Analog Electronic Circuits
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Lecture – 97
Applications of Feedback in Amplifier Circuits (Part-A)

Dear participants, so, welcome back to our online certification course on Analog Electronic Circuit. Myself Pradip Mandal from E and EC department of IIT Kharagpur. Today's topic of discussion it is Feedback it is rather continuation of feedback system. And specifically we are going to talk about Application of Feedback circuit in amplifier. So, on the amplifier may have transistor level circuit as well as op-amp based circuit.

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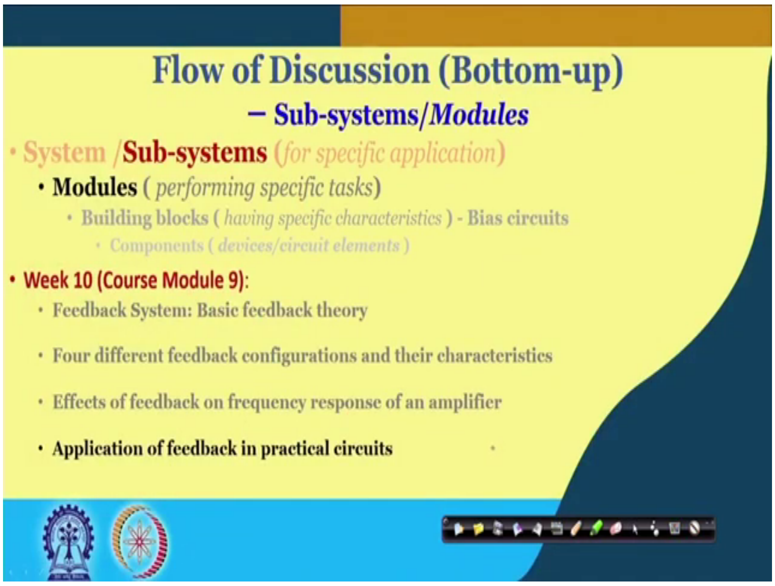

According, to our overall flow we are in a week 10 and we are in module 9. And we have discussed about basic four configurations feedback configurations and their characteristic we also have discussed about effect of feedback on a frequency response of an amplifier. And today's discussion it is more like continuation of the basic four configurations and specifically how those configurations can be deployed on practical circuits. The practical circuit can be either transistor level the example. So, we will be talking about is primarily BJT. And then also we will be talking about deployment of feedback system on op-amp circuit.

So, we can say that we are at module levels as well as at subsystem levels.

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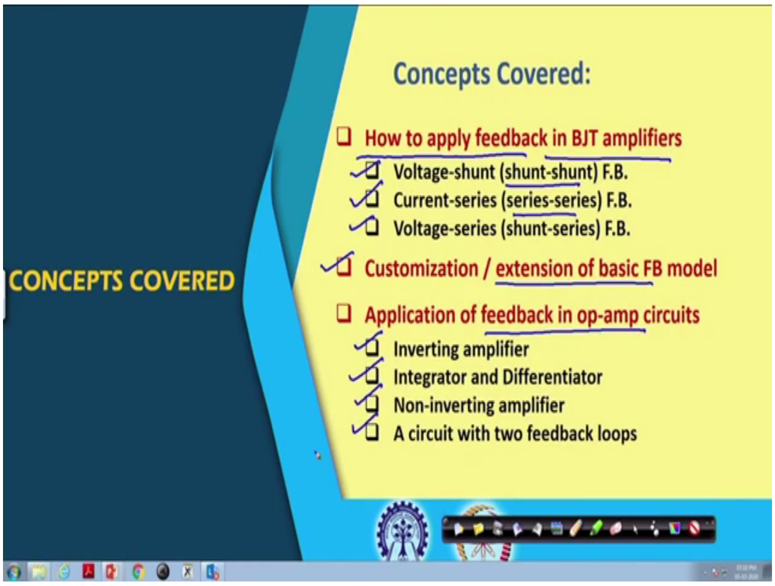

So, the concept, so, we are planning to cover today it is listed here. So, we shall see how we can deploy or how do we decide different feedback configuration in BJT circuits BJT amplifiers. And there we will be talking about specifically three different configurations, which you will be giving us fair idea how to deploy the feedback configuration these are the three possible configurations we are talking about of course, one more configuration it is skipped due to the shortage of time.

