Electrical Measurement And Electronic Instruments
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Lecture - 52
Background: Operational Amplifiers - IV

Ok; so, now, we are going to analyze the inverting amplifier ok; and the way we will do it is will be very much similar to the non-inverting one. So, if you have if you understand the previous one thoroughly and if you do this next one which is inverting amplifier on your own that will be highly pleasing. I will be very happy if you do that on your own without watching this video but I will also do it in this video ok.

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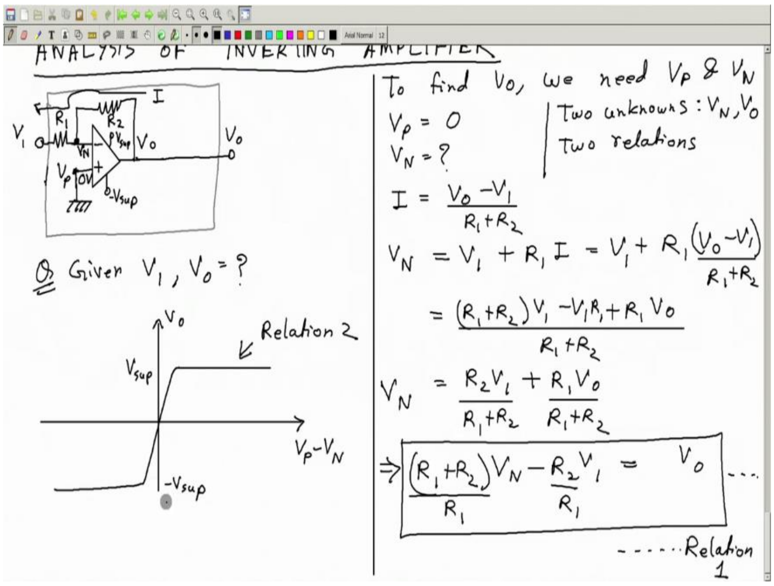

So, this is the circuit for the inverting amplifier it has one input V 1, one output V o, V P is connected to ground. I just have copied it from here we have said how to remember this circuits before fine.

But, now once again here the question that we will ask is given V 1 if V 1 is given V o output is how much how to find V o ok, how to find it we need the static characteristic so, that is the input output relationship.

So, why is that let me draw it, this is the static characteristic output versus input input is what V P - V N this is how we draw it and then this is this characteristic where this point is V supply V supply is the power supply and the minus power supply this is minus V sup ok; and so, this is the static characteristic now to find V o we need both V P and V; now V P V P is known V P = 0 ok.

So, as before to find V o we need V P and V; now V P is equal to 0 because this is connected to ground, but V N is how much? Do we know V N not directly, but we know something about V N. So, it is once again a potential divider rule kind of potential divider rule this point is at V o this point is at V 1 no current is getting out from this branch.

Therefore, V N will be somewhere in between V 1 and V o somewhere in between V 1 and V o some sort of average and we can do it quickly if you know something like Millman's theorem if you do not know we can still do it. So, let us find this current I which is flowing like this ok. So, from here to here this if this current is I how much is I?

$I = \frac{V0 - V1}{R1 + R2}$

$VN = V1 + R1\ I = V1 + R1\,\frac{V0 - V1}{R1 + R2}$

$VN = \frac{R2\ V1}{R1 + R2} + \frac{R1\ V0}{R1 + R2}$

So, this is one relationship between V o and V N ok. So, we have two unknowns V N and V N and V o to find V o we need as we have already said to find V o we need V P and V N and here also you see to find V N it depends one V o. So, it is once again that (Refer Time: 07:09) problem and so, we have two relationships we will have two relationship.

Now, this is this is this you called call relation 1 between V o and V N and another relation is here the static characteristic ok. So, this is relation 2 ok. So, we will also have two relations. So, we can solve for V N and V o ok.

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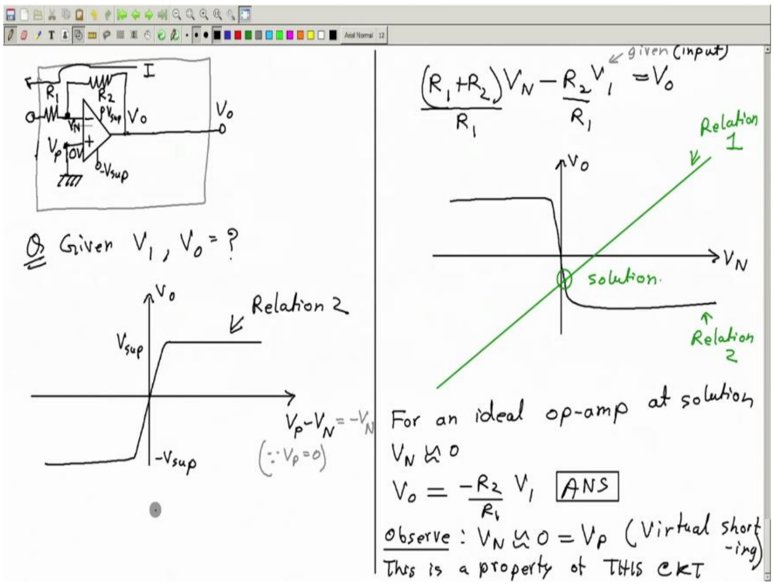

Now, once again so, I have just copied these diagrams from the previous page so that we can continue. Now and this is the relationship between V o and V N which is coming from this so, this is coming from the external circuit ok.

