Video course on electronics
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Module No. # 04

Feedback in Amplifiers, Feedback Configurations and Multi Stage Amplifiers

Lecture No. # 02

Reduction in Non Linear Distortion

We continue our investigation on the effect of negative Feedback on amplifier. We will shows shortly that incorporation of negative feedback in amplifiers, can bring the features, which we really required in an amplifier. Besides the stability, we can modify several other parameters also. Now, we continue and take that how this negative feedback in an amplifier can result in a much reduced non-linear distortion.

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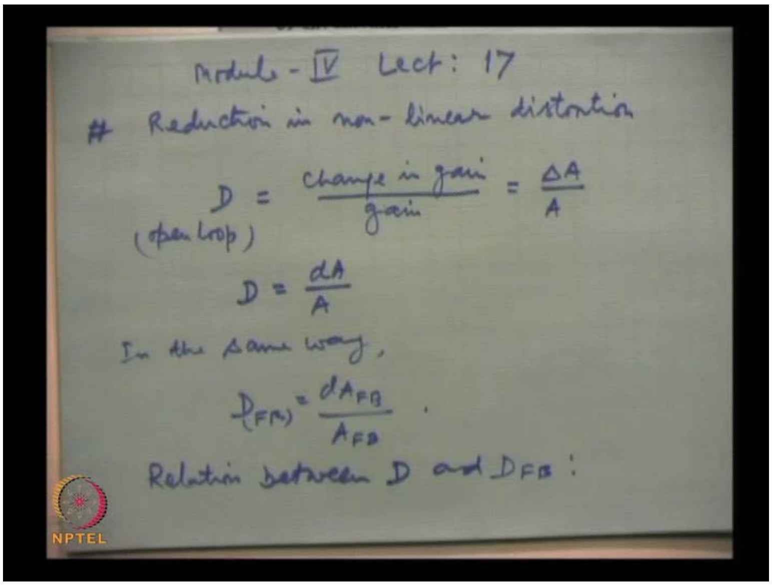

So, reduction in non-linear distortion reduction in non-linear distortion, I talk briefly in the previous lecture about the non-linearity, the characteristics the input characteristics, output characteristics of a transistor, whether it is BJT or it is FET there are in certain region there are non-linear. And there are various other components we cannot assume the complete linearity about their behavior.

Now, we saw earlier that how stability is achieved by incorporating negative feedback, now we study that this distortion, because distortion will finally come in the from of voltage fluctuation. So, for example, if a circuit shows without incorporating feedback, distortion of the weather of 10 percent; 10 percent that means the output voltage 10, then because of the fluctuation it may be plus minus 10; that means it vary from 11 to 9 volts.

Now, this fluctuation can be control, can be minimized by incorporating the negative feedback, it may be reduce to just 1 percent or 2 percent you have to decide, how much you want, because this will again as you will see, will dependent on the fundamental expression AFB, that is gain with feedback is equal to A that is gain without feedback desired by 1 plus B A, we have B is the feedback factor and and so on.

Now, the distortion non-linear distortion may be defined as D this is for open loop, definition is same for open loop or close loop. So, let us take for open loop, this is change in gain, divided by gain that is D A by A and if this change is a small, it is infinite similarly small, then the delta can be taken as differential.

So, gain the distortion in open loop amplifier can be represented by d A by A, in the same way for the feedback amplifier, the distortion can be written as D F B distortion with feedback, this is equal to d A F B by A F B. Now, we have to arrive at a relation between D and D F B, between this two distortion, we have to find what is the relation.

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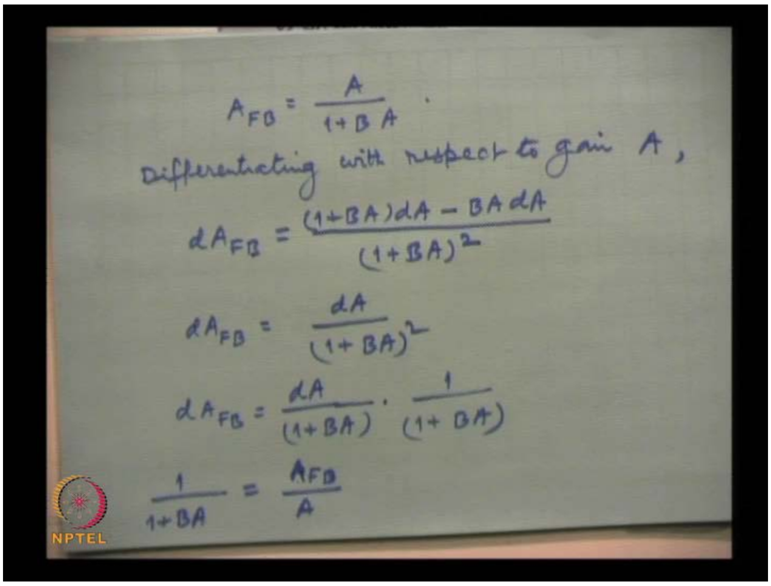

We make use of the fundamental equation of the of the gains, how the gains are related in to non feedback and with feedback amplifier, this is A F B equal to A 1 plus B A, we use this equation and we differentiated with respect to A. So, differentiating with respect to gain A, then we get (No audio from 06:19 to 06:33) 1 plus B A d A minus B A d A by 1 plus B A square, which this if you open it then, this term cancels and we are left with d A F B, this is equal to d A into 1plus B A is square.

