Electronics

Prof. D.C. Dube

Department of Physics

Indian Institute of Technology, Delhi

Module No. # 01

Feedback in amplifiers, Feedback configurations and Multi Stage Amplifier

Lecture No. # 04

Feedback in amplifiers, Feedback configurations and Multi Stage Amplifier

So far, we have completed 3 units or 3 modules in this course on electronics. Now, we start the fourth module which is on feedback in amplifiers, feedback configurations, modifications, which the negative feedback can bring about in the amplifier performance coupling methods and multi stage amplifiers. In practice we see that one is stage that is single stage amplifiers are of course, basic of understanding, but when we talk of the system then normally we have to use multi stage amplifiers. For example, operational amplifier which we will be studying later, this is you are you know it is as a single unit. It is a integrated circuit, which actually is a multi stage amplifier. So, how one amplifier can be coupled to the other, there are more than one possibilities all have there are advantages and disadvantages. So, we will study so, all this in the module.

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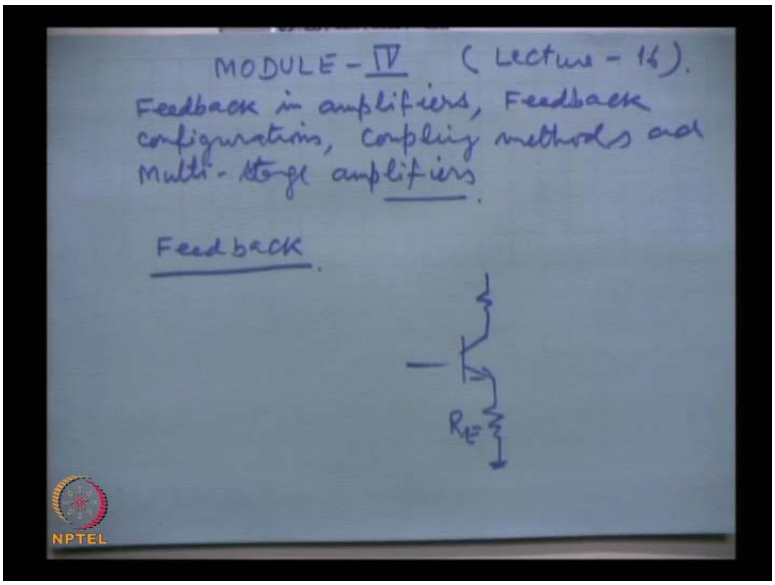

Now first we start with the feedback, first the general introduction of feedback I am sure you will recollect that we have used this term earlier too. When we were discussing the dc circuit design of the amplifiers that means various biasing is scheme we discussed. Then we you remember that we introduce one resistor with the emitter R E and we performed the analysis this R E and we said that mathematically, we show that it brings stability to the circuit by stability, we mean that the circuit performance is not affected by various kinds of variations. For example, change in temperature change in device one device goes bad you replaced by the another device which may have different characteristics or aging.

Aging is a use of circuit for long time then certain characteristics are bound to change. So, this introduction of R E the emitter resistance, resistance with emitter will lead of the transistors was very important. And we said that whatever this goodness, the stability to the circuit it brings that is because of the feedback. Similarly, we talked about collector feedback bias, there also be talked about this term feedback. So, first let us understand what is feedback what kind of feedbacks we have to encounter.

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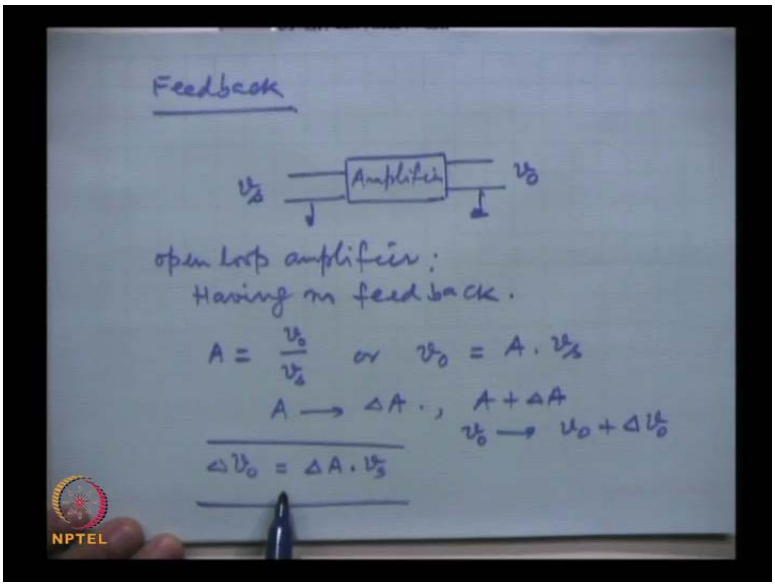

