Analog Electronic Circuits
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Lecture – 98
Applications of Feedback in Amplifier Circuits (Part-B)

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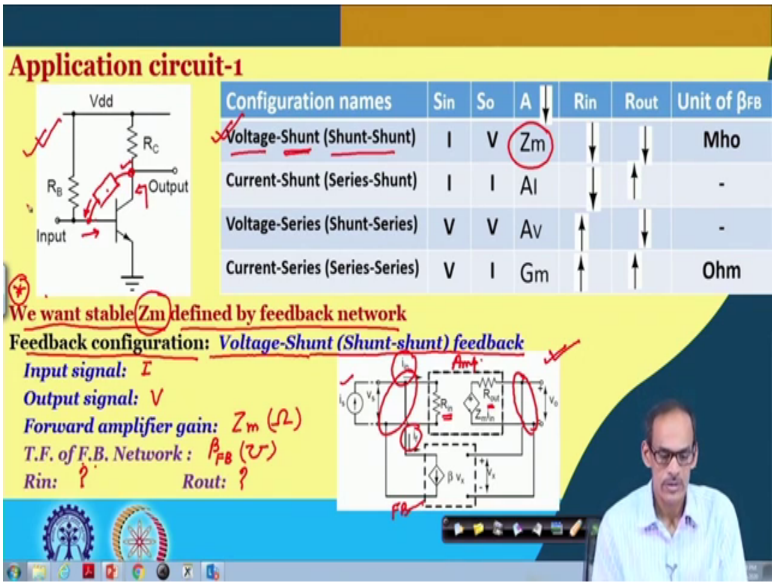

Welcome back after short [vocalised-noise] the break. So, what we are talking about the common emitter amplifier and what we are looking for is that Z m trans impendence of the amplifier we like to stabilize defined, it should be defined by the feedback network element [vocalised-noise]. So, as this table suggest that if we are looking for this Z m to be stabilized by the negative feedback then A should be Z m.

So, this is the configuration we have to use, where we need to sample the signal in the voltage form. And we have to mix the signal at the input in the shunt configuration or we can see that the currents fall or we can say it is shunt-shunt configuration. And so, that based on this table and the requirement, the feedback configuration it is voltage-shunt or shunt-shunt feedback configuration. And this is the corresponding model of the configuration, where this is the amplifier forward amplifier and this is the feedback network.

And here we do have the sampling of the output voltage and here we do have the mixing of the primary input and the feedback current to get the input current for the amplifier. So, we can say that in this circuit input signal it is current and the output signal it is voltage. So, the forward amplifier it is its gain it is Z m.

So, its it is unit it is ohm and then the unit of the feedback networks transfer function beta FB it is a mho. And the input now, next thing is that we need to find what is the corresponding input resistance and output resistance of the actual circuit. Namely, if I consider this circuit what is the corresponding input resistance and the output resistance of the circuit.

So, in the next slide what we can do? First of all we have to sample this voltage and then we have to make a connection here, probably we can make a make a bridging element from output to input. And this unit supposed to sends this voltage here at the output and it supposed to produce the current at the input port.

So, in the next slide we are going to have the corresponding circuit and yeah.

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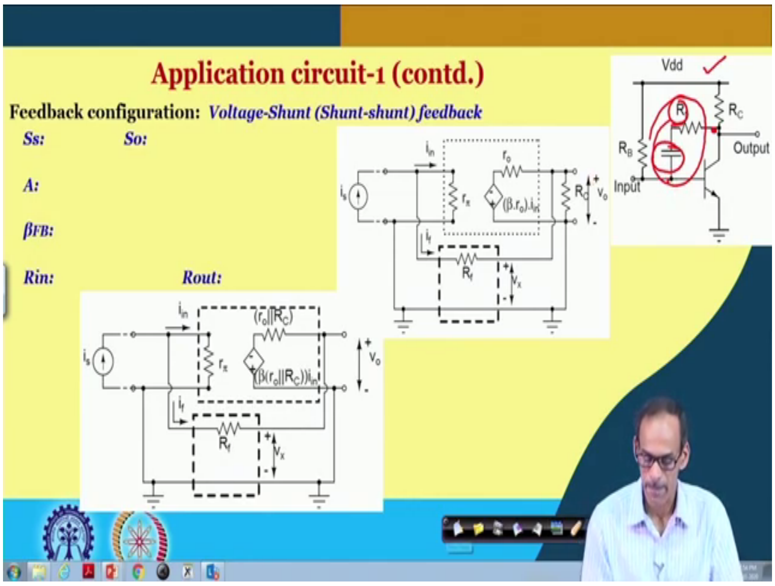

So, here we do have the common emitter amplifier along with its feedback arrangement and we are also adding one capacitor. So, that the DC operating point of the common ammeter amplifier it is not getting disturbed by presence of this R f. So, this R f it is sensing a voltage here and it is providing a current here.

