Analog Electronic Circuits
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Lecture 30
Advantages of Negative Feedback Amplifiers

30th lecture and we are going to discuss advantages of negative feedback amplifiers. Now as far as feedback is concerned whether it is positive or negative shall be determined by the sign of A beta. And you recall that our general block diagram was that we have an X s and an X f. Both are taken with a positive sign. This is X i and then you have the basic amplifier A. The output is X 0 through a, what do you call this network, sampling network which we show simply as a line.

We take a beta network through which is transmitted a signal X f and the basic assumptions were that A was a forward looking device. It transmits in the forward direction and beta transmits in the reverse direction only. Under these assumptions we derived the relationship that A f, the feedback gain which is X 0 by X of s is given by the gain without feedback A divided by 1 minus A beta. And the nature of feedback whether it is positive or negative is determined by the sign of A beta.

Now A beta can also be complex, okay, and that is when complications arise. If A beta is complex, it is frequency dependent complications arise that at some frequency the feedback may be negative, at other frequencies feedback may be positive, okay. So if the feedback is to be negative then we can do one of the two things. We can say A beta is equal to minus A 1 beta 1 or we can simply change the sign here. Instead of positive we can make it negative and say the gain would be A divided by 1 plus A beta.

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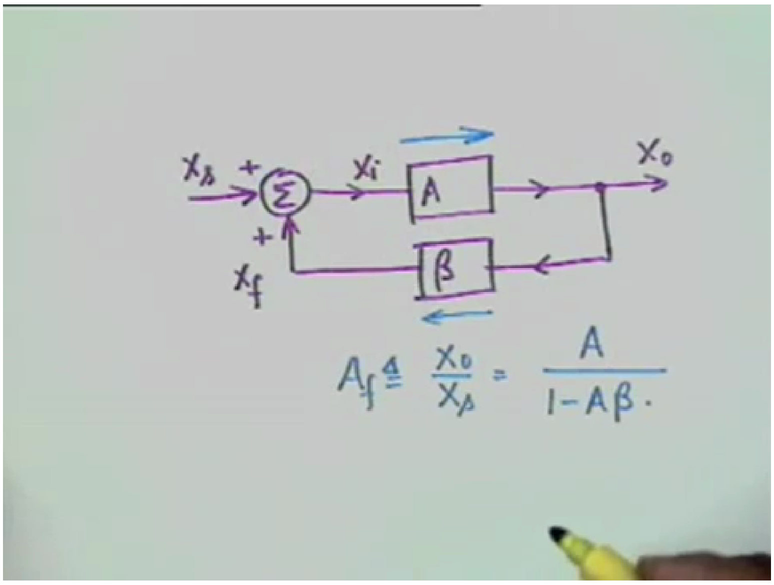

In the context of our discussions it should be clear as to what we have done but we are basically discussing negative feedback because that is what is used in amplifiers. Positive feedback is hardly ever used except in the case of oscillators, okay. So one of the good effects of negative feedback is desensitization. Yes.

Student: Sir, what was the Berkhausen criterion?

What was the Berkhausen? Oh! Berkhausen criterion was that if A beta is equal to 1 0 degree at some frequency, at omega equal to omega 0 then A f tends to infinity and the circuit oscillates at the frequency omega 0. This is the Berkhausen criterion. The criteria is simply A beta equal to 1 0 degree. This is the criterion for oscillation at the frequency at which this occurs, Berkhausen. Yes.

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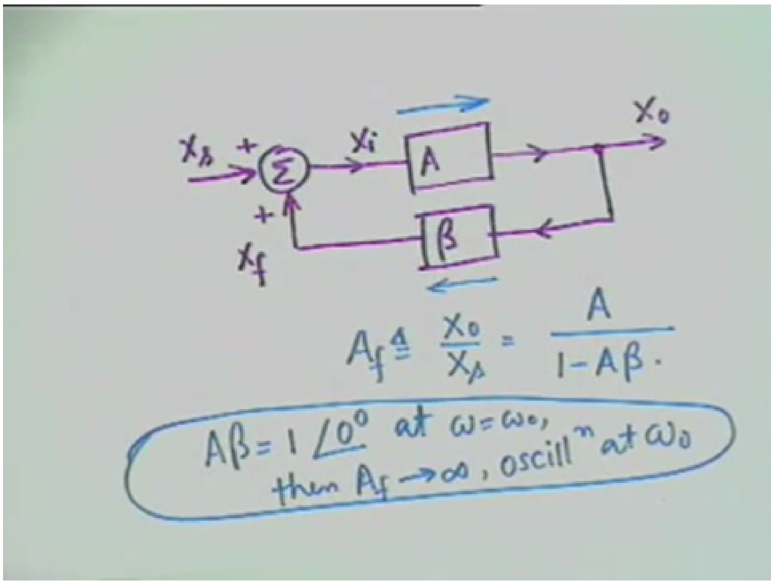

Student: Even if this is real A beta.

Even if A beta is real yes.

Student: Then it can be 1. What happens then?

What happen then? Nuisance. Since it is satisfied at all frequencies if it is real, you get noise at the output that is all, nothing else. All frequencies are present which means all frequencies mixed together will be simply noise. If you accommodated whole of IIT in this room obviously it would not make sense. But if you accumulate only second year electrical engineering students here and a senior here it is a W 204 class. It is meaningful. Is that clear? Okay. If A beta is real then all you get at the output is noise.

And for example it is an audio amplifier you can speak as loud as possible on the microphone, nothing will be heard. All that will be heard is noise, okay. So, one of the advantages of negative feedback as I had said is desensitization of the gain with respect to device parameters and environment. We have already seen environmental changes.

We have already seen manifestations of this in the case of the common emitter amplifier in an unbypassed resistor. But formally the sensitivity of any quantity G with respect to any of its parameters x, G is a function of x, is defined as, this is the symbol that is used capital S.

Student: What is G?

G is the gain, sensitivity of the gain. I am using a general symbol. I do not want to use A or A f because I am going to use them later. The general definition is G can be any performance parameter. It could be impedance, it could be admittance, it could be a gain, voltage gain, current gain, whatever it is. A performance parameter capital G is a function of the parameter x in the circuit then the sensitivity of G with respect to x is defined as x. Well let me give the definition first.

Delta G by G divided by delta x by x. In other words if the parameter changes by a certain fraction how much change does it affect on the performance? That is the qualitative definition. If delta x by x changes by 1 percent and delta G by G changes by half percent then half is the sensitivity, okay. So it is an indication of how much x has an effect on the performance.

Now as you can see this can be written as x by G delta G by delta x and this delta G is a finite change. Delta x is a finite change. Usually we find it convenient to make delta x to be infinitely small. Delta x tends to 0, then obviously S G x would be x by G, differential coefficient of G with respect to x. And this is the measure that is very widely used.

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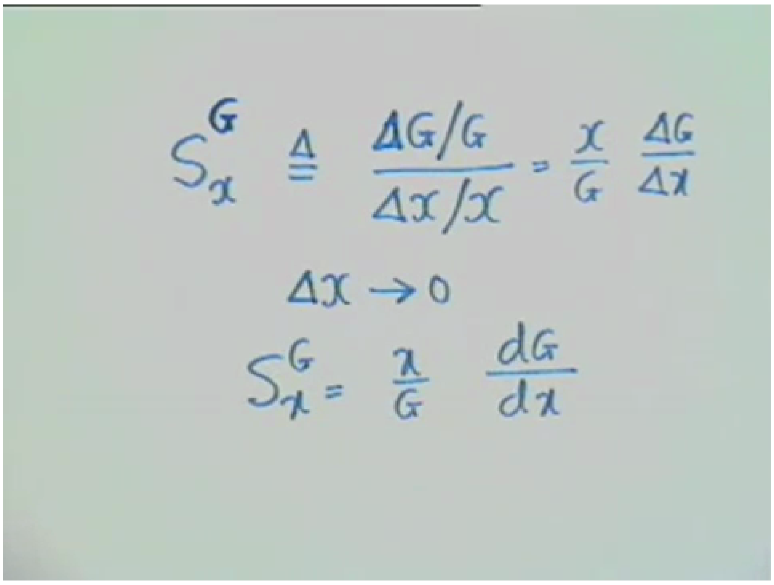

In practice we should use for example if you want to find the change of gain with respect to beta by device replacement. You know beta from one device to another can change by as much as 100 percent. So if you take two transistors, in one of them beta is 100 and in the other it is 200 obviously delta beta cannot be considered infinite, okay. So this definition will fail when delta x is not infinitely small. But nevertheless we use this as a convenient measure.

Student: (())(09:08)

Okay, capital G is usually a function of not just one parameter but many parameters. So if I say capital G is a function of x 1, x 2 and so on then the modification that you have to do is if this is x i then you have to put x i over G and instead of small d you have to replace it by the curly d or delta, the partial derivative. This is very simple to follow that if capital G is a multivariable function, it is a function of many variables then obviously total differentiation with respect to a parameter does not make sense.