So, feedback in a amplifier, this is the amplifier, these are the two outputs and these are the inputs the signal is given here and the signal is the taken out here. Now, you know what is the purpose of amplifier? The purpose of amplifier is to amplify the signal without changing its characteristics except its magnitude. So in obviously, the output in a

amplifier is the function of input. Now very important that if the input is totally independent of output that means, output does not influence the input to the amplifier then, the circuit is called open loop, open loop amplifier having low feedback.

Now, let us see this is the not a good circuit, because here we will see that the performance will change as the situations, which are bound to change will occur for example, temperature variation etcetera. Now in this circuit the gain, if we take voltages at the movement, we are taking voltages which are very frequently used otherwise remember in this whole analysis. In this chapter, these both can be voltages as we are taking and we are taking it, because they are most commonly used or both can be currents then, the gain will be the current gain or one can be voltage other can be current than it can be trans conductance amplification factor so.

But the analyses the valid for whatever is the amplification factor, but we will be considering voltages. So, under when the input is no way connected is no way affected by the output this is called open loop amplifier and in this, this is gain is output to input to input. So, since we are considering voltages. So, output voltage to input voltage or from here, simply the v 0 is equal to A into input signal. Now suppose, I will tell you what we change the performance for any reason the gain changes if the gain changes from A to say the changes is delta A, then so that it becomes equal to A plus delta A then the output will change from v to v 0 plus delta v 0 and you know that we can simply write from here that the if this change delta v 0 will be equal to change in A into v s. So, any change which occurs in the gain of the amplifier will be reflected in the output. This is not acceptable in most electronics designs. Now, what may cause the gain?

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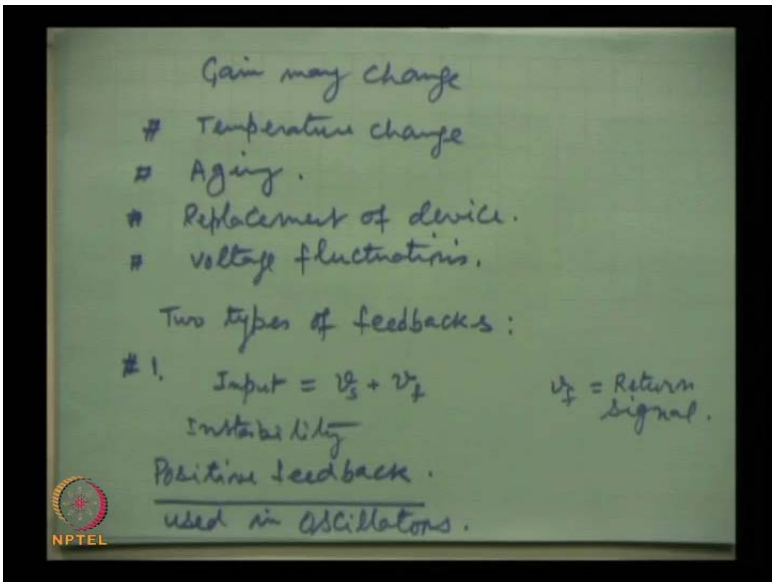

Let us see gain may change for example, from temperature variations. Temperature change now temperature changes of 50, 60, 80 degree are very common. And why the temperature will change for two reasons in summer in winter, there is the difference of 30, 40 degrees. More importantly, when we operate a circuit then the there are powered devices like transformers etcetera. And hence, the temperature there are semiconductors, which are temperature the characteristics bounds to change. So, the temperature change is one factor which may influence the performance of the amplifier.

The other is aging that means use of the circuit for several months and years may change its performance and then replacement of device. If we talk of the discrete circuit, then transistors or some resistors may go bad and they need replacement, and the characteristics of the device replaced may not be identical as the earlier ones, and these are the factor plus there are fluctuations voltage fluctuations for example, these are the causes which may change the performance of the amplifier.

Now as I said of the changes of this kind we are supposed to design a circuit which will not be affected by these changes. So, how we get it; this is the achieved by feedback by incorporating feedback. What the feedback does, it is the very important statement feedback as the name suggest. A fraction of the output is mixed with the input. I repeat if fraction of the output if we are as example in the present situation we are talking about voltages. So, the fraction of the output voltage is feedback mixed with the input. So, the real input is the geometrically sum of the applied signal and the fraction, which we are

feeding back and this is known as a feedback, and this we will see that it will bring stability not only stability there are various modifications, which are desirable actually in an amplifier and they can be achieved by using proper type of feedback.

