Analog Circuits
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Lecture-17
Feedback Theory

We were looking for a word feedback and we said a feedback amplifier which is of interest to us.

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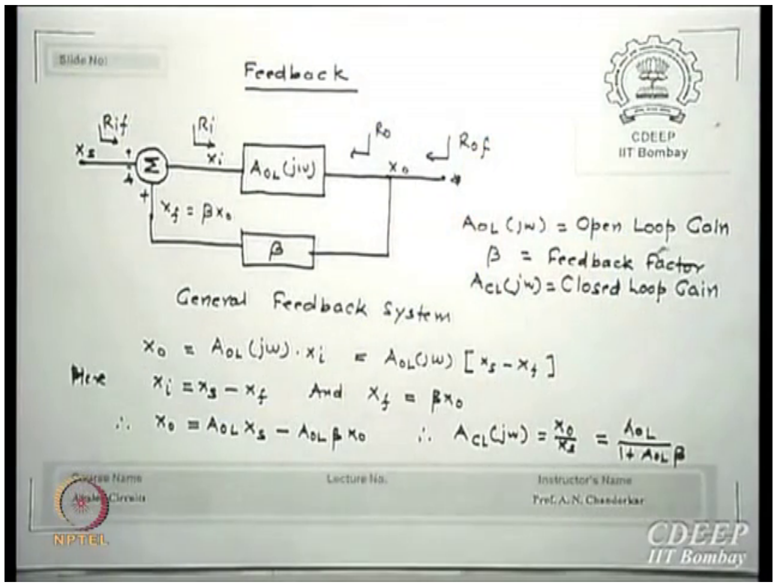

We have an amplifier which is say has a gain of AOL and it is called open loop gain and it gives you a port a output of X0 when an input of Xs is given or the Xi is given and we also said that the part of X0 is returned to input and mixed with the signal to form the new Xi. And if Xf is in opposite phase to Xs that is the input signal is reduced by Xf feedback signal and Xi will reduce. And if Xi reduces X0 will reduce.

And if X0 reduces the beta X0 which is the feedback signal also reduces. So, Xs - Xf will now increase and get a new Xi which when amplified by AOL will get a new X0 it is a slightly larger and this feedback will finally settle to 1 Xf, Xs and X0 values. So, negative feedback essentially stabilizes the gain X0 by Xs. This is the purpose of any feedback amplify, I want to stabilize the fixed gains.

So, if there is any noise or anything which is putting in this and if I have a feedback ratio then I will see that the gain stabilizes ok that is the purpose of negative feedback that is how we started with. We looked into a few, few things we talked about A beta, we talked about this we also looked into few properties of negative feedback one of them which said about gain D sensitivity and we said the closed loop gain is A0 upon 1 + A0 beta.

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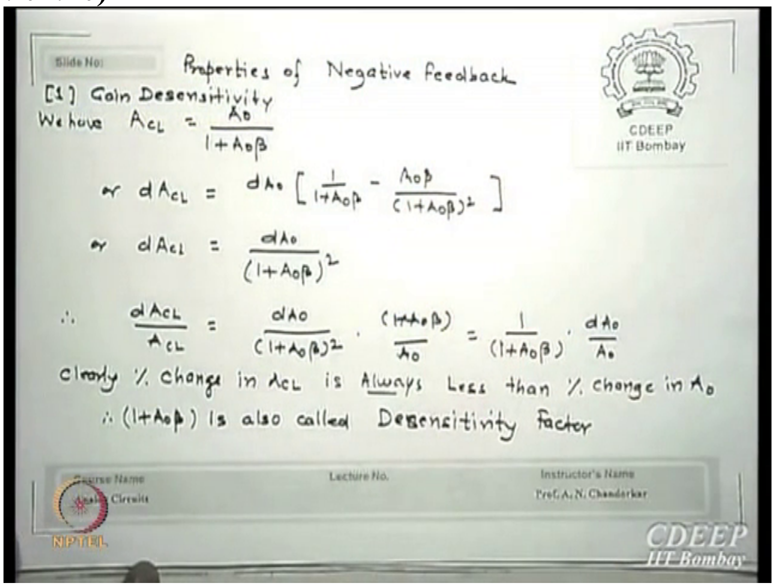

Now please remember if you are not working with Sedra Smith many books this value will come X0 1 - A0 beta do not get worried too much what essentially they are saying that the expression which I derived in getting this expression I said Xi is Xs – Xf. So, already that thought is a negative feedback. What they are saying is they are actually giving it this +, okay and because of that they will get a 1 – A beta values there.

But essentially they are saying whenever Xf is negative put a – sign correspondingly okay. So, beta will become - and 1 + A beta will again become A there. So, that is the trick of the trade, so if some books we are following in which they are writing 1 - A beta they are essentially using this + with no sign of Xf right. Now but if we do the negative feedback it will subtract and if it subtracts then that 1 + A beta term will appears okay.

So, we said that if we have a feedback network the closed loop gain with feedback means the change in such gain with reference to his initial gain will be proportion to 1 upon A0 beta times dA0 by A0 that means any change in this the closed loop gain will be much smaller by 1 upon A0 beta factor that means its desensitized the gain variation that is what I was saying stabilizing the gain dA0 by A0 is the sensitivity of A0.

If this sensitivity has to be reduced and if I divide by some fixed factor then the closed loop gain since it shows less sensitivity compared to A0 that is the purpose of negative feedbacks.

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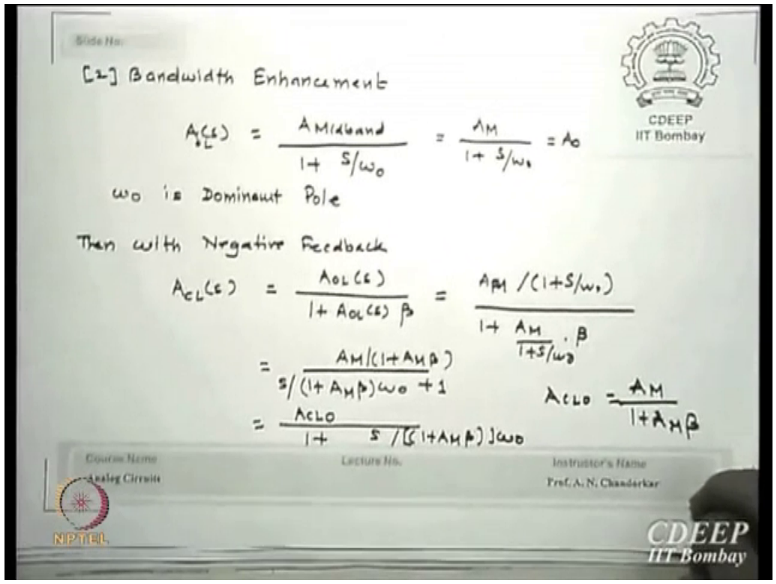

This is what we did last time we also said by same logic we figured out that if there is a bandwidth and if there is a pole midband upon something like this and we finally said in a closed loop gain the bandwidth will also increase by 1 + AM beta times Omega 0 that means the increase of bandwidth was essentially occurring because of what, because the closed loop gain was lower than the open loop gain AOL was higher than ACL.