It has to be partial differentiation, okay. And then the total change in delta G has to be computed. Well we cannot compute delta G, you can compute d G, total differential. That would be S G x i multiplied by d x summation of this.

Student: Sir G by x.

Student: No sir.

Student: Sir G by x.

Into G by x. That is correct. You have to multiply by d x I, agreed? Okay. So this is how it is done.

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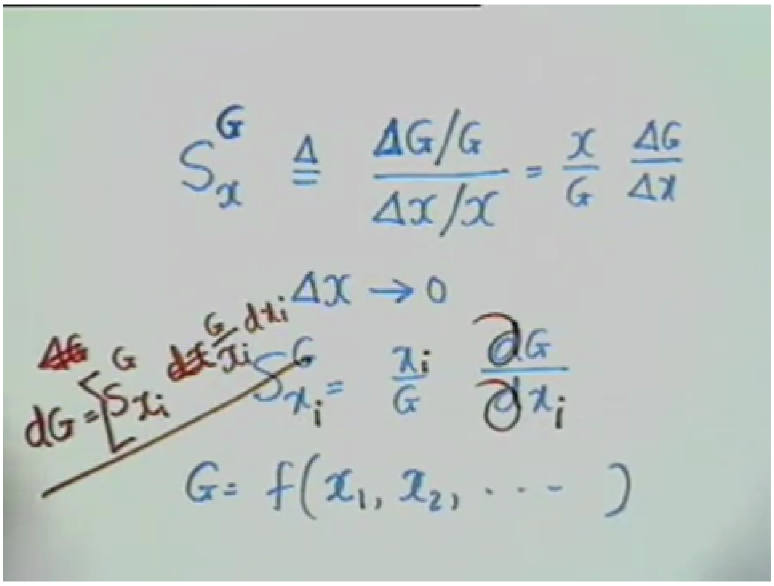

Now in the context of our discussion on negative feedback amplifiers we are going to consider one parameter at a time and we shall not be concerned with the total change. This of course we have done when we were doing the bias calculation, bias stability, is not it? We considered three parameters V B i, I C B O and beta and we found out the total change, okay.

Now in our case A f is equal to A by 1 minus A beta, alright, and we want to find out the sensitivity of A f, the feedback gain, with respect to A.

It is A which changes due to device parameter change or environmental change and you can easily show by differentiation and by applying the definition that this quantity is 1 by 1 minus A beta. And obviously this will go to 0 if A beta is very large compared to unity, okay. This will go to 0.

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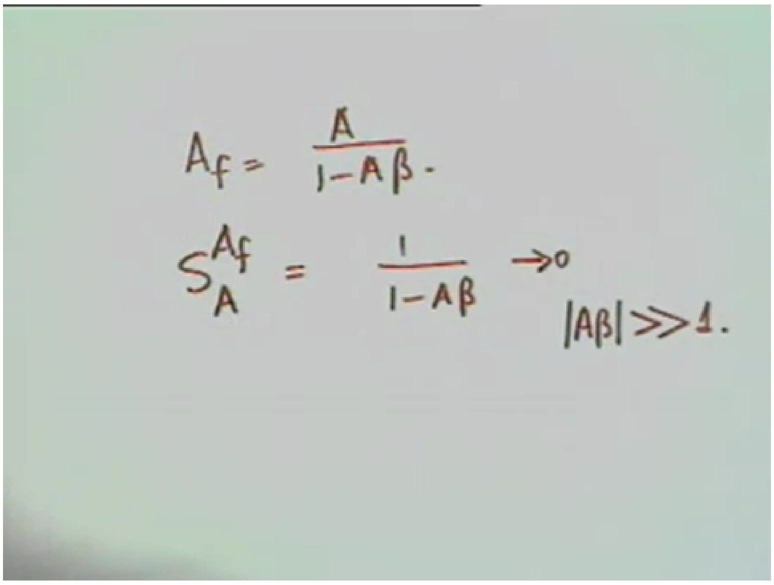

And under these conditions obviously A f, if A beta is very large compared to unity obviously A f tends to minus 1 over beta. That is the feedback gain is controlled by the beta network only. It is not affected by the gain of the internal or the basic amplifier. And many manifestations of this you have already seen. One of them for example is in this operation amplifier.

If you have two resistances R f and R i and your input is here, the output is here, this is grounded, the gain is A and you know if A is large there is a negative feedback through R f. And if A is large you know that V 0 by V i is approximately equal to minus R f by R i. That is the gain is controlled only by the external resistors and by the feedback network. R f and R i is the feedback network, okay. This is one of the manifestations.

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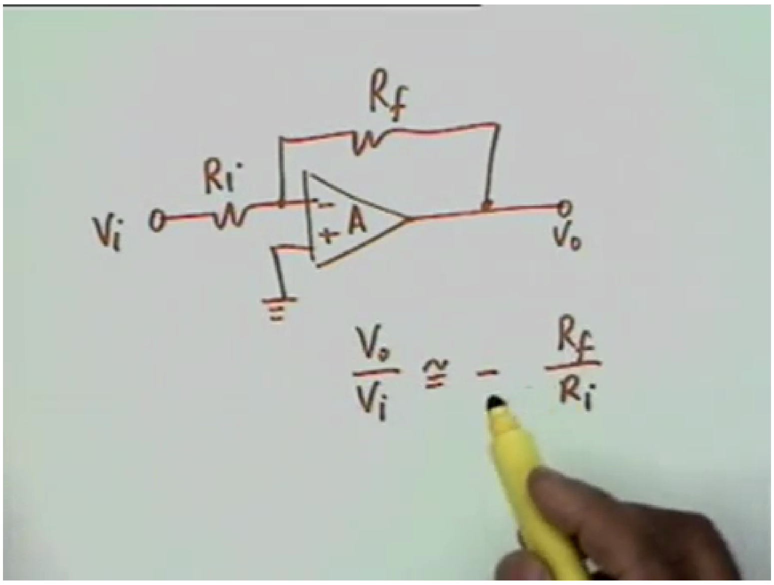

The other was when you have the common emitter amplifier with an unbypassed resistor R E then you have the gain was approximately equal to minus R C by R E. This is also a manifestation of negative feedback. Desensitization of the gain of the feedback amplifier due to negative feedback. So this is one of the major advantages. The second advantage that we are going to consider is about reducing nonlinear distortion, N L D. This you must follow very carefully because there are tricky points where one gets deceived. For simplicity we consider an ideal. Yes?

Student: (())(14:11)

Yeah but before that happens if A beta is very large in positive feedback the gain will take over. Okay, it is a good point. I was expecting this. In fact when I was writing this you must have noticed that I was slow in writing this because I was expecting a question. Nevertheless, better late than never. What he is saying is this is not true only about negative feedback it can also happen in positive feedback because what I have assumed here is magnitude A beta much greater than 1, okay.

Now if A beta is positive it cannot exceed 1, is not it right? If there is a positive feedback, it cannot exceed 1 because as soon as A beta becomes 1 the circuit goes into oscillation or nuisance, as the case may be, okay. Nonsense as the case may be and therefore it is not relevant to positive feedback, alright? This desensitization is not relevant to positive feedback because the circuit no longer performs as an amplifier, it becomes an oscillator.

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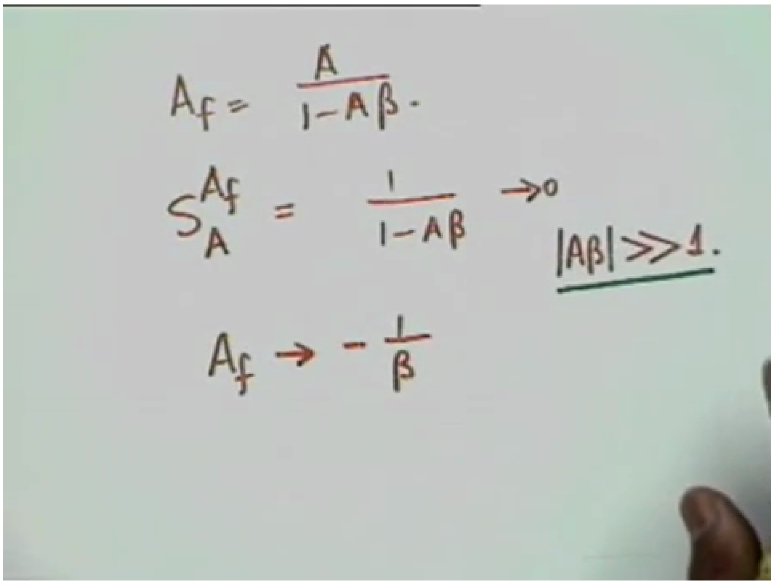

Okay, now to be specific we consider the basic amplifier as a voltage amplifier. That is we consider V s, R s an ideal voltage amplifier. That is R i is infinity so we have V i which is equal to V s and then we have A v V i plus minus. That is it. This is V 0 and the load is here R L. This is V 0.

