Electrical Measurement And Electronic Instruments
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Lecture – 50
Background: Operational Amplifiers – II

So, we are studying op-amps and so, far we have seen two important properties of op-amp or two important rules.

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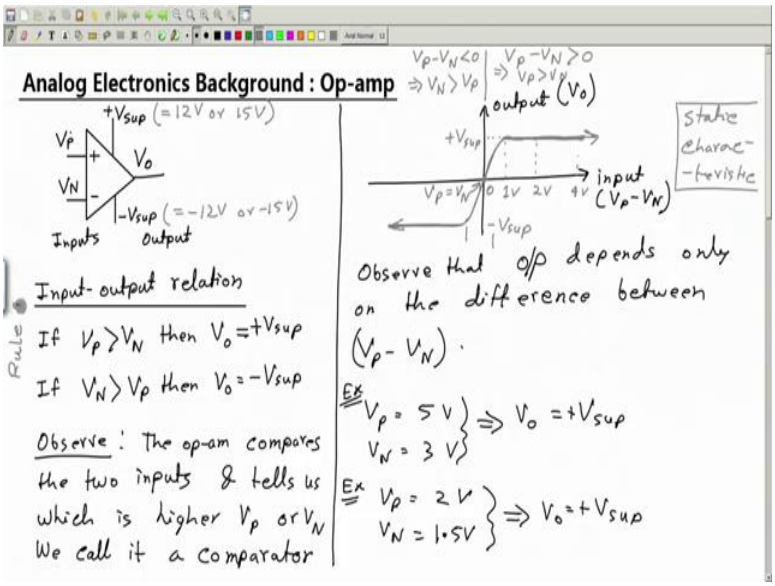

So, rule number one is this input output relationship, which says if V P > V N , V P and V N are the two inputs, then the output will be positive else output will be negative. This we also have represented graphically pictorially like this, which we call this static characteristic.

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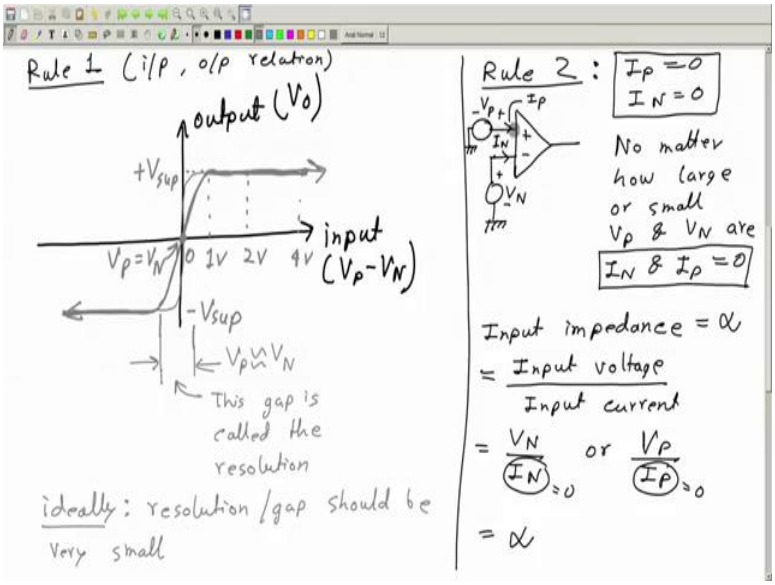

So, this is rule number 1 and then we have seen rule number 2, which is here, which says no current can go into or out of this input terminals, either of this input terminals of an op amp, which is same as saying the input impedance is infinite, because whatever voltage you apply current will be 0.

