from that, probably we can get a hint of how to calculate Gm f. Gm whenever we are saying that Gm dashed which means that what may be the current in presence of this resistance? If this is having 0 resistance this entire current it was flowing through this circuit. So, the i o it was simply G m into V in.

Now in presence of this resistance, this current it is getting segregated; 1 part it is flowing through this the other part it is flowing through this one and whatever the part it is flowing through this that gives us this i o. So to get this i o in presence of this resistance, we need to consider this factor and that is R out divided by R out plus R in of the beta network.

So, we can say this is the Gm dashed into v in where Gm dashed equals to Gm. Gm it is 100 milli into R out it is 4 divided by 4.1. So, it is whatever the value it is coming. So, that is equal to 400 divided by 4.1. So, that 97.56 milli ampere per volt. So likewise, you can also calculate the corresponding beta dashed.

And this beta dashed it is of course, here it is the signal it is we are mixing in the form of voltage, and the beta dashed it is the original beta multiplied by whatever the potential division it is happening due to this 4 k resistance here along with this input resistance R in and its expression it is R in beta into R in divided by R in plus R out of beta network.

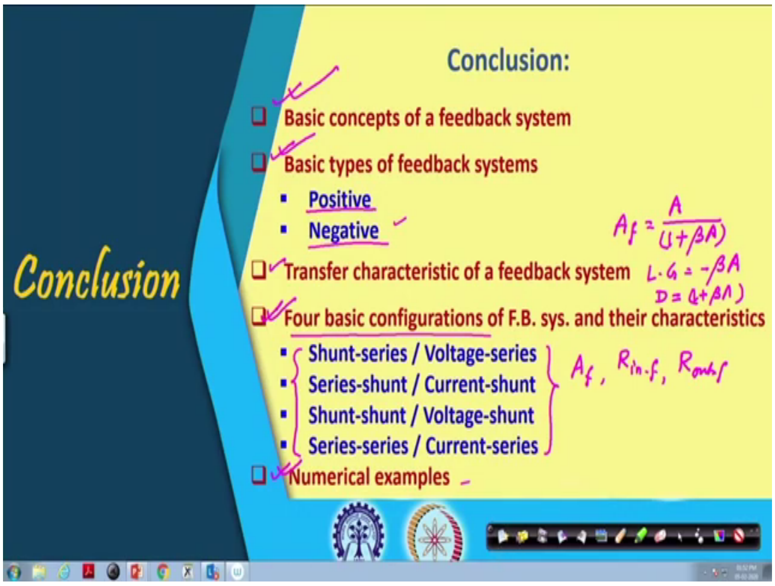
So that is beta it is 90 and R in it is 1 k and this is 4 k. So, this is 1 by 5. So, this is 1 k this is 4 k. So that gives us and this beta dashed it is equal to 18. So, that is how we can calculate Gm dashed and the beta dashed. So likewise, you can find what will be the R out dashed; that means, the output resistance in presence of this 100 ohms.

So, definitely this resistance it is in fact, if you see here, this resistance it is coming in series. So, this will be 4.1 kilo ohm and likewise, R in dashed we should consider. So in absence of this part R in dashed it is 1 k plus 4 k that is the 5 k. So now we obtain the load affected, all these load affected parameters and from that you can calculate what will be the Gm f and then R in f and R out f and so and so on for this case.

So what is the Gm f? You may recall similar to whatever we have done for the previous case, it should be Gm dashed divided by 1 plus beta dashed into G m dashed. We do have alternate expression also. But let we consider this. So likewise, when you consider R in of the feedback circuit. So, what should we consider? We should consider R in load affected and we know that input resistance it is getting increased by a factor of 1 plus beta dashed into Gm.

Sorry Gm dashed and likewise, whenever we are talking about R out, R out of the feedback system here the output resistance it is getting increased compared to its R out dashed. R out dashed we already have 4.1 k multiplied by 1 plus beta dashed into Gm dashed and Gm dashed it is given here and beta dashed it is 18, so, we can find what will be the corresponding factor. So I think you yourself can calculate this one it is now it is a matter of using your calculator.

(Refer Slide Time: 48:07)



So, to summarize all these 4 sub-lectures, what we have discussed in this topic of feedback system. So, far we have talked about basic concepts of the feedback system, there we have introduced how we define the feedback system and then we have talked about 2 basic types of feedback mechanism or feedback system namely, positive feedback type and negative feedback types feedback system.

And subsequent discussion it is mostly related to negative feedback system. So then, we have talked about transfer characteristic of feedback system namely, feedback system transfer characteristic Af is equal to 1 by sorry A divided by 1 plus beta into A. So also, we have talked about loop gain which is equal to minus beta into A then, D sensitivity factor, D is equal to 1 plus beta into A.

Then we have talked about 4 basic configurations which normally it is common in electronic circuit and we have discussed about their characteristic. So these are the enlisted 4 basic configurations we have discussed about how the gain it is getting changed.

And also we have talked about how the input resistance and output resistance of the system it is getting changed by the desensitization factor. And then we have discussed about 2 numerical examples associated with 2 feedback configure different types of configuration starting with ideal situation and then also we have moved to non-ideal situation. I think that is all we need to cover.

Thank you for listening.