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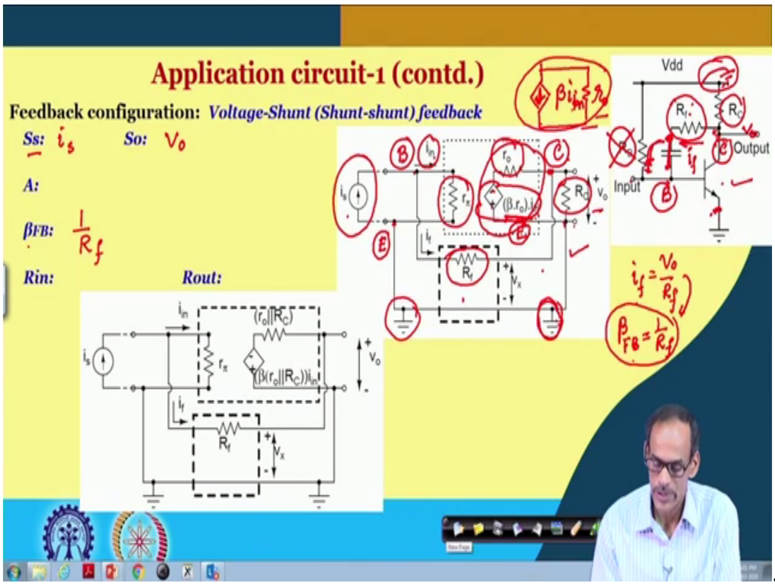

So, if you consider the idealistic situation, then if I say that if this point if it is connected to say ground the current flow here it is V o if I call this is V o divided by R f. So, that is the feedback current. So, i equals to v o divided by R f. So, from that we can see that this i f equals to v o divided by R f. So, from that we can say that beta FB equals to 1 by R f. So, if there is no load at this output port of the feedback network namely if I connect 0 resistance to ground, then whatever the current we are getting that is the i f and that gives us the [vocalised-noise] and using this equation we are getting the beta FB which is unloaded.

So, we can say a beta FB of this feedback network it is 1 by R f; in this circuit of course, primary input it is i s note that this resistance here bias resistance R B it is quite high compared to the other circuit. So, we may ignore this resistance for our [vocalised-noise] linearized analysis or AC analysis and then of course, we have to consider this is AC ground and the output node here which is the collector terminal. So, this is the collector node and then we do have the emitter node here. So, that is this node is the emitter node. So, let me use this point here which is of course, connected to ground.

So, this is of course, it is connected to the actual ground. On the other hand [vocalised-noise]at the at the base this base terminal it is the input terminal. So, this is the base terminal and the negative side of the input port it is connected to the ground. So, this is the corresponding emitter terminal or the negative side of the input port or negative terminal of the input port. [vocalised-noise] And this emitter it is connected to again ground and the register R f it is connected between R C and not R C the collector and the base through this capacitor and for signal we can assume that this capacitor it is working as a short.

So, we can see that this R f it is bridging this collector terminal and the base terminal for the signal. So, that is how this R f it is shown here in this equivalent circuit. Now, base to emitter we do have r pi. And then collector to emitter what we have it is we do have internal voltage internal signal voltage, which is beta times r naught into i in. In fact, this voltage we need to write in terms of the input signal which is current; because our main focus is to define a of this circuit rather Z m.

So, originally or most of the time what we use the internal circuit it is not an equivalent circuit where we do have the internal current source which is beta times i b or i in in parallel with r o which is the conductance here.

