Analog Electronic Circuits
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Lecture – 91
Feedback System (Part B)

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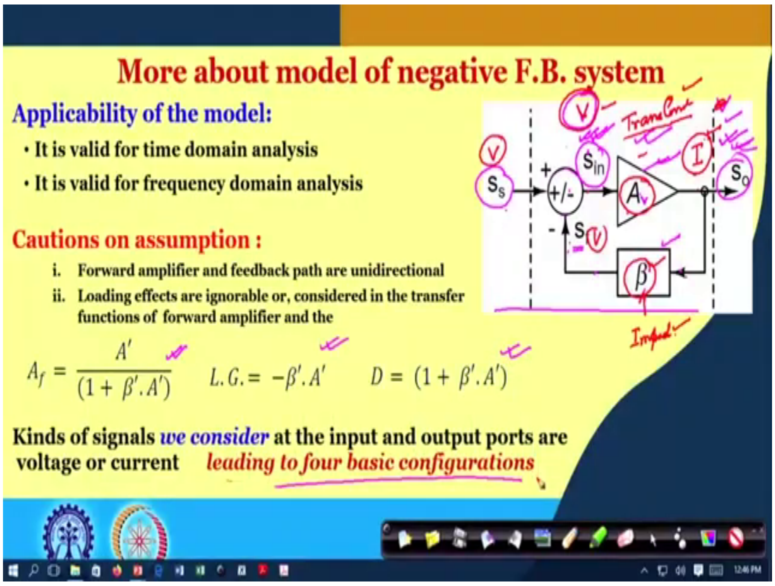

Welcome back after the short break. So, we are talking about different possible configurations basic four configurations. So, in the next slide we are going to see one of those four configurations.

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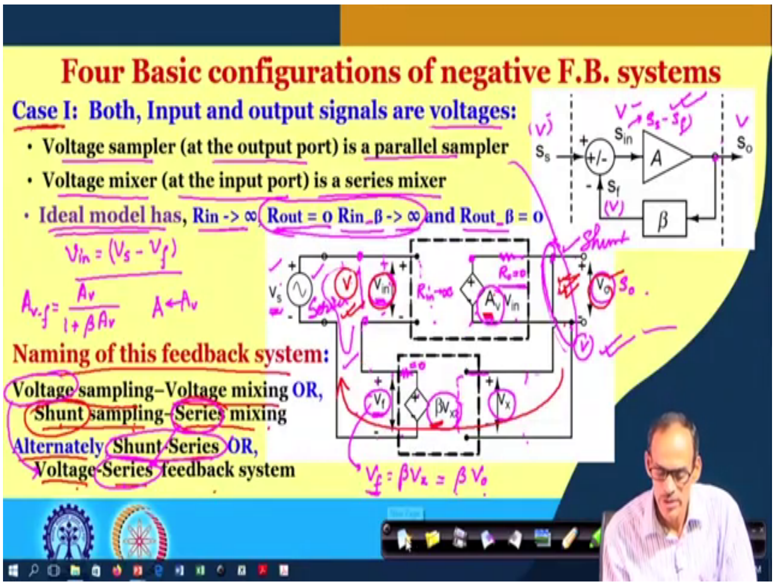

So, here we do have so, this is the basic model and here is the corresponding detailed model. In this case as I said that the input signal and output signal are say voltages.

So, here we consider it is voltage here also it is voltage, so the signal here it is voltage and this is also voltage. Now, since here the signal it is voltage as you can see that the sampler whenever we are sampling the signal, it should be parallel connection. So, we do have this is the output signal in fact, that is S o to sense this voltage the input port of the feedback network it should be parallelly connected.

So, that is why we say that voltage sampler at the output port it is having a parallel port. So, we do have parallel port. On the other hand if you see signal here they are voltages, so our intention is to use these two voltages to generate this S in or V in. So, this is S in and this is S s it is in the form of voltage and this is S f.

So, this signal and this signal we are mixing together to generate a voltage here which is if you see here if you consider this loop. So, if I say that this is V in this is plus and this is minus. So, V in equal to V s minus V f. So, if you see carefully the polarity indicates that V in equals to V s minus V f. In fact, that is what we are looking for S in equals to S s minus S f.