One thing again very important we will not bother weather the circuit performance changes, because of the temperature change aging or replacement or voltage fluctuations the cause of the variations is immaterial is not important for us. We simply say that the some characteristics of the transistors change cause of change not significant and we will design a circuit by incorporating feedback, so that the circuit is proper design of the circuit takes here for all kinds of variations and that we will show you soon.

Now, there are two types of basic feedbacks, but it depends that the two signals the input signals and the fraction of the output which are mixed how we are mixing in what phase. So, for example, a one situation is when the input the net input which will be going to the amplifier this is equal to the input signal or original input signal and the fraction v f; v f we will see later that this is known as returned signal. This is the returned signal; fraction of the output which we are feeding back at the input.

So, the phase of the returned signal is editing. They are in the same phase. So, that the factor input signal will be v s plus v f this is original input signal and the this is the returned signal and two are added up. In this situation, we will see even we can see it right from the fundamental equation that if the signal increases, then the output will increase. So, the output now increase hence this will give higher value of output again higher fraction.

Because, the feedback network is constant so, it will drive for example, if 10 percent then 10 percent whatever is available at the output. If the output is gone high the 10 percent portion which we are feeding is that also becomes high. So, this will keep on increasing now this will finally, it will amount to instability. If the output keeps on increasing every time then this will bring in the stability to the circuit and this is known as positive feedback; positive feedback is avoided in amplifiers. But it is the requirement of oscillator. So, positive feedback, remember always positive feedback is used in oscillator circuits; I said that the positive feedback brings instability to the circuit. And so, it is used in oscillators in broad sense what are oscillations; oscillations also periodic instability in periodic instability they are oscillations.

So, by proper networking in a if we have amplifier if proper feedback is used then, we can generate a oscillator and the networks which we used they bring proper phase and proper amount of the returned signal in oscillators. We will not talk further because oscillators is not our topic. We are going to talk about the amplifiers the basic amplifiers and how the feedback can modify the properties as we desired in an amplifier. So, positive feedback is to be avoided totally in an amplifier. So, always remember that the positive feedback is to be totally avoided in amplifiers when the purpose is simply to amplify positive feedback is going to effect adversely the performance.

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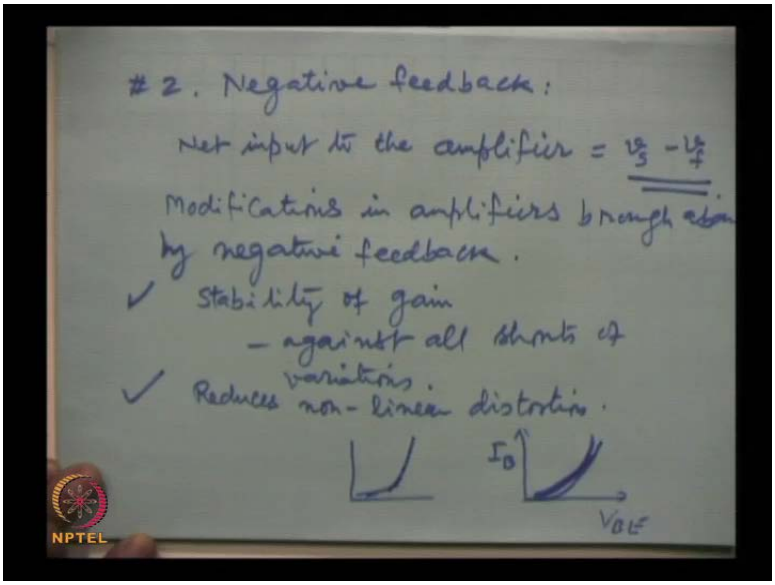

And we talk about the second type of feedback which is called negative feedback. In negative feedback we returned the signal which is having phase opposite to the input signal v s so, the net input to the amplifier is v s minus v f; f is the returned signal and v s is the input signal. So, this is the net input to the amplifier this is negative feedback. Now negative feedback can modify the circuit performance drastically; modify means desirable modification what are the things which negative feedback can bring so, modifications in amplifiers brought about by negative feedback following modifications are brought to the circuit number 1, stability of gain against all sorts of variations. Negative feedback brings stability to the amplifier. Then negative feedback reduces non-linear discussion.