Now, this i b it is same as i in. So, probably you can write this is i in and this circuit not only equivalent circuit we are writing here in this form which is Thevenin equivalent. So, in summary we can say that the internally developed voltage here it is beta into r naught into i in [vocalised-noise] of course, this polarity of this current positive current is from collector to emitter. So, that is why we do have minus sign here and plus sign here and this r naught it is directly providing the Thevenin equivalent resistance.

So, in summary this is the small signal equivalent circuit of the amplifier; considering a R f in to the picture and of course, ignoring the base bias resistance. And at the input we do have the we are expecting the signal should be current. So, this is the corresponding input stimulus ideal stimulus i s. So, in the feedback circuit the primary input S s it is there is i s. And on the other hand output it is the voltage here V o. So, we can see that V o is the corresponding voltage. Also we can see that this R C it is connected between collector and V dd. And V dd it is AC ground. So, this R C you can connect from collector to the AC ground which is also for AC model you can or AC or small signal equivalent circuit we can see that this is also connected to ground.

So, that is how we can see that [vocalised-noise] the transistor level circuit it is getting translated into the desired model and the model it is it consists of the different elements that the feedback network work as well as the main amplifier. So, let me clear up the diagram here again. So, what we have here it is output to input this R f it is working as feedback network.

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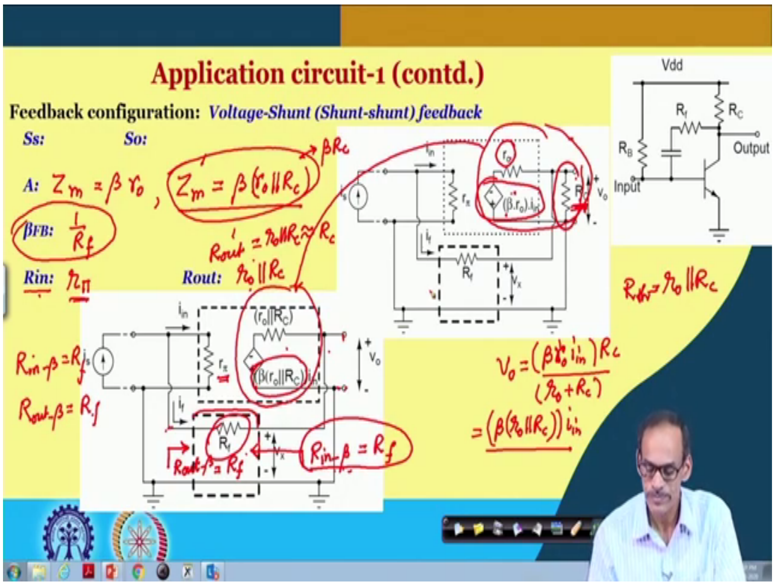

So, we can say that beta FB it is 1 by R f input resistance of the circuit it is r pi and output resistance in this case it is r o which is also getting loaded with R C and typically this R C it is much smaller than r o.

So, it is better to internalize this R C with this amplifier. So, once you modify this circuit or rather once you take this load within this, then the internal voltage it need to be changed in this form where you can see that the voltage available here it is. Once we have the R C the corresponding voltage V o it is equal to internal voltage beta into r o into i in multiplied by R C divided by r o plus R C or you can say that beta into r o in parallel with R C multiplied by i in.

So, this whole circuit it can be said that it can be represented by Thevenin equivalent voltage source, where the voltage it is the Thevenin equivalent voltage is given here and the Thevenin equivalent resistance of course, R th is r o in parallel with R C. So, the whole circuit it is getting reflected here in this form. So, the R C it has been consumed now the circuit it is unloaded. So, with this modification you may say that this R out instead of ro it is ro in parallel with R C. And in this model the corresponding A which is of course, this this is Z m in this model it was beta into r o.

But once we take this R C within the circuit, then the corresponding Z m or we can say that Z m dashed which is load affected Z m it is equal to beta [vocalised-noise] into r o in parallel with R C. So, that is the A the forward amplifier gain considering the load the other things of course, it is as I said that the output resistance got changed. So, either you may say this is R out dashed which is r o in parallel with R C. And this can be well approximated by R C for all practical purposes likewise this also can be well approximated by beta into R C.

And then if you look into the feedback network feedback network. And if you try to see what is the corresponding input resistance here of the feedback network what we say it is R in beta. If I consider the other side it is not loaded; that means, it is shunted to ground then it is equal to R f. Likewise, if I consider the output port and if I say that the output resistance of the feedback network R out beta that is which is given by a good voltage source.