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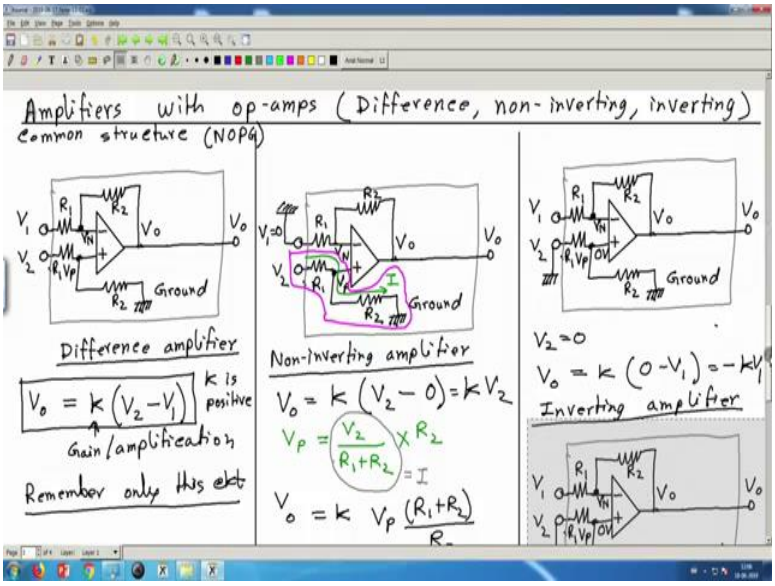

So, these are the two important rules and I already have said that, these are the two rules with which you can do almost anything you want with ideal op-amps ok. Any op-amp this

problem you can solve any op-amp based circuit you can analysis analyse with this just this two rules.

So, today we will see three important circuits, three very popular and common circuits amplifiers with op amps. So, amplifiers amplifier circuits with op-amps. So, we will see three of them namely we call them difference amplifier inverting amplifier and non-inverting amplifier. So, these are the three circuits that we will study ok. So, let me draw them first let me first draw the circuits.

So, let me make 3 columns ok. So, the first let me draw the difference amplifier. So, this is the op-amp you will have minus and plus inputs 1 output 2 inputs ok. So, for the beginners I mean who are starting op-amps for the first time before we understand them physically we will definitely understand them, but before that it may be a good practice at least for some students to just to identify a common structure between the 3 amplifiers we are going to see.

So, the common structure is like this. So, I will write this common structure ok. Ah. You can remember it like with this rule this is my thumb rule NOPG ok. So, which means negative should be connected to output N for negative, O for output, P for positive and G for ground. So, what you have to do? You have to connect the negative input, which is here connected to the output through some resistance.

Then, you connect the positive one to the ground. So, let this be the ground terminal or reference 0 volt terminal. So, this is output V o this is V N negative connected to output and positive connected to ground ok. So, this is so, this is the rule NOPG ok. So, negative to output N to O positive to ground PG, that is all that is all we have to remember and this is the, this is called the difference amplifier, why is it called difference amplifier.

So, it has two inputs. So, this two will act as the input of the overall circuit. So, this is my overall circuit it has two inputs and one output ok. So, the way it works is very simple. So, if you applied say two voltage that is called that V 1 and V 2 the output call it

$$V_o = k(V_2 - V_1)$$

So, this is how a difference amplifier looks like you just have to remember, this rule NOPG, Negative to Output Positive to Ground.

And, how it works or what it does, it gives a output which is proportional to the difference of the 2 inputs. So, this is the rule input, output relationship ok. So, this is difference amplifier. Now, next what we will do, I hope so, far you have understood ah. So, just 2 things we have said, how the circuit looks like. For now you just for now you just memorize it and what it does, what is the functional rule output input relationship ok?

So, these are the two things we have said now this is difference amplifier. Now, we will copy this here, now what we will do say we will connect the V 1 to ground ok. So, we will connect this terminal see to ground ok. So, V 1; that means, V 1 = 0. So, then what will happen this is the same circuit the only difference is that instant of applying a voltage V 1 I am just applying 0 volt.

$Vo = k (V2 - 0) = k V2$

So, we can also write K V P here. So, this is the rule and here you see the output depends only on, 1 input because the other input is constant fix. So, this has only one input ok, because the other one is constant it is not changing, but this circuit has 2 inputs you can change both of them ok. Here, I have made one of them constant that is the difference ok. And, so, this is called a non-inverting amplifier, one small thing I should I have missed sorry so, this is another thing you should note.

We should have resistances everywhere, then we will eliminate some of them later. So, this is this point is V P this point sorry this is V N and this is V P. Here also let me put this resistances first. So, this is V N this is V P negative and positive. And, right now, I have not retained the values or any name of this resistances, I will do that soon ok, or let me do it. So, you also remember that that the resistances should occur in pairs, if this one is R 1, then this one should also be R 1 same value, if this is R 2 then this should also be R 2. So, similar resistances like this 2, which are connected to the inputs this should be same.