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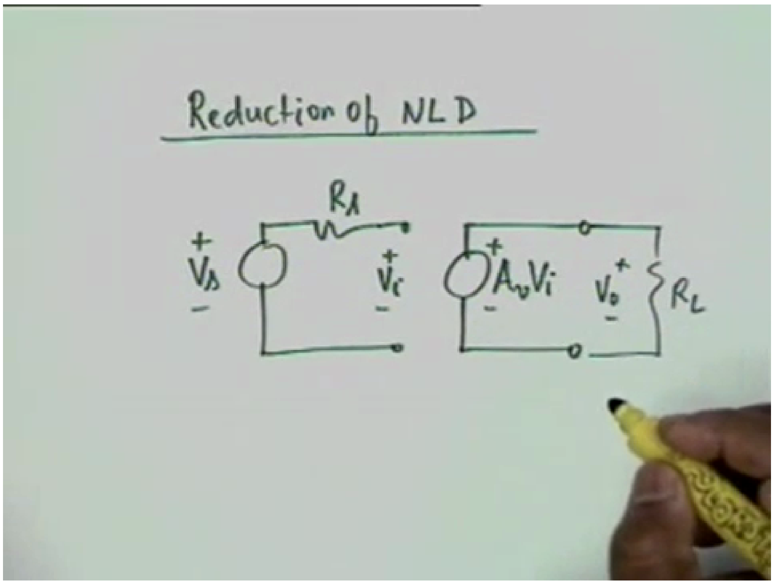

We consider the basic amplifier as a voltage amplifier. Now you know from your experience with voltage amplifiers that we have discussed so far that this ideal relationship between the output voltage and the input voltage that they differ only by a constant, that their ratio is a constant. This can be valid only over a certain range of input voltages, agreed? As soon as you go into saturation region or in the cut-off region, nonlinear distortion starts.

And therefore if I plot the curve of V 0 versus V i, now V i can go positive as well as negative. The curve would be a straight line passing through the origin. What is this origin? What does this origin corresponds to? 0 input that means the Q point, okay. So this origin actually corresponds to the Q point. And the curve would be a straight line like this only for a certain range of V i. Let us say for this range. Typically it could be 40 millivolts typically. Let us assume a figure of plus minus 40 millivolts, okay.

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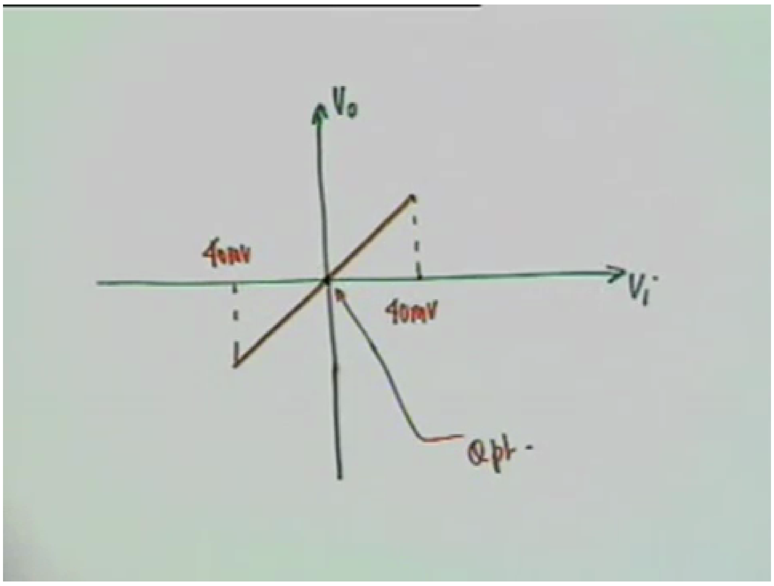

What will happen afterwards? As soon as we cross 40 millivolt limit, well saturation or cut-off will set in depending on the polarity and the curve will try to flatten off like this. Similarly here also, agreed? Now if I apply negative feedback suppose the gain is 100. Let us take a specific case. Suppose the gain is 100 then the slope of this curve shall be 100, okay. D V 0, d V i shall be 100 over the red region.

As soon as it goes into black the gain effectively decreases, drops down, okay. Suppose the gain is 100 in this region and suppose the input V i is equal to let us say 10 millivolt. What would be V 0 then? 1000 millivolt which is 1 volt, okay.

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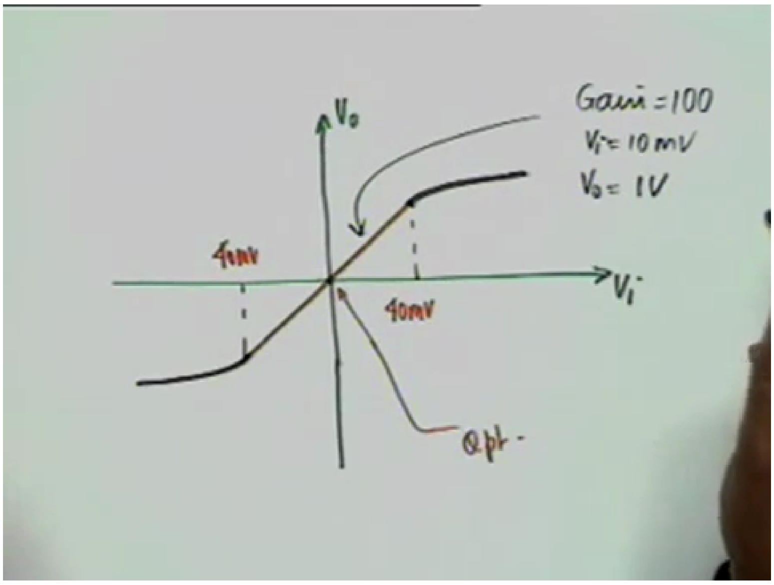

Now suppose we subject this basic amplifier to negative feedback, alright, and let us say our beta is equal to point 09 let us say. Take some figure point 09. Typically this is the figure. There is very small fraction of the output is fed back to the input. Then with negative feedback what is V s corresponding to V i equal to 10 millivolt? It would be V i plus point 09 volt which is 90 millivolt. So V s required would be 100 millivolt for V i equal to 10 millivolt. Is this point clear?

With negative feedback V i is equal to V s minus beta V 0 with negative feedback. That is what I have done. To make a V i of 10 millivolt we have to apply a V s equal to 100 millivolt, agreed? If I want to go to V i limit that is 40 millivolt then how much V s do I need? Okay. V s would be 400 millivolt obviously. Did you have to make this calculation? No. You could have said this just by looking at the figure.

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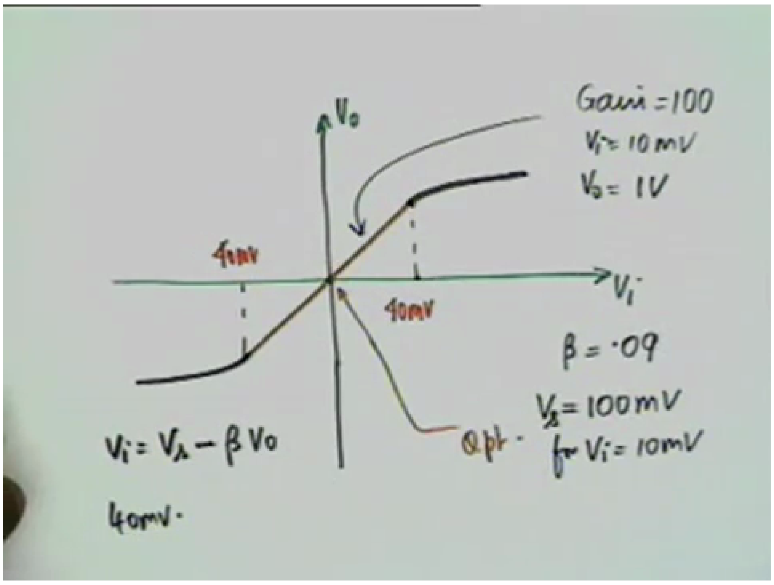

So now notice what I am saying. So instead of plus minus 40 millivolt, instead of limiting the input voltage to 40 millivolt we have to limit now V s to 400 millivolt, okay. Does this reduce distortion? Is it a reflection of distortion reduction? No, it is not. It is only a reflection of the property that the dynamic range of the amplifier is increased, is not it right? Instead of limiting your input voltage to plus minus 40 millivolt you are now able to increase it to 400 millivolt. At what cost?

Student: The gain is reduced.

The gain is reduced to how much?

Student: 10 times.

The gain is reduced by a factor of 10, agreed? So there is no reduction of nonlinear distortion it is only that the dynamic range is increased, alright?