Now, this can be re written by breaking this square term by writing two terms, so that it becomes d A F B is d A by 1 plus B A into 1 by 1 plus B A; and for this 1 plus we can write from the fundamental relation this one, we can write that 1 by 1 plus B A, we can write as A F B by A. So, this term we replaced by d F, from here this is yeah A F B by A.

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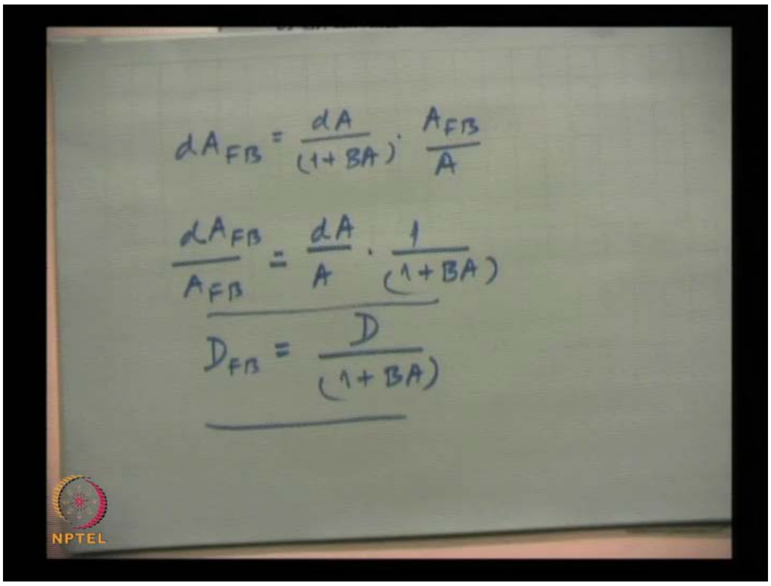

Therefore, this equations becomes d A F B is equal to d A 1 plus B A into A F B by A, I have replaced that 1 by 1 plus B A, by the fundamental equation in this ratio, because we want to bring the expression final expression in the format, which we can immediately use and which is having same term, which we are aware off. So, this can be now re written in the form d A F B by we take this on the this side A F B equal to d A by this A into 1 by 1 plus B A.

And remember how you define, these are the defining equation here (Refer Slide Time: 09:54) this is distortion non-linear distortion in the with negative feedback and this term is the distortion non-linear distortion for a amplifier without feedback. So, this is equal to D F B non-linear distortion with feedback, this is equal to and this is D by 1 plus B A, this is the expression, which shows that the distortion non-linear distortion in a amplifier with negative feedback can be reduced over the non-linear distortion of a open loop amplifier by a factor 1 plus B A.

We have seen in the one example, which was taken that is this term this term is (()) for example, there it was 100, it was 100 that means that the distortion will be 100 times reduced and if it is less, if it is 50 it will be reduced 50 times, if we set this as 10, then it will reduce to 10th, the distortion will remain only 10. So, we can decide how much modification we want, remember by bringing this term more and more the scarifies of the gain will be of the same magnitude, if this parameter is 100, then the distortion reduced to 100th but, gain will also reduced to that extend, it will be 100th of what it was in the absence of the gain of the feedback negative feedback. Now in the negative feedback itself, there are different configurations possible and they give rise to different types of negative feedback.

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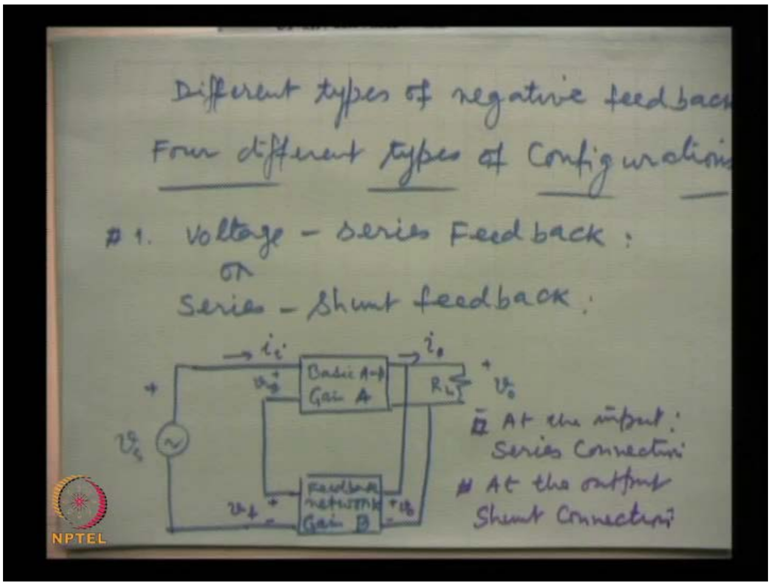

So, different types of different types of negative feedback (No audio from 12:22 to 12:34), there are depending on how we connect the feedback network at the input and output, that will decide that, what type of configuration, we are going to have; and how will what factor will decide that will be, you will see that it will influence properties of interest. Whether we make a shunt connection at output or series connection at output similarly, at the input, so there are four possible negative circuit negative feedback amplifier.