So, if it is if I consider it is a good voltage source then it is in ideal condition this is also R f. So, along with the input resistance of the forward amplifier and output resistance of the forward amplifier, we also have input resistance of the feedback network which is equal to R f. In fact, R out beta it is also R f.

So, with this setup information we are now in position to make use of the equation particularly [vocalised-noise] what will be the feedback system trans impedance Z m f [vocalised-noise]. But then we have to consider that once you once you have this beta R in beta connected here we should consider its loading effect on the circuit it is negligible. So, likewise the loading effect of this input resistance here on the feedback network should also be considered as negligible.

So, that gives us an idea that what may be the meaningful range of this R f or what maybe the meaningful range of this beta FB. That is very vital to construct a practical feedback circuit where we can we can directly use the equation to find what is the what are the changes are happening namely what is the value of the Z m f and what is the value of R in and R out ok.

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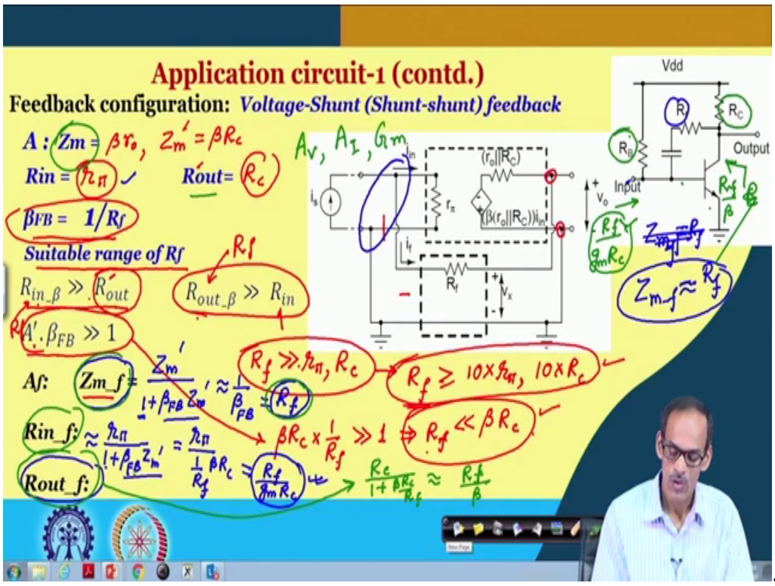

So, in the next slide we are going to do that ah. So . far what I said is Z m it was beta into r o, but more important thing is that Z m f Z m dash rather [vocalised-noise] it is equal to approximately equal to beta into R C and R out dashed it is R C, R in it is r pi, beta FB it is 1 by R f. And then next thing as I said that we need to find what is the suitable range of this R f. And to get that since we are sensing the signal here the voltage.

So, one condition it is that R in beta it should be much higher than R out here or R out dashed. Likewise to avoid the loading effect here or to ignore the loading effect here the r out of the beta network it is it should be much higher than R in. And as I said this is equal to R f this is also equal to R f and R in it is r pi and R out dashed it is R C; which gives us that R f should be higher than much higher than r pi and this also R C ok.

And whenever do we say it is much higher than this, all practical purposes what we can do we can see that R f it is higher than or equal to 10 times of r pi or 10 times of and 10 times of R C. So, that gives us the lower limit of R f; on the other hand if I consider the other condition namely A dashed into beta FB should be much higher than 1. And A dashed it is beta into R C.

So, we can say that beta into R C and beta FB on the other hand it is it is 1 by R f we want this should be much higher than 1 or we can say that R f it is much lower than beta into R C.

So, if I combined say this lower limit and upper limit of R f to really make this feedback system effective we can get a suitable range of R f. And once you get that and once you make sure that both these conditions were satisfying then we can say Z m f Z m f equals to Z m dashed divided by one plus beta FB into Z m dashed. And that can be well approximated by considering by ignoring this 1 with respect to this. So, we can say this is approximately 1 by beta FB which is equal to 1 by R f. So, it is giving us R f.

So, Z m f it becomes equal to R f. So, we can see that in this circuit Z m of the feedback system once we have this R f it is equals to R f; which means that Z m f equals to all practical purposes equal to R f. And the input resistance on the other hand as you can anticipate that in put resistance it is getting reduced because of the shunt connection.

