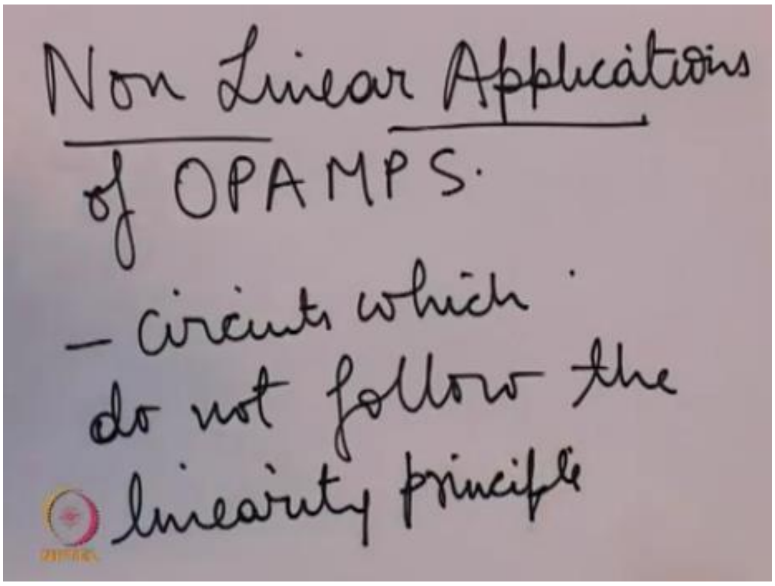
Analog Circuits
Prof. Jayanta Mukherjee
Department of Electrical Engineering
Indian Institute of Technology-Bombay

Week -06
Module -04
Non Linear Applications of OPAMPS

Hello, welcome to another of this course analog circuits, so in the previous modules we have never come across what we called non linear circuits, all the circuits we have discussed so far including you know the Butterworth filters, the Chebyshev filters they are all belong to category called linear circuits because they follow the principle of linearity, even opamps as we were discussing initially they are linear circuits.

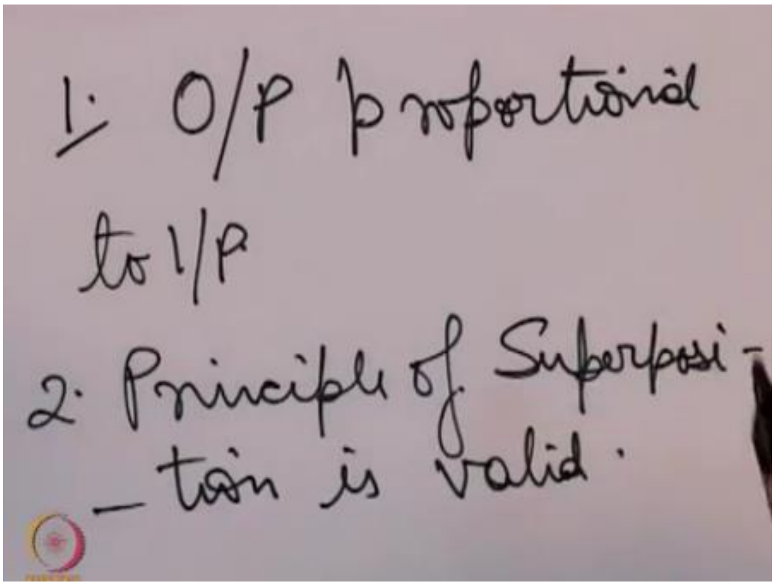
But I mean opamp is used for a simple summing amplifier for amplification in general opamps act as linear circuits, but the use of opamps is not just limited to linear circuits there are some specific non linear circuits which can also be designed using opamps using the various properties that an opamp has and these non linear circuits have a number of application as we shall see later, so let us start with some non linear applications of opamps.