Student: (())(21:44)

Oh! Instead of limiting our input voltage to 40 millivolt because of negative feedback we are able to increase the input voltage to 400 millivolt without nonlinear distortion setting in, okay. So what we have done is. Yes?

Student: Sir you could have as well done this by a potential divider.

Of course, we could have done that, yes. So virtually we have gained nothing.

Student: Sir, are we limiting the input voltage or source voltage?

Source voltage, yes. Okay.

Student: Curve is in (())(22:19)

Curve is in V i and we know we can plot a curve V 0 versus V s also. We can plot a curve and that curve will be, what would be the nature of that curve? It would be linear with a less slope and it would go right up to 400 millivolt on this side and 400 millivolt on the other side, okay. The slope of this curve will be simply 10 because the gain was 100 and 1 plus A beta is equal to 10, okay. It would be 1 plus A beta now because negative feedback, alright?

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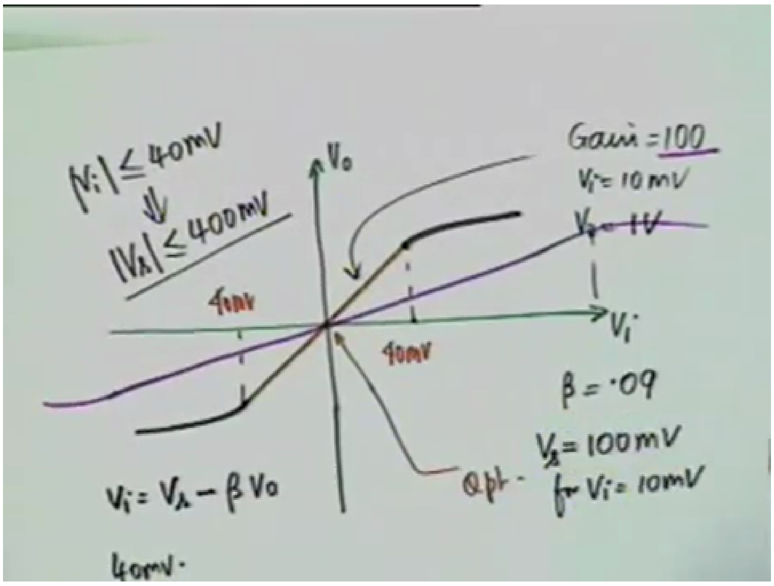

So we have gained nothing by this negative feedback. We have only reduced the gain and we have been able to increase the source voltage, the dynamic range of the amplifier. However make an approximation to this characteristic through piecewise linear curves. That is let us say you have this as the linear region and suppose the gain here is 1000.

As soon as we exceed the dynamic range the curve tends to saturate if you approximate that by piecewise linear curve. Let us say the curve goes like this, okay. Obviously if the input range goes right up to here and here, there will be lot of nonlinear distortion because of this kink in the gain curve. Let us say the gain here is 100, okay.

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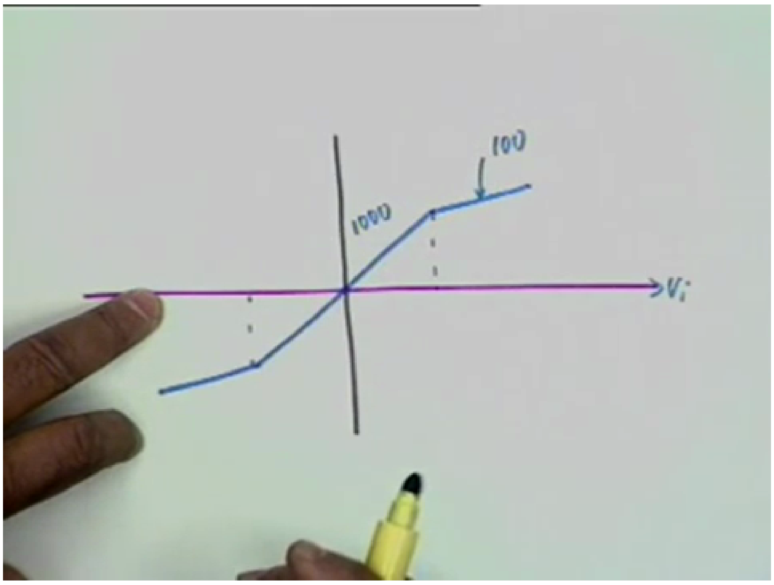

Now let us see what happens with negative feedback? Suppose the beta factor is let us reduce it further. Suppose beta is point 01. Then when the gain is 1000 what is the feedback gain? It is 1000 divided by 1 plus, 1000 multiplied by point 01, so it is 10. That is 90 point 9 approximately, okay.

So in this range the curve gets reduced, the curve gets flattened. The slope decreases to 90 point 9, okay. So maybe it becomes something like this, fine. What happens to the gain in this region? It becomes 100 divided by 11 which is.

Student: Sir divided by 10.

Student: 9 point.

Student: Divided by 2, sir.

Student: Divided by 2.

100 divided by 2. I beg your pardon. 100 divided by 2 because 1 plus 100 multiplied which is 50 and therefore the gain flattens off maybe like this.

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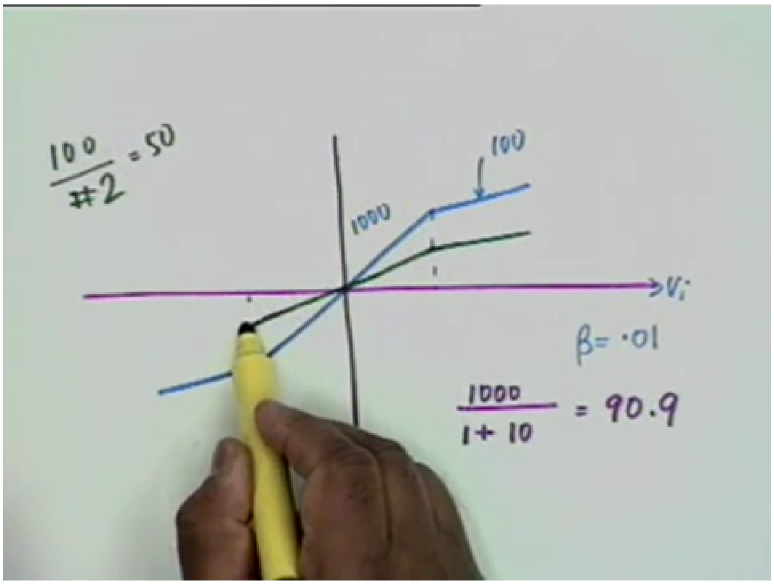

Now a change of slope from 1000 to 100 and a change of slope from 90 to 50 by a factor of 2, previously it was a factor of 10, therefore the nonlinear distortion in the feedback amplifier would be much less as compared to nonlinear distortion in the non feedback amplifier. Is the point clear? This picture is worth a million words. It explains how nonlinear distortion is reduced. In other words the transitions or the discontinuities are smoothed out by nonlinear distortion.

And if you apply sufficient feedback and the gain was sufficiently large, you can make this curve almost a straight line, okay. These kinks are reduced and therefore there is a reduction in nonlinear distortion. This is a qualitative picture. Now let us look at it quantitatively. What is the price that you pay? The gain is reduced by a factor of?

Student: 10.

10 or 11?

Student: 11.

So the gain is reduced by a factor of 11. Now, one can argue that this feedback amplifier that you have A f, you have reduced nonlinear distortion by introducing the negative feedback and the factor is 11. So why do not you add a preamplifier of gain 11 such that this gain reduction is compensated for? Now this is a very tricky suggestion. You must make sure that this preamplifier does not introduce nonlinear distortion. Now would it or would it not? That is the question.

Since the gain is small, the nonlinear distortion introduced by this preamplifier would be much less as compared to the feedback amplifier. Small gain and therefore the excursion of voltage at the output will not go to cut-off or saturation. And therefore it is easy to design a low gain preamplifier to compensate for the reduction of gain in the feedback amplifier qualitatively.