We reduced that by 1 upon A beta factor and because of that use by same factor the gain bandwidth, bandwidth also increase. Is that point clear that the bandwidth increases by same ratios because what is what why it should be of same because gain bandwidth for an amplifier will still remain constant unless transistors are changed, is that clear. So, since we are not changing anything else so if the gain reduces by 1 upon 1 + A beta.

The bandwidth is proportionally increased by that much amount this is the trick of increasing the bandwidth whenever you are looking for a larger bandwidth amplification. Where do you think you need larger bandwidth amplifiers? For example of course these not these are not the amplifiers which we use there, but, let us say we are using mobile application, mobile systems in which there are amplifiers.

Of course they are at very high frequency, so is television signals both video and audio there are 62 megahertz to 67 megahertz, 5 megahertz bandwidth. In case of GSM it may be almost around a gigahertz bandwidth so which means I want an amplifier which has a large bandwidth. But I may not have larger gains at larger bandwidth this has to bend. So, in many cases I do not really need gain of 100, I need gain of 10, 15.

So, but I need larger bandwidths so feedback is one way to improve the bandwidths correspondingly reducing the open loop gains okay. This is universal and there is nothing to do with any of the kind of amplifier everything feedback all the ways reduces the gain a negative feedback I must clarify negative feedback always reduces the gain. Why positive in fact what we will do, in fact it will gain will start enhancing or the output will start enhancing because every time you give a feedback input rises.

So, output rises part of reason output is further fed back as a larger feedback, so further output, so it is called growth functions okay. So, now you can understand if I have a system in which I have two kinds of feedbacks one which is negative feedback, one is which is positive feedback and I adjust their feedback such that the net feedback is 0 okay. Such systems will be called oscillators okay. We will see what exactly oscillators are okay.

So, it must go but it should not go all randomly so it should reduce from me and that kind of system will follow a law which we will see used using this theorem itself latter called Barkhausen criterion okay. I mean see if the Barkhausen criterion is not violated or if are violated oscillations danced down okay or infinite growths can start in either case.

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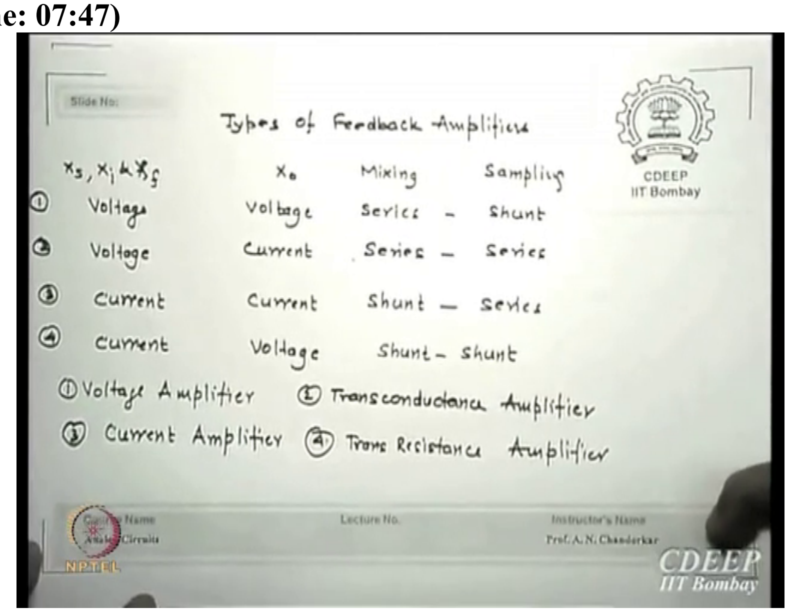

We also I think last time showed you there are four kinds of possible feedback amplifiers. The mixing is the word used at the input that is the feedback signal mixes with input signal and sampling is the word use part of the output is feedback. What is the part coming from there okay that part is essentially called sampling? However output part of it is feedback okay so that is called sampling.

So, I can either have sampling done on currents or I can have something done on voltages. Same is I can have a mixing of voltages at the input source or I can have current at the same node which may also mix with the current at the input. So, essentially there are four possible amplifiers in which the input signals and feedback signals are of this kind, output is of this kind. And mixing can be series or shunt depends on the way we define. We show you that a little later.

And these amplifiers are also therefore classified as voltage amplifier in which there is a series mixing voltage is series mixed okay and the output is sample also voltage wise okay and therefore it is called voltage output divided by voltage inputs such an amplifiers are voltage amplifiers. Please remember all amplifiers can be called voltage amplifiers in there. And even the output is the current if I put it across a load resistance it will create a voltage at the output.

So, do not think that I am meant by current amplifier means only I am looking here, I am saying current will enhance and correspondingly I have dropped may also enhance but the gain essential I will define only with the increase of whatever relationship I am taking okay. So, one will be current amplifier, one will be if the input is voltage and output is current then we say it is a transconductance.

If the voltage input is current and output is voltage we say this transresistance amplifier. So, this 4 amplifiers I repeatedly saying that all amplifiers can be current amplifiers or voltage amplifiers per see. That is output to input ratio you can choose anything you like but the basic amplification is voltage to current or voltage to voltage or current to voltage is what we are saying by these 4 terms. We will see this now when we start having an example.

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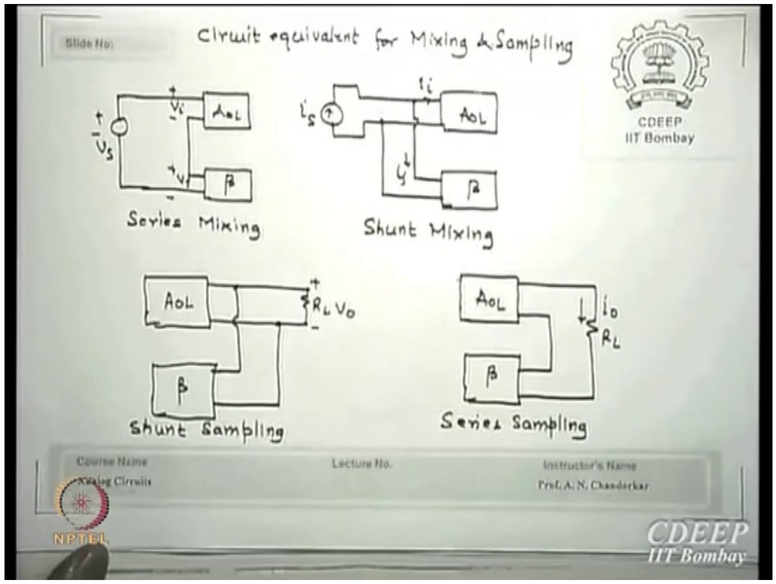

We said that can be 4 possible mixing and shine sampling. Here is two kinds of mixing we showed.