Four different types of configurations, four different types first is voltage series feedback voltage series voltage series feedback and this is also called actually or series shunt feedback. In this new (()) this talks about the input connection, that how feedback network is connected to the basic amplifier at input and this is at output. While in this configuration this (()), what we are feeding back the output the fraction of the output voltage or current.

So, it is voltage or current feedback but, how we return that signal, how we mix that signal that the input in series or shunt. So, this terminology this is for the input side, this is for the output side, while in this (()) this is the input, side this is the output side.

Now, so for voltage series feedback this connection is this (No audio from 15:09 to 15:26), this is the load resistance R L and this is the basic amplifier and having gain A, this is the feedback network with gain B and then (No audio from 15:57 to 16:30) v e (No audio from 16:32 to 16:42) this is the current and this is the output current. So, this is the configurations and here remember that we are assembling the output voltage, so plus minus v 0, is the input to feedback network and what appears here is v f with this polarity and this is v e error signal, which is coming from the mixtetion mixture of the two signals v s and v f.

The feedback signal v f in this circuit will vary according to how the variations occur in v 0. The output impedance of the amplifier will decide, what is the fraction of that we are feeding back to the input. This is one configuration here see, carefully and remember that at the output there is the shunt connections, we are taking it in parallel and we returning it in series.

So, this is sampling the voltage and the gain here off course will be the voltage gain, then this is one circuit, so at the input, this has series connection, at the output it has shunt connection. And the sample the voltage fraction of voltage is feedback and that become part of the input, this is one kind that is voltage series feed back or series shunt feedback.

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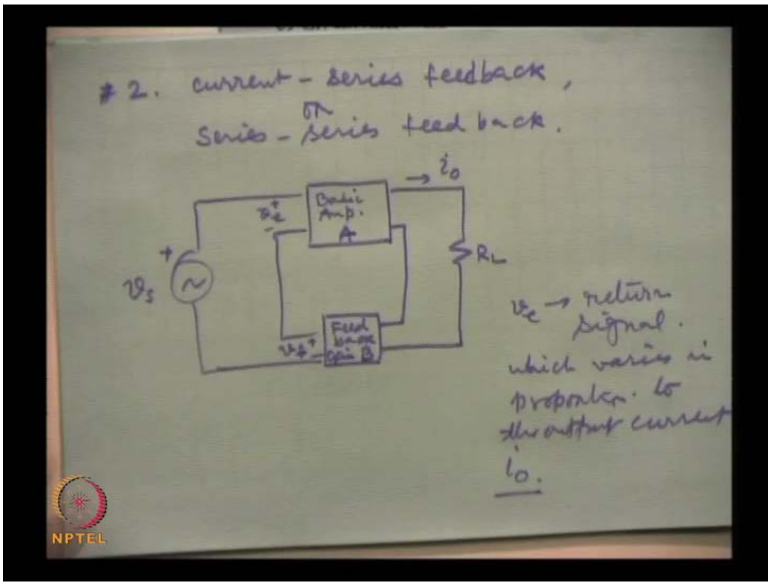

The second type is once, we take this we will see that, how how we take actual actual circuits actual amplifier circuits for at the movement we are showing them in block diagram. So, these is current series feedback current series feedback or this is series, series and the circuit for (No audio from 20:02 to 20:36) this is this is the basic amplifier with gain A, this is the feedback network and here, the gain is B; now and this is the error signal v e and this is v f with polarity plus minus.

So, this is the current series feedback, why we call current series? Because the voltage which we are feeding we are feeding back voltage and this voltage will vary according to the proposition to the output current i 0. This current will decide, when it is flows through this feedback network and then it will generate a voltage, which becomes the part of the input. And hence the negative feedback, this is current series feedback and v e one thing to remember is v e is the return signal, which varies in proportion to the output current to the output current i 0, this is the second type.

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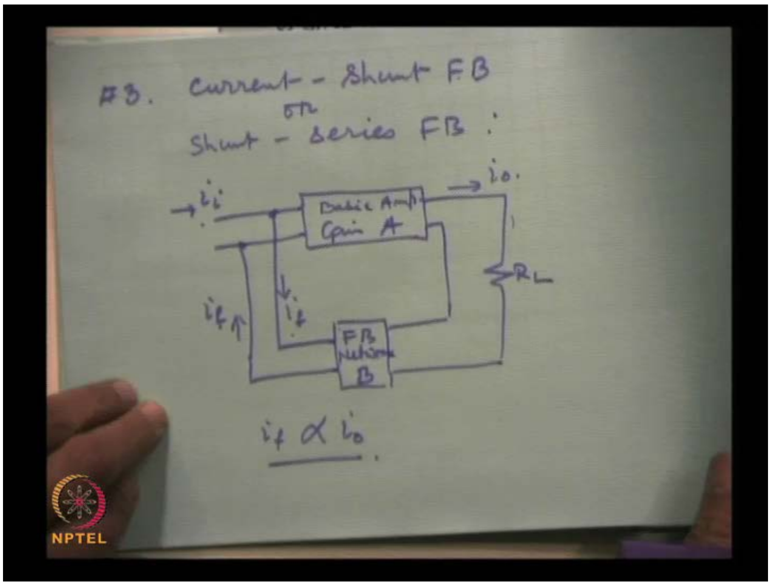

Then, the third type (No audio from 22:28 to 22:38) this is current shunt feedback, the third is current shunt feedback or shunt series feedback, this circuit is this (No audio from 23:08 to 23:37) this is basic amplifier gain A and this is feedback network gain B, this is load resistance and here, we will connect the signal which we generate the input current i i. Now, i 0 this sends current i f, i f here, we are feeding back, the current i f which is the outcome, which goes from the feedback network.