It reduces non-linear distortion by a non linear we mean that for example, if we look at the input characteristics of the p n junctions which is the input part of the transistors then these characteristics I v this is base current. And this is voltage this is non-linear.it is varying like this exponentially it increase slope here different then here then here. This is non-linear. So, here the same amount of variation of this voltage will give different amounts of current we double the voltage current does not double in all regions. This is non-linearity. So, the negative feedback reduces the non-linear distortion.

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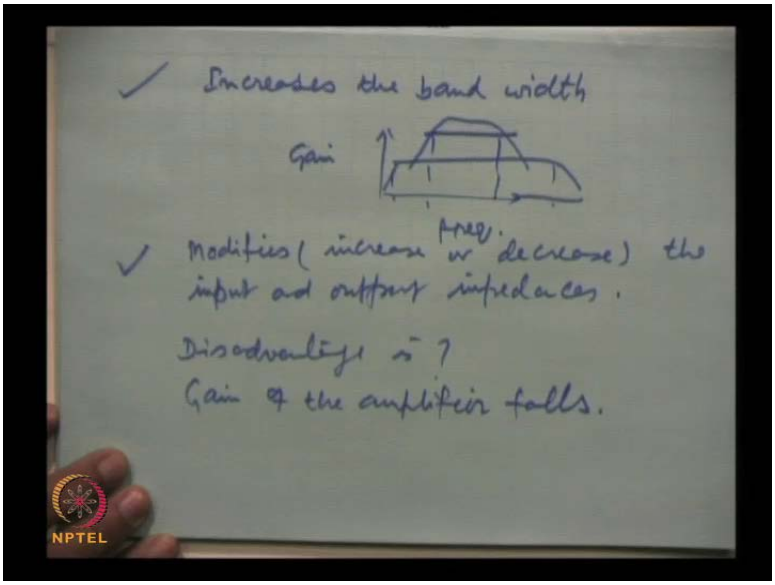

Further, it increases the band width for example, the gain frequency characteristics in general for in an amplifier are like this and this is called the band width. This bandwidth can be increased by incorporating the negative feedback.

So, which is the requirements some applications like television and similar there are situations. We require large band width. So, how we achieve by incorporating negative feedback? So, increase is bandwidth then the negative feedback modifies by modification. We mean it may increase or decrease. The input and output impedances input and output impedances are drastically effected they can change quite a bit by incorporating negative feedback. Now how it is that the negative feedback may increase or decrease for example the input impedance yes, because negative feedbacks are also of

several kinds. We will see that four kinds; so we can choose the proper configuration out of four possible configurations for negative feedback.

And that will decide whether the input and output impedance will increase or decrease or so on. So, these are the major modifications which negative feedback brings to the amplifier. No gain no advantage is without paying a prize, negative feedback all these advantages are for that you have to pay the prize. So, what is the major disadvantage? The disadvantage is that by incorporating negative feedback the gain of the amplifier falls; for example, the open loop gain may be 10000 which is reduced to 200 when we incorporate negative feedback for various things. We have talked about but let me tell you this, fall in voltage is not a series problem.

We can add another additional stage to have the gain of the desired value. So, additional stage and we remember two stages connected in series the gains multiply if, we have 50 and 50 stages and when there are coupled; this we are going to studying multistage amplifiers then for the coupled amplifier for 2 stage amplifier each stages has gain 50 50. So, the gain will be 50 into 50 that means 2500. So, fall in gain is not a series problem. Just one additional stage can compensate for that completely.

So, was the general introduction the feedback the positive feedback in which the returned signal has the same phase as the input signal and as we have talked this brings instability and hence in amplifiers this is avoided completely. The other type is negative feedback in which returned signal has a phase opposite to the input signal so that the two are subtracted and this is known as negative feedback which can change the parameters in our favor and the circle performance can be improved drastically incorporating negative feedback.

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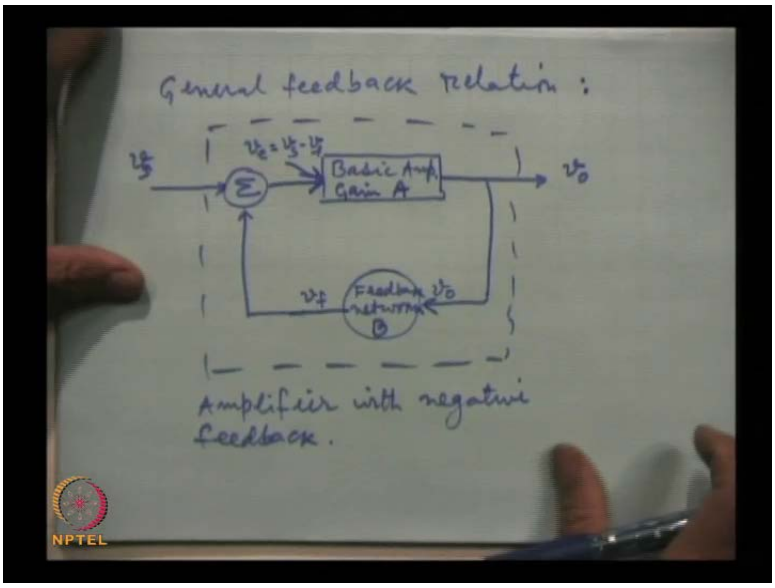