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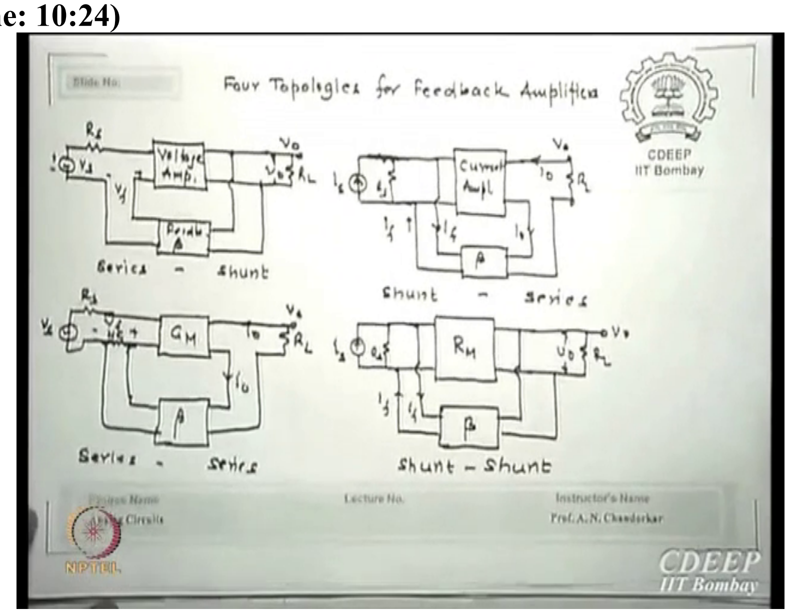

I think instead of this I can directly show you the better ones I mean they are separated now I mixed both of them. So, you can see I have any voltage amplifier which are the voltage gain so if it receives an input Vi please remember it receives an input Vi here okay and the output of an amplifier is V0. This is an input this is an output. So, if there is no feedback what will be the gain of this transistor this amplifier V0 by Vi is always called open loop gains is that correct.

V0 By Vi is the open loop gain is that but clear to you because feedback has been taken away then we say whatever is received at that; in this case what may happen Vs may become ratio of

Rs by Ri + whatever into Vi. But Vi is the real input to a transistor and therefore the gain is Vs by Vo By Vi okay and that is called without feedback whatever gain occurs we say it is open loop.

In the feedback one can see from here I have taken taking a voltage across RL okay. These two terminals are voltage I am picking voltage across the output load RL and I am going pass in that voltage across a feedback network which has a gain factor of beta. Since it is a voltage it will give you beta times V0 will be output somewhere here beta times V0 will be output here. Which I defined as Vf beta times V0 is the sampled output.

So, the what kind of sampling I did here this is my V0 and I am putting a shunt across. Across the load I am picking the voltage. So, this is a shunt connection what a series connection series to the this will be series connection, across is shunt connection. So, I am picking across outputs so it is a shunt connection here so it is called shunt sampled, is that correct. This has shunt sampling this receives a voltage Vf.

Which is beta times V0 and gives you a series voltage to the signal. Vf is equivalently saying there is a voltage source here as if here in series to the signal, is that correct. So, how I am mixing series, series mixing I am doing and since I am doing a series mixing and I am putting voltage + voltage - or + sign correspondingly then I say it is mixed series way at the input, is that clear. So, input is also voltage output is also voltage.

Feedback is also voltage such amplifiers will be voltage amplifiers is that are also called series shunt amplifiers. What are these called? Why it is called series shunt? The mixing in and series and sampling as at the output is shunt, so it is called series shunt amplifiers okay, if I am looking for shunt series amplifier then I do little trick I say okay the series connection at the output can only be taken if there is a current which can be input in series.

Voltages there is no voltage source except coming from there amplifier. So, what we say if there is a current amplifier whose output is I0 is passing through RL. In normal case this will be connected okay, so what will be actual voltage drop to you I0 - I0 either - is because of the phase shift phase shifts. So, V0 is still output if you need, is that clear. But what is the real output for this amplifier I0, I0 is the real output of this amplifier.

So, I0 by Ii, if I use it then I say it is current amplifier okay but the feedbacks we start looking if this is my current and series to this, part of this current is fed back to a network which gives me beta times I0 as my feedback current. Now this current I have connected to a node, this node for them, then I say if I had to connect it at a node then I say it is a shunt. Any node what is shunting across at any node if you put a current you say you are actually shunting at that point is that correct.

Shunt means what between two nodes so I am adding a current and ground to the other side. So, I am actually putting a current at a node and I say it is getting into that. So, this you can see the way I have fed I have connected I which is the path of feedback current. It goes like this and comes like this, is that correct. It goes like this and comes like this okay. So, this is essentially we say shunting the current at the input.

Remember what is being entered here current, this is the current source I am entering a current here that is getting modified by this current source which is feedback current okay. That what is the Ii current will be here, can you tell me now, if this is opposite phase Is - If will be the actual current Ii flowing inside the amplifier, is that correct. If this current is leaving, this current is entering so this current is Is - If is whatever is going to the amplifier.

So, if I have increases what does that mean that is feedback is larger what does means? Ii is smaller if Ii is smaller I0 is smaller, if I0 is smaller If will become smaller next time. If, If reduces Ii increases. So, I0 increases and this will in a loop kind it will start reducing slowly, slowly and finally it will settle to a value in which I0 by Ii is the gain of the amplifier and fixed If it is not there, is that correct.

This is the purpose of negative, is that point clear what is negative feedback. You get above it reduces, if you do below it pushups okay, is that point clear. Why it stabilizes? If that current increases then the feedback will reduce here itself. If it reduces the feedback is lower and therefore input rises so output rises. So, it settles itself to a value which is essentially called shunt inputs, a shunt currents here and currents are series wave picked up okay from the output.

Such amplifiers are called Shunt Series amplifiers by same logic we can do the other two. This is very interesting, both you can see from here this is scratch part I am taking a same sampling current sampling that is I0 amplifier. Output is what? What is the output of this amplifier? Current I0, please remember I keep talking keep on telling I0 into RL is going to give you V0, anyway, is that point clear to you.

So, voltage can always be picked up by any current outputs okay. But this amplifier is essentially has I0 and Ii is the current flowing here, sorry voltage is the voltage across this amplifier is Vi. So, what we are now saying that whatever is I0 is proportional to Vi by what factor? What is again here? Transconductance current by voltage, so such an amplifier is there transconductor output is current input is voltage, so current by voltages is transconductance.

Our input is voltage output is current so we have a transconductance amplifier and it is given by term GM okay. Then our case we keep calling A everywhere but other A can be GM, A can be RM, A can be current, Ai it can be AV. But in our definition of feedback we keep A constant okay, is that point clear. How many A's can be a can be AV? A can be AI, A can be GM, it can be RM. But essentially there are four separate amplifiers, is that correct.

Now in this case beta is which are this whatever is voltage across I am creating so network it says that I put a series voltage in series to the source then whatever this voltage is negated to this correspondingly Vi will change and correspondingly I0 will change part of it feedback again is a negative feedback circuit. Input is at series, output at series is that correct. Current is also in series and voltage is also in series this is called series-series amplifier are also called transconductance amplifier.

By same logic both side are shunts this is voltage this is current, current voltage divided by current is resistance. So, these amplifiers are shunt-shunt which are essentially called transresistance amplifier, is that correct. So, feedback allows you to create 4 possible amplifiers okay. Now why are you want to do because many of the circuits which we have done earlier without knowingly that there was a feedback you will see suddenly.

