Electrical Measurement And Electronic Instruments
Prof. Avishek Chatterjee
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 51
Background: Operational Amplifiers - III

So far we have seen 2 rules; 2; you can call theorems about op amps. What are they? Input output relationship. If V P is higher, output is positive if V N is higher output is negative. Rule 2; no current goes into or out of the input terminals of an op-amp and next class in the class we have seen three circuits three amplifier circuits made up with a op-amps.

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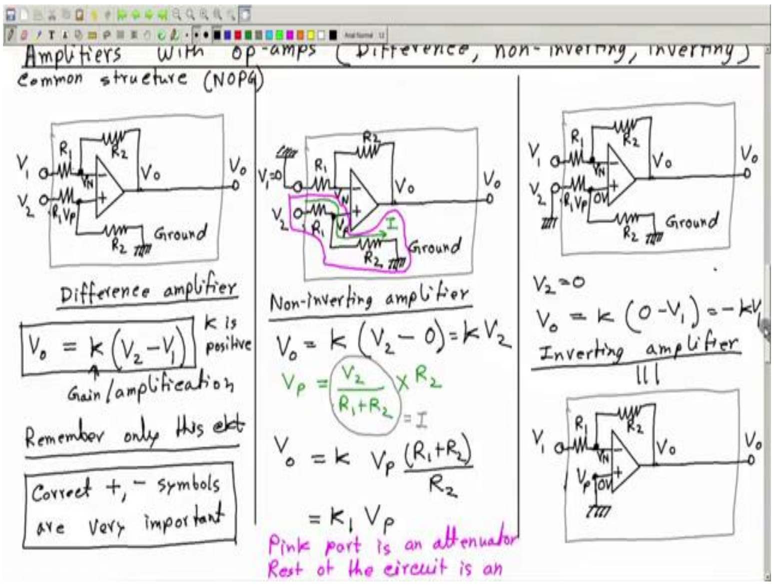

Namely, difference amplifier non-inverting amplifiers and inverting amplifier; once again we said just remember one circuit and from that you can derive the other two ok. And never ever by mistake make this plus or minus symbol wrong ok. Never swap this plus minus symbol this is very crucial I forgot to mention.

So, correct plus minus symbols at the inputs are very important. Otherwise the circuit will not work, you will not get correct answers in the exam. So, plus minus symbol is something you must put correctly and we will also see as we go on why so ok.

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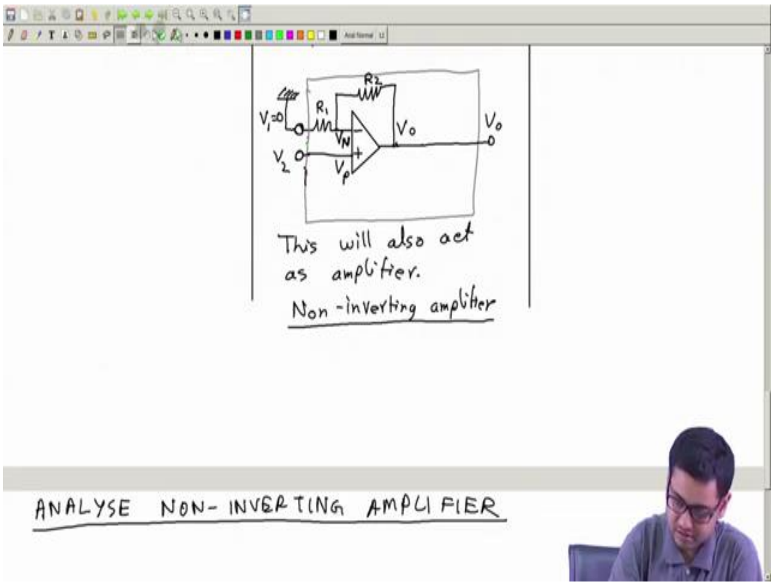

So, today we will analyze these circuits one by one rigorously. So, please pay your attention. So, let us start with may be this one non-inverting amplifier ok. So, we will analyze non-inverting amplifier. So, before that let me just copy this circuit. So, this is non-inverting amplifier.