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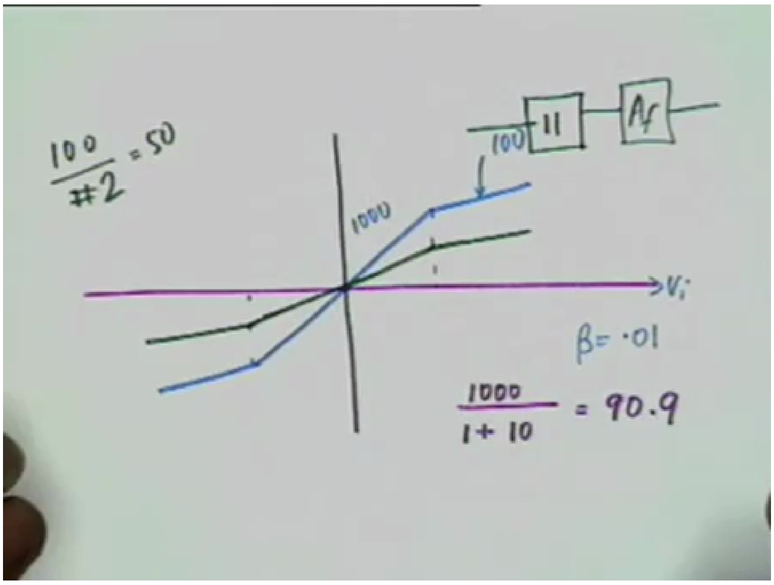

Now let us look at it quantitatively. It is very important to establish this and be convinced that nonlinear distortion can indeed be reduced by feedback. Let us consider the usual feedback block diagram. The basic amplifier and now because of negative feedback we use a negative sign here, alright? We use a negative sign here, this comes from the beta network, this is V 0, this is V f. We are now considering voltages.

This is V i and this is the beta network. Now the occurrence of nonlinear distortion obviously, this block diagram is valid when everything is linear and we can derive that V 0 by V s is equal to A divided by 1 plus A beta because negative feedback has been assumed here, okay.

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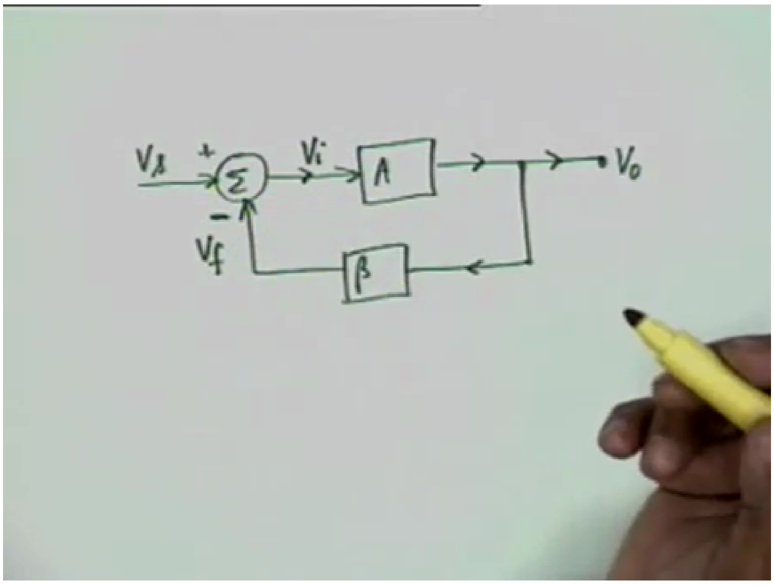

Now the nonlinear distortion obviously occurs in the amplifier and can be taken care of by introducing the distortion term as a summation term here. Let us say that the distortion voltage or distortion component of the output is V D. Then obviously distortion can be shown in this diagram by means of an additional voltage V D. And if you now analyse including V D then obviously V 0 would be equal to A V i plus V D. Is the point clear? A V i is the undistorted output, add to the distortion, okay.

So the output becomes distorted. If you now analyse this circuit you can show very simple algebra that V 0 is equal to A V s divided by 1 plus A beta. That is the undistorted output. Plus V D divided by 1 plus A beta.

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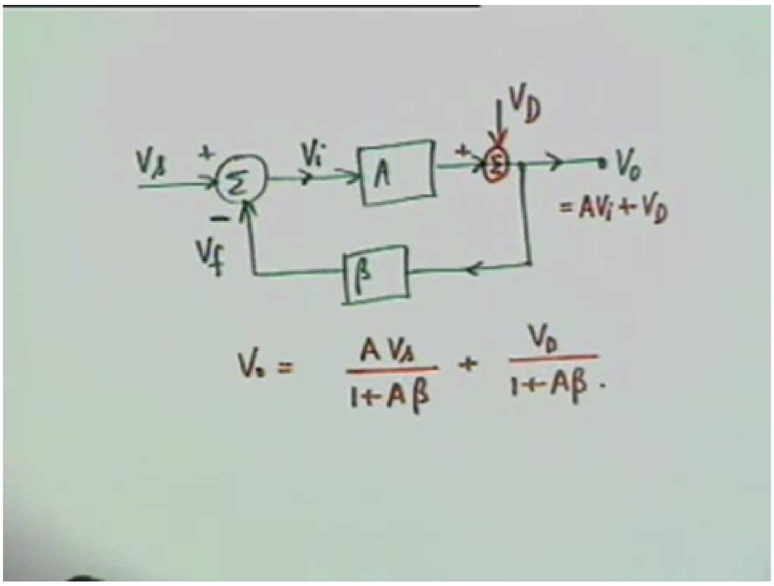

Now have we been able to reduce nonlinear distortion? Obviously not, because we still have A V s plus V D divided by 1 plus A beta. Both the signal and the nonlinear distortion have been reduced by the factor of 1 plus A beta. So the relative values have not changed, right? The nonlinear distortion in the output has been reduced by the same factor as the signal. So the relative values have not changed.

But suppose now we add another amplifier here, a preamplifier whose value is 1 plus A beta and let us say the actual input source voltage is V s prime. Then obviously V 0 would be equal to A V s prime, okay, plus V D divided by 1 plus A beta. I beg your pardon this should be, okay. No, this is okay. Is it A V s? It is A V s. That is right. If I multiple this I can put it here or I can put it at the other end. Shall I put it at the other end post amplifier? Yes or no?

Student: No.

No, because then the distortion will also be, so I have to use a preamplifier with a gain of 1 plus A beta and 1 plus A beta at preamplifier stage shall handle much less excursion of voltage than the basic amplifier and therefore that nonlinear distortion 1 plus A beta can be reduced and I can regain the original amplifier gain, A with a distortion which is reduced by the factor of 1 by 1 plus A beta, okay.

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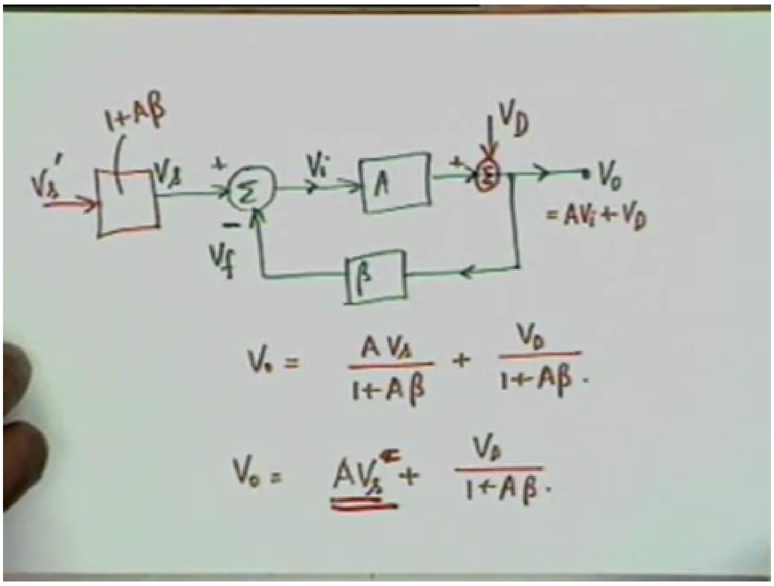

No? There is no distortion here and therefore this voltage V s is equal to V s prime multiplied by 1 plus A beta, alright? That is all the change.

Student: Output should be V s prime.

Output should be V s prime, okay. So what we do here is we consider this as V s, is it okay now? We have applied instead of V s we have applied 1 plus A beta times V s, okay. Is the difficultly taken care of? Alright, so we convinced ourself by qualitative analysis. In qualitative analysis will look at the kink and the kink is straightened out, okay. So, nonlinear distortion is reduced. Quantitatively we see that the distortion can be reduced by the factor 1 plus A beta by negative feedback. Yes. It is important that you understand this.

Student: Sir, in the qualitative distortion they did not give any knowledge about the relative distortion in the circuit. (())(34:12)

That is right. This is why I wanted you to understand qualitatively first. Qualitatively what is happening is if the gain goes like this then with negative feedback these are straightened out. So it becomes more of a straight line then with a kink and therefore the nonlinear distortion is reduced. Now is it not also obvious that if this amplifier generates some noise at the output then this noise will also be reduced by the same factor? Is the point clear?

If instead of nonlinear distortion, the distortion was due to noise, shot noise, junction noise, whatever the source of noise is. Noise at this point, at the output of the amplifier then obviously this noise will also be reduced by the same factor 1 plus A beta. But now, Ankur this is for your attention. Now there is a problem. You cannot make up for the gain by a preamplifier. Why not? Because the preamplifier will have noise. Noise is omnipresent. It does not depend on the signal level.