So, the i f varies in proportion and i f varies in proportion to i 0 and here, so we are assembling actually, we are feeding a fraction of the output current output current it is the mixed with; it is compared with the input current i i, which goes in the circuit and the circuit function. And this (()) shunt connection at the input, series connection at the output and this (()), we are assembling this current returning that signal into shunt form at the input. So, this is current shunt feedback or shunt series feedback.

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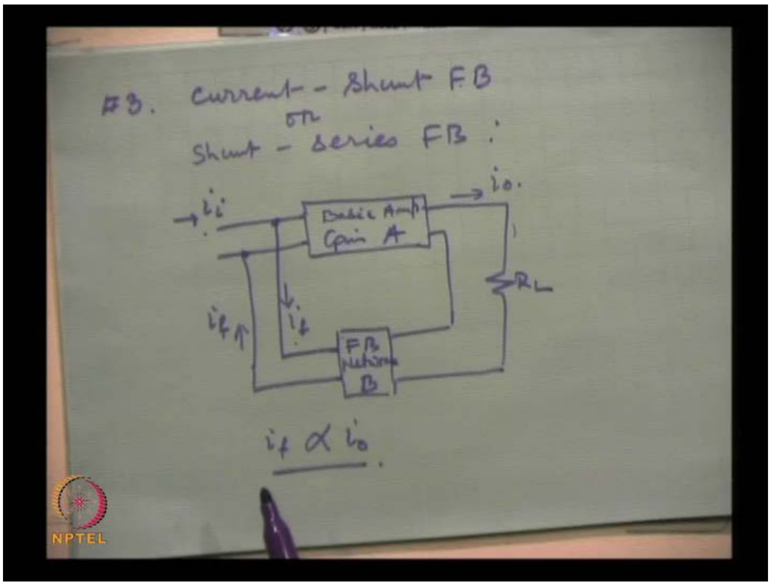

And the forth and the last is (No audio from 25:34 to 25:52) forth and last is voltage shunt feedback (No audio from 25:54 to 26:08), which is also known as shunt, shunt feedback (No audio from 26:10 to 26:26). And the circuit for this is (No audio from 26:27 to 27:10) basic amplifier having gain A open loop gain and this is feedback network having gain B. And this we are sampling the output voltage fraction of the output voltage, we are sampling and the current which will be independent, which will varying in proposition to the output voltage v 0.

This is the current, which will be compare at the input with the input current i i, so i f is proportional to v 0 and i f this compare here, so this is voltage shunt feedback. I just summaries this four circuit, the four types of because there is very important, they will modify the impedance level at the input, output differently and here (Refer Slide Time: 28:33).

And this is voltage series feedback or this is series at the input or shunt at the output voltage series feedback (Refer Slide Time: 28:42), current series feedback, current shunt feedback and the forth one is voltage shunt feedback. So, two possibility with the current, current shunt, current series; the two possibility with voltage, voltage shunt and voltage series.

Now, we take that how will choose, that which of this four configurations, we are going to select, how we select, we will select we will make only out of the circuit, we cannot in corporate to two or three different types of feedback in one circuit, that will not work. We have to choose out of this four configurations, one configurations and what will be deciding factor, because they are going to affect the impedance level. So, the impedance level whether you want increase or decrease, so that will decide that, which of this configurations, we are going to incorporate. So, now we study further, this where all basic now, we really see that how effect of negative impedance, what is the effect of negative feedback on impedance levels.

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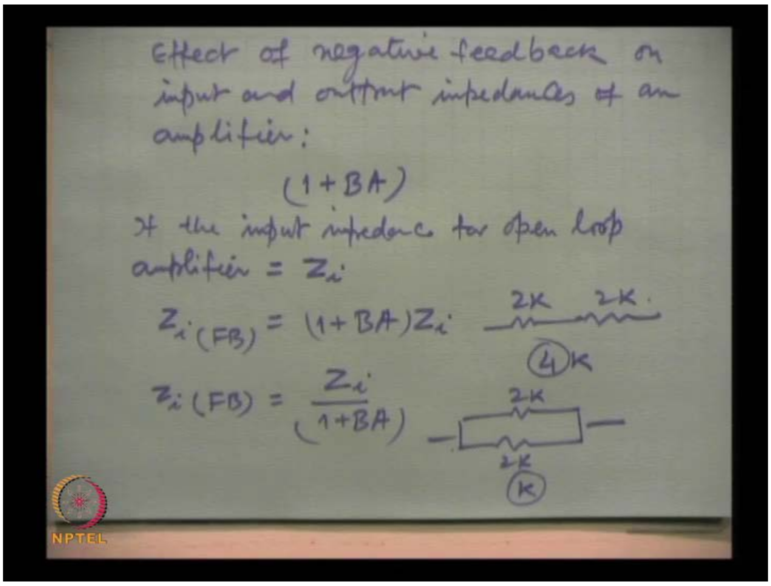

Effect of negative feedback effect of negative feedback (No audio from 30:28 to 30:38) on input and output impedance is the effect of negative feedback on input output impedance of an amplifier. I have been seeing this I am sure now you have understood this treatment, that all properties in negative feedback amplifier are modified to the tune of 1 plus B A in depth, we will see here also.