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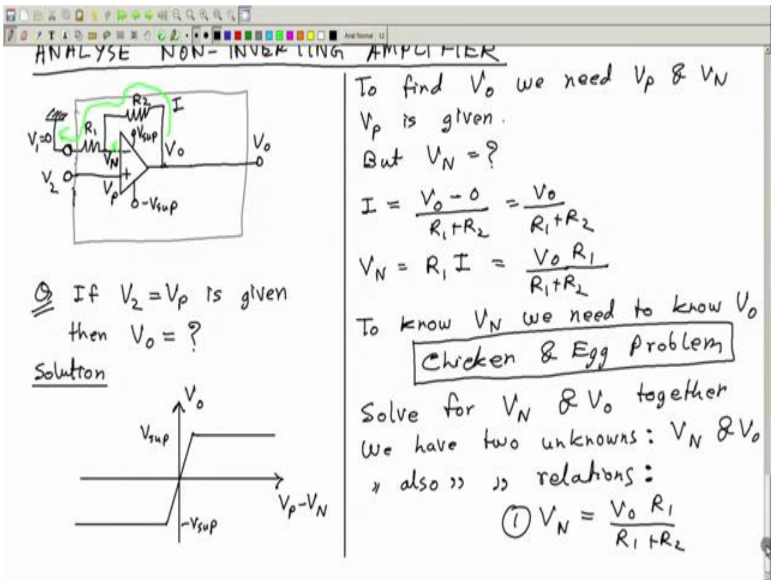

Now, the question is if I tell you the value of say V 2; if V 2 = V P ok. Because, they are directly connected if V 2 which is same as V P is given I tell you that V P is 5, 4; V P is minus 2 volt whatever.

Then V o that is output is how much? So, this is the question we are going to find ok. Now, how to find this answer? So, for that we have to use input output relationship of an op-amp and the input output relationship ok, is given by the static characteristic. So, we have so solution. So, let us try this solution.

So, we have to use the static characteristic; here x axis is what (V P – VN) and this is V o and we know it looks like this. This part may or may not be a straight line and this value is if it has power supplies like V supply and minus V supply. Then this point is V supply this point is minus V supply.

So, this is the input output relationship. So, if I know V P if I know VN then I can find the value of V o right. If I know V P and VN then I can find V O. Now V P is given do I note the value of VN? No, VN is not given to me directly ok.

So, to find V o we need V P and VN; VN is given sorry V P is given; but VN equal to how much, do you know that? No, but we can say something about VN how? You see that this point is at potential V o this point is at potential 0.

No current flows through this input right. So, if any current flows from here it will go like this only or it will go like this only; no current can by pass through this terminal. So, the current can only flow like this; nothing can go in this branch ok, I put a cross sign. So, therefore, VN can be found out using potential divider rule again this is V o this is 0. So, VN is somewhere in between. So, I can write VN is equal to or before that let me also write I maybe that will be easy.

I = $\frac{V0}{R1+R2}$

VN = $\frac{V0}{R1+R2}\ R1$

So, this is V N so, to know VN we need to know V o so; that means, to know VN we need to know V o and once again here to know V o, we need to know VN so, it is a chicken and egg problem. To get V to get output we need VN and to find VN we need the output; it is tough problem it is I call it as chicken and egg problem to find one we need the other. But we do not have the other because to find the other we need the first one ok.