The noise generated by an amplifier, a device, a resistance, a capacitance or whatever the device is, it is independent of the signal and therefore there shall be the noise generated by the preamplifier shall also be amplified, okay. And therefore compared to nonlinear distortion the noise reduction is to a much less extend. In other words what we have to do is we have to design especially a preamplifier with a gain of 11 or whatever the gain is which is noiseless.

We have to take special components which generate less noise or have a special architecture for the circuit which is a noiseless architecture. So noise reduction is not as easy as nonlinear distortion reduction, okay. I also said that negative feedback controls impedance levels. This we shall illustrate with the help of again a very ideal amplifier. Suppose you have a series connection at the input.

You have a voltage source V s and then you have the feedback voltage V f, okay. I am looking at the equivalent circuit of the input V f and you have an R i, okay. The input resistance without feedback is R i. What I want to find out, this is R i. Let us say this is V i and this is I sub i.

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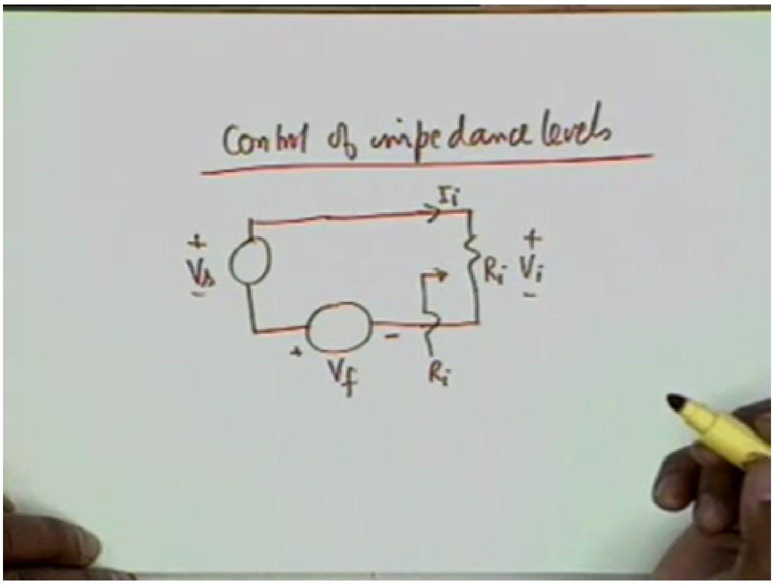

Student: Polarity of V f is opposite.

If it is negative feedback, okay. Let us do that. Good point. Let us make it negative feedback, minus plus. Then what is the input resistance that is seen by V s? Obviously it is V s divided by I sub i and V s is V i, what is the KVL? V s equal to V i plus V f divided by I sub i, agreed? This is the negative feedback and this would be equal to V i plus beta A V i divided by I sub i, agreed? The feedback voltage is beta times A multiplied by V i. Beta times V 0, V 0 is A V i, okay.

So this is equal to R i multiplied by 1 plus A beta. So in series connection the input impedance increases by the factor 1 plus A beta and this is independent of what the output connection is. Whether the output connection is series or shunt it does not matter, agreed? The input impedance increases with negative feedback if the input connection is series. Can you see it qualitatively why it happens? Yes?

Student: Sir, the same V s we have less current.

So the same V s we have less current. For the same V s we have less current because there is an additional source here, agreed?

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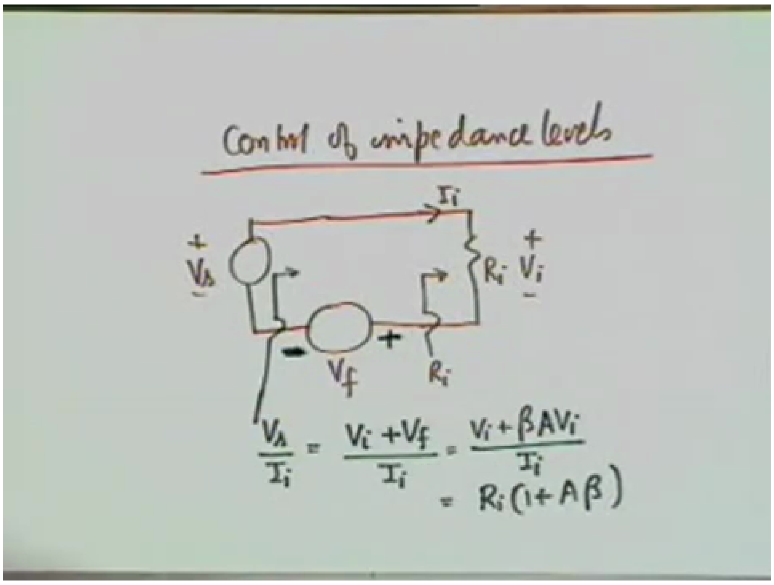

Qualitatively this is obvious but this is the quantitative relationship that the input resistance R i f is equal to this. By the same token can you now say that if the connection was shunt, negative feedback with input shunt connection, then what will happen to R i f? Shunt at input, shunt means current has been taken away or another additional impedance is coming in shunt in parallel. So the input impedance should decrease. And it is very easy to prove that if it is shunt at input then R i f is R i divided by 1 plus A beta. Once again it is negative feedback.

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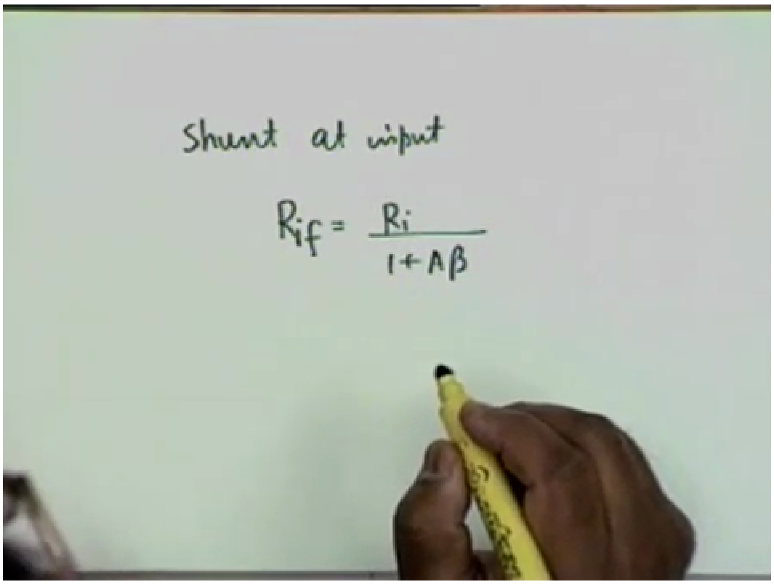

It is very easy to prove. I will skip this proof if you do not mind. What can you say about the output resistance? Again you can do it quantitatively but qualitatively you see that if the output resistance R 0, if the connection is series, then the output resistance would increase or decrease if it is series? It increases. Why is it so? Because if the connection is in series, let me draw the amplifier. You have the basic amplifier, then you have the load and then you have a series connection. This goes to the feedback network.

So the output impedance that is seen by the load is not only the output impedance of the basic amplifier but it is added to the impedance that it sees here and therefore the output resistance effectively increases. And this increase is again by the same factor 1 plus A beta and this increase is independent of whether the input connection is shunt or series, it does not matter.

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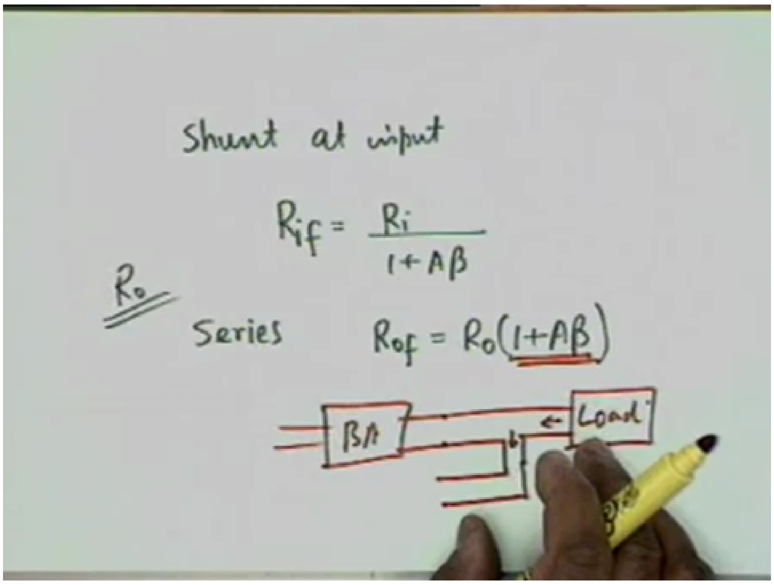

If the output connection, sampling connection is a series connection then the output impedance increases. In a similar manner if it is a shunt connection R 0 shunt at output then the output impedance R o f. Pardon me.

Student: Decreases.

