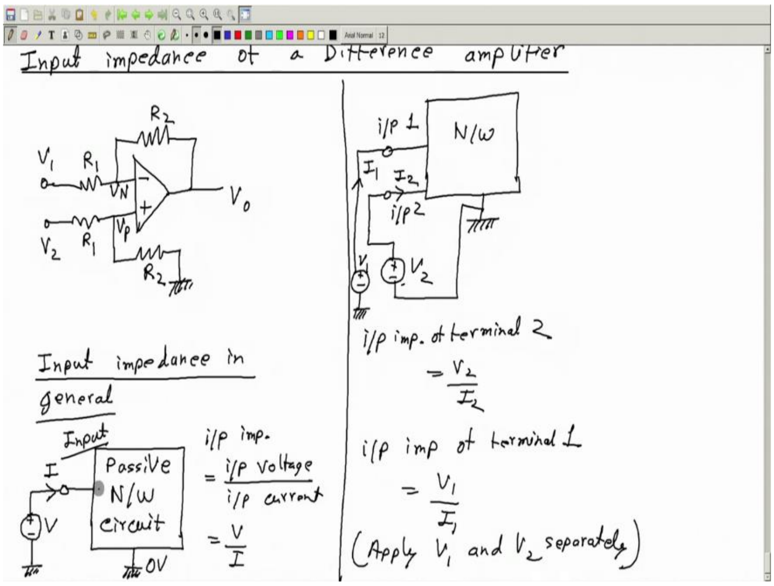
Electrical Measurement And Electronic Instruments
Prof. Avishek Chatterjee
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 57
Difference amplifier - III

(Refer Slide Time: 00:33)



Welcome again, today we are going to talk about the Input Impedance of a Difference Amplifier. Let me quickly copy the circuit of the difference amplifier. Now what is input impedance, what is input impedance in general? If I have a complicated circuit, very complicated circuit in this box inside, this box and it has many passive elements resistance, no active source at ok.

For say for example, then and say one of the nodes in the circuit is taken as the reference or grounded 0 volt; it has input terminal, it may have some outputs. Now what we can do say, we can connect a voltage source between this input terminal and the ground call it V plus minus; this side plus, this side minus and if we do so, it may draw some current I ok; then we will call the input impedance of this terminal is this input voltage divided by this input current ok.

So, input impedance this is equal to input current sorry, input voltage divided by input current, input voltage divided by input current ok. So, this is the input side, this is the complicated network in a box or a circuit or and it is passive; means, it has only resistances for example, no active source, no voltage source, no current source this is equal to V/ I this is in general the input impedance.

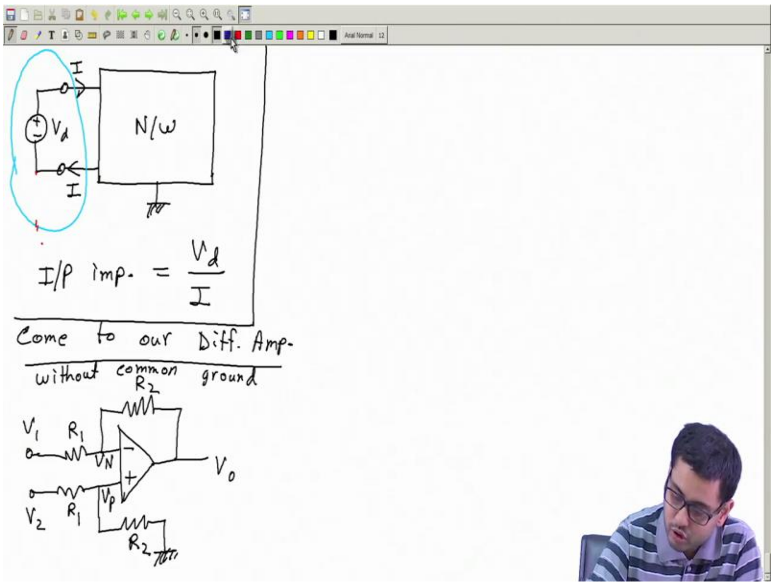
Now, if a circuit, if a in general if a circuit or a network has multiple inputs. So, this is a network and it has multiple inputs say, call it input 1, another is input 2 this is the reference terminal or ground terminal of this network. Now we can connect multiple sources, may be one source like this call it V 2 plus minus you can connect it like this, or if like you can also connect it like this.