So, we can see this is equal to r pi original R in getting reduced by 1 plus beta FB into Z m dashed. In fact, this is also coming in parallel with R f, but if you see this part [vocalised-noise] first. So, this is r pi divided by if I say that this part it is dominating over 1. So, we do have beta FB it is 1 by f 1 by R f and then we do have beta into R C. So, that is equal to so, r pi here and within the beta we do have G m and r pi so, that r pi you can cancel. So, this is coming R f divided by G m into R C. So, the initial resistance here it was r pi now that is becoming R f divided by G m into R C.

On the other hand, if I consider the output resistance. So, let me use this space here and use a different colour. So, this resistance it is a output resistance it is R C [vocalised-noise] and that divided by so, that is the R out dashed divided by again 1 plus beta [vocalised-noise] beta FB into Z m dashed and it is expression it is beta into R C divided by R f.

So, this is it can be well approximated by R f divided by beta. So, both R in and R out they are getting reduced by the same factor. And so, in this circuit we can see that output resistance it is even after considering this R C within the circuit it is R f sorry R f divided by beta and input resistance here it is R f divided by G m into R C of course, we have ignored this resistance and that should not be a problem because the typical value here it is much smaller than this R B.

In fact, R B it is much higher than r pi itself and this feedback resistance it is a reduced version of this input resistance. So, naturally it should not be having any problem. So, now, next thing that lets also look into the consequences on the other parameter. So, here what we said is Z m it is getting defined it is defined by the this Z m rather Z m it is changing from beta into R C to this R f. And we like to see what other changes are also happening on the other parameter namely voltage gain and then current gain and then trans conductance ok.

So, in the next slide again we will be using the overall consolidated table to check what are the changes are happening there in other parameter yes.

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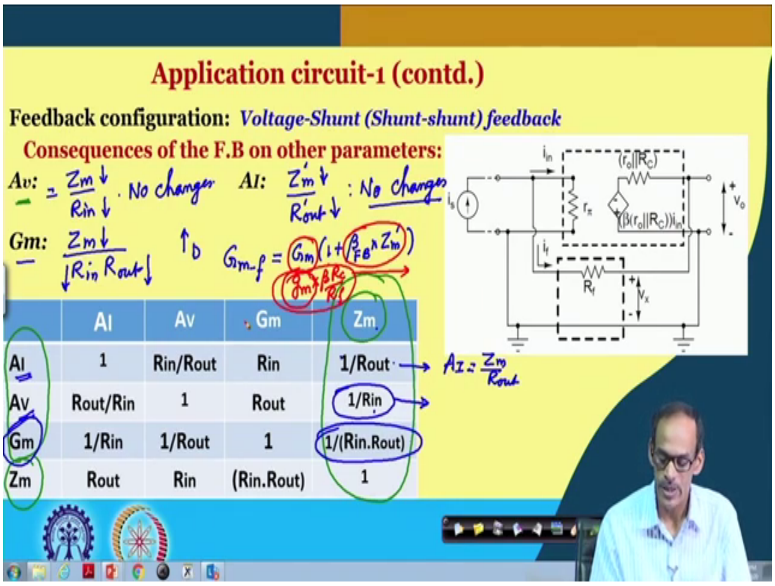

So, this negative the feedback system here it is of course, we are expecting that there will be changes on the other parameter, but if you see the configuration here we do have this configuration where the main parameter it is Z m. And so, we already have seen what kind of changes are happening in Z m. And we like to see what are the changes happening in the other parameter and to get the information we need to see this column.

So, as I said that this circuit it is having the input not input the current gain A I. A I if I consider this equation it is giving us an expression A I equals to Z m divided by R out. So, [vocalised-noise] since this A I it is having an expression of Z m divided by R out whether their load affected or not both of them [vocalised-noise] are getting reduced this as well as this by the same desensitization factor and hence no changes. So, likewise if I consider the voltage gain, which is which can be its expression can be obtained from this entity; namely voltage gain it is Z m multi divided by R in.

So, this is equal to Z m divided by R in and both Z m and R in are dropping by the same factor and hence no changes. On the other hand, if you see the trans conductance G m and if you look into this entity. So, that gives us G m equals to Z m divided by R in and R out both R in and R out getting reduced by the same factor Z m also getting reduced by the same factor.