Now, having set this we go for general feedback relation, what is first I draw in block diagram the basic feedback amplifier and then, I will explain that terms which are used and you should get familiar with these terms. Now, the basic circuit is this; basic amplifier having gain A and this is the feedback network and having gain B feedback network. Do not be afraid it is not a complicated network. Network feedback will contain mostly 1 or 2 resistances is in the addition resistances in the circuit to incorporate the negative feedback of your requirement to meet the requirement.

And here, this is the output fraction of the that is taken by this network to be fed back this is point, which we called summation of the two; we are considering voltages at the movement and so, this is the applied input signal v s and here, this output is v 0. So obviously, this is v 0 and this goes in this and here it comes out is v f and these two are mixed here and then, this goes here and this is known as v e which is equal to v s minus v f; this is the net signal here at the input.

Now, this is the basic amplifier which has open loop gain A and since we are considering voltage amplifier then A is will be the ratio of the output to the input to the amplifier and this hole when we incorporate the negative feedback. This whole is the negative feedback amplifier; amplifier with negative feedback. Now, what are the terms which we are using they are very important that you should remember always when we are talking of feedback you must remember this terms. Various quantities involved; first of all, A is

remember, this circuit A is the gain of the basic amplifier in this basic amplifier is the open loop amplifier this whole becomes closed loop amplifier with feedback.

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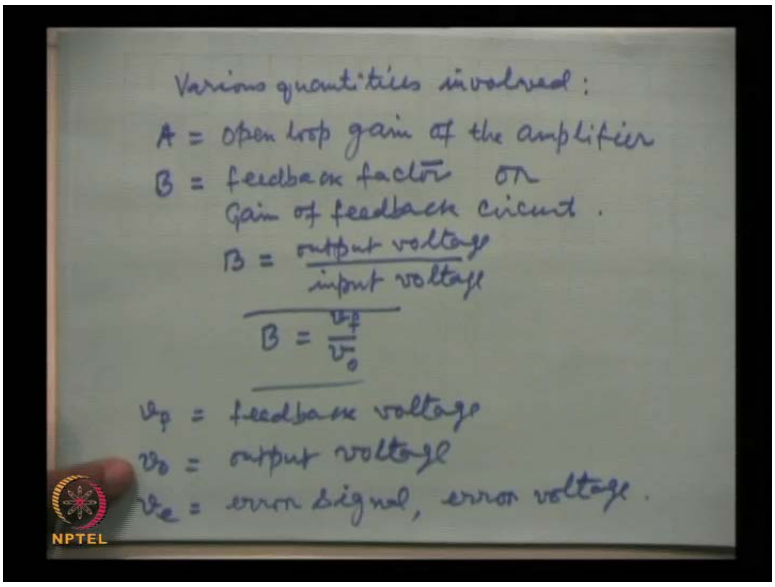

A open loop gain of the amplifier open loop gain that means gain without feedback and B; B is feedback factor or gain of feedback circuit gain always you see is defined as since remember of I am reminding that we are considering voltages. So here, this is output voltage to input voltage here this is the input to the v 0 is input to the feedback network and output is v f. Therefore, B is equal to v f by v 0 and what is v f? This is very important relation you should remember and v f is feedback voltage and v 0 is output voltage. When we will consider suppose, we consider this is current this also current then this will also current, then A will be the open loop gain of the amplifier, which will be the ratio of the output current input current. Similarly, we will be also in the current form the output current input current.

So, there is no confusion, but we will always used in our discussion voltage amplification so, we are considering voltages and v e this signal which is actually going to the basic amplifier. So, v e is called error signal, error signal another signal in general and since we are considering voltage so, this is error voltage, why error actually this is the corrective voltage. Now, input which is going to this amplifier is not constant as v s, but it will vary with v f and error, because the effort this that error should be minimum. That this factor becomes clear to you later. So, these are A, B, v f, v 0, v e these are the

parameters which we are using. Now, what are the relations which is exist among this varies quantities remember this circuit and we can see this.