(Refer Slide Time: 01:21)



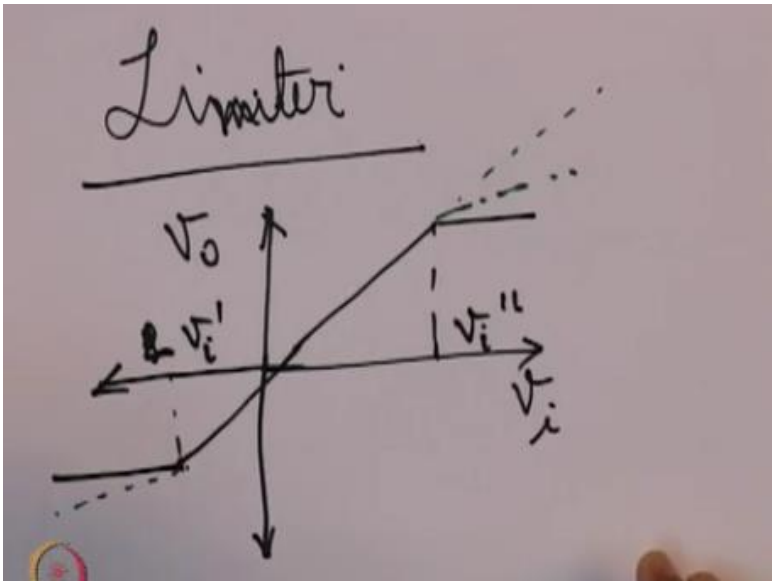
So when I say nonlinear application, it is those circuits which any circuit which does not or do not follow the linearity principle is a nonlinear circuit, so recall again what is the linearity principal first is that the output should be proportional to the input.

(Refer Slide Time: 02:10)



So these are the 2 main linearity properties which strict linear systems have output proportional to input and the second is principle of superposition is valid, so any circuit which does not follow any one of these 2 principles is a non linear circuit, now since linearity is easily defined non linearity as I said you know any circuit that does not follow the linearity principle so that implies that you know there can be lots of non linear circuits, so we shall discuss some specific ones that are useful for practical applications and one such circuit is that what is known as a limiter.

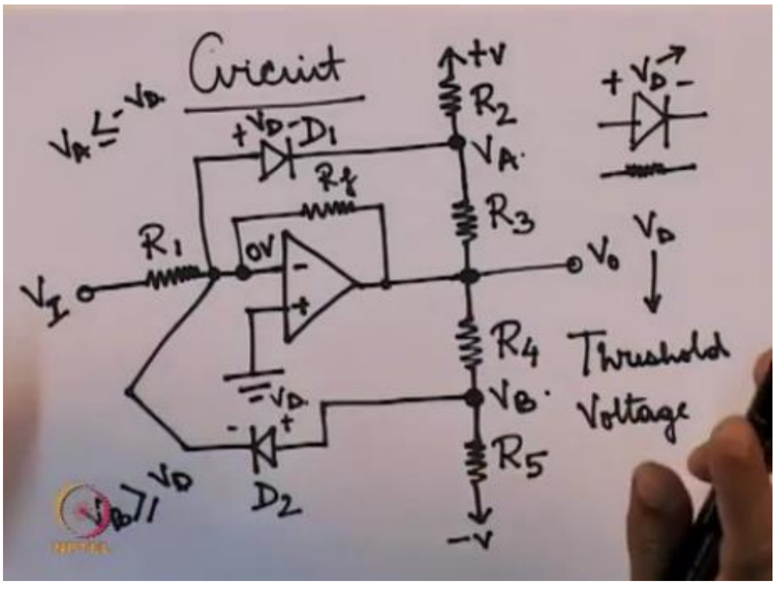
(Refer Slide Time: 03:08)



So limiter is the circuit that you know does not allow suppose this is my Vi and this is my Vo so Vi is the input voltage and Vo is say the output voltage limiter is a circuit that will not allow the output to go on increasing at a constant so ideally a limiter should be like this similarly on the negative side also if I extend my axis on the negative side also beyond a particular negative voltage Vi some value say L or say let us call it Vi dash and Vi double dash, it will again for an ideal limiter it will not allow the output voltage to go any further down so that is an ideal limiter.