So, we will be talking about voltage sampling and shunt feedback referred as shunt-shunt feedback. And then current sampling and a series mixing referred as series-series feedback and then the third one it is voltage series feedback or shunt-series feedback. And then we shall also talk about a little bit extension of the basic feedback models, which we need to discuss before we go into the feedback circuit using op-amp. And for feedback configuration around op-amp we do have different possible examples; namely inverting amplifier, then integrator and differentiator and then, non inverting amplifier. And then also we can discuss about a circuit which is having two feedback loops.

So, these are the these are the enlisted items we do have for this lecture. So, to start with we let us summarize whatever the things we have discussed in our basic four configurations.

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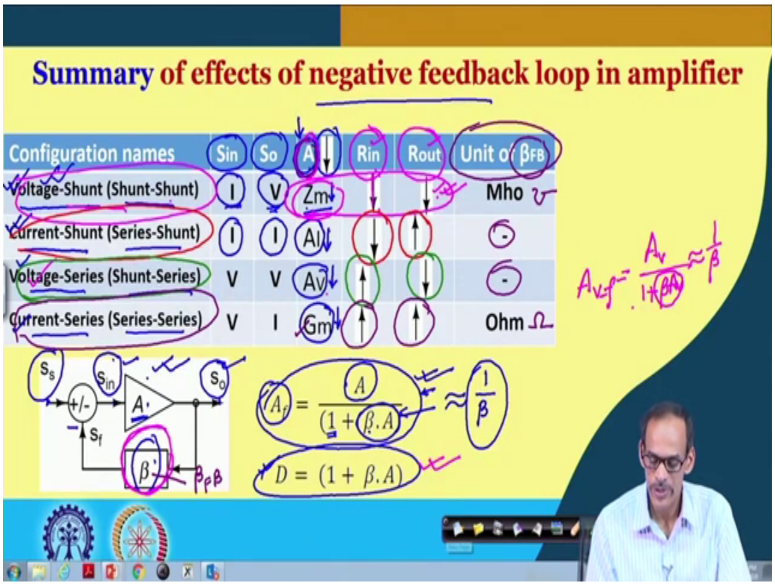

So, yeah. So, here we have four different configurations, so the name of those configurations are given here; namely voltages shunt, current shunt, voltage series and current series or you may say shunt-shunt, series-shunt and then shunt-series and series-series.

So, you may recall that now, depending on these configurations we also can say what type of signals we do have at the input. And also we can see what type of signals we do have at the output of the system. Here we do have the basic model of the feedback system negative feedback system. The input either we may call this is the primary input or just by observing this input we can tell that what kind of amplifier we do have or rather this the input type and the output signal type it will decide what kind of amplifier we do have and that also decides that what kind of feedback we do have or feedback network we do have.

Say for example, if we consider the first one it is the signal here it is current and signal here it is voltage. So, the amplifier the forward amplifier it is essentially trans impedance amplifier or we can say that A is Z m. So, then of course, we know that once we are deploying the negative feedback system, according to this formula the main the forward amplifier gain A it is getting reduced by this factor, which is referred as a desensitizing factor 1 plus beta into A. Where this beta is the feedback factor here and A depending on the type of signal it may vary from Z m then A i the current gain voltage gain and trans conductance Gm.

So, whatever the configuration we do consider essentially this is the formula by which we can say that A it is getting reduced. So, the arrow we are putting here indicating that the feedback effect of the negative feedback it is reducing this A by a factor desensitization factor of the circuit. So, if I on the other hand, if I if I consider say this configuration then the input is current output is also current and A is current gain. And once we have the proper feedback connection, we are expecting that this current game it will get reduced.

So, likewise if we consider the third configuration the voltage gain it will be getting reduced, likewise the fourth one trans conductance it will be getting reduced. So, whatever the configuration we do have if based on that configuration once we know that what is A and then we can say the corresponding A it is getting reduced by this factor. And the factor here what is the basic purpose of reducing this A what you can say that if I assume that beta into A it is much higher than 1.