So, that is the; that is the situation and while we are mixing to generate this input voltage from V s and V f, these two signal sources they are connecting in they are connected in series. So, the voltage mixer at the input port it is a series mixer. So, we are connecting the two voltage sources in series. And also in this ideal model while you are say tapping or sampling the signal from the output port we assume that there is no loading effect, same thing here also we are assuming it is loading effect.

So, to create that situation we have considered this ideal situation namely the resistance here it is infinite. So, I am keeping this is open so, R in it is infinite. On the other hand output resistance here R o, so that is equal to 0. So, output resistance here it is 0.

So, the since the resistance here it is 0. So, whenever we are trying to tap the signal for the feedback network, so then it is not creating any loading effect. In fact, we do have a double precaution R o or Rout it is 0 and also here the input resistance of this feedback network in fact, this is R in dash beta. So, it is not Rin beta it is Rin dash beta.

So, this Rin dashed beta; that means, input resistance of the feedback path that is also infinite. So, by this arrangement; by this arrangement, we said that the A is remaining A we do not have to consider A dashed. On the other hand, Rout of this feedback network which is Rout dashed beta which is we are assuming it is 0 and also in combination of this resistance is infinite.

So, whatever the input we are or the feedback signal V f we are producing here that is directly coming there. And this voltage of course, it is coming from whatever the voltage we are sensing, if I call this voltage it is V x. So, the internally developed voltage it is beta times V x.

So, I should say V f equals to beta times V x and incidentally this V x and V o they are same. So, we may say that this is beta times V o. So, whatever the desired equation we are expecting? Namely V f it will be beta times V o that we obtain and here we got V in equals to V s minus V f.

And also here we do have the output voltage which is A v times this V in. So, I should say this A v representing voltage gain, so A in our formula we need to replace by this A v. So, if you see here the primary input to primary output transfer characteristic. Namely, if I call voltage gain of the feedback system in this situation it is A v divided by 1 plus beta into A v.

Now, also you might have observed that since the signal here it is voltage and here also it is voltage. So, this A it is unit less and beta is also unit less both of them are converting voltage to voltage. So, this is one possible configuration out of the 4 configurations.

And how do we name this configuration? As you can see here we are summarizing the naming conventions again it may vary from textbook to textbook; but you should not get confused with different naming. If you see here the feedback signal it is going through this path.

So, whenever you will be naming you should say the this type of the mixture and sorry type of the sampler and type of the mixer. So, in this case what you are having it is voltage sampling and voltage mixing feedback system. Since this voltage sampling it is what you are doing is basically a shunt connection. So, we may say shunt sampling and voltage mixing it is actually series mixing.

So, we may say that shunt sampling and series mixing. To compress it typically we use a this word and this word. So, alternatively this configuration it can be named as shunt series feedback system or you may say that here the signal it was voltage, so we can say that voltage series feedback. So, this voltage it is coming from coming from here and this series it is coming from here.

So, in summary this configuration typically or most of the time we refer as shunt series feedback. So, this is shunt and this is where series; shunt series feedback or you may say that this is voltage and then series feedback.

So, likewise if you consider other situation to get the second configuration where probably one of the signal type we can change. So, let me see what I do have in the next slide, yes.

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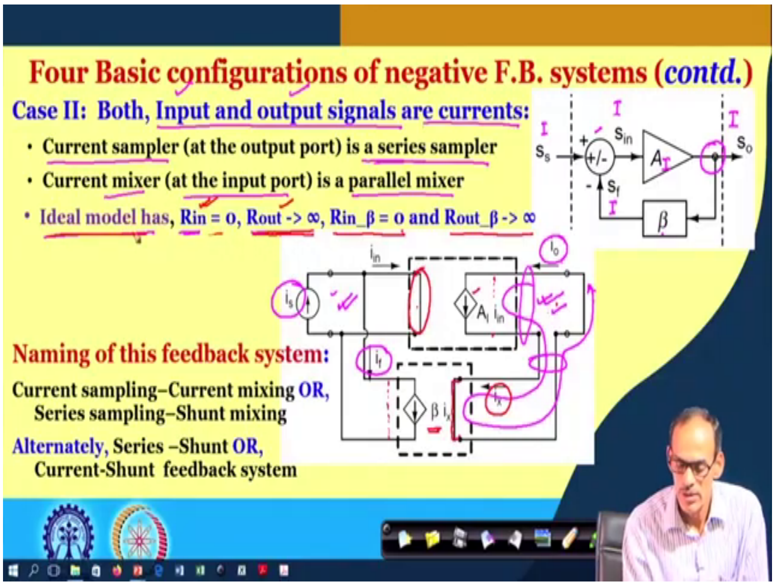