But suppose instead of such a strict cut off I have a circuit where instead of the output becoming flat after a certain input voltage say Vi double dash, say the slope also changes abruptly whereas original it was supposed to go like this but after this voltage input voltage Vi double dash the output follows a different slope and in this case also say the output follows a different slope then that circuit is also called a limiter, so how do we design a limiter? Now there are many circuits for limiter we shall discuss 2 of them so let me first draw the limiter circuit and then try to explain its properties.

(Refer Slide Time: 05:08)



So this is the circuit why am I saying that this is a limiter first of all note that there are 2 diodes here, now we will discuss about the properties of a diode a little later but for now you can take it that a diode is a device that allows current to pass through it in only one direction, so if this is a diode then a minimum voltage called the threshold voltage so this VD is known as threshold this has to be supplied across the terminals of the diode in order to make it conduct similarly for this diode D2 also in order to make it conduct.

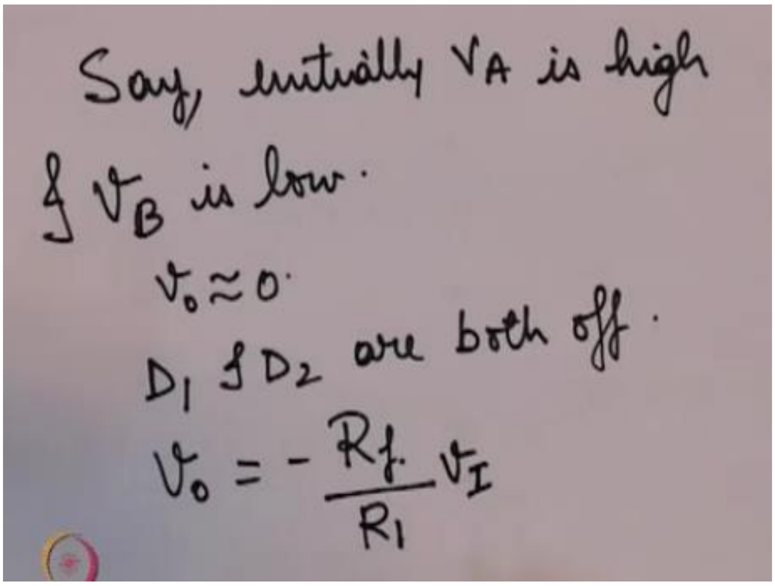
Now this triangle points to the direction in which the diode allows current through it, so in this diode current will pass only from this terminal to this terminal and also for this diode to conduct minimum voltage VD has to be applied ok, now so as I said a diode is a device that allows current to pass in only one direction so in this case of course a diode has some minimum internal resistance also but for that is a very small resistance and for this particular circuit we shall ignore it.

Now if this diode is conduction in one direction and if the internal resistance of the diode is very small then we can simply assume that this is a short between this terminal to this terminal, so if this diode is conducting then there is a short existing between this terminal and this terminal let us say the voltage at this terminal is called VA and the voltage at this terminal is called VB, now this terminal is at virtual short with the non inverting terminal hence and since the non inverting terminal is grounded therefore this terminal will also have a voltage of 0 voltage.

So if VA is lesser or = - VD then this diode D1 will conduct similarly if VB is greater or = VD then this diode will conduct if VA is lesser than - VD, therefore this diode will conduct and so this resistance R3 will then be in shunt with RF similarly if D2 conducts that is if VB is greater than VD then R4 will be in shunt with RF okay it can be shown that both D1 and D2 can never be conducting at the same time ok.