So, what is the solution can we not do anything. The solution is solve for VN and V o together because, there are two unknowns we have two unknowns namely VN and V o

VN = $\frac{V0\ R1}{R1+R2}$

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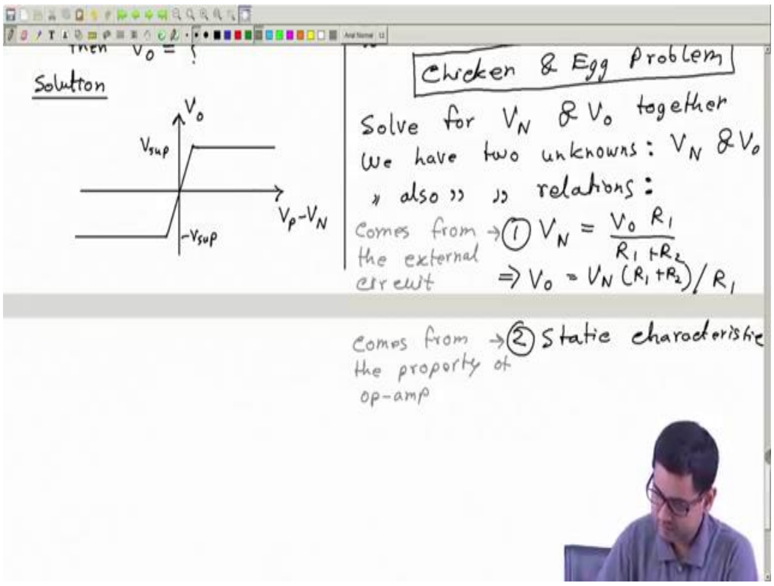

So, this is relation one relationship between VN and V o and second relationship is what is given by this static characteristics so, there is a relationship between VN and V o. So, I write it so, this comes from this static characteristic ok. So, you observe this relationship comes from the property of op-amp; and this comes from the external circuit external to the op-amp ok.

So, this relationship this is nothing but the potential divider applied in this part of the circuit R 1 and R 2 ok. So, this comes from the external circuitry. So, you have two relationships; one from the op-amp; one from the external part and we have to now use them together to find VN and VN and V o simultaneously how ok. So, here you see that V P is given V P is given let me just copy this once again.

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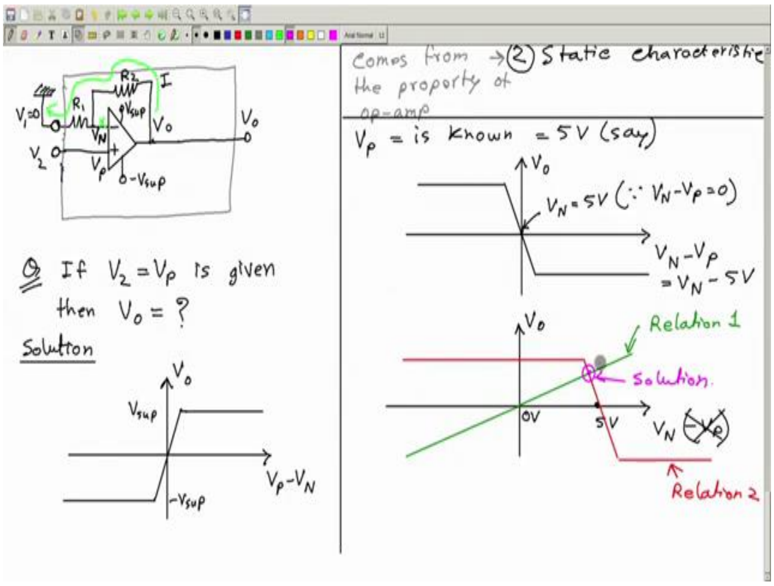

So V P is known so, it is unknown value it is like unknown number ok. Say V P is equal to V 2 ok, so V P is known V P is known V P is known equal to V 2 say and VN is unknown. Now what we will do, we will draw this graph in a slightly different way how. V o here we will draw VN - V P here it is V P- VN here we will draw VN - V P.

Now, so this now this will then look like this opposite right, so this is VN - V P. And also let us take an example that say this is equal to 5 volt ok. So, if this is equal to 5 volts; then here we can write this is same as (VN – 5) volt right. Now we will modify these graphs further how? We will draw V o versus VN.