So, in fact we have changed both we have changed from voltage to current. So, what we said is that input as well as output both are current. So, here it is current and here also it is current. Of course, then this is unit less and you may say this is current gain.

And likewise beta is also unit less because it is converting current to current. And then this signal primary port signal should also be current, so that the mixer will be able to mix the feedback signal and the primary signal to generate S in. So, now the sampler current sampler so, whatever the sampler we will be using at the output port it should be in series.

So, if you see here, and if you recall the previous configuration there it was shunt connection; but in this case we do have output signal say I o and this I o need to be flowing through this path right. So, to have this current flowing through this input port.

So, this port and this port they should be in series. So, the sampler these the sampler it is actually series type of sampler. On the other hand if you consider the input port. Since, we do have the feedback signal which is in the form of current and then primary signal it is also in the form of current; and if you want to mix two currents we have to make a parallel connection. So, the mixer it is a parallel mixer.

So, in summary what we have here it is series and here it is parallel compared to the previous case here the situation got changed. Also, the if I consider ideal model to avoid the loading effects, the situation here for the input; and output resistance of forward amplifier and the feedback path need to be appropriately changed.

So, what we have here it is to avoid the loading effect here the input resistance it is 0. And the output conductance here it is 0 or output resistance is infinite ok. So, if I am having conductance then definitely internally generated current it may get reduced. So, to avoid that situation or to avoid the loading effect, we are considering the output resistance of the forward amplifier it is infinite and input resistance it is 0.

So, on the other hand if you consider the feedback network again to avoid loading effect we want its input resistance should be 0. So, that it can nicely sense the signal input signal V x. So, b sorry Rin beta that is the input resistance of the feedback network, we want this should be 0. And the output conductance of this current source of the Norton equivalent model this should be 0, or we can see output resistance is infinite. So, this is what the ideal situation.

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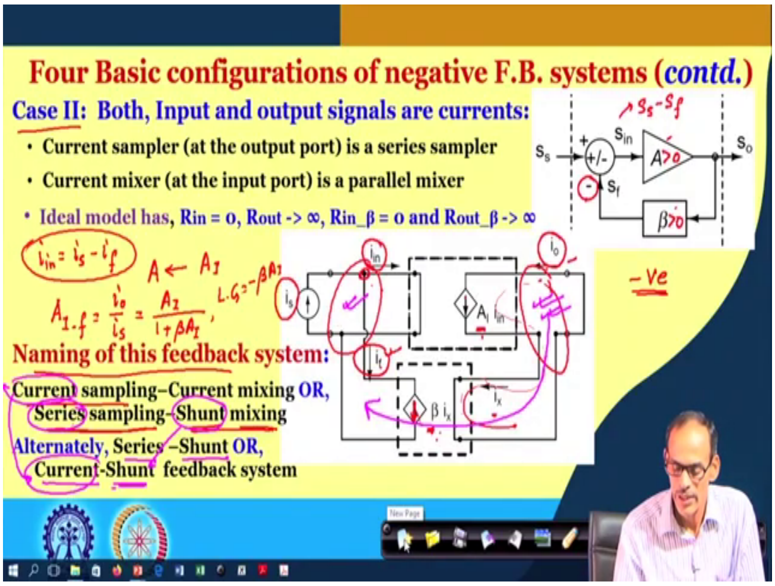

And if you see here the polarity of the signals particularly at the input port you need to be very careful. We call this is the positive direction of the current; we call this is the positive direction of the consider that is the convention. And this is also positive direction of the current.

So, if I consider say this net and if I consider the KCL at that node, so we can easily see that i in equals to i s minus i f. In fact, that is what we are looking for, we are looking for S in equals to S s minus S f. So, this minus ensures that we are satisfying this minus sign. And also if you see the at the output port this is the positive direction of the output signal.