Then we can approximate this A f feedback system gain A f is equal to beta, which means that the system transfer function or primary input to primary output it can be decided by the feedback network. So, if we want to stabilize the specific parameters say Z m then we should be selecting the first configuration. On the other hand if we say wan to stabilize say voltage gain. So, if we want to stabilize the voltage gain, then we should be selecting the corresponding configuration here. So, then we can say that Av that corresponding A v of the feedback system if I call A v f. So, this A vf it is getting converted into A v divided by 1 plus the corresponding beta into A v. And again if I consider this is much higher than 1. So, this can be well approximated by 1 by beta.

So, the basic objective of having this negative feedback system it is to stabilize this A whether it is Z m A i A v or G m. And it should be stabilized to a value which is defined by the feedback network, which can be decided by a designer based on the requirement. So, for every configuration while A is getting reduced the resistance input resistance and the output resistance, on the other hand they may have a different changes. Say for example, if I consider shunt-shunt configuration then input resistance it is expected to decrease by the same desensitization factor and also the output resistance it is it is getting decreased by the same factor.

So, while we are trying to stabilize this Z m, you we should be aware that the corresponding input and output resistance they are also getting decreased. So, there may be different objective to follow this configuration or to get this configuration one of them it is of course, to stabilize the Z m. The other objective on the other hand it can be reducing the input resistance and or reducing the output resistance.

So, this combination; however, this combination is fixed reducing Z m and then reducing R in and R out it is fixed. And if we are reassured that we are looking for this characteristic then we can add the negative feedback system in this shunt-shunt configuration. And so, likewise if you if you are very clear that which parameter you liked to stabilize, namely defined by the parameter or the feedback network based on that you can select the corresponding circuit configuration. And also, you should be aware that what maybe its corresponding consequences. And the consequences as I said that for this case both R in and R out they are getting reduced.

On the other hand, for the second case for the second case the R in it is getting reduced, but then R out it is getting increased. So, likewise if I consider the third case excuse me, likewise if I consider the third case, we do have the third case here and for this third case the input resistance it is getting increased and output resistance on the other hand it is getting decreased.

So, likewise the final one the for series-series configuration feedback configuration both R in and R out they are getting increased. So, this table this summary it is very handy and this will be helping us to decide which configuration we are looking for to achieve some requirement. Namely to change the input and our output resistance or probably either current gain, voltage gain, trans impedance or trans conductance we like to stabilize defined by the feedback network. And while we do have the A it is having different possibilities, the corresponding feedback factor beta FB we are calling this beta as beta FB to avoid confusion with the beta of BJT transistor.

So, if A it is say Z m the unit of beta FB it is more. And on the other hand, if the A it is trans conductance or the unit of beta if it is ohm. And on the other hand, if A is either current gain or voltage gain then beta FB it is unitless. So, now, we should also be aware that suppose if I decide one specific configuration and we know that the corresponding changes are happening then we should also be aware that what will be its consequences namely what will be the variations on the on the other parameter.

So, in the next slide we are also having one important table along with this table, which tells us that what may be the corresponding consequences on the other parameter.

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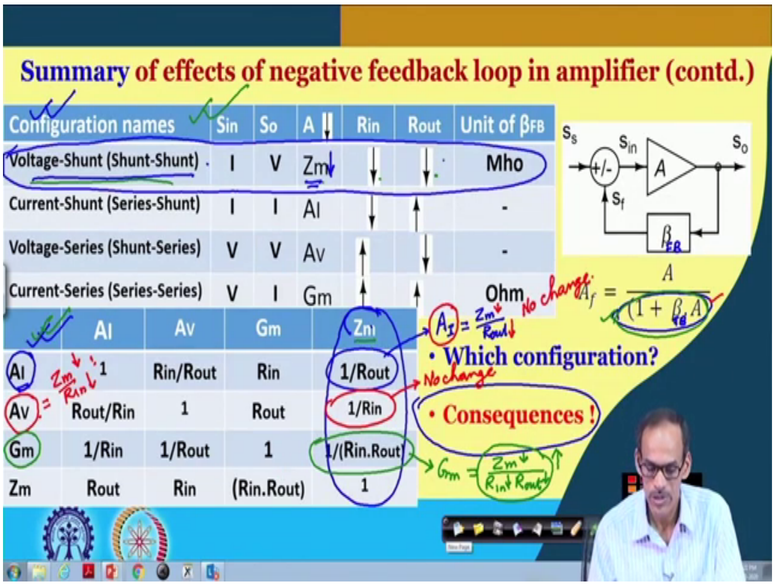