Decreases by the same factor 1 plus A beta. I leave these proves to you. Please do try to establish them, okay.

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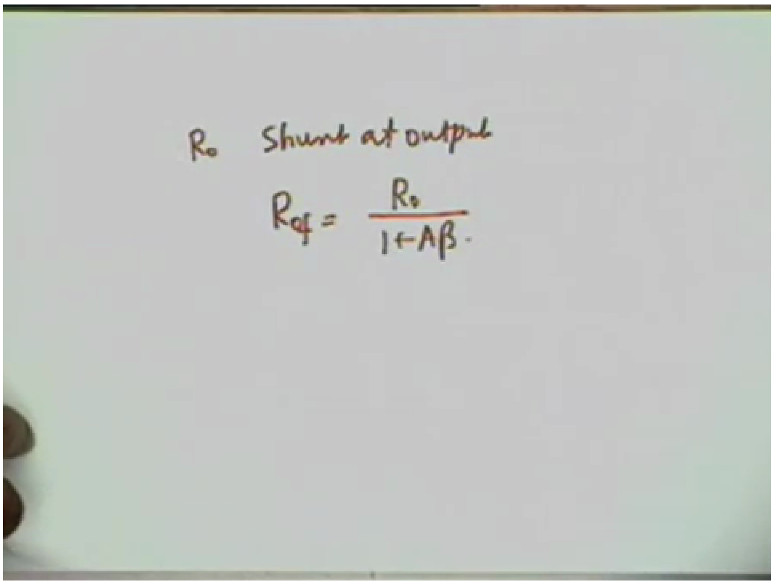

Student: Sir, what this result hold for negative feedback?

All these results hold for negative feedback, yes.

Student: (())(42:14)

That is right in positive. But make sure that A beta is less than 1. That A beta is never allowed to exceed unity. If it is allowed to exceed unity then the whole amplifier falls to the ground. It can be junked, okay. Now I also told you that a negative feedback increases the bandwidth of an amplifier. It helps to improve the bandwidth of an amplifier and that is very easy to establish. Suppose we consider the high frequency response of an amplifier.

At high frequencies an amplifier A of s is of the form A 0, the midband gain, divided by, yes, 1 plus j omega by omega H. We replace j omega by s, so it becomes s by omega H, agreed? Midband gain is A 0 and the 3 dB point is omega H. We replaced j omega by s. We work in the Laplace domain, okay. This is the expression for the high frequency gain of an amplifier. Now take A f s which is A of s divided by 1 negative feedback so plus beta. We assume that beta is resistive that is beta is not a function of frequency, beta A of s.

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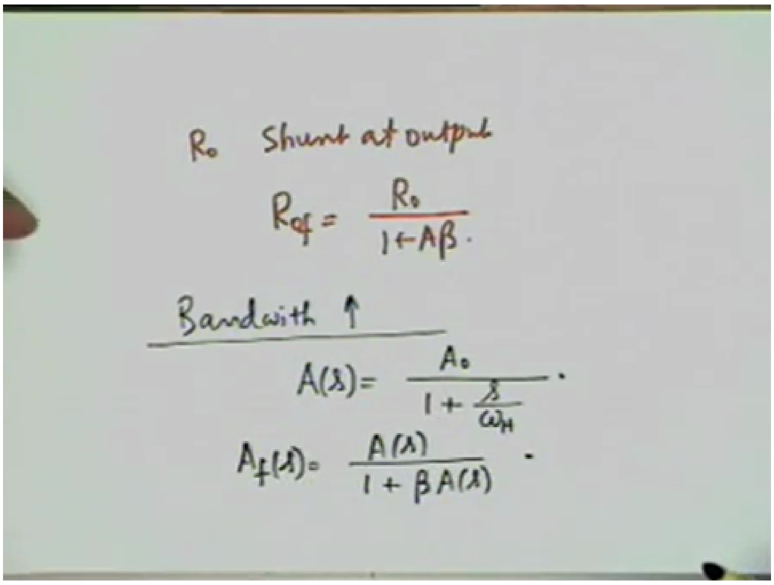

If you substitute this in this relation and make some simple algebra the result is A f s becomes equal to A 0 divided by 1 plus A 0 beta. This is expected, at midband this must be the gain divided by 1 plus s divided by omega H multiplied by 1 plus A 0 beta which means that the omega H with feedback increases by the factor 1 plus A 0 beta, okay. At what cost? The gain. The gain is reduced by the factor 1 plus A 0 beta. So what you gain in bandwidth, you lose in gain. Is that clear? It is a trading.

You want more bandwidth, you sacrifice gain. The product obviously you see A f 0 multiplied by omega H f this product is a constant. It is equal to A 0 omega H, is not it right? Okay. This is another example of the uncertainty relationship that you have the famous uncertainty relationship of physics that you cannot increase both simultaneously, okay.

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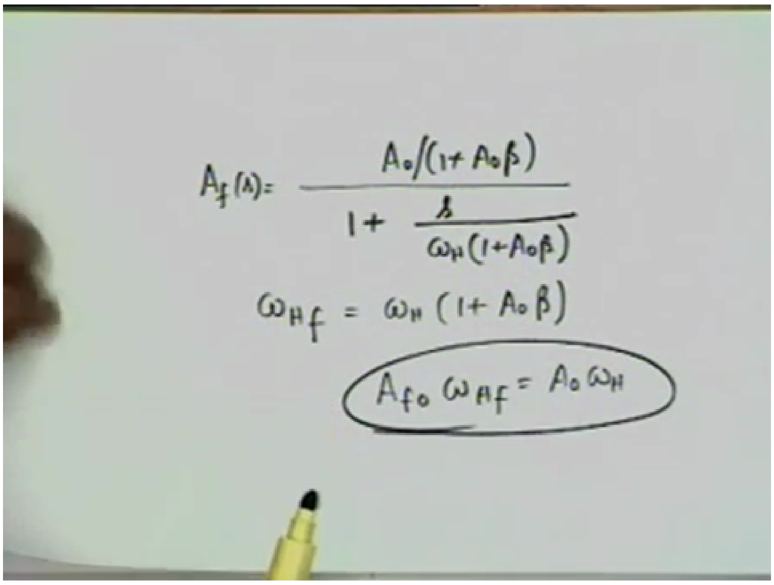

On the other hand if you look at the low frequency gain, at low frequency what is the transfer function? A of s is A 0 then 1 minus j omega L by omega. So I can write this as 1 plus omega L by s. Do not bring in a negative sign here because that would make a pole in the righter plane and the system will automatically be unstable. The expression was A 0 divided by 1 minus j omega L by omega. Now it can be written as 1 plus j omega and j omega you replace by s. So the pole is at s equal to minus omega L. It must be in the left plane, okay.

So if I now substitute in this A f s as equal to A of s divided by 1 plus beta A of s then you can very easily show that A f of s becomes equal to A 0 divided by 1 plus A 0 beta. As usual the midband gain becomes this and what we have is 1 plus omega L divided by s times 1 plus A 0 beta which means that omega L with feedback becomes equal to omega L divided by 1 plus A 0 beta.

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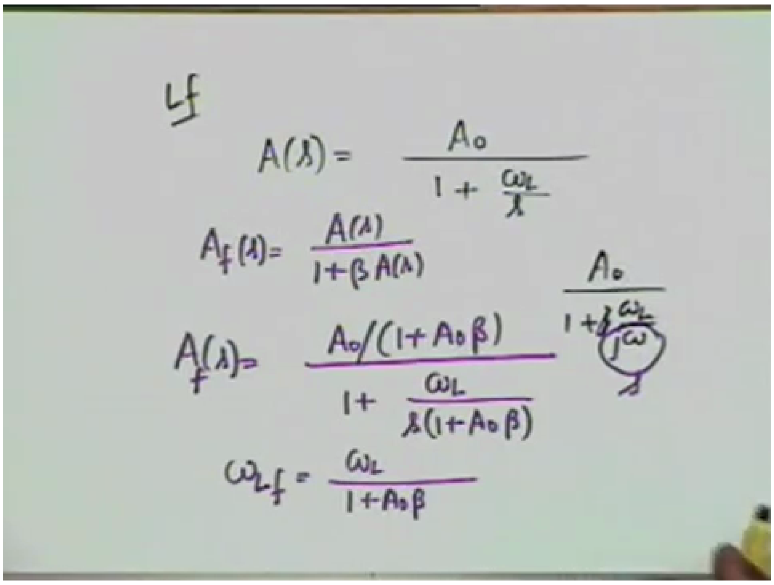

So the low frequency 3 dB point decreases which means that the total bandwidth increases, okay. So if I have without feedback a gain curve like this then with feedback it would be like this. The bandwidth increases by the same factor as the gain reduction, okay. So what you gain in bandwidth you lose in gain. Yes.