So, we are expecting that this whole entity it is getting increased by desensitization factor D which means that G mf it is getting increased this is getting increased by 1 plus beta FB multiplied by Z m dashed. And for this circuit this G m it is g m of the transistor and this entity we already have discussed. So, that is we can say it is much higher than 1 and it is expression it is beta into R C and beta FB it is 1 by R f. So, that gives us G m f equals to yeah.

So, this is the quantity it is saying that g m it is getting increased by this factor with respect to its original value or g m. Now, let us look into a numerical example associated with this application circuit to get a feel of the value of different term parameters or particularly how to get the value of this you know R f.

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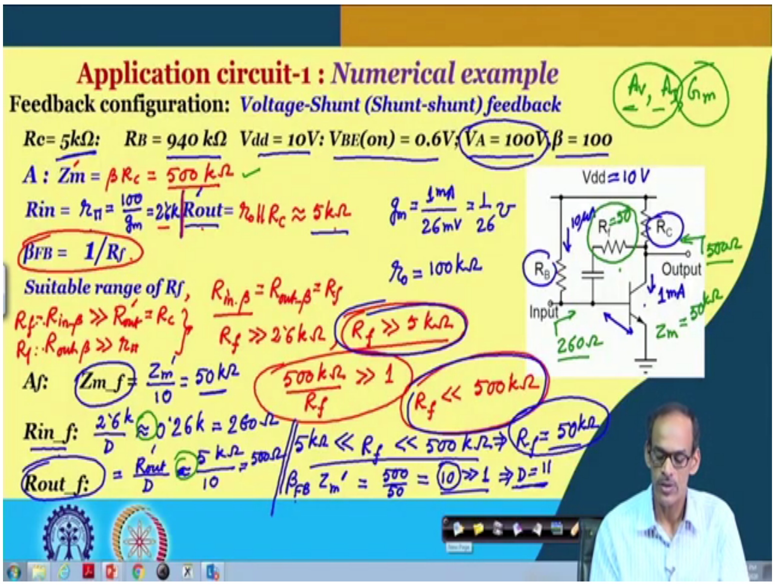

So, in the next slide we do have the same example having a specific value of different bias elements as well as the device parameters. So, in this circuit the value of this R C it is given here it is 5k R B it is 940k kilo ohm and supply voltage it is 10 volt.

And let you consider V BE on it is approximately 0.6; early voltage of the device it is let say [vocalised-noise] it is 100 beta of the transistor current gain it is a 100. Now, with this information quickly we can say that the DC current here it is 10 micro ampere and the beta is a 100. So, we can say that the collector current it is 1 milli ampere. And so, that gives us the r pi and g m and so and so. So, we can see that r pi the input resistance r pi here it is a 100 beta divided by the g m. And the g m it is a 1 milli ampere divided by v t 26 milli volt so that is equal to 1 by 26 mho.

So, r pi it is equal to 2.6k. So, that is the input resistance of the main circuit the output resistance if I consider load affected. So, that is and in fact, with this value of early voltage we can say that r o intrinsic output resistance it is a 100k 100 volt divided by 1 milli ampere so, this is equal to 100k.

And R out dashed it is R out dashed it is equal to r o in parallel with R C and R C it is 5k. So, we can say that 5k it is dominating. So, we do have the input resistance we do have the output resistance and also [vocalised-noise] the Z m or other let us let you consider directly Z m dashed Z m dashed it is beta into RC. So, that is equal to beta is 100 R C it is 5. So, that is 500k.

Now, using this information let us try to see what is the suitable range of this beta FB or a suitable range of R f. So, first thing is that a R f which is also equals to R in beta and R out beta and by considering the situation such that the loading effect of the R in beta on the amplifier if we have to ignore it then you can see that the R in beta it should be much higher much higher than output resistance R out dashed. So, that is equal to R out dashed. So, that is equal to R C and this is of course, R f on the other hand the other condition it is V 1 R out beta is much higher than in put resistance r pi. So, combining these two we can see that and this is also R f.