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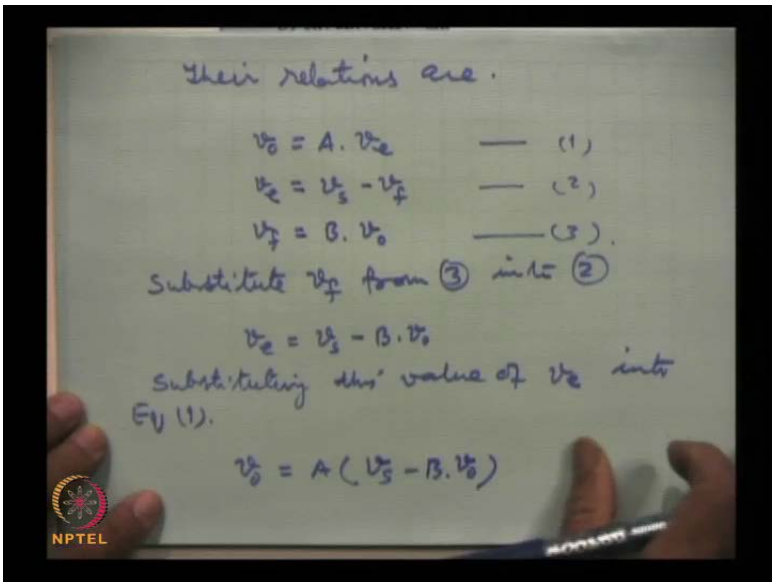

Their relations are v 0; v 0 is gain into v e here for this amplifier are; A is the gain. So, A is equal to v 0 by v e because v is the input to this amplifier and so v 0 becomes A into v e; this is what I have written and v e is the error signal is simply v s minus v f and what is v f; v f from here B; B is the feedback factor gain of the feedback circuit and this is v f by v 0. So, v f is v into v 0. Thus, is called equation 1, 2, 3. Now we substitute v f from 3 into 2 then we get, v e is equal to v s minus B into v 0 are just put v f from here and this value it put substituting this value of v e into equation 1 here. So, what we get v 0 equal to A into v s minus B into v 0 or you continue simple analyses from here.

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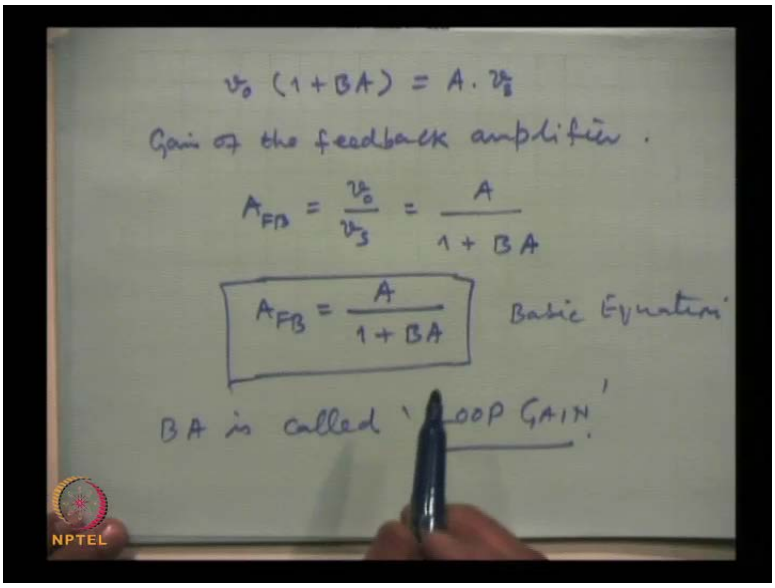

We get v 0 into 1 plus B into A equal to A into v s. Now gain of the amplifier, gain of the feedback amplifier or amplifier with feedback gain of the feedback amplifier is this is the feedback amplifier to the output is v 0; input is v s; v s is the signal strength which we are feeding and so this total amplifier has input as v s and output is v 0. So, then we have and we write this gain as A FB. FB for feedback A was open loop gain. That means gain of the amplifier having no feedback. This is with feedback so, this is obviously equal to v 0 by v s and from here from the top from this equation it simply becomes equal to A 1 plus BA this is the relation among varies quantities of interest. So, this is the fundamental relation very important relation. Wherever a feedback analysis used or feedback quantities will be calculated this relation will be used. The gain A that falls in feedback network 1 plus BA in all quantities which will be modified they will have the parameter 1 plus BA and remember, A is open loop gain and B is the feedback factor or gain of the feedback circuit.