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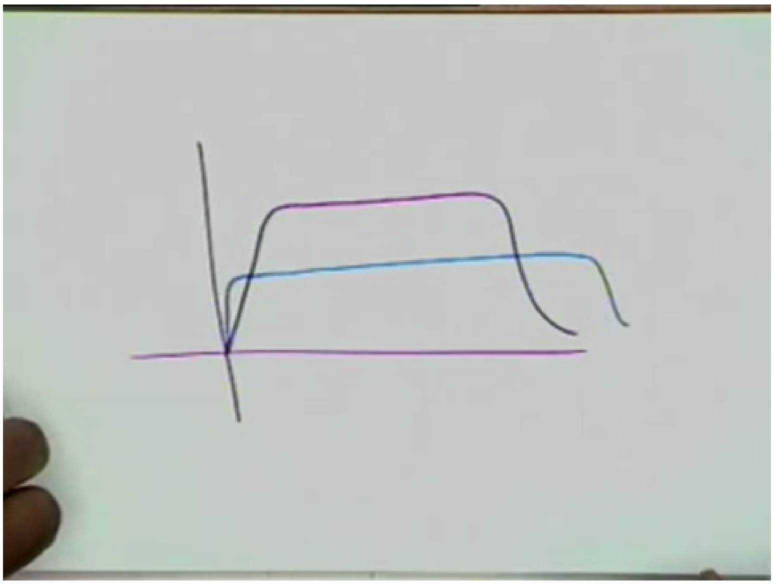

Student: (())(47:28)

That is right. Preamplifier stage should have a gain of 1 plus A 0 beta to be able to bring the gain back to the previous quantity. I want to draw a couple of examples of practical feedback amplifiers and just to give you a test of what a practical feedback amplifier looks like. But in this drawing I will skip the biasing part. You can draw that separately. I will only draw the signal part, okay. A typical feedback amplifier maybe like this. I s, R s, this could be a high impedance source.

High impedance source we usually model as a current source. Can you give me a example of a high impedance source in practice? A capacitive transducer. In a measurement if you use a capacitive transducer to transfer let us say mechanical strain to an electrical signal. Capacitive transducer is a high impedance source or even a microphone is a high impedance source, okay. Now suppose we have a two stage amplifier like this. Q 1, this is what I mean by excluding the biasing circuit. I am only drawing the AC, the signal circuit.

For the biasing I have to show V C C, I have to show how the base is biased and things like that. I skipped all those. I only show the AC equivalent circuit and then you have a Q 2, another transistor in which there is a resistance R sub E which is unbypassed, okay. And the Q 2, this is R L 2 and this current is I 0, the output current is I 0, okay. R E is a small resistance.

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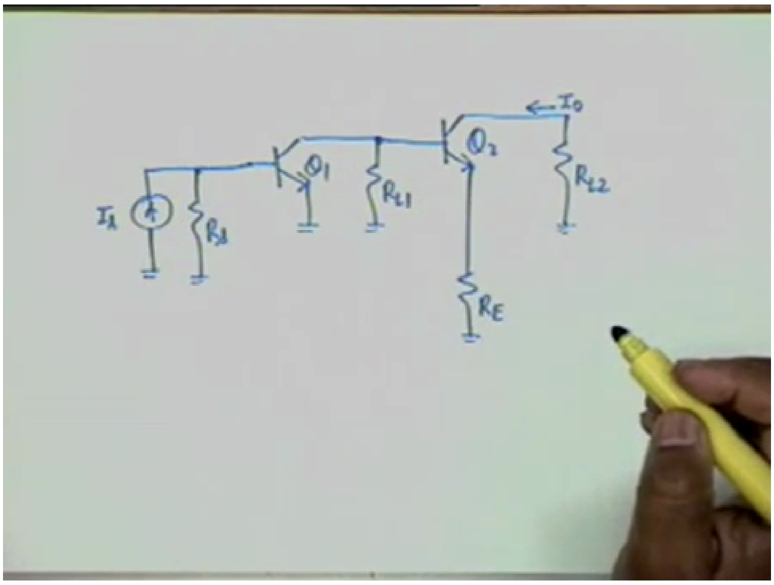

Now if I want to apply a feedback to this what kind of amplifier is this? Current to current. It is this current which is of importance, current to current. So it is a current amplifier, okay. It is a two stage current amplifier. I 0 is the quantity of interest. Now if I want to apply a feedback, a sample of the current is to be taken. In other words I have to make a connection from here. I do not want to do that because if I do that then the feedback will depend on the load. Is that clear?

So what I do is I take an approximately equal current. You know this current is approximately equal, the emitter current. It is I 0 divided by alpha where alpha is approximately 1. So I sample this current. Now I do not sample the current as a current. I use a small resistor here to drop a voltage which is proportional to the current. And this is what is applied here through a resistance let us say R F.

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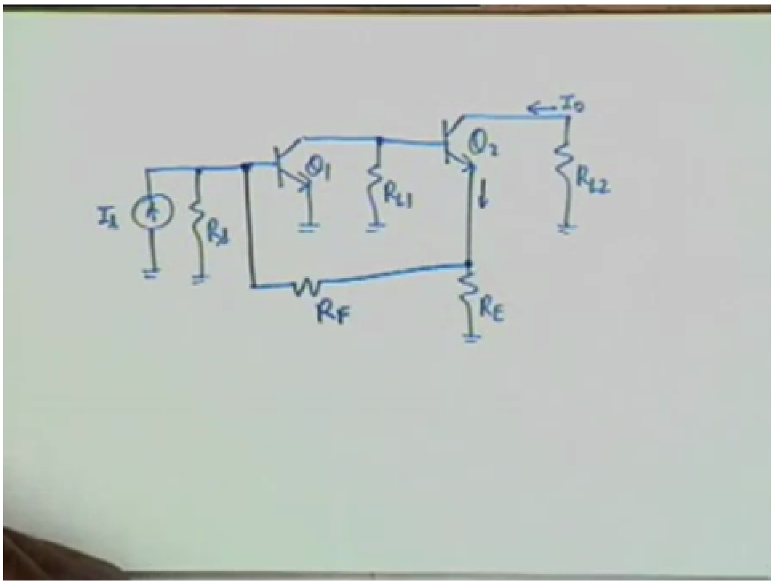

Student: Sir, if I 0 is dependent on (())(50:46).

Pardon me.

Student: (())(50:49)

If I make a connection here obviously the effective R L will be disturbed. I do not want to do that so I used a small resistance here and make this connection here, okay. Now what is the kind of input connection here, series or shunt? Series, okay. Let this current be I f. This current I I if R f is not there is obviously I s minus I f. So it is negative feedback. How do you know it is negative feedback? Because I could have drawn I f in the other direction also.

No, for that you have to do a little bit of analysis and I will do it in half a minute. Suppose I s increases, this will make I I increase, okay, and this will make the collector current of I C 1 increase or decrease?

Student: Increase.

Increase. If the collector current of I C 1 increases what about the load voltage?

Student: It must increase.

No, it must decrease. Current increases so the collector voltage decreases. If the collector voltage decreases then what happens to I 0? It decreases. If I 0 decreases then this voltage, if you call this V E, V E decreases. And if this voltage V E decreases then what happens to I f?

Student: Decreases.

Increases. In other words a tendency of I s to increase is arrested which means that it is negative feedback. This is called a qualitative loop analysis.

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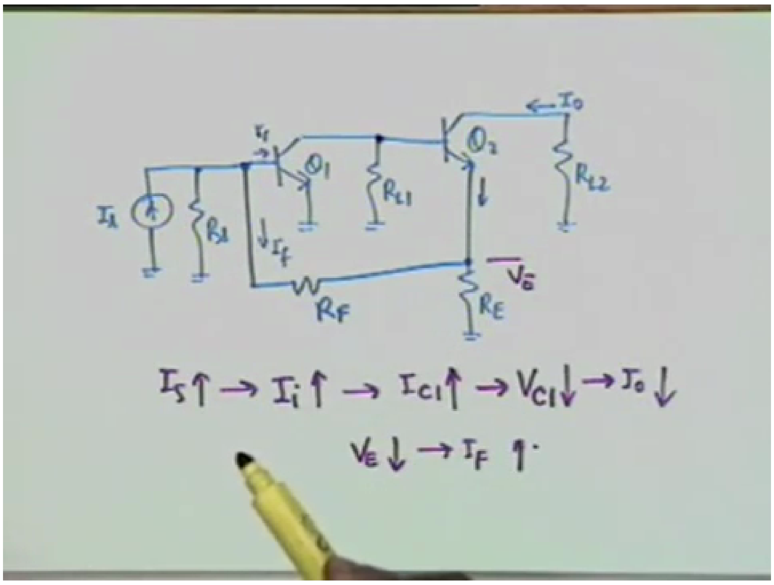

And it requires much more than analytical ability. It requires intuition. It requires careful consideration and application of the strongest tool of an engineer namely common sense. More on the eleventh.