So, the internally generated current it is consistent with that, and we are assuming this A I current gain it is positive, so which means that this is also positive. And if the current is flowing in this direction it is producing a current in this direction which is aligned with i f.

And then we can say that for a positive current of i x it is producing a positive current of beta into i x which is consistent with i f.

So, that again ensures that in this configuration beta is also positive. So, we do have this is positive, this is positive and this is minus sign and hence, the system it is negative feedback system. So, if you make any changes here then there is a chance of your negative feedback system may get converted into positive feedback system.

So, if you also have observed that A need to be replaced by A I and beta of course, beta is remaining same. And A I it is converting current to current so, it is unit less beta is also unit less. And hence, we can say that the overall system gain A I f equals to which is defined as i o divided by i s which is equal to A I divided by 1 plus beta into A I. And of course, the loop gain as you can see here loop gain it is minus beta into A I.

So, this second case this configuration it is having different naming based on this connection and this connection. As you can see that this current sampler it is if you see here it is a current sampler, and current mixer. Current sampler it is a series kind of connection, or a series sampling. So, that the output current should be flowing through this input port of the on the feedback network. And also whenever we are mixing if you see here it is a shunt connection.

So, the naming of this configuration it can be said that it is series sampling, shunt mixing, negative feedback system. Alternatively, we can probably consider series, and shunt. And as I said that the feedback it is in this direction. So, we should start from sampler and then going to the mixer. So, we do have series is the sampler and then shunt is the mixture. Alternatively we may say that we are sampling the current and then we are feeding back to the input port and there the connection it is shunt connection.

So, this current again it is coming from this name and this shunt it is coming from this one ok. So, that is see that is about the naming of this feedback system. So, now we can consider the other situation other rather two more situations where one of them it is voltage; another one is current.

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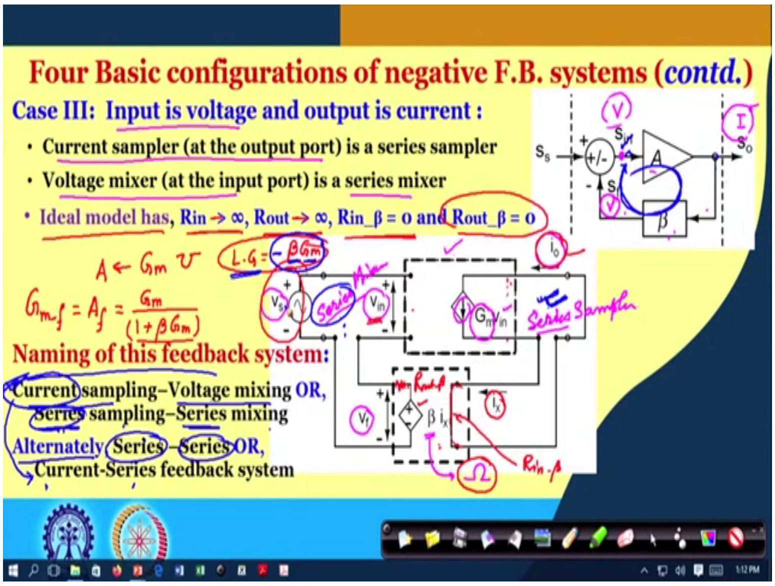

Let me see what I do have in my next slide, say in the third case. In third case what we have it is input it is voltage. So, here we consider the signal it is in the form of voltage. And the signal here it is in the form of current.

So, now you need to be a little alert that this is of course, it is converting voltage into current. So, this should be trans conductance which is taking the voltage at the input and it is giving the current at the output that is why trans, and since its unit is more so it is conductance.

So, in the model here if you see I do have instead of A here I do have G m representing m represents trance and G represents conductance. And it is taking the voltage from the input port and it is generating a current here. And on the other hand if you consider the feedback path beta here the signal it is in the form of voltage and here of course, it is current. So, it is converting current into voltage.

So, now this beta actually its unit it is ohm. So, you can say it is trans impedance kind of network and. So, if you see the nature of the sampler and mixer at the output port we are sampling current so, definitely this will be series.