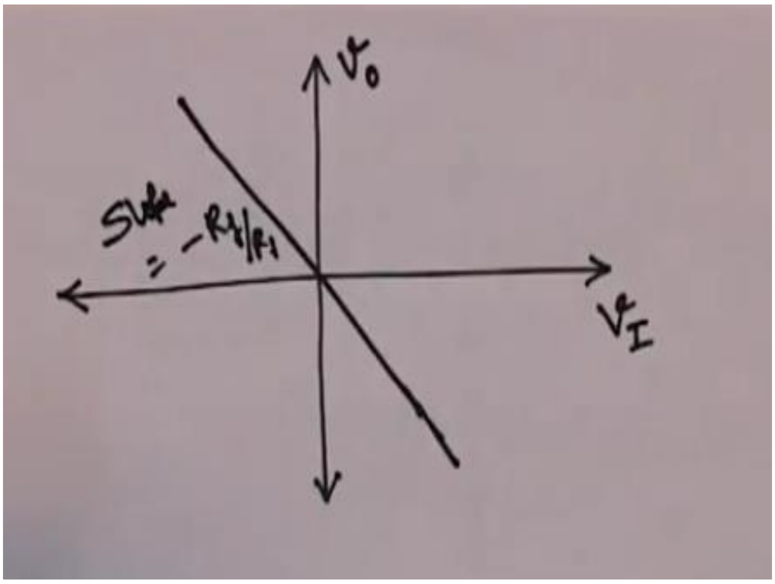
So let us see now how the voltage VA and VB change also remember that when D1 or D2 are not conducting suppose D1 is not conducting then this there is an open between this terminal and this terminal if there is an open between this terminal and VA so that means the total resistance appearing across this point and this point is RF if D1 is conducting then the total resistance between this point and this point is RF in shunt with R3 similarly if D2 is conducting as I said R4 will be in shunt with RF but if D2 is not conducting then simply RF will be in shunt between this terminal and this terminal so with these in mind let us try to write some equations.

(Refer Slide Time: 12:05)



So suppose initially VA is high and VB is low and say Vo is nearly = 0 okay D1 and D2 are both off okay then V0 will be = - Rf upon R1 Vi okay right isn't it V0 will be simply = Rf upon R1 that is a inverting opamp configuration Vo will be proportional to Vi okay, so then how will it look like if I draw the input output characteristics how will the input output characteristics look like if both D1 and D2 are off okay.

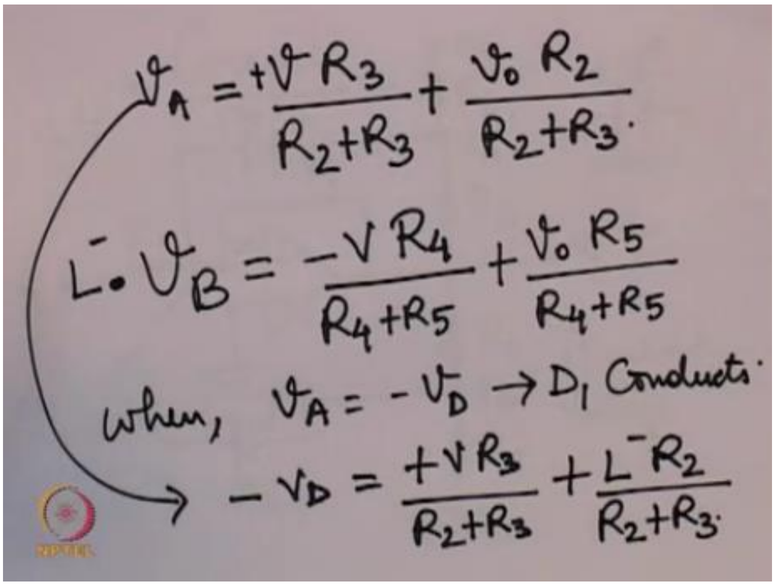
(Refer Slide Time: 13:28)



If it will be like this, now you see that as Vi becomes larger my Vo becomes smaller or rather I should say more negative till a point where Vo is so less okay that if you go back to a circuit for a minute so as Vi increases we see Vo goes on becoming more negative and as Vo goes on becoming more negative VA also goes on becoming more negative.

So now what is the relationship between VA and V0, so this is a simple see D1 is off so there are 2 voltages which are influencing the voltage at VA one is Vo and other is the supply + V, so in order to get an expression for the voltage VA we can apply the superposition principle where we first consider the effect of this + V voltage after shorting Vo and in the second case we short this terminal and consider the contribution of V0 to VA so if we do that the expression that we get for VA is as follows.

(Refer Slide Time: 15:37)



VA will be = V R3 upon R2 + R3 + V0 R2 R2 + R3 so what we have here is this if let us just consider this part of the circuit only (Refer Slide Time 16:09), so see if V + V voltage is shorted then the contribution of V0 to VA is R2 divided by R2 upon R3 multiplied byV0 and if V0 is shorted then the contribution of + V2 VA is R2 R3 I beg your pardon divided by R2 + R3 into + V.