Then when you apply this voltage it will draw some current call it I 2, then you can also then you can define the input impedance of this terminal, input impedance of this terminal, terminal 2 this is V2/ I2 ok. Similarly, if you connect instead of connecting this voltage source here, if you connect another voltage here plus minus; if this is V 1 and if then it draws a current I 1 here, then input impedance of terminal 1, here also input impedance of terminal 2 this will V1/ I1 ok.

So, do not I mean apply this voltage sources one at a time; when you apply this V 1 do not apply V 2, when you apply V 2 do not apply V 1, apply V 1 and V 2 separately ok. The in general I mean, if you are doing if you are finding this input impedances with an in an experiment in the lab by applying some voltage and measuring this current with an ammeter, then apply this one at a time ok. Because it is possible that when you I mean, if you apply V 1 and if you also have V 2 connected to simultaneously; then V 2 may affect this current I 1, V 1 may affect this current I 2.

So, in general we should apply one voltage source at a time. So, this is the note, apply one source at a time or make the other source equal to 0; when you apply the other one. So, this is one way of defining input impedance. So, now, if we have many terminals, we will have many input impedances for each of the individual terminals ok.

(Refer Slide Time: 07:56)



Another way we can define input impedance say, if we have a network with two input terminals, this is a circuit with two input terminals; we can apply a differential voltage like this V d plus minus connected like this, without any common ground ok.

So, then a current will flow I, if this current is I this current must also be I; why because of conservation of charge ok. You just think of this part of the world, so from this part of the world only one wire goes out and one wire comes in. So, if I want to it conserve the charge inside this, then whatever current goes out same current must come in. So, both these currents are same, they have to be same I and I ok.

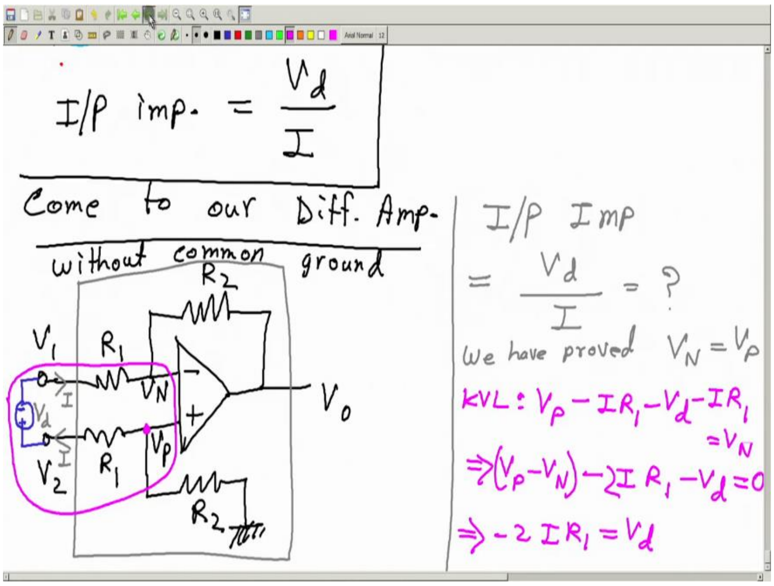
So, now, I can define the input impedance in this way for this type of connection input impedance, this will be equal to this voltage V d / I. We have no confusion about which current to take, this current or this current; because both of them are going to be same, they have to be same ok.

But if we had a common ground then, let me draw it and then I will erase it. If I have a common ground then it is not necessary that these two currents are same because there is another path through which current can go in or out. So, then there is a question which. So, if then I call this as I 1, then this as a I 2, should I put I 1 here or should I put I 2 here I do not know; but when I do not have this ground then I know I 1 = I 2 definitely and then there is no confusion you can put either I 1 or I 2 or you just call them as I, just put this. So, this is another way of defining input impedance for some circuit where you have two terminals and you can give a differential input ok.

So, this is what is, input impedance in general. Now let us come to the difference amplifier ok, which is here ok. So, it was not necessary here, let me cut, paste. So, now, we come to the specific case of our difference amplifier. So, come to our coming to our difference amplifier, diff amp ok.

So, now we as we have said we can connect this in two different ways; one with a common ground, another without a common ground. So, first let us take without common ground. So, how we will connect the input; so let me connect the input this way, a voltage source which I will connect between these two terminals V 1 and V 2. Let me call this side as plus, this side as minus; let me zoom in plus and minus. So, this is the input and this is the output, and the circuit I will seal it in a box ok.

