Basic Electrical Circuits

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Lecture – 109

In this lesson we will look at another frequently used op amp based amplifier circuits. It is used widely in instrumentation applications and it is rapidly called the instrumentation amplifier.

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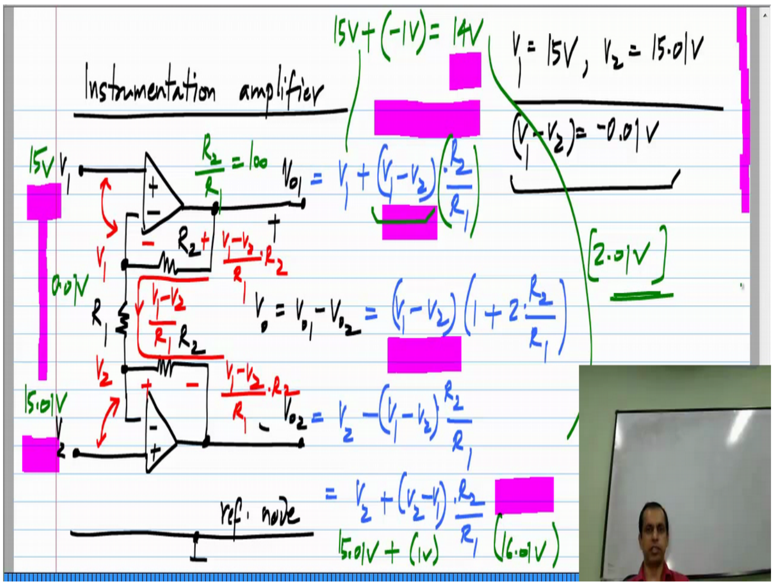

It is based on the non inverting amplifier and it can be derived from that, but I am here just putting down the circuit. This has two op amps and you will be able to verify that each of them is a negative feedback. And let say I have V 1 and V 2 are the two inputs, again this means that they are V 1 and V 2 with respect to some reference node and I have these two node voltages as the outputs V o 1 or V o 2. In particular the difference between these is considered to be the output V o which is V o 1 minus V o 2 and the resistance values are chosen systematically.

So, let say this is R 2, this is R 2 and this one is R 1, I will show the analysis with ideal op amps, if you want to see what happens with non ideal op amps that is op amps with the finite gain, then you can replace each of this op amps with voltage control voltage sources and carry out the analyses yourselves. Now, ideal op amp circuit analysis is very easy, I will use the virtual short between these two, there is negative feedback around each of these op amps that can be verify as I mentioned earlier.

So, the virtual short at the input of this op amp means that the voltage here is also V 1 with the respect to the reference node. Similarly, the virtual short at the inputs of this op amp means that, the voltage difference between these two is 0 and this node voltage V 2 with respect to the reference node. So, this resistance R 1 it is upper terminal is connected to V 1, the lower terminal to V 2, so the current flowing through this is V 1 minus V 2 divided by R 1.

That current goes in to this resistor; nothing goes in to the op amp and similarly goes into that resistor. So, the voltage drop across the R 2 is in this polarity, this current times R 2 it is V 1 minus V 2 by R 1 times R 2. And similarly across this R 2 with this polarity we have V 1 minus V 2 by R 1 times R 2. Now, if you look at each of these voltages V o 1 will be V 1 plus the voltage drop across R 2. So, V o 1 is V 1 plus the voltage drop across R 2 which is V 1 minus V 2 times R 2 by R 1.

Similarly, V o 2 will be V 2 minus the voltage drop across this lower R 2, these two resistors have to be of the same value, V o 2 would be V 2 minus V 1 minus V 2 times R 2 by R 1 which is also the same as V 2 plus V 2 minus V 1 times R 2 by R 1. Now, what is special about this? I can also compute V o 1 minus V o 2, you can see there it is V 1 minus V 2 times 1 plus 2 times R 2 by R 1.

So, we have V 1 there and this V 2 gives you V 1 minus V 2 and we have V 1 minus V 2 times R 2 by R 1, V 1 minus V 2 times R 2 by R 1, so we get 2 times R 2 by R 1. What is special about this? The point is you can set this R 2 by R 1 ratio to be a large number, then what happen is even if you look at each of these outputs V o 1 and V o 2 a large part of that consists of the difference V 1 minus V 2, the individual voltage V 1 here is multiplied by again 1, whereas the difference voltage V 1 minus V 2 is multiplied by R 2 by R 1.

So, what it means is that, this prefers the difference V 1 minus V 2 as oppose to V 1 or V 2 by itself and if you take the difference between these two V o 1 minus V o 2, you will find that it is proportional only to the difference. Now, why is this useful? This is useful it turns out that many times you have to compute the difference between two large voltages, but the difference is small, but each of the voltages is large.