Now, we are studying the impact of negative feedback on input and output impedance is now see, am saying that changes will be of the order of this, whether it increase, it will increase by this amount, if it falls it will fall by this amount meaning that the input impedance, if the input impedance if the input impedance for open loop amplifier, the input impedance of open loop amplifier. Suppose, this is Z i, Z i is the input impedance when we do not attend in negative feedback, we do not incorporate negative feedback and with negative feedback with negative feedback, this may be if it is this has to increase, then Z i which feedback will become 1 plus B A of Z i.

Similarly, if the output impedance without feedback, no let be complete here itself and it has to fall, then Z i input impedance with feedback will be reduced to this; two things one thing is this is positive parameter, positive quantities, positive number and this can be 10, 20, 100 depends on your design. And your design is and what you how much for example increase input impedance you required; similarly, here it will increase in the similar faction.

Now, as guiding principle remember if we have two resistance is of 2 k each for example, very elementary example am taking, so that you grasp the concept, if there are connected in series 2 k 2 resistance, effective resistance is 4 k at increase. So, remember if we are talking of input impedance, if connection is series connection at the input, then input impedance will increase. If the same impedance is 2 k and 2 k impedance is, if they are connected in parallel this is 2 k, this is 2 k they are connected in parallel; then apply the simple that resistance rule, then you know it come out to be k 1 by 2 k plus 1 by 2 k is equal to 1 by effective resistance and then consult to be k.

So, this is reduced to k, so in shunt they reduce, in series they are they increase, so when at the input if the connection is series connection; you remember shunt and series we have been talking four configurations. So, if the input is the series resistance, the resistance will increase by the factor 1 plus B A, if it is shunt resistance, this will decrease, this will be by the factor 1 plus B A again. Similarly, at the output if the connection is the shunt, then the output impedance will fall, if it is series the output impedance will rise remember this basic fundamental.

We derived an expression for the input and output impedance; I take just one example each at the input and output. And similarly, the analysis can be done for all the four circuits, because we have to devote the time for other thing, so call the four analysis are not required to taken but, as an example only one I take that is voltage series negative feedback.

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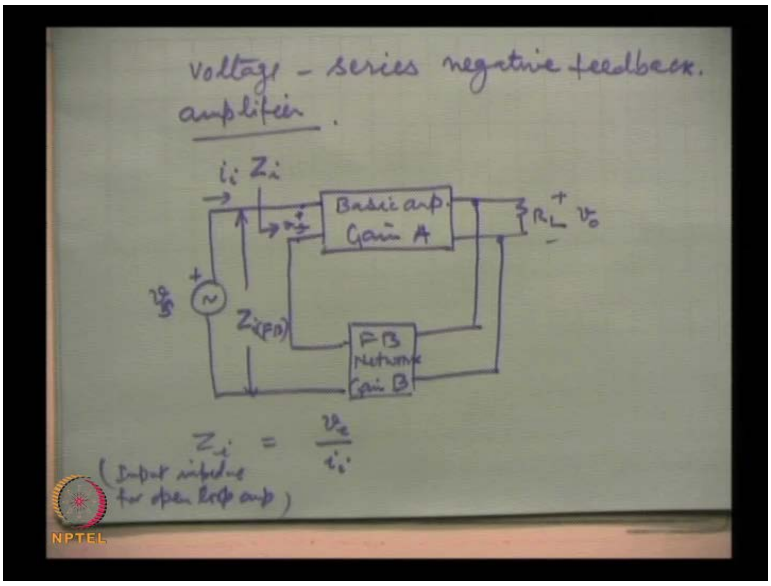

Voltage series negative feedback amplifier, for this amplifier we will determine the after incorporating the negative feedback, what will be the input impedance, what will be and what will be the input impedance? What will be the output impedance? The circuit is this, this can amplifier gain A, this is the feedback network and here the gain is B and R L (No audio from 37:34 to 37:50) this is the applied input signal v s, this as alternating but, we show at instant, when this is positive.

And similarly, here this is v 0 and here is plus minus v e, this is the circuit, which from we are we started the first circuit c m circuit (Refer Slide Time: 38:19) voltage series feedback circuit here at the input as series connection and at the output is the shunt connections, so, this is voltage series feedback.

We measure the impedance here, if we measure between these two terminal, that will be the input impedance without feedback and we when we measure between theses two terminals from here to here this will be Z i F B with feedback, because this does not we as (()) this. So, when we measure the input impedance here, this will be open loop input impedance, what when we incorporate it, that is between this terminal and this terminal, when we measure the output, the input impedance it will be z i Z i F B.

So, by the definition in this circuit, Z i which is input impedance for open loop input impedance for open loop for amplifier this is obviously, if the current here we take as i i, the voltage is v e, so this is v e simple and slow by i i, this is Z i is the impedance without feedback open loop impedance; so remember this definition and then in the same way look at this circuit (Refer Slide Time: 40:22) here, the input was v e, here the input is v s.