For example as source follower or an emitter follower which will take an example like that which kind of amplifier do you see it is? It is a voltage is being sampled and voltage is in series to the input itself. Re is common between the world output and input part of the voltage is picked up across Re maybe one here because the same is fed back beta can be unity in that case. So, whatever is received at the output is also a part of input Re is common to both sides.

Than series of that so we say it is a voltage I mean you can see it is a series at the input and what is at the output? Series, so that we can similarly if I have a capacitance or a resistance between gain and the drain, is that correct. That will be a shunt because output is voltage but input is at that node. So, we say it is their transconductance amplifier sorry transresistance amplifier. So, each name we may not have given there but the amplifiers we already seen them, is that correct.

Whenever there is a connection between output and little bit by any impedance whether it is resistance or capacitance or RC networks these will form a feedback amplifier, is that correct. The nomenclatures we are now defining with the word feedback (FL) here we are already done those amplifiers. Like for example the commons so sampling a common source amplifier with source degeneration.

The feedback is from where from the load side, is that correct. So, the; and but the feedback is in from this side you are feeding it back, so one is current and one is voltage okay. So, now that we are already done both amplifiers okay but we have never named up which kind of amplifiers we are using because there we always say we are looking into voltage by voltage. All amplifiers here also we can look as a voltage by voltage.

After all a current source is equivalent to a voltage source and a series resistance in feminine source. In northern source is equivalent to a feminine source. So, essentially we are not actually trying to say we are done we are doing something great. All that we are saying we are doing more generalized way of doing it and all other cases are more specific cases of that okay that is what you have to say.

But they advantage what we get probably there we did not; Do you remember in common source amplifier with so degeneration or common emitter with emitter region what is the gain? The load divided by the degenerated resistance typically all other factors are small so our RL by Re or RL by Rs that is what we said. What is the advantage we said there? The gain has reduced but it is independent of transistor stabilized.

The word we did not say very specifically that time stabilized, is that correct. Yes feedback stabilizes the gain and gain reduced, is that correct. So, please why I am bringing this fact again, again just to tell you that we are already done most of the amplifiers in some way or the other. Many of them where feedback amplifier and that part we did not hear because we saw list of equations, is that correct.

If it is a feedback so, (FL) so, we actually took care of feedback without actually telling it is a feedback. Whenever between drain and gain we connected it was a feedback output input was connected or between collector and base we connected we were connecting it, is that correct. So, without telling you that this was a feedback amplifier we saw as I could shuffle off without thinking because then I do not have to think anything.

So, what is this feedback theory is trying to tell I need not do all that analysis for all of them I can do something interesting I can calculate the open loop gain by I will show how to get it. I can calculate A beta for that okay and then I directly cannot A beta upon 1 + A, A upon 1 + A beta is feedback gain and I can find input impedance and output impedance. That is something what I want to do quickly once, I know that.

But otherwise even if you do not know any feedback we were anywhere solving the circuit is that correct so do not think that this is trying to do something over and above that it is only trying to generalize the same thing which we did earlier okay. Their individual case we shall hear you say you do not have to solve you particular case is a specific case of this case okay.

So, this is what I keep telling you that the books do not want to tell this they have a separate chapter telling as if this is an individual extraordinary work we are doing, no it is not. Another thing which feedback provides us is something called a word which we call nonlinear distortions. Well (FL) now first let us get distortion word linear and nonlinear.

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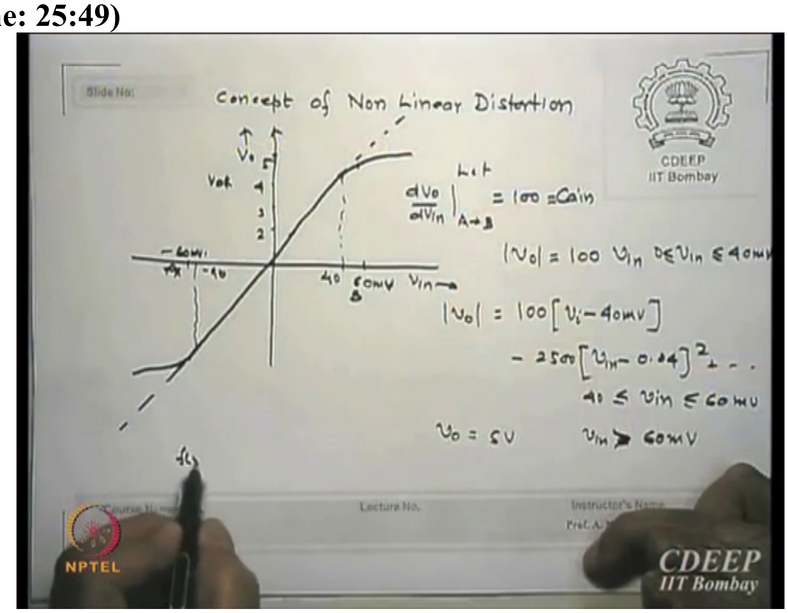

If I have a function fx and if it is linear it may have a coefficient A0 okay. It is a linear system but if I have a turn it has become nonlinear is that correct. Higher terms for me that is non linearity will keep on increasing as we could 3 term, 4 term. But if x is your signal sinusoid signal let us say Vi is A sine Omega t, so what is VI square, A square sine square Omega t, sine square Omega (FL) sine 2 Omega t is how much 1 - 2 sine square Omega t 2 Omega t, is that correct sorry, it is either way.

So, what does that mean square terms will give you what terms to us the Omega t terms is coming from the first one but 2 Omega t terms will coming from the square terms okay and higher order terms will give higher order frequencies. So, these are called harmonics Omega is called fundamentals any number proportional to this Omega 2, Omega 3, Omega these are called harmonic.

But whenever harmonics are present output will also show you corresponding, those frequency outputs V0 will also have components of 2 Omega t, 3 Omega t apart from Omega t Omega what does that mean? In real life I will see to it that I receive power only at Omega my fundamental I am going to do some what we call tuned circuit there which will pick up only signal at Omega. But what is it means then that the power which has or energy which has gone to 2 Omega, 3 Omega or n Omega I have lost.
So, the efficiency of an amplifier will keep reducing as non linearity starts increasing is that current because you will actually not get equivalent voltage if you have got linearity. Some part of it is as if is lost by you, is that correct. So, if you see this is what theory I was telling and you can now see very see there is a V0, Vin characteristics from some value say here to here 40 to 40 volt, millivolt it is linear.

Output is - 5 to +5 it is not necessarily this form opamp, so one typical value I chose from an open. So, we say let us say this linearity has a gain of 100 any gain can be assumed just for the heck of it. So, if Vin is less than 40 millivolt or greater am I actually -1. From here to here one can see that output will be proportional to Vin 100 times Vin, is that correct, but if you look for little term which is ahead of this where non linearity has started.

It is not maybe that does not cube terms are smaller there that is A3, A2 coefficient are smaller but at least square dancing will appear because it is not linear so second term (FL) so, if we say V0 100 within this range +- and the second time we will know V0 course square Vin - .04 square and as I just now said when I square the inputs I will see in outputs also A omega t equivalent terms.