Now, further very important thing I just remind that negative feedback we have already taken into account when we write v e equal to v s minus v f. So, this minus sign itself shows that the negative feedback is under consideration. We are taking into the account negative feedback. This is the fundamental relation for negative feedback when it will be positive feedback then simply the sign will be minus that is it that the expression for positive feedback becomes A FB equal to A divided by 1 minus BA. So, forget about positive feedback we are talking about negative feedback. This is the basic equation this

quantity A B, BA which will appear in all the relations is called loop gain. BA is called loop gain and we have been saying this that A amplifier with feedback with negative feedback is a closed loop amplifier. Open loop without gain without feedback and then the gain will be A.

We will be using this expression we are we will see that how the quantities of the interest get modified. How the gain is stability is obtained? How the distortion can be reduced all this we will studying. So, in this relation we should use we should remember, what are the quantities?

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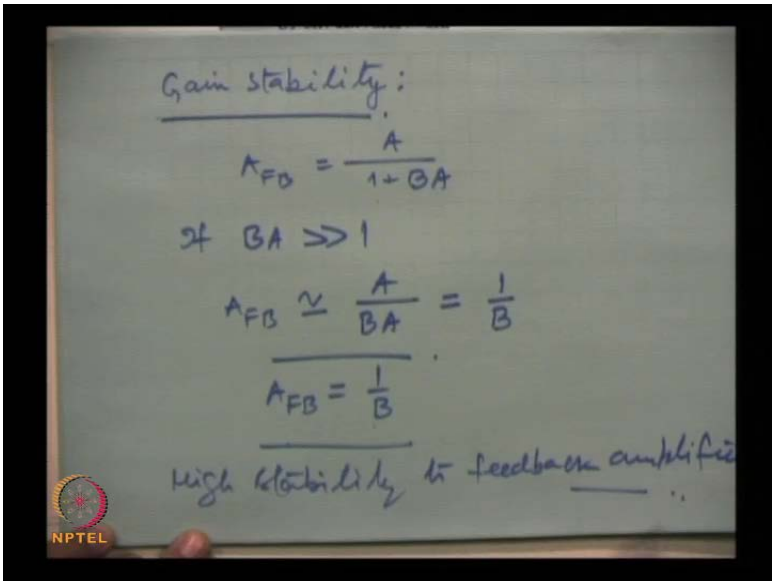

First, we talk about gain stability gain A stability by stability I repeat that the gain and currently we have considering voltage gain so, the voltage gain should not be affected by temperature change of the device and so on. So, we are now showing that how the gain will be made stable by using the negative feedback so, the basic equations A FB equal A 1 plus BA. Let us see that if BA this quantity loop gain is made large as compared to 1 is very large in comparison to one then one can be dropped here now this condition can be easily satisfied, and in practice this loop gain is kept quite high by taking the A open loop gain very high. We will solve certain examples and we will see when we say high very high what we mean.

So anyway, if this is the conditions then we can dropped one in compression to BA and A FB becomes equal to A by BA or this will be equal to 1 by B that means A FB equal

to 1 by B this expression the gain of the feedback amplifier is totally independent of changes in A see this expression because if by design v A is high as compared to 1; 1 is dropped this is this expression mathematically, simply you see that the gain is totally independent of A. So, the variations are certainly not going to effect at all the closed loop gain the gain stability will dependent on B.

And what is B? B that is the gain of the feedback circuit this is the feedback circuit and as I said in the beginning that here there are only 1 or 2 resistances. So, they are anyway quiet is stable. So, this is high stability to feedback amplifier. Now, this becomes clear to you further the quantities, which I have been using you should get familiarity with them and for that we must solve a simple example very simple example, I take that how we can calculate for example, open loop gain closed loop gain and the gain beta, these are I take simple example.

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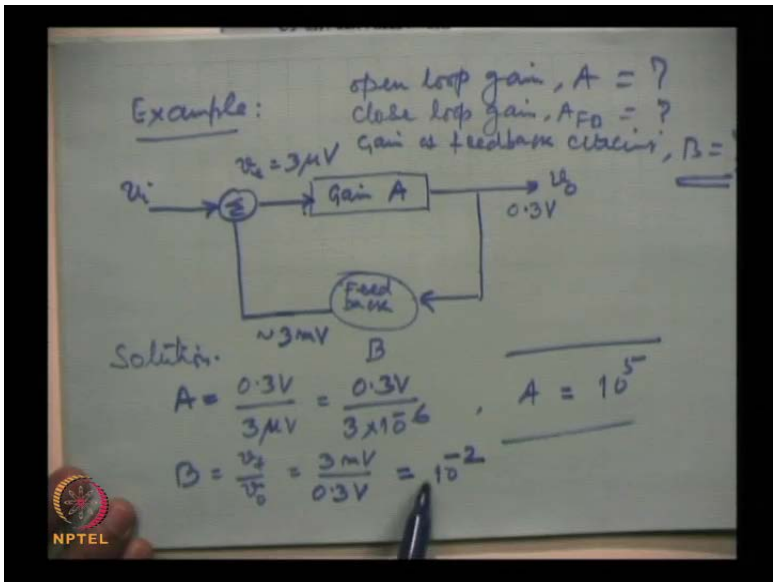