So, let say I have 15 volts V 1 is 15 volts and V 2 is 15.01 volts and I am interested in only the difference V 1 minus V 2 which is actually a very small number, which is minus 0.01 volts. I need a circuit that amplifiers this very small difference and ignores the fact that each of these voltages large, so that is it emphasizes the difference. So, what happens if I apply those two voltages to the circuit? So, let say I have 15 volts and 15.01 volts, now here I will have 15 volts plus let me assume that R 2 by R 1 is 100. So, I have 15 volts plus this is a 100 and V 1 minus V 2 is minus 0.01 volts.

So, I will have 15 volts plus this V 1 minus V 2 times R 2 by R 1 which is minus 1 volt. And similarly here I have V 2 which is 15.01 volts plus V 2 minus V 1 which is 0.01 volts times R 2 by R 1 which is 100, so I will have plus 1 volt. So, if I take the total, this at 14 volts and this is at 16.01 volts, so now, the value of the circuit is very clear. We have 2 voltages with the very small difference between them they have been amplified in to 2 voltages with the much larger difference; we have 15 volts and 16.01 volts.

Again this is important in instrumentation applications, were you have trying to sense difference between two quantities prissily each of those quantities can be large, but the difference can be small. So, what happens is that what is the very small difference 15 and 15.01 there is only 0.01 volts difference between these two has been converted in to 2 voltages, which have 2.01 volts difference between these two. So, that is the value of this circuit this is clear. So, very useful circuit and we will find, that it is commonly used in instrumentation applications.

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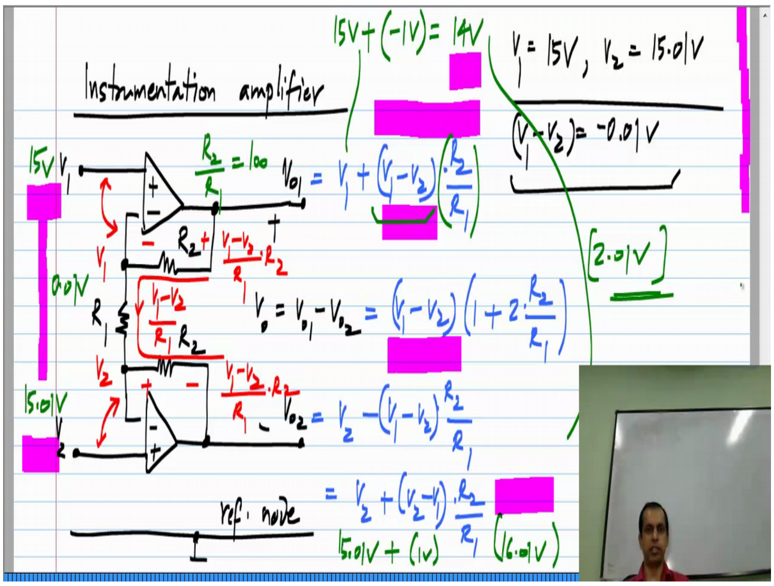

So, clearly recognize the value of the instrumentation amplifier we can compare it with another structure based on non inverting amplifiers which also amplifiers the difference by the same amount, this is instrumentation amplifier the inputs are V 1 or V 2 as we have seen, the difference output is V 1 minus V 2 times 2 times R 2 by R 1 and more importantly the individual outputs are V 1 plus V 1 minus V 2 times R 2 by R 1 and other one is V 2 minus V 1 minus V 2 times R 2 by R 1.

Now, if I have two input voltages we can think of using two separate non inverting amplifiers, I will replicate the exact same circuit on the other side, if you do this what happens is the individual outputs will be V 1 times 1 plus R A by R B, the other one will be V 2 times 1 plus R A by R B and the difference between them would be V 1 minus v 2 times 1 plus R A by R B, it appears that if I set 1 plus R A by R B to be the same as 2 times R 2 by R 1, the difference output will be the same, but the important difference in the individual outputs.

Taking the same example values are before, if this is 15 volts and this is 15.01 volts and we also say that R 2 by R 1 is 100. We saw that this would be 15 minus 0.01 times 100 or 14 volts and this will be 16.01 volts. Now, the difference between these two is occurs minus 2.01 volts. Now, if you do that in this case, let us say this is 15 volts, this is 15.01 volts and I said this 1 plus R A by R B to be the same as 2 times R 2 by R 1 which is 200 because R 2 by R 1 is 100.

So, this is 200 so; that means, that the output should be 15 times 200 which is 300 volts and this one will be 15.01 times 200 which is 302 volts. So, you can see that the difference output is minus 2.01 volts here and minus 2 volts over there 300 minus 302, but the individual voltages are much higher in this case. In fact, this is completely impractical if you have op amps with let us say 20 volts power supply you cannot have a 300 volt output this will say a later.

But, you can see that this 300 volts is too high and this 302 volts also too high two separate amplifiers like this individually amplifier V 1 and V 2 whereas an instrumentation amplifier like this does not amplifier the individual voltages much V 1 comes out as it is, V 2 comes out as it is what gets amplifier is only the difference. So, such properties known as common own rejection we want going to that you can refer to some book to get more details of that, the point is individual voltages are not amplified, but their differences and that is the value of the instrumentation amplifier, which is require to sense small differences of two large voltages in many, many applications.