(Refer Slide Time: 12:51)



So, it has two input terminals, one output and I connect a differential input without any common ground like this; then of course, you can immediately recognize that these two currents here and here must be same. If this is I, same current must comeback right; because of the conservation of charge and now if I call this voltage as V, what you can call it V d or V I; I for input or d for difference between these two, whatever ok. So, then the input impedance is how much, then the input impedance I will define it as this voltage V d / I input voltage by input current, in this case the voltage is a differential voltage applied ok.

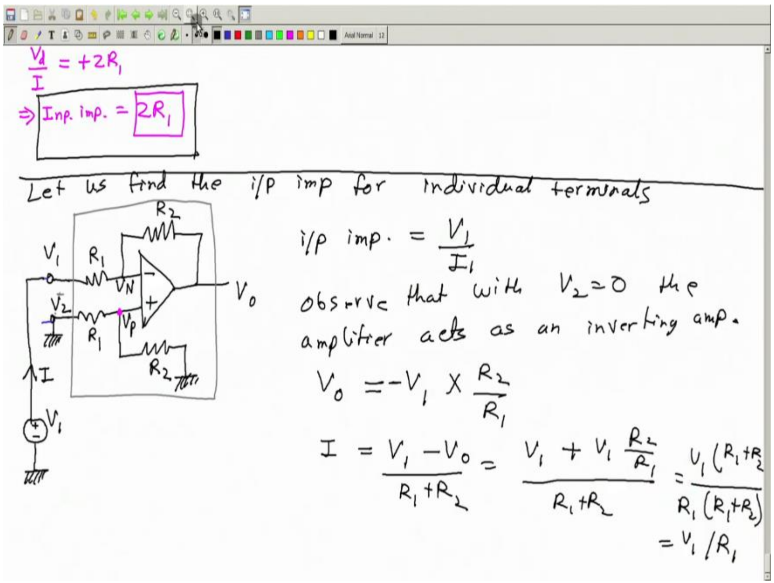
So, let us now find out this is equal to how much ok. Now you observe that we have proved previously that V N = V P, if we do a detailed analysis of the circuit; because in the circuit virtual sorting is going to work ok. So, this two will be at the same potential. Now let us apply KVL Kirchhoff's voltage rule in this path, in this along this purple circle. So, in this loop let us apply KVL, KVL in this purple or violet loop. So, what can we say let us start from this point. So,

KVL : $V_p - IR_1 - V_d - IR_1 = V_N$

$$V_p - V_N - 2IR_1 - V_d = 0$$

$$V_d = -2\,IR_1$$

(Refer Slide Time: 17:52)



And take from this we can write that, V d / I = - 2 R1 right. This minus sign is coming because I have chosen I in this direction ok. I should have actually chosen I in the opposite direction; because if I am applying this voltage with plus here, then I am interested in how much current is drawn out from this plus side, because these voltages trying to drive the current in this direction, in this direction, right. So, this voltage source is trying to drive the current in this direction. So, I should better write I in this direction ok.

So, let me take also this I in the opposite direction, this is also I. So, everywhere in this equation wherever I have I, I will just put minus I ok. So, this will become plus, this will become plus, this will become plus, this will become plus. So, therefore, this will become plus ok; I did a small mistake that is why I got this quantity negative.

So, now this is what, this is nothing but the input impedance, this is the input impedance; input voltage by input current input impedance, this is equal to 2 R 1 ok. So, I should take the current in the proper direction, this voltage source is trying drive the current in this direction. So, I should take it in this direction; otherwise I will run into this trouble of plus minus symbol. So, this is the answer. So, let me write input impedance of this difference amplifier is this 2 times R 1, where R 1 is this resistance ok; and this is for this type of connection, I repeat for this differential connection without common ground, right.

Now let us come to the situation where we have inputs connected in a different way, how like this. Instead of connecting the input like this, I can connect say one voltage source plus minus like this; this, between this and the common ground here or I can also draw it like this, this means this terminal is connected to here ok, right. So, then I have only one source ok.

So, now let us find the input impedance for one terminal at a time, individual terminals ok. So, this voltage is applied which is V 1, so this is applied; and this, so I have to take the current this current I, this is the input current, this is the input voltage, this is the input current. So, now, the input impedance will be equal to V1/ I1, input voltage by input current right; what should I do to this terminal V 2, I should apply no voltage to it or I should apply zero voltage to it, ok. So, that is the rule.