Now so we say from 40 volt to 60 millivolt we may say only second harmonic appears that is the dominant other frequency than Omega is 2 Omega. But if we go beyond 60 millivolt the gain is really becoming flatter now which means there will be more cube and maybe fourth order fifth order terms will also start appearing that means gain will start reducing drastically. So, beyond this we may say voltage become fixed to 5 volt maximum does that occur in open if Opamp.

The Opamp is the power supply of -5, +5 it saturates at +5 all it is saturates at -5. So, I guess what that is what I said that typically Opamp characteristics are chose to explain my terms. So, I want to see that if there is a non linearity how much non linearity is tolerable to you. So, we want to see since our swing is now 40 millivolt only – 40, +40. But I have a signal which is 100 million then what will happen where the output will go, fixed 5 volt nothing else can be done now okay.

But I want actually linearity there, so one method of improving the linearity of a nonlinear system is to give a negative feedback, is that correct. So, what is the advantage of negative feedback will be seen that if I give a negative feedback but at what cost I will get it, lower gain or (FL) 100 okay.

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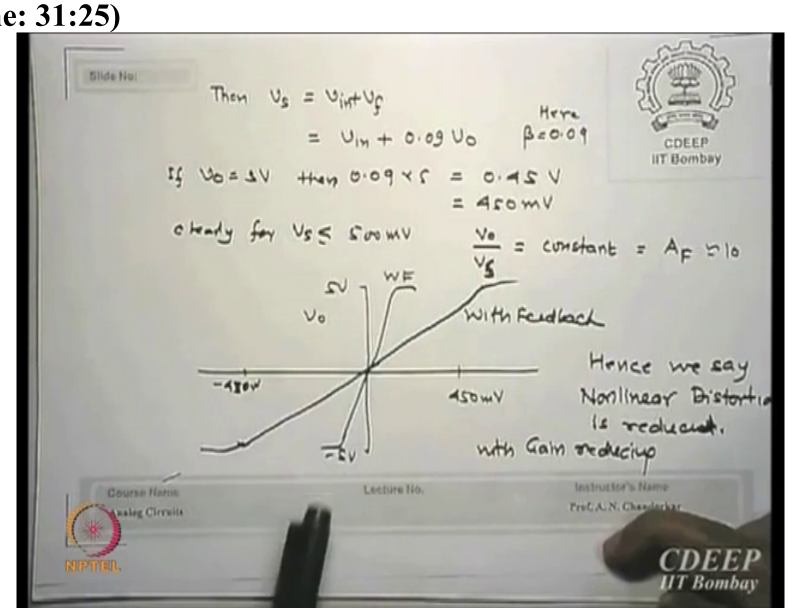

If I do if this is my normal amplifier 100 (FL) I have reduced the gain 10 times okay but what did I achieve the input signal range has now increased by 10 times okay 450 or 400 millivolt - for the large signal amplification in the (FL) feedback amplifiers use (FL) so do you know now I have reduced nonlinear distortion in this why what do I do I say I had reduce not because now up to even 450 millivolts or - 450 millivolt there is no non-linearity.

And if there is no non-linearity in that range then we say there is no distortion in that range is that clear. If the gain is linearity is up to higher values of signal there is no non-linearity. So, by actually providing you a feedback what did I achieve linearity was improved by me by order because the gain I reduced by an order, is that correct. So, this is another advantage I see whenever I have a large signal amplification desired what does that mean?

Where does this large signal amplification will be required? First stage of a normal amplifier may not be a feedback amplifier (FL) but I want to amplify still this signal which is higher voltages. So, what should I do then, I put a feedback for the second stage reduce the gain but still boost that, is that correct. By increasing my linearity range to higher input range I have now been able to actually have a two stage amplifier with a larger outputs available for inputs which are larger now okay.

This is the advantage of having nonlinear distortion reductions is that correct yes saturation is the ultimate now it may be 100 polynomials non linearity or 1000 polynomials is that correct. But even at the when the gain; linearity starts bending down and signal output based not bending there is a non linearity term has appeared and that means first order term (FL). So, at the edge also if you have a normal amplifier (FL) this is just to give an example young man.

Where ever it will start bending and if I say you; say why feedback then I am only trying to say you that redo by increasing the if I want increase input range I can actually put a feedback to reduce the gain and then increase the linearity. This is the purpose that means at least in this range the linearity is maintained by me therefore nonlinear distortion does not occur in this way. In this case even here itself I have a non-linearity starts okay.

So, my input swing is very low. So, if my input swings are higher then what do I do and I want linearity. Normally in what we call tuned amplifiers which are different kinds we are just now looking for amplifiers called Class A. But if you are looking for amplifiers like Class C or Class D or Class E, Class F we are not interested in linearity anyway there, is that clear. Since we are not talked please remember there are Class A, Class B, Class C, Class D, Class E, Class F six kinds of class of amplifier also exist.

All classy amplifiers are essentially linear amplifiers is that correct output is directly proportional to inputs. So, all amplifiers so far we are talking is class A. All that we said if I want in a class A, amplification in which I do not want distortion I can put a feedback, is not correct. But not every amplifier need be but there is also another in between called class AB, okay. So, I think maybe at the end of the day I may show you quickly what are these classes then where do they use.

All radars for example will be using either the Class C if it is sinusoid. If it is their pulse transforms then you will have class D, class C or class F amplifiers like all mobile systems mobile transmissions which is running at 890 Mega hertz and above or Bluetooth running at 2 to 4 gigahertz there we are using Class A, Class C amplifiers, is that clear. But there we are not worried of; actually using non linearity is that correct.

So, it is not my contention that non linearity is always bad is that point clear to you. What I am saying a Class A amplifier if I have to improve the input range for distortion free input range then I must put feedback is that point clear. So, having told you this let us do something more.

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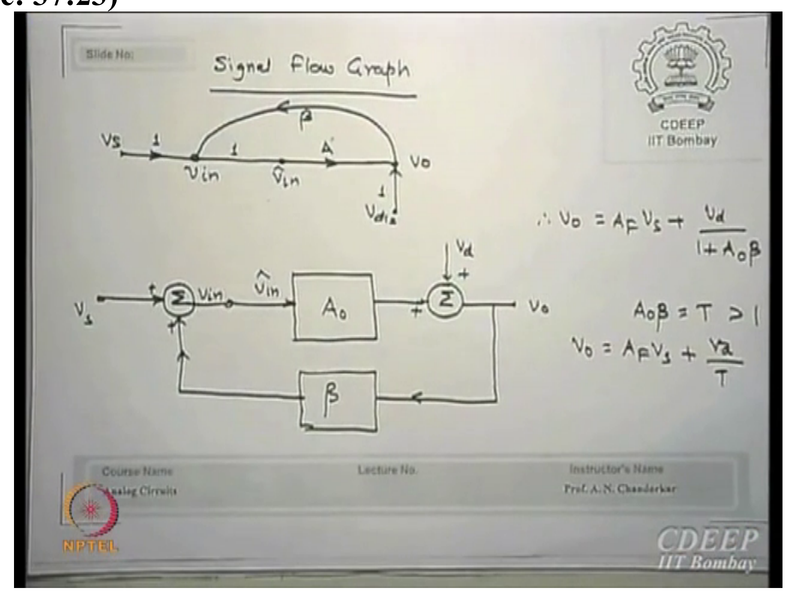

So, here is something which I will like you to so this is a graph which is called signal flow graph okay. This is only shown for this circuit but can be shown for any circuit. What is saying this is my amplifier okay this is my signal in Vs input to A0 the output of this is some Vin and from Vin to input or signal V will say why it is Vin dash a hat. Then there is an amplifier A0 and then this another term we say let us say all distortions are taken care at the noise at the output okay.