So, here we do have the same table, which will be helping us to decide basic configuration. And then, we do have the other table here which it will be helping us to understand that what may be the consequences on the other parameter. So, say for instance if I consider this configuration and I know that Z m got reduced by the desensitization factor like this one 1 plus beta into A or whatever you say beta FB into A. And R in also is getting reduced by the same factor same thing for the R out.

Now, suppose we like to know what maybe the what kind of changes are happening on the other parameter; namely current gain, voltage gain or trans conductance for this configuration. Then we need to know that how do we express those parameters in terms of this Z m and R in and R out. Here we do have a table which is representing the other parameters say current gain in terms of Z m and R in and R out.

So, if I if I see this this column that gives an indication that the current gain of this circuit this configuration which is Z m divided by R out. So, we can say that this is indicating that current gain of the circuit A I is equal to Z m divided by R out. And this table suggests that both Z m both Z m as well as this R out they are getting reduced by the same factor. So, we can say that this A I the current gain will not be having any change. So, we can say that it will be having no change.

Now, we can also work out on the other parameter say for example, if I consider the voltage gain. And the voltage gain its expression it can be given by this factor multiplied by Z m. So, we can say that this A v equals to Z m divided by R in. And again both the Z m and R in are getting reduced by the same factor desensitization factor and as a result here also there will not be any change. So, I should say here also we do not have any change.

On the other hand, if I consider say trans conductance. So, the trans conductance of the circuit under this configuration we can say that it can be expressed by in terms of Z m and R in and R out by this or we can say that trans conductance of the circuit G m equals to Z m divided by R in and R out in the denominator. And as this table suggests that both R in and R out are getting reduced by the same factor and of course, Z m is also getting reduced, but since we in the denominator we do have two factors.

So, we can say that the net effect here the denominator is getting reduced; that means, it is getting increased by the desensitization factor. So, I should say that by looking into by combining this table and combining this table we can also see the changes in the other parameter by considering the corresponding parameter here. Now, let you consider other example say let me clear it. Let you consider say the circuit in this configuration voltage-series or shunt-series configuration, which indicates that A v it is getting stabilized or reduced by the desensitization factor.

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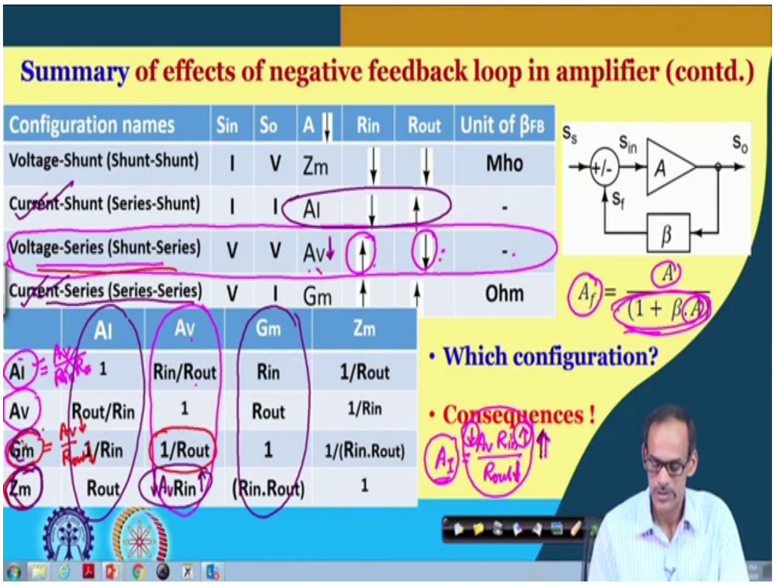

So, we can say that this A it is A v and appropriately you have to see what is the corresponding beta of course, it will be unitless and this is also A v. And we suggest that after having the negative feedback configuration the system gain voltage gain it will be reduced by this factor. And while we are making this configuration as this table also suggests that the input resistance is getting increased by the desensitization factor. And the output resistance on the other hand it is getting decreased by that factor.