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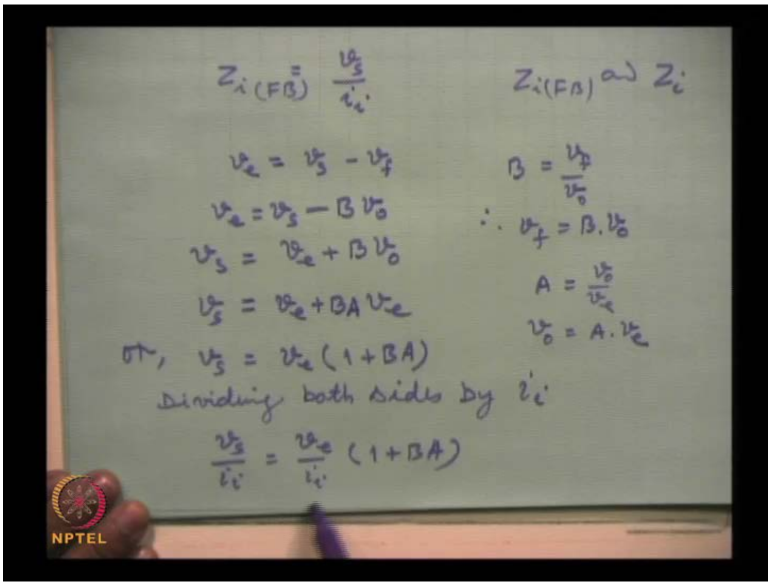

So, for feedback circuit Z i feedback this is equal to v s by i i, now what is our purpose our objective here is to show, that what is the relationship in this circuit, voltage series negative feedback, what is the relationship between Z i F B and Z i. What is the relationship this is what we are driving by simple analysis this is simple but, it is complete analysis, there is nothing like dutile analysis for this amplifiers.

And so, now we remember that the error signal that comes, because of the superposition of the return signal and here (Refer slide Time: 41:42) and this amplifier, the return signal is v f, v f. And I am sure we are not forgotten the basic equation, the input v f, v 0 the output v r. So, obviously B is equal to v 0 by v f, this is suppose proposed to what is the input signal v s. So, the error signal is the v s minus v f and from what I have written B is v f by v 0.

Therefore, v f equal to v into v 0 this substitute here, then v e becomes v s minus B v 0 from here, what is the value of v s, v s is simply v e plus B v 0. And now you know that A was the open loop gain and open loop gain, in the circuit we can see (Refer Slide Time: 43:16) if the input is v e output is v 0, then the gain is v 0 by v e. So, A is v 0 by v e or simply v 0 is A into v e A in to v e that we substitute here, so that this expression becomes v e plus B A into v e, this is v s or v s equal to v e 1 plus B A from here, we can immediately obtain. If we divide both sides, dividing both sides by i i the input current, we get v s i i equal to v e i i into 1 plus B A. And what is this? This is look here how we define, this is the input impedance with feedback and this is the open loop impedance impedance of the open loop.

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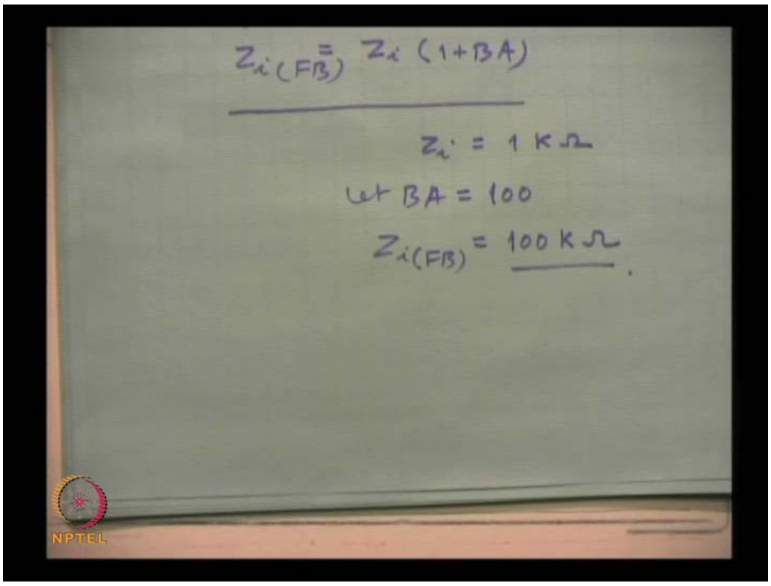

Therefore, we get the relationship from here that Z i F B is equal to Z i into 1 plus B A this is the relation, we get the relation that how much modification in the input impedance will occur in this voltage series circuit, which is under consideration by incorporating feedback. The input impedance becomes high by the factor 1 plus B A and this is again (Refer Slide Time: 46:06), because this is series connection at the input and I through this 2 k extends example the resistance the suppose to increase, so it has increased.

If Z i is 1 kilo ohm 1 kilo ohm and if this factor is for example, 10 for 100, say 100 let B A, because one can always be neglected in comparison to A B normally and let it be 100, then, the impedance feedback, negative feedback will be become 100 kilo ohm are interesting. Negative feedback in the circuit and hence is the input impedance, if the connection is voltage series negative feedback. In fact for all wherever the input is series the resistance will be this much I will summaries little later but, this is the thing but, when the connection at the input is series feedback connection is series the impedance relationship will be this and then let us, find out the output impedance.