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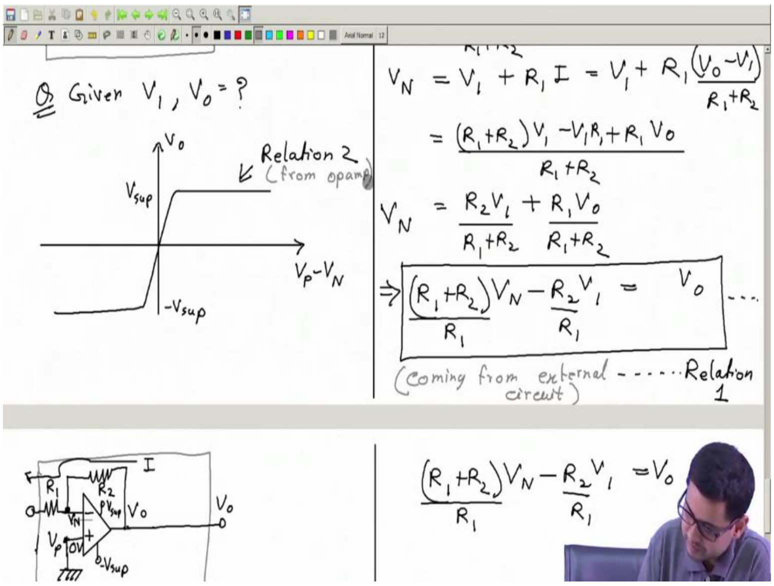

So, this relationship let me write here this is coming from external circuit; and this is from op-amps property op-amp ok. So, now once again we will draw two curves that expressing this relationship and this together but now we know that V P = 0 in this V P = 0 therefore, this is same as minus V N.

So, in this curve x axis is same as minus V N since V P = 0. Now, if I want to make this minus V N to plus V N what I have to do is simply switch swap this and make a mirror image of this diagram like this. So, this is a mirror image ok. So, this is V N versus output because V P is 0 and the second relationship the other relationship between V o and V N is like this.

$\frac{(R1+R2)}{R1}\ VN$ - $\frac{R2}{R1}$ V1 =V0

So, you see V o is V N times something minus V minus something V 1 is known. So, this is known this V 1 is given ok. So, this is like y is mx minus c. So, how can we draw that y = mx c; this will be as straight line with positive slope and with intercept. So, at V N = 0 ,V o will be negative.

So, it will start from a negative intercept. So, this will be somewhat like this. So, this is relation 1. So, this is relation 1 this is relation 2 and what is the solution the solution is at the intersection which is here ok, so the solution is just this.

So, now, for an ideal op-amp this line is almost vertical right. So, this almost goes along the y axis. So, for an ideal op-amp here you can say that at solution at this point at solution the value of V N will be almost 0 V N is almost 0 very close to 0 ok.

V0 = $\frac{-R2}{R1}$ V1

So, this is the solution. So, this is the answer ok. So, the question was what will be the output this is the answer and you see the output is input times a negative factor that is why we call it an inverting amplifier because it the output is always of opposite sign from the input ok. So, yes and then what is next.

So, next let us see how the output will change if we change the input ok. So, if we change the input what is input; this is input; input is V 1. So, if we change input this term will change this will remain same. So, in; that means, this relationship which is depicted here this will change its position how will it change? This will change this factor will change. So, the y intercept will change slope will remain same ok. So, therefore, if I change V 1 then this curve is going to move like this ok.

So, then this curve is going to move like this up or down y intersect is going to change therefore but you observe that V N. So, at this solution V N is going to remain almost 0 ok, because this line is almost vertical ok. So, V N is going to remain 0 and this will also be true. So, this is how the solution varies as you vary the input. Now say if you make V 1 too much high if V 1 is too much high; then, this will be too much negative.

So, this will go down like this and then you see the solution will not be here the solution will be here at the saturation region it will not be here it will be here and then V N will not be equal to 0 if V N will be minus sorry V N will be this and output will be minus this amp. Similarly, if you make V 1 too much negative then this term will be too much positive. So, then this will go up up, up, up, up up to this V N will be 0 but beyond that, the solution will be here will no longer be on this access will be here ok.

So, this is how it moves let me keep it here this is for some value of V 1 positive V 1 ok. So, this is how input and output changes. Now once again observe, V N is almost equal to 0 which is same as V P, V P is 0. So, V N and V P are almost same this is once again is virtual shorting. So; that means, virtual shorting is also true for this circuit which is inverting amplifier.

But once again let me tell you this is not true for only the op-amp , if we do not have all this connections V P and V N will not be same; it will not be same for all circuits it will not be same for only op-amp . Once again this is a property of this circuit not of the op-amp this is a property of this circuit of this circuit ok, but not in general so that is virtual shorting ok.

So, next we will try to do the same analysis for difference amplifier but I will request you that, if you have understood how to do it for inverting and non-inverting amplifiers as we have done in the last two talks; last two classes then you should try it on your own for the difference amplifier and you can do it; it will be really a fun.

Thank you.