So, we are clear that this configuration it is having impact on voltage gain input resistance and output resistance. So, we can say that A v we know for this configuration now we like to know what will be its effect on the current gain. So, to look at the effect on the current gain now, we will see this column which represents that the expression of all the parameters in terms of A v and input resistance and output resistance.

So, if I see the current gain which is A v times R in divided by R out. So, we can say this is equals to A v divided by R in and R out sorry, let me let me write here A I is equal to A v times R in divided by R out. And as this table suggests that A v it is getting reduced R in on the other hand it is getting increased and R out on the other hand it is getting decreased. So, in effect this A I it is getting increased by this factor desensitization factor because this decrease and this increase they are getting canceled we do have the denominator is getting reduced and hence the net effect it is the A I it is getting increased.

So, I should say that before we make the feedback connection whatever A I we are having that A I after making the feedback connection is getting increased by this desensitization factor. So, likewise if I consider say G m. So, if I consider G m here for this configuration and the G m it is its expression in terms of A v it is given here. So, this is equal to A v divided by R out and as this table suggests that both A v and R out are getting decreased and hence this G m it is not having any change.

So, G m remains unchanged. And then if you look into the trans impedance Z m. So, if you look into Z m. So, Z m it is A v into A v into R in. And this A v it is getting decreased and R in it is getting increased. So, again here also this Z m is not having any change. So, both G m and Z m are not having any changes, but the A I it is getting increased and A v of course, it is getting decreased.

So, like that you can look into the other configurations namely series-shunt and maybe series-series and you can see what kind of changes are happening in the main parameters. And what kind of corresponding effect it is falling on the other parameters by looking into either the first column for the series-shunt connection or for series-series connection you can look into say third column to see what kind of changes are happening in other parameter.

So, I think this summary this summary table it is very useful to deploy the feedback configuration and deciding what configuration you are looking for to achieve some objective and also it will it is giving us the information about the changes or consequences on the other parameter. Now, let us look into more towards the actual circuit then.

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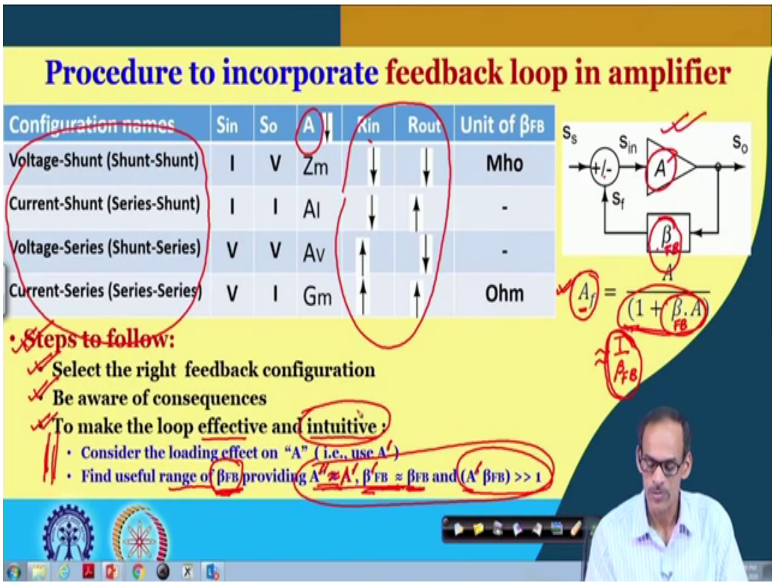

So, what we will be looking for it is. In fact, let me also summarize some other aspect namely. So, we do have the table we do have table, which gives us the information about how to select the configuration after that what you do?

So, rather what maybe the overall procedure to incorporate feedback loop in an amplifier. So, here we do have the list of the activities we have to do first thing is that we have to select the right circuit configuration. And also we need to be aware about the consequences what are the changes are happening, not only in input and output resistances, but also in other parameter such as transconductance or voltage gain and so and so.