And, the other 2 which are not connected to the inputs they should be same ok. So, this is another important thing which I missed. Here also let me now then put the values R 1, R 2 here R 1 and R 2 this is called non inverting amplifier. Why is it called non inverting amplifier? Because the output depends only on 1 input and it simply is the product of some factor constant times the input V 2. And, if V 2 is positive output is also going to be positive, that is why it is called non inverting ok. Now, you observe one small thing which is this.

So, I am giving input V 2 here and so, therefore, some current will flow and it will flow like this, it will start from here and will go to ground, no current can go through this input that is rule number 2 right. So, the current will go only like this, no current can go 2 or out of this input terminal. Therefore, the potential at this point which is V P so, V P is we can

$$Vp = \frac{V2}{R1+R2} \text{ x } R2$$

$$Vo = k\ Vp \frac{R1+R2}{R2} = K1\ Vp$$

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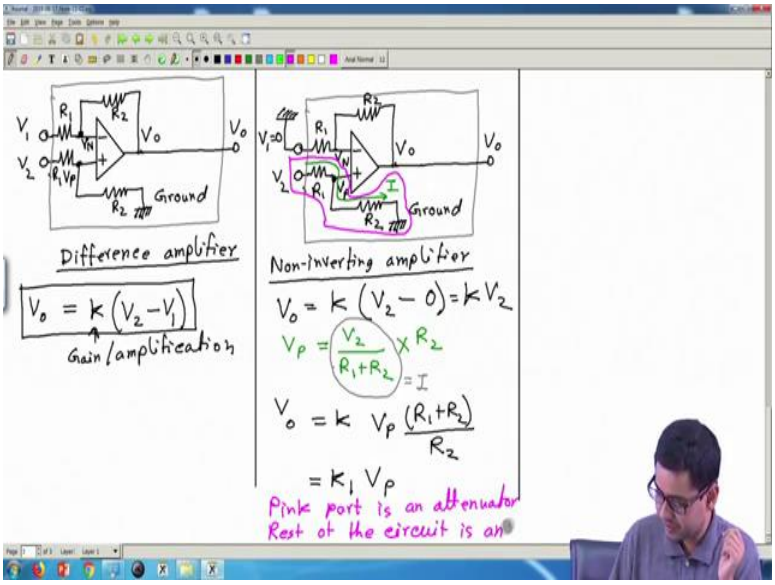

So, this voltage is first getting reduced or what is that called opposite of amplification attenuated ok. So, the voltage is first getting attenuated at this point and then it is getting multiplied by a factor K and this is the output view. So, in this circuit we therefore, have first attenuation. So, this part is an attenuator and the final output is we see that it is V 2 multiplied by V 0. So, we can say that the input voltage is first getting attenuated and then getting amplified by the rest of the circuit.

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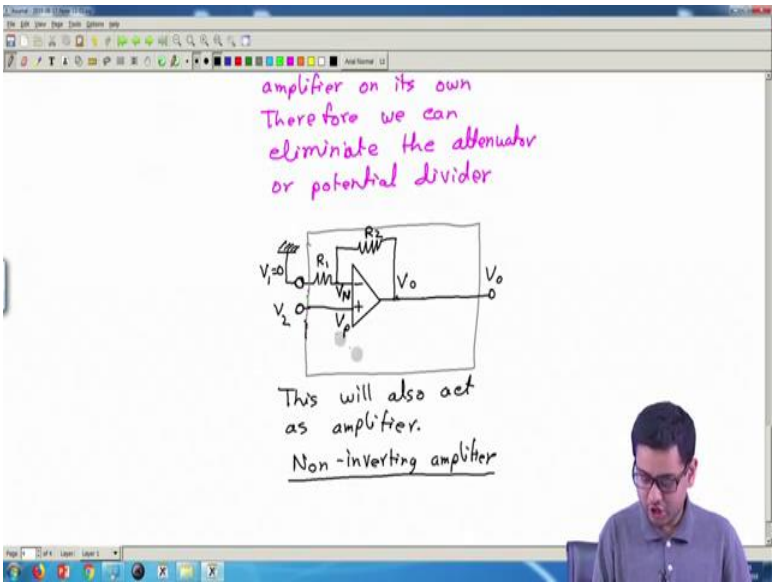

So, the rest of the circuit is an amplifier on it is own is an amplifier on it is own. So, the rest of the circuit is therefore, an amplifier. So, what we can do? We can eliminate this part ok. So, therefore, we can eliminate the this attenuator or potential divider and it will still be a amplifier because rest of the circuit will do the amplification.