All distorted outputs are take another equivalent of a Vd noise at that so we say whatever is coming from amplifier will be added by this Vd, is that correct. But if you have a feedback here they directly then it will come as a Vd, but if you have a feedback like this, one can say V0 is

not only AF VS but + Vd times divided by 1 + A0 beta you can do this analysis as we did earlier okay.
So, what does this essentially means now the noise factor is actually reduced by 1 by 1 + T factor is that correct, gain of course has also reduced doing so earlier I would have been A now it is AF but by doing that I have actually seen that the distortion outputs are noise outputs also get reduced by 1 + A beta times so one can say this term being very, very small output is proportional to input that is what the graph I was trying to show.

Looking at the VS to Vin there is no any network why this 1 has been put here because there is a direct transmission here okay. But if there is a RS or some combination this itself will have some gain there less s than 1 but RS upon something by this so this (FL) we also right now do not tell you but why I want hats so I will come back when I draw a feedback full amplifiers from Vin to Vin hat there is no change its same connection.

So, we say it has also a gain of 1, V in hat goes through an amplification of A to get to AV0 at this point we have a distortion through a sigma and we say all of it is connected at the output if there is a network here also it may further reduce like in feedbacks. So, here is V distortion and all of this through a gain of beta is fed back to Vin, is that correct. (FL) Whatever I am showing here this has a gain of 1, this has a gain of 1, this has a gain of beta times whatever it is.

So, we say whatever amplifier we say we can represent that circuit by a signal flow graph, is that correct (FL) I tell you another thing there is a error you have to show everywhere what does that error means signal path going from where to where from this node to this node signal is going in this direction so this node this node signal has gone from this direction okay. From here it has gone to Vin hat with a gain of 1.

So, it has gone to this node which is Vin hat node by gain of 1 so here also I must have an arrow. From being V in hat there is an amplifier to go to V0 so I gone to V0 which has a gain of E at the same point I have a distortion input with again assuming here say (FL) so it is this point and from here I am feeding back beta gain (FL). So, any amplifier circuit can be represented by signal flow graph is that correct.

So, (FL) but they may not show you all that they say ok this is the signal flow graph for the system design and this in this for you okay. But essentially it is this system, please remember there is nothing great in signal flow graph okay. All that it does it is larger such a blocks of circuits can be represented by only lines and they can also represent the function going through these are called signal flow graphs is that correct.

Now why do we are why are we interested in signal for, if not (FL) you know it since I have a graph I can manipulate it better than anything okay and then I can my solutions will be faster and then I only have to saw smaller parts okay. So, signal flow graph do help us and then to give a smaller circuit solutions okay. Therefore signal flow graph to be is relevant okay the most important thing in a feedback amplifier is feedback gain.

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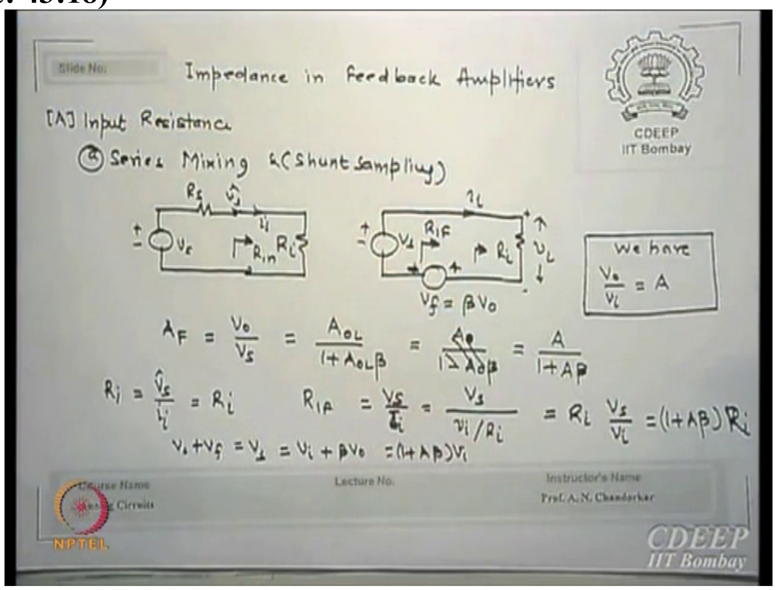

But that is smaller value we already said A by AB ,1 + A bit again reduces your thing but doing this do we achieve something else or do we lose something else I call it achieve or call it loose. So, we say okay the other two parameters of interest in an amplifier one is gain of course also a bandwidth all right. Now please remember I am not talking of bandwidth part. This will still do separately what man bandwidth we did say that bandwidth increases okay.

But we will actually see borders plots or feedbacks and how do they change okay but I said right now we are not talking of bandwidth. So, what two other parameters of an amplifier of interest to us is the input resistance and the output resistance. So, we say start looking into it because the feedback does it happen differently then. So, we figured out yes feedback has also influences on the RI and RO both sides are out both sides. So, we see what are in 4 cases which we had to series one series mixing, shunt mixing, series sampling, shunt sampling.

So, all (FL) so we said okay let us look at this is the normal amplifier okay. For the simplicity right now I mean it neglect RS, we can always that this VS can be modified by something into this and use the new source germinal source. So, right now we say VS is the source and this is beta times V0 this is series mixing what one thing I am talking about series mixing voltages in series to the signal. And the in input imprints resistance is seen before the feedback that is after the source after this is RI will be seen.

Please remember RS is not part of RI is that correct, RS is not part of RI. So, whatever voltage actually I am looking at here is I am calling VS, is that correct. There it is it may be ratio of something but essentially I am saying because I am only interested here okay. So, this is my source this is my feedback which is reducing VS because then you get a feedback and I want to know what is the input resistance here.

Without this feedback how much is our input resistance all right there is nothing else if I put a voltage source there V and VS there is nothing to see about there is only one register sitting here if I see it only I see that nothing else I see okay, is that correct. But something else I may see this Ri may include the bias resistor network or any other thing which you say may include in this Ri but for me it is only on Ri, is that correct.

So, I am seeing here R in is only Ri but if I have feedback then I want to know I say AF which is the gain which is V0 by VS AL by A beta which is a this is our feedback gain for an amplifier. We say Ri is VS hat that is the voltage at this point okay divided by ii which is my; in the first case this is VS hat I put it, so it is Ri. With the new one I find Ri f is VS by current is that kind. What is the resistance seen here voltage divided by current (FL) is that correct.