And the third one is very important that, if we consider the practical application. And if you really want to make use of this feedback connection to create some effect. And if you really want to know what is the effect and intuitively if you want to calculate what is the corresponding changes, then definitely we need to have a fair understanding of a suitable range of the parameters or rather feedback resistance or feedback network.

So, here we do have some guidelines which helps us to make the loop really effective according to this formula also we can intuitively say that what kind of changes are happening. So, what are the guidelines we do have? The first thing is that whenever we are considering say this feedback system model we assume that in case if there is any load and the effect of the load it has been considered in A which means that we need to consider A dash instead of A or at least we make sure that the effect of the external load it has been taken care if it is possible, to do so.

And then next important thing is that we need to find the meaningful feedback network or other feedback factor beta FB. So, that the loading effect of this feedback network on A. And loading effect of the mixer circuit on feedback network you can say it is it can be ignorable. Or we can say that this A double dash it should be approximately equal to A dash A dash is the load external load effected gain. And also the beta FB dash should be approximately equal to beta FB. And if we follow this follow this appropriate range of beta FB to satisfy these two condition then you can intuitively say that what kind of changes it is going to happen in the circuit.

Now, in case if you if these two approximations are still not valid, then also the circuit it will be working, but whatever the simplified expression whatever the equation it is giving us in intuition that what kind of changes it will happen that may not be really effective. And they are maybe a significant amount of deviation from the simplified theory the apart from this two approximation we also need to say that beta into A or we can say that A dashed into beta FB if it is much higher than 1, then only we can say that this is approximately 1 by beta FB. And then only you can say that the feedback system characteristic it is solely or predominantly defined by the feedback networks parameter.

So, to achieve this property namely the A f solely defined by the feedback network we need to have meaningful selection of this beta F B. And then only whatever the changes we are we have summarized in this table, namely increase or decrease of the resistances defined by this desensitization factor it is directly applicable.

But of course, even if you are not satisfying these conditions then also the R in and R out will increase or decrease the according to this table for this different configuration. Only thing is that their increase and decrease may not be defined by this same desensitization factor, we have to consider the corresponding deviation to get the more accurates change in the input and output resistance and also the change in A.

So, for practical circuit as I said it is better to have a meaningful range of on this beta FB. So, in the next slide let me discuss about what is the guidelines to really get a range of beta FB rather going little detail of whatever the guidelines we are discussing now.

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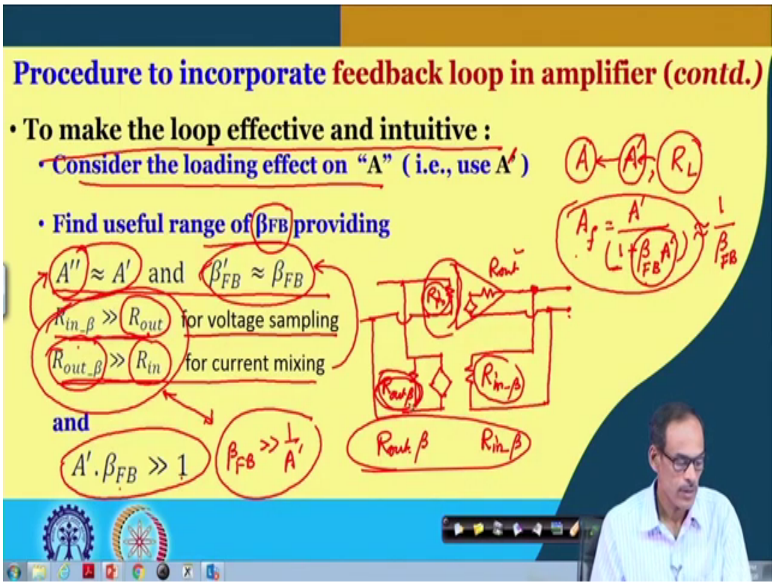

So, yeah so, to make the loop really effective and intuitive, first thing is that let you consider the loading effect on A. So, we should say that instead of A, it is better to consider A dash after considering the external load effect.

So, in case if you have external load R L and if you consider that R L on the circuit. Then we can get load effected A and then we can proceed further. Namely we can try to calculate what may be the A f in terms of this A dash divided by 1 plus beta FB and then A dash.