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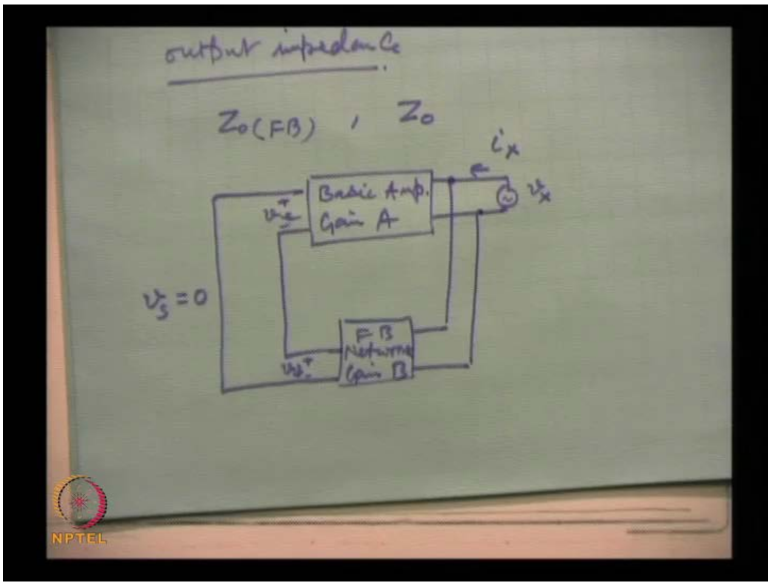

The output impedance (No audio from 47:32 to 47:45) output impedance for the amplifier under the investigation and which amplifier we are investigating voltage series negative feedback. And for this now, we have to apply we have to find out the expression, the objective is find out the expression output impedance with feedback; how it is related with Z o, that means the output impedance without feedback.

Is suppose your given any circuit and we ask you that find out the impedance, what you will do? You will apply a test signal, a small voltage and find out the resulting current and the ratio of the two will be the impedance. Similarly, so the rules of the gain here are, that we have to find out the impedance here (Refer Slide Time: 48:51) the output impedance here. And this can be done the first thing, which will have to do is, we have to remove this load resistance.

Load resistance is not the included this is the general principles of that the analysis, that when the output impedance is to be taken, take out the resistance and connect a voltage source v x. So, when we do that we will observe the corresponding current i x, so what we are talking is this, this is basic amplifier gain A, this is feedback network gain B, here we have removed that resistance R L maintaining the same connection (No audio from 49:54 to 50:10) This is a test voltage v v x which sends current i x and remember besides when we are taking of input voltage output voltage, then the input signal v s is to be said to 0 and test signal is connected output and here this is v e, this is the return signal v f.

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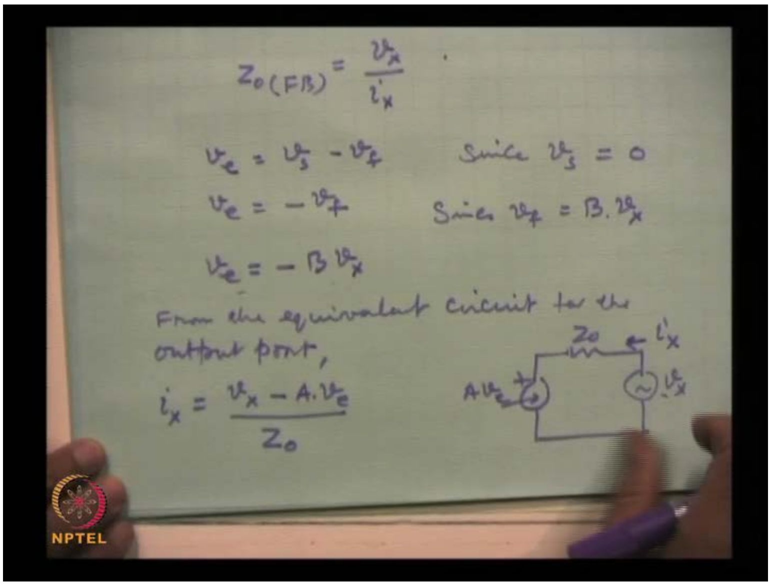

The output impedance with feedback is equal to the ratio of the test signal and resulting current i x (Refer Slide Time: 51:12), this is the test signal, this is the current which is generated and that amount of the current will dependent obviously on the impedance the output impedance of the circuit. Now, from the above figure we already we already understand that v e error signal, which is the some of the v s minus v f but, in the present case v s as 0 (Refer Slide Time: 51:47) we reduce v s to 0. So since v s 0, v e equal to minus v f and v f (Refer Slide Time: 52:09), this voltage plus minus v x, so obviously B is output is v f input is v x.

So, v f is equal to v into B x, this is input to the feedback circuit this is the output; so output to input this is the ratio, which is gives v f equal to v B x and that v f is substitute here. So then, since v f is equal to B into v x our error voltage, because minus the B v x, we dropped a equivalent circuit for the output port this, we just take the output port and we dropped the circuit.