So, minus V P is not there so, this part is not there so, only VN. So, what how will this curve changed ok. So, you see that here at this point what is the value of V P VN? Here (VN - V P) = 0 which means VN = V P which means VN = 5 volt ok.

So, this at this point VN = 5 volt; since VN - V P = 0 at this point so; that means, at the value of 5 volt of VN this a crossover occurs. So, therefore, in this curve if I have 5 volt here somewhere this is 0 volt this is 5 volt then this curve will shift like this ok.

So, now this is the curve for VN versus output. So, this is one relationship between in VN input and output ok, which is coming from the characteristic statistic characteristic of op-amp. And so, this is relation 2, this relationship. And we have another relationship between VN and V o which is here ok.

So, therefore, we can write we can draw this like a straight line passing throw the origin. So, let me draw this like this ok. So, this is relation 1, this relation this one. So, now, we have two relationships between V o and VN one is this and other is this. So, what will be the solution? So, the solution will be definitely here at the intersection.

So, therefore, this will be the solution ok, so this is how to find the solution. Now for an ideal op-amp, we know that this static characteristic is very sharp very vertical at this region or here the resolution is very small so, this slope is very high almost vertical. So, therefore, so now, let me just modify this for an ideal op-amp ok.

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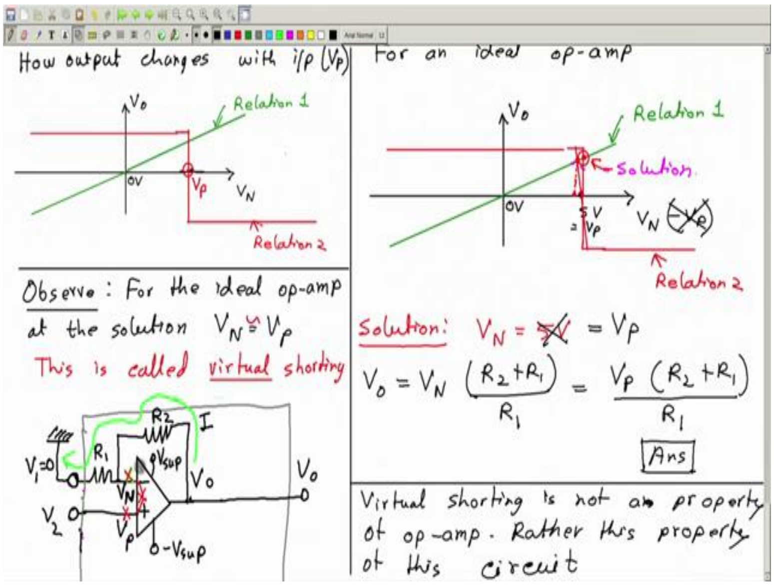

So, for an ideal op-amp, what is the modification I have to do? I have to make this line vertical as vertical as possible; and this and I can erase the previous one. So, now, the solution will be at this point. So, this is now the solution ok. So, what is the solution? So, the solution is that VN at this point VN = 5 volt but what is these 5 volts? These 5 volts is nothing but the value of V P ok.

So, if you have retained a general value V P, this should have been V P only. So, you could you could just write this as V P 5 volt is just as specific example in general this is V P. So, therefore, it is better we write it this is equal to VP. So, the solution is that VN is equal to V P; and how much is V o?

$V0 = VN\ \frac{R2+R1}{R1}$

Now let us take a pause and then think of few things. Firstly, I need to pause the (Refer Time: 20:55).

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So, I have just copied this diagram once again here. And now I want to show what happens if you change the input what is the input? The input is this value which is V P. So, if you change the input what will change this second relation this will not change because this does not depend on V P at all.

But what will change is this red curve which comes from the static characteristic why will it change? Because, the point at which this vertical line is there is at the value of VN = V P. If V P 5 volt it will pass through this if V P is 3 volt it will pass through this and so on ok. So, what happens I will show you through this animation.