So, VS by ii is the resistance seen by the source into the circuit, is that correct. But now I see this ii current it is not same as it is now getting as if modified by feedback. If that is not there ii will be same as the old current okay but if there is a feedback I now see ii is nothing but Vi divided by Ri, is that clear, Vi divided by Ri. But this I know ii have VS by Vi, VS divided Vi. Now we say VS you can see here Vi + Vf is VS this this voltage drop + this voltage drop is this.

VS is this voltage + this voltage is that correct. So, Vi + Vf is VS which is essentially Vi and what is Vf beta times V0 but what is V0 A beta times Vi (FL) A beta times Vi. So, we say VS is nothing but 1 + A beta times Vi substitute here. so, I get Ri f which is the feedback resist input resistance as Ri times 1 + A Beta 1 + T (FL) so this series mixing (FL) the input resistance (FL) what is the current in the circuit decided by; the voltage divided by a resistance is the current.

In the feedback the voltage reduces that is what the feedback voltage reduces across this if it reduces the current also reduces (FL) so what essentially feedback is doing it is reducing the current in the input mesh, is that correct. And because of that the input resistance is, is that physical work layer because that reduces current reduces that means the net resistance increases and the feedback essentially stealing the input resistance of a series connected at the input mixing will always be higher than (FL).

Beta times RI will be reflected inside is that correct beta times RI will be reflected so R pi + beta times Ri Re will be the actual input seen by the transistor, is that clear. What does that means input resistance increases whenever Re is present and bypassed. Common source of common emitter amplifier with soles degeneration or emitter and also will increase Ri, is that correct. Will also increase Ri.

So, whenever there is a series mixing where the input voltage is modified by another feedback voltage the resistance at the input will always increase (FL) where do you need your input resistance be higher. Generally amplifiers how smaller R0's, is that correct. Now if I have a smaller R0 and I am feeding it to a next stage which also has equal and resistance there, so, what does that mean in terms of maths.

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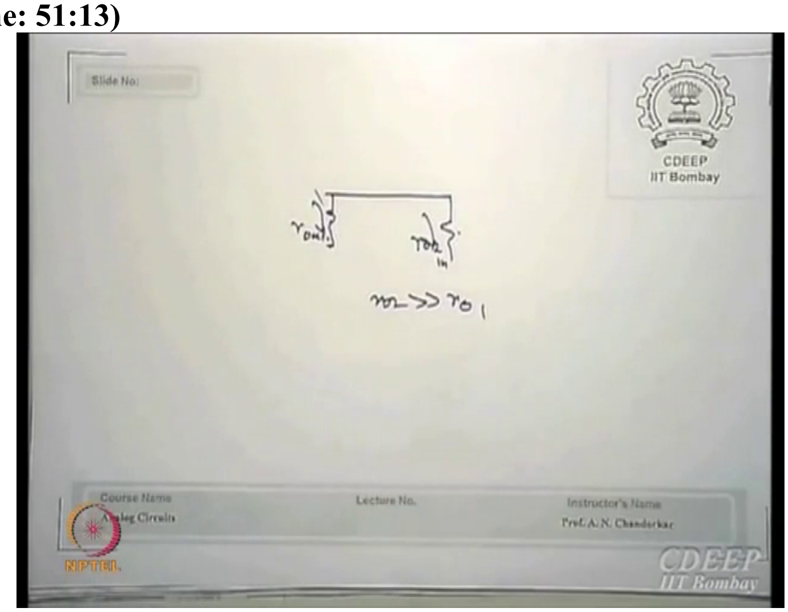

If I am having a circuit whose r out of one is lower and I have a next stage whose ro 2 in if these are comparable part of the current is going here part will go here okay what is it called essentially the resistance will actually reduce and therefore the voltage at the input will not remain voltage which you were feeding, is that correct. So, what should be ideally ro2 should be much greater than ro1 then what will happen all the current is only here so this voltage remains constant.

So, the next stage sees same output of s first stage otherwise it will get modified and what does that word in other circuit be called loading the next stage starts loading the first stage is that correct (FL) so it will be larger there so any source now coming from there will not get modified for the next stage is that point clear that is why buffers are required, is that correct. What is the advantage of buffer other than the input wrestle match its output is still low okay.

So, if you have a circuit which requires low next which is lower this you have ro lower at the same time you are matching with the first stage is that correct that is why this impedance transformer as we can say. Higher impedance connected to a lower impedance is that and what is the gain of a such stage normally buffers unity gains because they common image source follower or emitter followers okay is that clear to you.

Always a emitter follower or source follower is kept whenever impedance need to be matched between two individual stages which make buffer (FL) okay, is that clear. So, this is the technique we use everywhere so this is why we say we want to reduce this effect of loading we need to know some kind of impedance modifications, is that correct. In some circuit you may require ro reduction or ro increase.

We can do all four we can increase Ri, decrease Ri, increase ro, decrease ro they are all possible there is no hand the hat was done here because you know you would ask is it VS here, this VS okay call it yes actually are not, what we are trying to say whenever I calculate input impedance I do not consider real source and it is series resistance, is that correct (FL) is that clear. I am well saying Rs is 0 because that is something tomorrow (FL)

Any signal source you put there is a series I cannot avoid it any voltage source will a series resistance is that clear, no ohms, 50 ohms sector but (FL) the lowest is 50 ohms okay.

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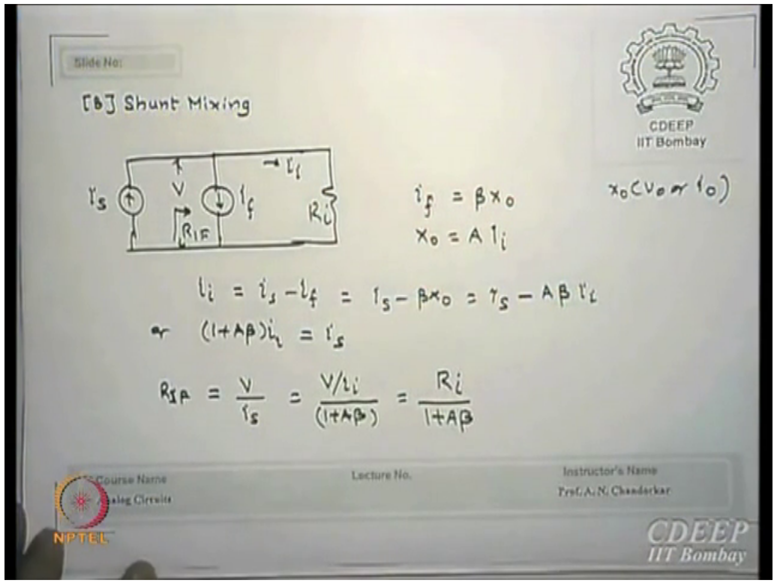

If I go shunt mixing at the so at the input please remember shunt what kind of mixing can be done by shunt not by voltage, voltage cannot be shunt across a voltage (FL) so this is my current source is and this is the feedback If and I am putting in Ri F here okay. And I want to know what is the Ri F now I know if is beta times; why I said X0 generally because I am not saying either there at the output sampling and the voltage or sampling can be current.