So that is what we have similarly you know we can also write an expression for this part the lower VB and the expression that we will get is the only difference between VA and VB is that VB is influenced by - V and V0 whereas VA is influenced by + B and B0 therefore proceeding similarly we can write and expression for VB as okay now if you go back to the circuit once again.

So as V0 Vi increases my Vo becomes more negative and as we can see from this expression the more negative Vo becomes the more negative VA also becomes and there might be a point at which you know VA becomes so low that this diode starts conducting note that this terminal of the diode is connected to 0 volts so if VA becomes sufficiently low that is if the voltage across the diode crosses the threshold voltage then this diode starts conducting.

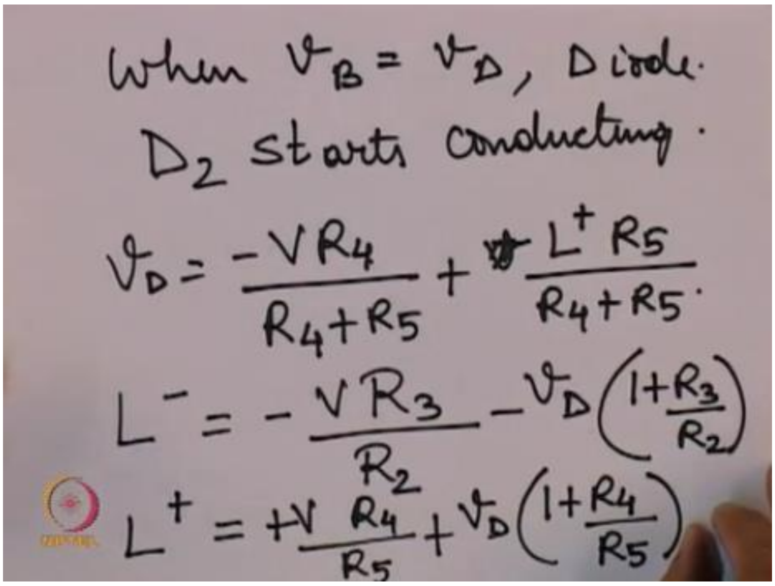
(Refer Slide Time 18:20) Now what is that voltage suppose so we can say that when VA is = - VD the threshold voltage D1 conducts so then from this expression we can write from this expression just one arrow - VD is = + V R3 upon R2 + R3 and let us suppose the value of the output voltage when VA is = VD is = is what I call L- L- + L- R2 upon R2 + R3.

So, if we go back to the graph once again so what is happening is that at this particular extend this is a certain value of output voltage which I am calling L- at this output voltage diode starts conducting similarly when Vi is becomes more negative there will be another output voltage value which I am calling L+ where diode D2 starts conducting so for D2 diode D2 what should be the condition let us once again go back to our circuit

When Vi goes on decreasing the Vo goes on increasing and as Vo goes on increasing Vb also goes on increasing and that is also verified from this equation isn’t it this is not there as we can see as Vo goes on increasing my VB will also goes on increasing and there will be a certain value of VB when the voltage across D2 crosses the threshold voltage and D2 starts conducting.

When that voltage is achieved this diode will start conducting and that output voltage for which VB crosses the threshold voltage and I am calling that as L+ and that is what I have marked in this graph L+ so what is the value of this L+ how will we determine we will determine it from this equation okay so let us plug in the value of VB in this equation.