So, series sampler and on the other hand at the input port we are mixing two voltages V f and V s to generate this V in and since we are mixing voltage they are getting mixed by the series connection. So, mixer is series; so, series mixer. So, if you see here for avoiding loading effect again the input and output impedance of these two blocks need to be appropriately consistent.

So, if you see here the signal it is voltage to avoid loading effect input resistance should be as high as possible. On the other hand at the output to avoid loading effect we want conductance to be 0. Since, it is not only k equivalent conductance we want to be 0 for avoiding loading effect. So, the Rout is infinite and on the other hand the feedback path it is sensing the current and to avoid the loading effect as I say that we are trying to be doubly sure that loading effect is not there.

So, the input resistance here if I call Rin underscore beta should be as small as possible ideally 0. And at the output port of the feedback network since, we are generating voltage again to avoid the loading effect, the corresponding output resistance here Rout underscore beta should be 0.

So, to create the to create a situation to avoid loading effect this is what it is assumed. And hence we considered A is A and of course, A need to be replaced by trans conductance G m. And beta we are using same beta, but of course, its unit it is ohm and unit of this is mho. Now, in this situation of course, input primary input to primary output transfer function, it is we can say G m f, or you may say that this is what A f.

So, that is equal to A which is G m divided by 1 plus beta into G m. And loading f that the loop gain on the other hand equals to minus beta into G m of course, this part it is the desensitivity factor. So, you can probably you can see yourself that this loop gain of course, you are retaining minus sign; but most important thing is that unit of G m and unit of beta they are complementing each other.

So, that it becomes unit less, that is very obvious that if I start from a point and then we are converting voltage into current and then current it is getting converted back into voltage. So, if we really go through this loop the signal here it is of the same type. So, the complete transfer function going through this loop should be unit less. So, that is consistent with this case that loop gain it is of course, it is unit less.

Now, about the naming of this feedback system it is as you can see that how the we do have current sampling. So this is the current sampling and the voltage mixing. So, either we may say that this feedback configuration it is current sampling and voltage mixing, or while you are sampling it is basically the connection it is series. And voltage mixing it is also series, so we can say series sampling series mixing or to abbreviate it alternatively you can say that series connection.

So, this series is in the first one and then this was the second one. The other possible option you might have you may get in the literature is that instead of calling this series, we may use this term and we call current series feedback. So, we are sampling current, and then we are feeding back here in the form of series network. So, the fourth; so likewise the fourth configuration fourth possible configuration where we can say this is current and this is voltage.

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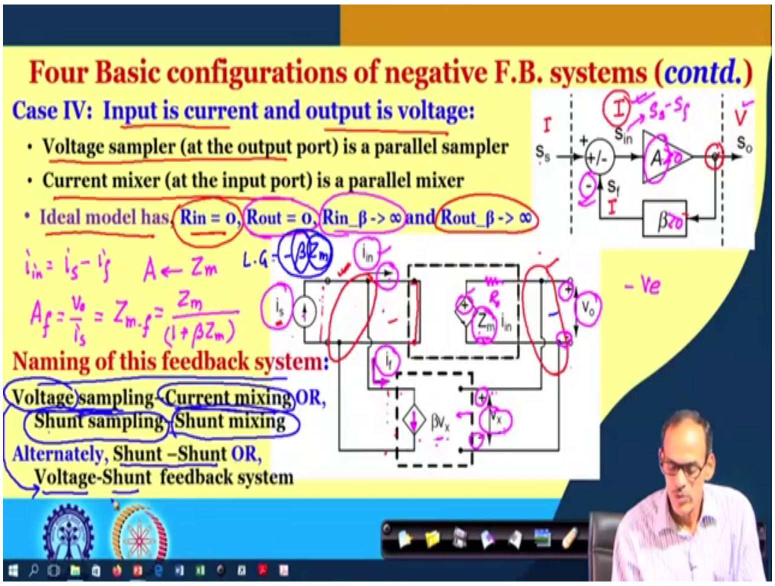

So, in the next slide we will be seeing that. So, the here input is current and output is voltage. So, we are expecting this is current and here the signal it is voltage and we one the feedback signal should be consistent with this current. So, this is also current and the signal source also need to be current. You might have observed that based on the situation in the signal source we are appropriately modifying. And also we are making ideal signal source without considering its Thevenin equivalent resistance, or Norton equivalent conductance.