But that the input it is all shunt is that what clear to you. Input is always shunt but output is always a can be voltage or series or shunt either case so many (FL). So, is that point clear it can be V0 or i0 either of them can be X0 but I am in a generalized this because it does not matter I X0 (FL) what we are looking essentially inputs (FL) so X0 is A times Ii now as I say it can be either of kinds.

What is ii current is - if is Ii which is entering Ri is – beta times X0, is - A beta Ii 1 + a beta is, is so Ri f is Ri upon 1 + A beta. Whenever I want to find an impedance input impedance what do I do in real life I shot all outputs, is that correct. I remove all independent sources other than the, for which I am finding that is the case I was solving if they are (FL) so that is what all that I am doing, is that point clear.

So, Rs (FL) is that clear so what is that disadvantage from the system or advantage is (FL) is that clear because current is a feedback the net current Ii essentially is reducing a sorry Ii is fine wise if you see that means V by Ii upon 1 + beta that means the (FL) never considered in calculating output resistance. So, here is one more case I install and we will solve and stop on this I want to find shunt sampling.

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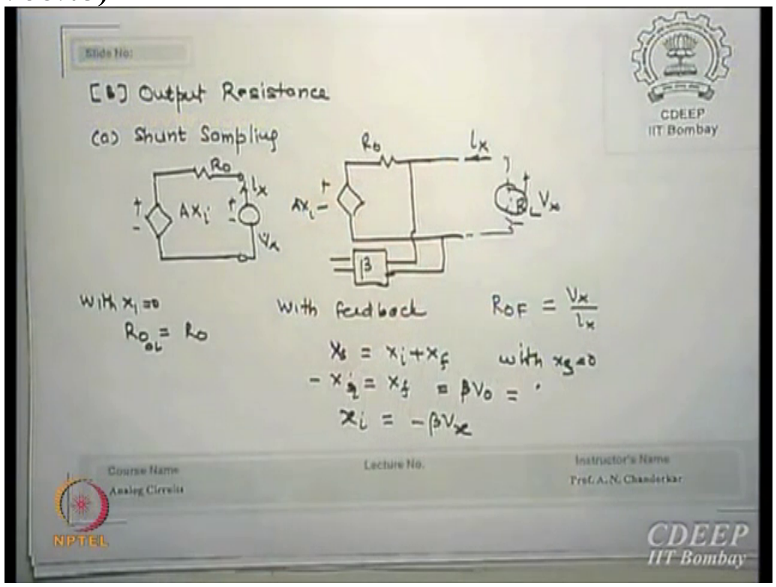

Let us say AXi the gain again what is the Xi (FL) AXi is the voltage which is appearing AXi anything may +- of a voltage equal (FL) R0 and this I now applied VX iX, VX is the source I applied the output and measure the current iX with feedback Xi will be 0, input will be shorted is that correct. For output resistance input (FL) whatever resistance seen here is same as ro okay. So, no without feedback the output resistance is the Ro of the source, okay.

But any feedback (FL) Rf is VX by iX Xs is Xi + Xf I have X can be current or voltage whatever it is with Xs = 0 my you said it now Xs = 0 Xi- is Xf which means beta of V0, so Xi - beta VX because V0 is same as Vx. So, Xi - beta Vx substitute what did I do this is a shunt sampling going on is that correct. So, current voltage (FL) is that correct. I applied a Vx source and I want to see what is the current coming out to get my resistance Vx by iX.

So, I said at the input side I shunted the source shorted source. So, Xs is Xi + Xf (FL) Xf is - Xi is not it. But what is Xf beta times V0 (FL) so beta times V0 is the voltage sampled at the input of the feedback so Xi - Beta and V0 is how much Vx, so Xi is - beta Vx is that point clear. (FL) This is voltage which is same as VX sampling is beta times V0 because it is a shunt sampled. Feedback is voltage now beta V0 (FL) source + = Xi. In the sick at the input of the amplifier + the feedback is that correct.(FL)

If Xs is 0 the feedback is opposite of Xi but Xf is beta V0, so Xi is - beta V0 or beta Vx excise the input to the soul; this amplifier (FL) is that clear. So, that is the word which I use there. So, what is the Xi - beta VX,

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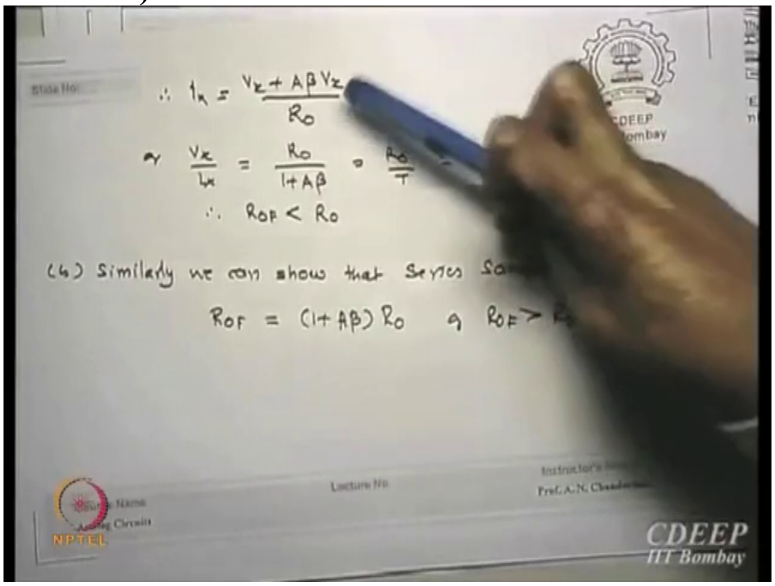

So, if I now say Ix which is the current flowing here is Vx + A beta Vx by R0 which is my current now (FL) ix = Vx + job at A beta Vs coming from here, Xi (FL) what is Xi? Beta Vx (FL) Vx+ A beta Vx divided by R0 is the current is that point clear. This voltage + this voltage (FL) divided by this current is the by this resistance is the current, is that correct. So, Vx + A beta + Vx upon R0 is the iX.

So, Vx by iX is Ro upon 1 + A beta, so it is Ro f is 1 Ro by 1 + T (FL) so the Ro (FL) we did not do it do it for the opposite case, a second last case I have a series sampling (FL). By similar logic if you solve that you will get Ro f = how much 1 + A beta times R0, so the feedback output resistance is higher than the resistance without output aside without feedback. If you have a current sampling going on, is that correct.

So, now you are four cases series mixing, shunt mixing, series sampling, shunt sampling. So, now could you get I can get both lower one higher one lower first lower next higher are both higher by a proper choice of mixing is that point clear. I will repeat since I have four amplifiers I can increase Ri and increase Ro simultaneously. I can increase Ri but decrease Ro, I can decrease Ri, increase Ro or I can increase both Ro and Ri.

All four possibilities for amplifiers will give me so whatever requirement I have in my actual circuit requirement I can choose one of the feedback blocks of that kind and I will use them in between to create the R in are Ro's of my choice, is that clear. This is the advantage of feedback that at what cost all that I am doing every time the gain (FL). The output gain is essentially proportional to your input work do whatever you say thank you very much you.