So, R f should be higher than much higher than r pi which is 2.6k and also it should be higher than much higher than this R out dashed which is 5k. Now, if I say that these two are and in fact, this is defining the lower limit on the other hand if I consider beta FB into [vocalised-noise] Z m which is giving us 500k. So, 500 kilo ohm divided by R f should be much higher than 1. So, this is giving us that R f should be much smaller than 500 kilo ohm.

So, by combining these two limits the upper limit and the lower limit. So, we do have the upper limit and the lower limit we can see that R f it is having a meaningful range and its lower limit it is 5k upper limit it is 500k. And let you consider one example and so, we can consider from say R f equals to say 50 which is definitely helping us to satisfy both upper and lower limit.

And if I consider R f is equal to 50 then beta into beta FB into Z m dashed it is we do have Z m dashed it is 500 and beta FB is 1 by 50.So, this is equal to 50. So, this is equal to 10 we can say that this is much higher than 1.

So, we are satisfying this condition and then we can say that desensitization factor actually it is to be more precise it is 11 or rather we can say that this is 10. So, we can say that Z m f it is Z m dashed divided by this desensitization factor or approximately you can say this is divided by 10 and this is equal to 50k which is same as the value of this R f. And the input resistance on the other hand it is of the feedback system which is 2.6k divided by D so, either you can consider D is equal to 11 or approximately equal to 10.

So, we can see if I consider it is approximately 10. So, it becomes 0.26k or you may say 260 ohms the output resistance on the other hand it is R out dashed divided by D. R out dashed it is 5k divided by either you consider 11 or approximately 10. So, that gives us a value of 500 ohms.

So, in summary what we can say that if we put this to resistance this is equal to 50. So, that gives us the output resistance here which is 500 ohms input resistance to this circuit it is 260 ohms of course, these are approximation. In fact, they are even lower than that which means that the input and output resistance it is getting decreased by this shunt-shunt configuration.

And Z m we said it is getting decreased and the Z m plot it is equals to 50 kilo ohms. Now, you can find what will be its effect on Av and voltage gain and current gain by considering that consolidated table and also and [vocalised-noise] Z m. In fact, ah. So, we already have discussed that this will not be having any change this will be having a change and that gets increased by a factor of D which is approximately 10 [vocalised-noise]. So, this g m it will get increased by [vocalised-noise] 10 and then voltage gain and current gain approximately remaining unchanged.

So, that is about the numerical examples to say that by connecting this feedback [vocalised-noise] circuit what kind of changes we do have.

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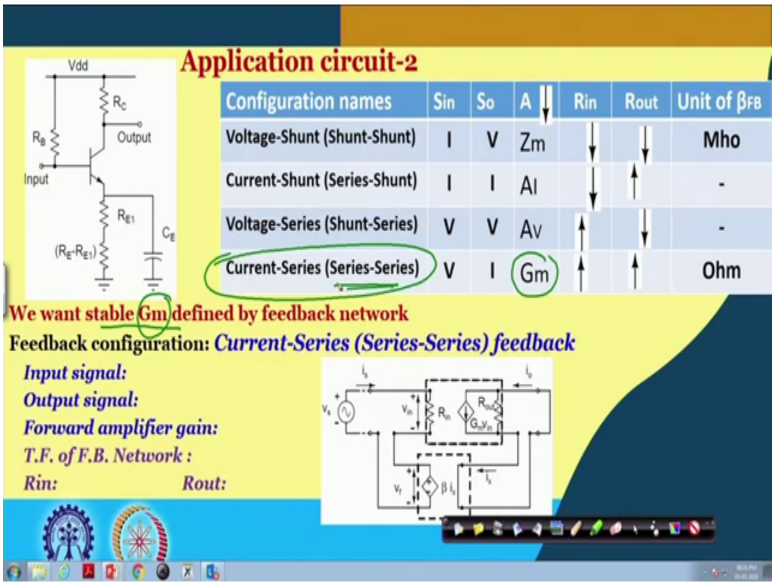

So, likewise we can go for other examples. So, here we do have another circuit which is again common emitter amplifier, but here the objective is it is different namely we want a stable [vocalised-noise] gm. And in case if you are looking for stable G m and then the corresponding configuration here as this table suggests that it should be current sensing and series mixing or we can say series-series configuration. So, we will be discussing this one in the probably in the next lecture. So, let we break here and then we will we will continue this topic of discussion.

Thank you.