So, that the loading effect it is ignorable. Later we will be coming back to the loading effect so, but anyway so, this configuration at the output port we do have voltage sampler. So, we are having signal in the form of voltage. So, the input port of the feedback network should be parallel connected. So, as you can see here it is a parallel connection, or shunt connection.

And also the input mixer side. So, mixer it is of course here the signals are in the form of current.

So, the while you are mixing the signals in the form of current it should be a parallel connection, or shunt connection. So, that is what we do have here it is parallel and here also it is parallel, this is for voltage sampling and this is for current mixing. And again to create the ideal situation the since the signal here it is current, we want input resistance should be as small as possible ideally 0. And, the corresponding conductance here it is 0, or the output resistance of the feedback network it is 0.

So, these two is creating this loading effect it is ignorable. So, we can consider only beta not beta dash. And also we are considering 0 conductance for the signal source. On the other hand at the output port to avoid the loading effect the resistance here R o Rout we are taking 0. And the input resistance on the other hand we are considering it is infinite, so that we have to consider A not A dash. Now, here the signal it is current and this is voltage which means that this forward amplifier it is converting current into voltage.

So, naturally its unit it is ohm and we call this parameter it is trans impedance. So, instead of A we write this is Z m, m stands for mutual or trans and Z stands for the impedance. So, the voltage getting generated here it is Z m multiplied by input signal which is i in.

On the other hand in the feedback path it is sampling the output signal in the form of voltage let me call it as V x and based on this V x it produces a current which is beta times V x. And again the polarity convention if you see here we do have plus sign here and this minus sign here which is consistent with this plus and this minus.

And this V x positive V x it is producing a current in this direction which is consistent with the direction of this i f. And the positive direction convention of i f; and i s and i in it is such that i in equals to i s minus i f. So, that gives us S in equals to S s minus S f and hence it supports this minus sign. And the polarity here, and the positive direction of this current insists that this Z m it is positive.

So, that means this A is positive so, likewise here also the output current and input voltage they are consistent for the positive sign. So, the beta is also positive. So, that makes again this is negative feedback system; because of this minus sign, and this both are a positive.

Now, with this we can say that A should be in this case A should be replaced by trans conductance theorem. And the overall feedback system transfer function from i s to V o which is A f. So, V o by i s in fact, we may write this is Z m of the feedback system which is equal to Z m divided by 1 plus beta into Z m.

And the loop gain as you can guess that loop gain equals to minus beta into Z m here also we can see that unit of Z m it is ohm and unit of beta on the other hand which converts voltage to current it is Mho. So, together it is unitless so, as I said that loop gain should be better be unit less.

And coming to the naming convention of this feedback system, it is the sampling it is happening in the form of voltage or we are sampling voltage at the output port. And then we are mixing the signal in the form of current.

So, we can say that this feedback configuration it is having a voltage sampling, and current mixing, or we can say that voltage whenever you are sampling signal in the form of voltage it is we can say it is shunt samplingand current mixing is shunt mixing. So, we can say this is shunt shunt feedback configuration, or we can say voltage shunt feedback configuration ok.

So far we have talked about the ideal situation. Now, of course the situation whenever we consider practical examples there we will see that the we will not be having any guarantee to have this situation or maybe the other situation.

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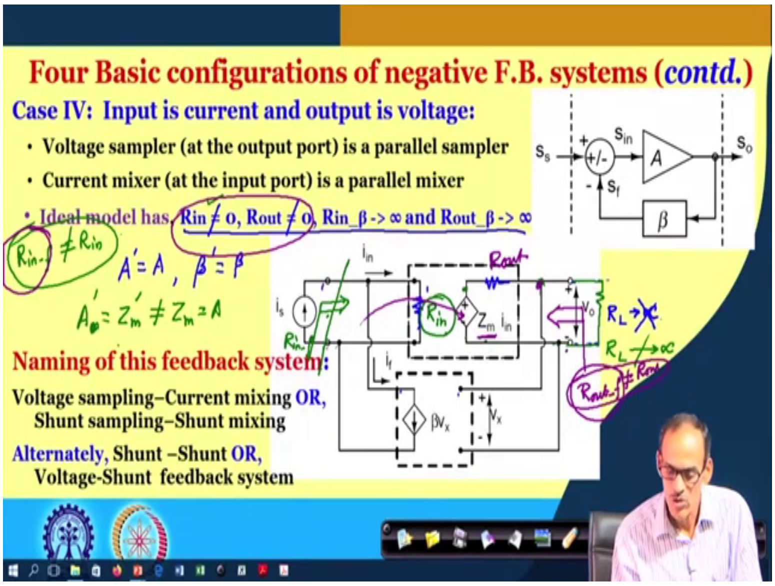