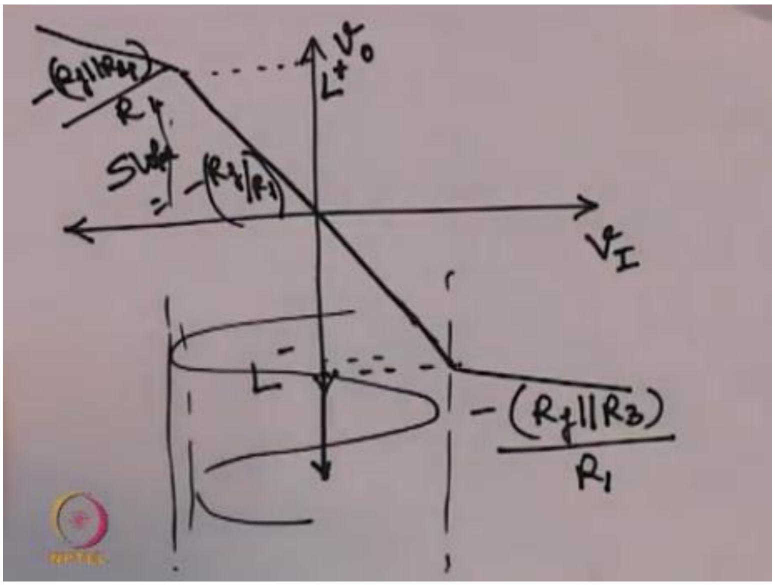
(Refer Slide Time: 21:33)



When VB is = VD diode D2 starts conducting so then VD is = - V upon RF upon VR4 divided by R4 + R5 + if I call that value of V0 as L+ R5 upon R4 + R5 so we have these 2 expressions for finding out L+ and L- and the value of L+ and L- that we obtained are as follows.

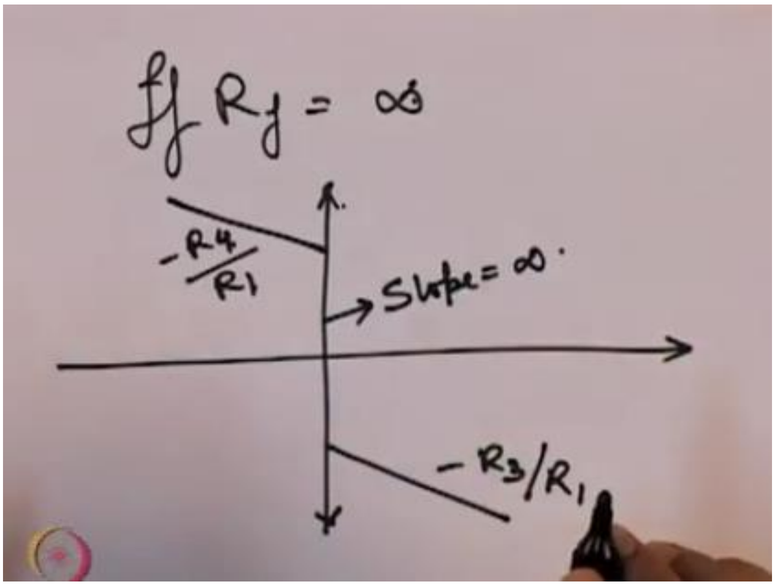
So L- is given as - VR3 upon R2 - VD 1 + R3 upon R2 and L+ is given as + VR4 upon R5 + VD 1 + R4 upon R5, so once this happens you know that we reach these when VA reaches L- or I should say the Vo reaches L- or Vo reaches L + diodes D1 and D2 start conducting and if they start conducting then what happens as I had mentioned at the beginning when Diode D1 conducts in the net resistance appearing across the feedback loop is R5 RF in shunt with R3 ok.

(Refer Slide Time 23:52)



So then what we get here is that beyond L- the slope will change so here the slope was - RF upon R1 here the slope will be - RF in shunt with R3 upon R1 okay and here the slope will be - RF in shunt with R4 upon R1 now see that this L- and L+ can be at just as independent the reason why the limiting action is happening suppose you are giving a sinusoidal input to the Vi okay so beyond this point the output will be clipped any input voltage which exceeds this value will be clipped or will be amplified with a different gain factor that is why the limiting action happens.

(Refer Slide Time: 25:15)



Now if you make RF is = infinity, if RF is = infinity then the characteristics becomes something like this the slope is - R3 upon R1 and here the slope is - R4 upon R1 here the slope is infinity, in this lecture we studied one of the 2 types of limiters that I had mentioned. In the next module will be continuing our discussion on limiters and also studying the in somewhat detail the properties of a diode, thank you.