Now, next thing is that we need to find the suitable range of the beta FB of course, based on the nature of A beta FB it is complimentary in nature. So, that this product it becomes unitless rather you may say that loop gain minus of loop gain it becomes unitless. And that is once you once you know that what maybe the nature of this beta FB next thing is that what is the meaningful value of it.

And to get that to get a suitable range we do have two things to satisfy as just now I was talking about. A double dashed it is approximately A dashed. And what is A double dash? It is the loading effect of the input resistance of the feedback network say R in beta, if it is much higher than the R out of the amplifier particularly for voltage sampling then we can say that this A double dash it is approximately equal to A dash.

So, if I if I ensure that this condition is getting satisfied, then you can say that loading effect of the feedback network on the forward amplifier it can be ignored. So, pictorially you may say that suppose this is the amplifier and it is having R out and suppose we are making a voltage sampling, which means it is a parallel connection and we do have the input resistance of the feedback network which is R in beta. And so, this R in beta if this R in beta it is a much higher than this resistance then you can say that the loading effect on the amplifier or this output voltage hardly changes even if I consider this R in beta.

So, this is specifically true for voltage sampling and of course, for current sampling the condition it will be the other way. On the other hand if I consider the input resistance of the amplifier R in and then, we do have say current mixing. So, if we have a current mixing here.

So, this is shunt configuration and then we do have R out of the feedback network beta. So, if I consider this shunt mixing or current mixing then if we satisfy this condition.

If I say that this R out beta it is much higher than this input resistance here. Then we can say that the loading effect on the feedback network from the input resistance of the amplifier it is ignorable. And hence, if I satisfy this condition then we can say that this beta FB dash it is approximately equal to beta FB.

So, this is giving us a good range of or it is helping us to define what may be the suitable value of R in of the feedback network R in beta and R out beta. And then also if you consider that this equation, if it is giving us giving us the expression of A m sorry A f in terms of beta FB to get this we want this part should be much higher than 1. So, we can say that A dash into beta FB it should be much higher than 1 and this gives us the beta FB it is much higher than 1 by A dashed.

So, this two condition here along with this condition, it will be helping us to find what is the suitable range of for the feedback network circuit components and that will be helping us to get very effective feedback connection. I think this will be very clear once you consider one practical circuit. Probably, I do have the practical circuit in the next slide yeah.

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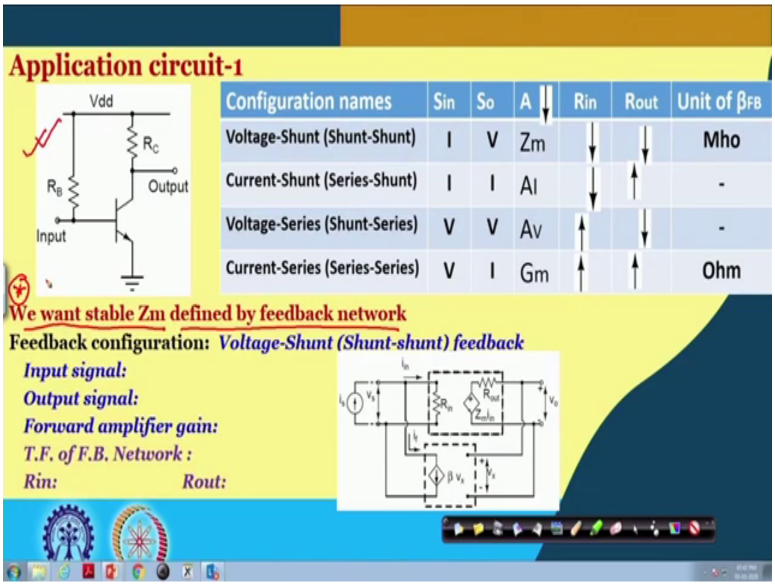

So, here we do have one application circuit shown here, which is a common emitter amplifier. So, we do have common emitter amplifier. In fact, this is fixed by us common emitter amplifier. And we will be talking about its feedback connection and our main target it is that we want a stable Z m defined by the feedback network. So, this is our main objective. And then we will be discussing how to decide the configuration and then how to select the component value; but before that let me take a short break and then I will come back. 2 minutes.