So, in case say we do have finite value of resistance so, in case this is nonzero likewise in case if we do have output resistance which is nonzero and still if I say that this is infinite and this resistance is 0 this is having 0 conductance. So, even in this situation since we are not having any load here. So, we consider load resistances in finite. So, even then in this case the loading effect is 0.

So, we need not to consider A dash rather A dash it is same as A and likewise B dashed it is beta dash right. But then in case if it is not so, in case if we have say finite value of say finite value of say R L, then naturally the voltage coming here it will not be same as whatever the voltage we are generating here. So, in that case instead of Z m we have to consider the corresponding Z m dashed, or in that case I need to consider A dash which is Z m dash. And in that case; obviously, this is not same as Z m, or A.

So, if we have a practical load then we have to consider that situation. And also you have to keep in mind that whenever I do have nonzero value of input resistance. Then if you look into this port; if you look into this port the input resistance of the feedback system it will not be same as whatever Rin in fact this Rin.

Of course, the input resistance of the feedback system I can call this is Rin f. So, R in f it is not same as R in because we do have another path parallel path we do have active path that we do have. So, we need to find what may be the corresponding relationship. So, likewise when you consider this Rout and if I look into this circuit. And if I want to know what will be the corresponding Rout of the feedback system and if I call this is R out underscore f.

So, this is not same as this Rout because we do have a parallel connection here which generates internal signal and it is making some internal voltage there. So, in case if I consider this practical situation then we will see that not only A it is input to output gain A it is desensitized by a factor of 1 plus beta into A. But, also this input resistance of the feedback system and output resistance of the feedback system they are also getting changed by the same factor.

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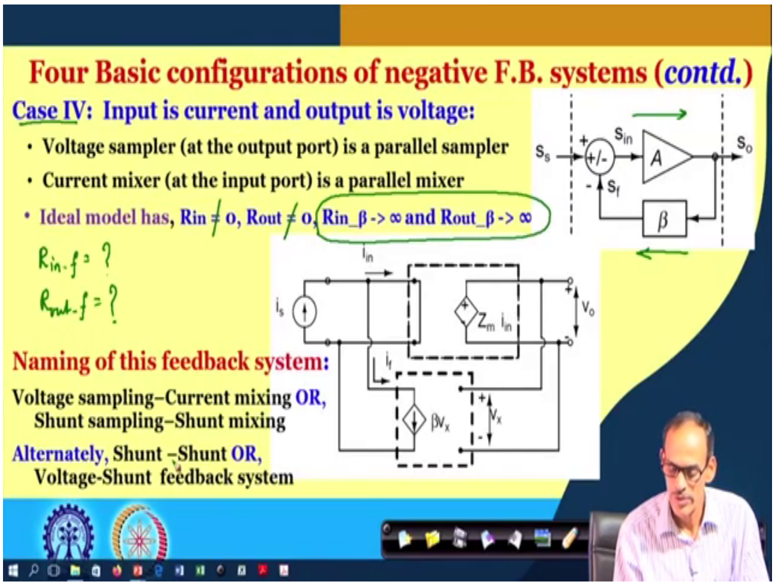

So, in our next analysis what we will be doing is so, what will be doing it is we will consider this is non zero; this is non zero. So, that we can find what will be the R in f and R out f, but for all practical purposes we may continue the ideal situation of the feedback network.

And also we considered all practical purposes it is unidirectional. In fact, this is what I said for only Case IV namely; this shunt shunt configuration, it is valid for the other configuration for example, if we go back.