So, from the equivalent circuit from the equivalent circuit for the output port draw it here and then we write at a small simple relation, this is the impedance z 0 and here we have connected v x which has send current i x; and here is the another voltage source from where it will arise here (Refer Slide Time: 54:08). This signal is amplified A times, what is the voltage here v e into A, A times it is amplified. So, this is this is A v e, I hope derived no confusion about it, one voltage we have connected, the other voltage that wear because of v e which is amplified A times, so there are two voltage source. Now it is simple that we can find out value of i x, if we have a resistance and one terminal is at the potential v x.

At the other terminal is the connected is having the potential A v e, then obviously, the current will be the difference of is two potential, that is v x simple ohms law minus A v e divided by Z 0. This is the relation, which we get and now we substitute for v e what we are find out here here we substitute this v e by minus v x, so what we get.

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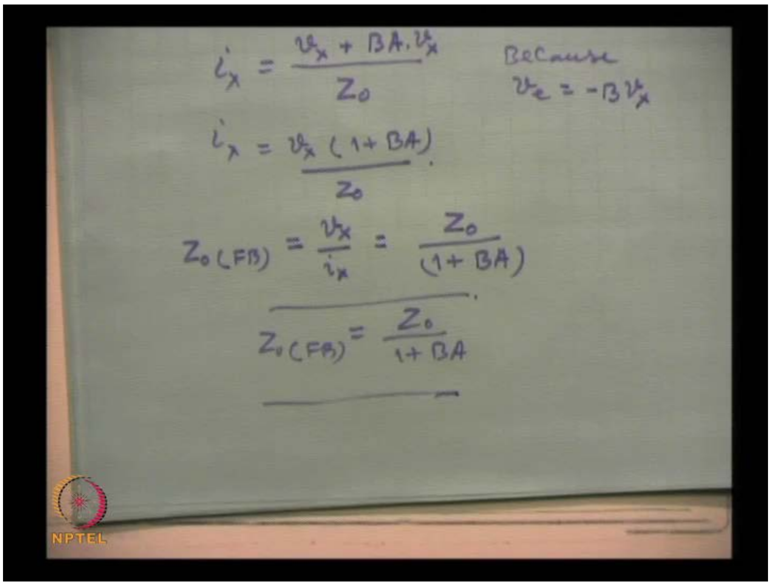

The relationship for i x becomes equal to v x plus B A into v x by Z 0, because because v e the error signal as we have shown ever is minus B v x. And from here, we come out to this is i x this is equal to v x we take common 1 plus B A by Z 0 or the output impedance with feedback by definition is v x by i x and this is equal to Z 0, 1 plus. That is z 0 F B, Z 0 1 plus B A this is the relation, that how the output impedance will be reduced by the factor 1 plus B A yes. I said in the beginning the same thing we are now finding that this configuration the output is (Refer Slide Time: 57:16) having the shunt expression, shunt connection.

And shunt connection is going to reduced the amplitude of the magnitude, of the impedance and this is reduced all variations are govern by the factor 1 plus B A and therefore this is the impedance. And in fact, so this relation this have derived just for one output and one output but, the analysis can continue for all, just to summaries the in the table that the feedback configurations.

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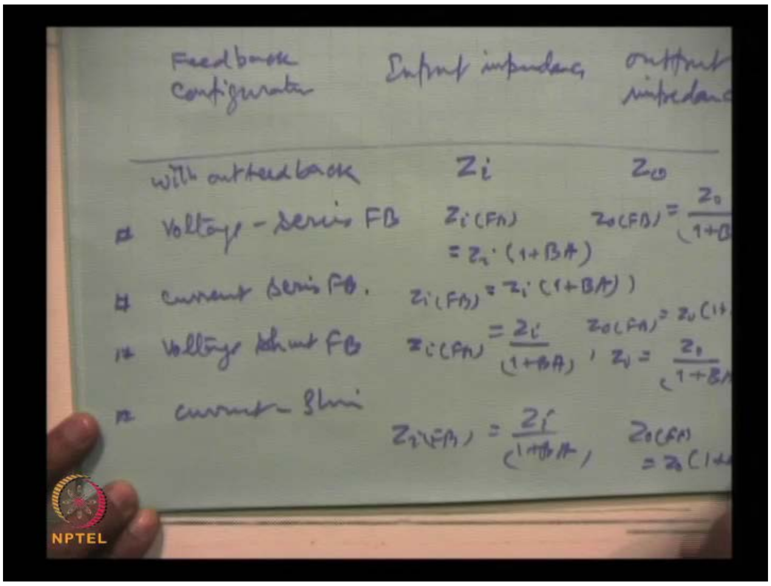

Feedback configuration this is the input impedance and this is the output output impedance here, without feedback without feedback, this is Z i and output impedance Z 0. In voltage series voltage series feedback, this is increase to Z i F B is equal to Z i 1 plus B A and this is reduced, because this is actually series shunt, so at the output is shunt. So, Z 0 F B is equal to Z 0 1 plus B A for current series feedback this both increase that Z i F B becomes Z i 1 plus B A.

And similarly, output becomes Z o F B equal to Z o into 1 plus B A, for voltage shunt feedback this is reduced F B Z i 1 plus B A this is increased, this is also reduced Z 0 is, so all kinds of combination are there. And finally, and lastly this is the, I can just say this is current shunt current shunt this is reduced Z i F B it is reduced Z i 1 plus B and this is increased 0 Z 0 F B, this is Z 0 into 1 plus B A. This is how impedance level are changed or modified by the incorporation of the negative feedback.