Simple example and I give a circuit in the block diagram itself then we will go to actual circuit that here is the amplifier and this has a open loop gain A and here this is feedback circuit. Feedback network which has A gain B; this is B 0; this is fed here and this comes out here. Now I assigned the values this is for example, 0.3 volts and this is around 3 milli volts and this error signal here which is going to this is v i the error signal v e is 3 micro volts. Then in this circuit we have to find out what is the open loop gain. Open loop gain A we have to find out closed loop gain A FB we have to find out and we have

to find out the gain of the feedback circuit feedback factor as we call. So, gain of feedback circuit that is B these three quantities we have to find out very simple. we can get it the solution first we can find out what is A the open loop gain open loop gain is the output to the input of the amplifier and the output is 0.3 volts divided by 3 micro volts.

So, this is 0.3 volts divided by 3 into 10 to the power of minus 6 and this is obiviously, gain A becomes equal to 10 to the 5, 100, 1000's is the open loop gain and what is the factor B that is gain of the feedback circuit also popularly known as feedback factor this is we have been using all through this is we have been using all through this is v f by v 0 and this is equal to this is the input 3 volts 0.3 volts to the feedback circuit and output is coming 3 milli volts. So, this is 3 milli volts by 3.3 milli volts by v 0; v 0 is 0.3 volts and this comes out to be 10 to power minus 2. So, we have got the value of A 10 to power 5 B 10 to power minus 2 now we use.

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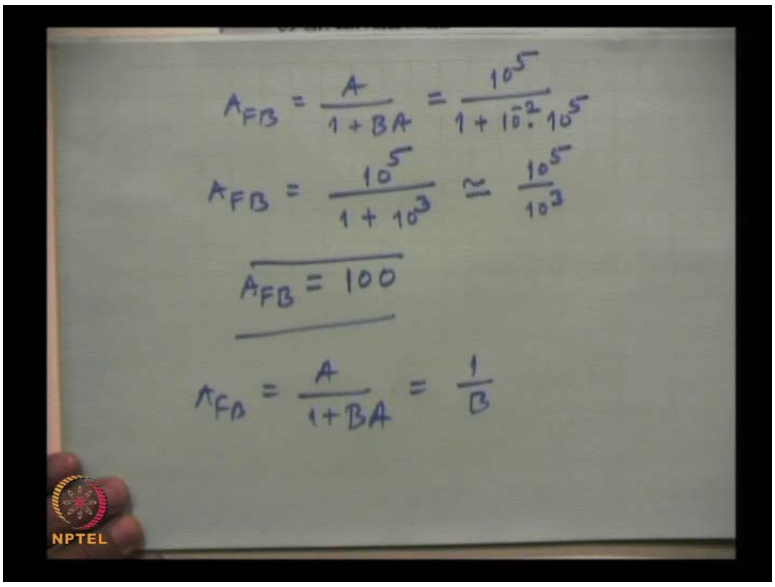

The basic relation A FB equal to A 1 plus BA, this is equal to this quantity open loop gain 10 to power 5. This is one and this is 10 to the power minus 2 into 10 to power 5; so that A FB is equal to 10 to the power 5 1 plus 10 to the power 3. Obviously, we can neglect 1 easily. So, that it is equal to 10 to the power 5 by 10 to the power 3, which gives the closed loop gain as equal to 100. These are three quantities, which we have found out the open loop gain was 10 to the power 5 and closed loop gain is 100. So, there is the reduction. So, that is I said so, this s not a serious problem.

So, this I took this example I took so, you get clarity in the use of the various parameters A A FB B, because these are requirements for this expression and I said will continue that all quantities are basically modified by this. Here you can further conformed, because in the expression A FB, this is A 1 plus BA is very high so, 1 is neglected. So, then gain comes out to be this which you can see here to then this was 10 to power, this is 10 to power minus 2 and this gives A FB again equal to 100 we will continue.