So, this is also connected to ground ok. So, I told you in general when talking about a network we should, which has multiple inputs and we want to find the input impedance of each terminal, we should apply input voltages one at a time. So, I connect the other input to 0. So, no voltage is applied there. So, now, let us find, you can find this current and then you can find the input impedance.

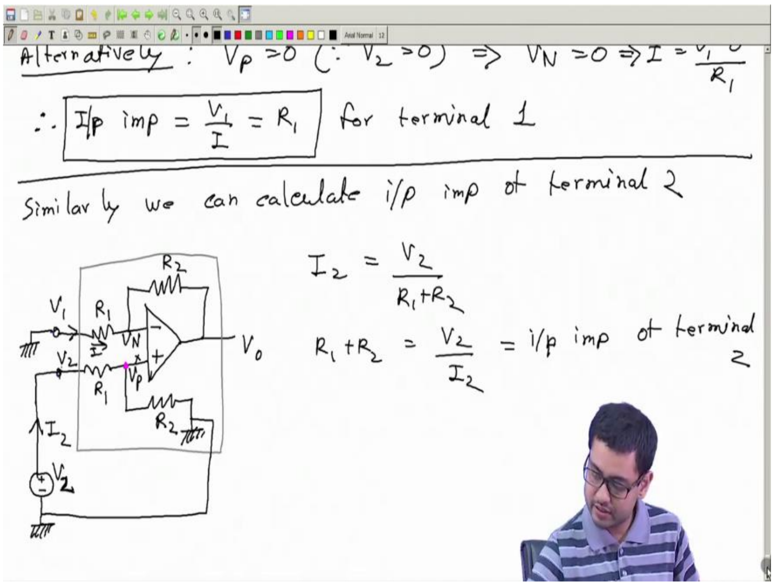
So, how much will be this current ok? So, now, you see, observe with this terminal grounded; that means, this terminal is actually grounded, this part acts like a inverting amplifier, observe that with V 2 = 0, this is V 2 the amplifier acts as an inverting amplifier ok.

So, therefore, we can use the derivation that we did for inverting amplifier and we can directly write that V0 = -V1 (R2/R1) ok. So, this we can write directly or we can do a thorough analysis, once again no problem, we will get the same result. So, this if this is V o and this is V 1 ok; and therefore,

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

You can actually do it quickly; you can also do it quickly another alternatively. So, you just observe that this point is at zero potential, this is 0, this is 0, so this is also 0.

(Refer Slide Time: 26:36)



So, alternatively, so you can do this in many different ways, so this is 0, this is 0; that means, V P = 0. Since V 2 = 0 and this is also equal to 0; so, that means, V N = 0, because we know for this circuit, virtual sorting works we have seen that.

I = V1/R1

I/p imp = V1/I = R1

So, this is the input impedance for this terminal; similarly, you can find the input impedance for the other terminal here, ok. So, similarly we can calculate input impedance of terminal 2. How? So, this is the circuit where instead of applying this voltage source to terminal 1, I will apply it here. So, I erase it and I apply this voltage source to this terminal, let me call it V 2 and this terminal should be grounded ok; otherwise if there is a voltage here that may also affect this current ok.

So, now I have to measure this current I 2 ok, and then the input impedance will be V 2/ I 2. So, I have to find the value of this current I 2 ok. So, you just observe that, the current will flow like this ok, current will flow like this, no current can flow here; therefore, what can we say about this current, so this is at zero potential, this is at zero potential. So, and the current only flows like this. So, how much will be, so you can also connect this to, right; and no current flows here, this two are at a same potential you can connect it. So, see you how much is I 2, I 2 is nothing but this voltage divided by this total resistance, right.

So, that is it. Now from this you can write that R 1 + R 2 = V 2 / I 2 right; and this is what? This is the input impedance, input impedance of terminal this is 2; that is simple.

So, therefore, you can either calculate the input impedance of the two terminals individually or like this, so this is for terminal 2 and previously we did for terminal 1 or you can also define an input impedance in this way, when the when a differential voltage is connected like this between the two terminals without any common ground between this source and this part of the circuit, then you can then you know these two currents are same. So, you can define the input impedance as this voltage by divided by this current and we also have found the expression for that.

So, in this case the input impedance was here 2 R 1; 2 R 1 sum of these two resistances and if you define input impedance for individual terminals, then for terminal 1, this is equal to R 1; and for terminal 2, this is equal to R 1 + R 2.

Thank you.