So, if I say reduce V P then this red curve will be moved from right to left like this and if it is moved here so, it is now this is V P then this point where my curser is will be the solution will be the value of V O. If I now increase the value of V P, you see this red curve is moving towards right and therefore, this crossing between the red and green curve is also moving towards right and upwards ok.

That means V o is also increasing so that is nice observation you see, if I reduce V P if I reduce input output reduces if I increase V P output increases and it keeps increasing, increasing, increasing until at this point. After this you see output is not going to increase because, now the intersection of this green and the red curve is here at the saturation region flat region.

So, even if I moved this V P further and further, the solution is at this point which is constant V o equal to constant and constant at the value this is what this is V supply plus V supply so, it is not going to change. Similarly if I bring it down bring it down, down, down at this moment output will be 0 I make it negative output you see now in the output is negative if V P is negative output is also negative.

I make it further negative further negative further negative and at some point which is going beyond the limit of the screen. Now you see that if I go further the intersection will be here. So, this is once again as saturation level ok. So, output cannot go below this minus V supply or above this plus V supply and if the input is within this region starting from here this is the maximum value to these somewhere here where when this interstate.

So, if the input is between this range then output changes linearly proportionally with the input. So, this is one observation. So, let me write how in output changes with input that is V P or V 2 ok. Now next think let us discuss let us observe, observe that for this ideal op-amp at the solution; that means, at this crossing point. At the solution this value of VN is how much is a vertical line so, it is same as V P.

So, here we have written it VN = V P at the solution VN = V P this happens because of the intersection of these two curves is at a point where VN = V P. So, this means as if the two points VN and V P in the circuit so these two points. So, they are at same potential and when two points in a circuit and at same potential it happens. If those are electrically connected or sorted together then it will happened ok.

But here between these two, VN and V P there is no connection no connection at all no short circuit at all, but yet they are at the same potential. So, this fact is called a virtual sorting between VN and V P ok. So, there is no actual shorting between VN and V P not here not even through the I mean logically in nothing there inside the op-amp because ideally, no current goes like this or this because here the current is 0 here the current is 0.

So, there is no actual sorting between these two points yet, they are at same potential almost same potential. Not at exact same potential because this line is not exactly vertical this is slightly tilted ok. How much tilted that depends on how good the op-amp is. For perfect op-amp this is perfectly vertical almost vertical good for good op-amp this is very much vertical.

So, therefore, the solution this solution; this is the solution now at this. So, therefore, this is value of VN which is almost close to V P very close to V P ok. So, therefore, for a good op-amp V P is equal to VN are very close to they are very close to each other ok. So, therefore, it is better if I put this ok.

So, this is called virtual sorting, this is not actual sorting because there is no connection between these two points ok. So, let me zoom it in an tell you once again that there is no current here. So, there is no therefore, no current at all here or here or do not think that there is some current flowing like this; from here to here or here to here not at all.

So, this is called virtual sorting and an important fact is that this virtual sorting is not this is not a property of the op-amp ok. So, virtual sorting is not an property of the op-amp rather, it is a property of the entire circuit everything together ok. If you just have an op-amp with say this resistance these connections are not there do not say that V P and VN will be always same ok.

So, but it is true for this particular circuit. So, rather this is a property of this circuit this circuit and it is also true form for others some other circuit. But in general, it is not true for all circuit it is only true for some circuits and not for the op-amp alone ok. So, if you just have the op-amp alone do not ever without all these connections, it is not that these two terminals are going to have same potential no ok.

And also this is true only when only when V P is within the limit of the saturation ok. So, as we have seen so if I increase V P like this so now, V P is this much. So, V P is here now the solution will be here and therefore, VN is here so, this is VN and V P is here so VN and V P are not same.

So, once this circuit saturates because input is too much high then, then this virtual sorting is not going to be true ok. So, that is about non-inverting amplifier. Next, we shall see inverting amplifier.

Thank you.