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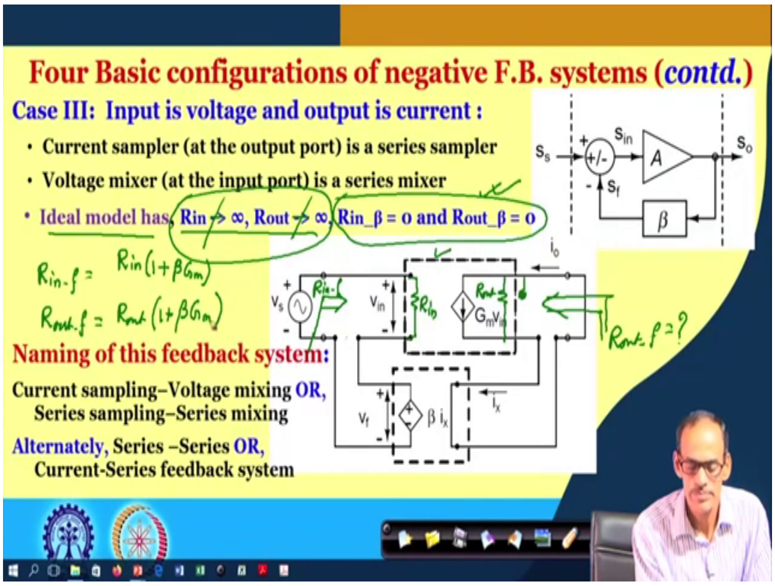

So, if you consider this case and if I say sorry if I say that to support the ideal situation we have considered this, but in case if I am having some finite resistance here. So, suppose this is non infinite, so if I am having R in and say this is also not infinite.

So, we do have some internal conductance or we may call R out. And then if we want to know what will be the corresponding input resistance Rin of the feedback system. And likewise, R out of the feedback system then we need to again analyze the circuit. So, but then to simplify the analysis even though we may consider this non ideal situation for the amplifier, but we may continue to consider this ideal situation. And then we will see what is the expression of R in f in terms of R in.

In fact, what we will see here since it is series connection it is expected to be this resistance you will get increased, and this increasing factor it is the desensitization factor 1 plus beta into A and in this case A is G m. Likewise, R out it is R out f is equal to R out multiplied by 1 plus beta into G m. So, if I consider the fourth case in case if I consider this fourth case and if I consider that these are nonzero.

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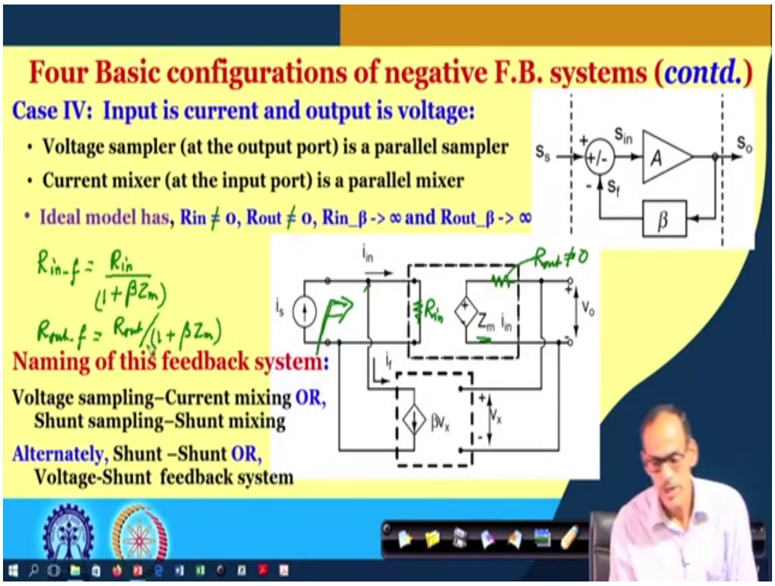

And if I want to know what will be this R in f which is equal to R in and since it is parallel connection we are expecting that input resistance. So, R in and if I know what will be the corresponding feedback system input resistance this R in it is getting decreased, or desensitized by the same desensitization factor which is 1 plus beta into A and A it is Z m.

So, likewise if I consider R out f equals to if I consider the finite R out here which is nonzero. So, that will be R out divided by 1 plus beta into Z m. So, we are going to discuss that, but again please let me take a break and then we will come back.

Thank you.