So, what we do is this, let me copied ok. So, now, what I will do? I will simply remove this part and connect the input directly to V P ok. So, let us remove this part this potential divider completely and connect the input directly to V P ok. This is and this is not there. So, the this will also act as an amplifier and you might have already seen this circuit in books or elsewhere where it is written as the non inverting amplifier.

So, it is non-inverting amplifier, but it is not much different from the difference amplifier. So, what we have done? What is ok, what I want to say you is that you do not have to remember three different circuits, for difference amplifier non inverting amplifier and the another one I will do is inverting amplifier. You just have to remember only this one remember only this circuit ok, remember only this circuit difference amplifier.

And, from this you can find out the other two variants non inverting amplifier and the other one that I will do inverting amplifier quite logically ok. What is the idea? So, it has 2 inputs and you make one of them 0, you make V 1 equal to 0, say then you connect it like this. Then this circuit becomes like this and then you observe this is nothing, but the potential divider ok. So, the input is first getting reduced and then getting amplified.

So, why I mean if I just want to amplify why do, I need this attenuator, I can connect the input directly here. So, that is what we have done. So, then it becomes the standard non inverting amplifier which you might have seen in books ok. You do not have to remember it separately. Now, let us see the inverting amplifier. Once, again we will derive it from the difference amplifier how I will copy it first. So, this is difference amplifier and here the output is K (V 2 - V 1).

$V2 = 0$

$V0 = - K V1$

So, you observe that output is proportional to input 1 and it is opposite to input 1 because of this minus sign.

So, if output is positive sorry input is positive output will be negative and vice versa. So, therefore, it is called inverting amplifier, because this sign of the output is inverted, this is called inverting amplifier, because of this minus sign. Here, there was no minus sign that why, it is called non inverting amplifier K is a positive number ok. So, K is positive great.

So, now, you see so, this is the circuit which we have derived from the difference amplifier, now can we simplify this circuit. So, like we did some simplification from here to here can we also do some simplification here, yes you see that this point is at 0 potential this point is at 0 potential.

So, what will be the potential here? Somewhere in between 0 and 0 once again you can apply potential divider rule ok. So, here V P will be 0, because this is at 0 this is at 0 V P some somewhat half way between 0 and 0, no current is flowing in this part through the input that is the rule of an op amp. Therefore, V P must be between V 2 and this ground V 2 is 0 this is also 0, so V P should be 0. So, therefore, this point is at 0 volt ok.

So, this is at 0 volt now if this is at 0 volt why do I draw it with 2 resistances like this, why do I not directly connect this point to ground I can do it. So, let me just do that. So, let me copy paste. So, this is the circuit I know this is at 0 potential. So, why do I need this I can directly replace this with ground similarly, I do not also need this. It is gone this is V P ok.

So, this is equivalent to the previous circuit. So, this 2 circuits are equivalent ok. So, and this is the circuit that you have possibly seen in books or elsewhere. So, here so, let me

just recap this topic. So, far we have seen 3 circuits and their names are difference amplifier, non-inverting amplifier, inverting amplifier.

What do they do? Say this non inverting amplifier this has finally, 1 input and 1 output. And, output is some amplification K times the input, what does this do? The output is this input V 1 multiplied by some negative factor minus and what does this do this has 2 inputs. So, therefore, output depends not only on V 1, not only on V 2, but on both of them and on the difference between V 1 and V 2; V 2 is connected to V positive. So, V 2 minus V 1 this multiplied by sum factor K will be the output, this is called difference amplifier, this is how it works? Ok.

Now, how to remember this you just remember only one circuit difference amplifier, how to remember, remember this rule NOPG. So, draw the op-amp connect the negative terminal to the output into output positive to the ground P to G put resistances everywhere. Here, here and also this two will be the inputs put resistances here output, do not put resistance here at the output ok.

And, you just remember that the similar resistances like this one and this one which are connected to the 2 inputs should have same value R 1 and R 1. The other 2 resistances also should have same value R 2. So, this is how to remember the circuit? Ok. So, next we shall see the circuit theory of this 3 circuits ok. So, let us take a break.

Thank you.