Course name- Analog VLSI Design (108104193)
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Department – Electrical Engineering
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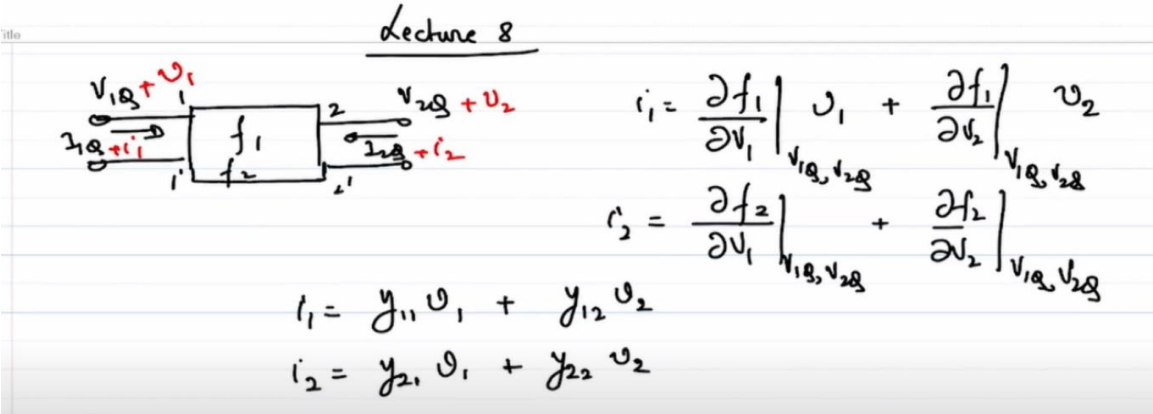
Week- 3
Lecture- 8, module-01

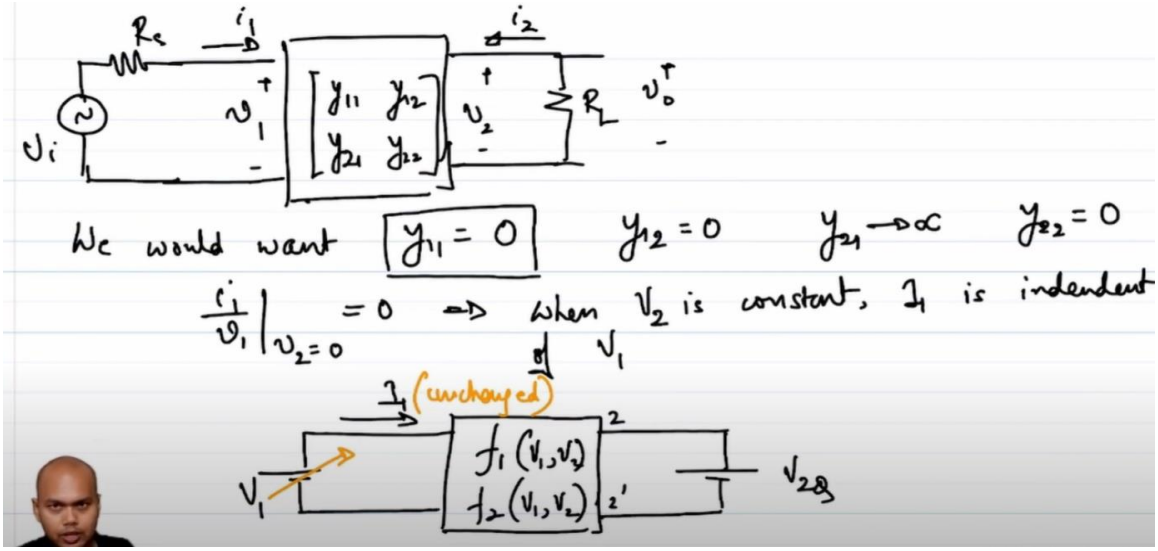
Now, welcome back this is lecture 8. So, in the previous lecture we saw we saw the use of incremental Y parameters, incremental short circuit admittance parameters or the Y parameters which are supposed to help us in analyzing two port networks, supposed to help us in analyzing non-linear two port networks right. And what did we do? We simply said that if I have a non-linear two port network and these were Biostat voltages V1q, V2q and if these currents are I1q and I2q and if we perturb the port voltages right, we perturb these port voltages by small v1 and small v2 then these currents would change, these currents would change and the new incremental currents and voltages that is if we represent them as I1 and I2 right. So, we could represent I1 as del F1, this one F1, V1, V2 simply let me simply write these non-linearities as F1 and F2 with understanding in that both F1 and F2 are functions of V1 and V2 right. So, this becomes del F1, del V1 around operating point V1q, V2q times V1 plus del F1, del V2 around operating points V1q, V2q times V2 right. Similarly, I2 we could express as del F2, del V1 again around operating point V1q, V2q plus del F2, del V2 around operating point V1q, V2q.



And then we further say that instead of writing these differentials around the operating point repeatedly there is a more compact way of writing these expressions or these currents and voltage relationships and that we could write in terms of short circuit incremental y parameters right. And simply we rewrote these as I1 equal to y11 V1 plus y12 V2. Similarly, I2 plus y21 V1 plus y22 V2. And why are these called short circuit admittance parameters? It is called short circuit admittance parameters because in order to find out one of the parameters let us say I want to find out y11 right.

y11 is a relationship between the current at the input port and the voltage at the input port under the condition that V2 is 0 that is incrementally O2 is short circuited. Similarly, if I have to find out y12 I will have to short circuit the incrementally short circuit the input port and find out the relation between I1 and V2 that is I have to excite O2 right, I have to excite O2 and figure out what will be the incremental change in the current in I1 under the condition that the voltage at I1 is held constant or incrementally shorted ok fine. Then we also said that now we if we now go completely into the incremental domain and apply an incremental current voltage to these y-parameter, to this y parameter network which is incrementally expressed right. We noticed few things we found out we find we found out the relationship between V0 and Vi and we noticed few things and we derived few conclusions and we notice that in order to get an ideal amplifier right in order to if we were to get an wish list of an ideal amplifier what what eventually realized what eventually was an ideal wish list for our amplifier as far as the incremental parameters were concerned the wish list was we would want y11 would be equal to 0. y12 to be equal to 0, y21 should be as high as possible and also y22 should be 0 ok.

So, now time has come to now time has come to dig a bit further into what these conditions actually mean right ok. So, let us start off with the first one the easier one y11 equal to 0. So, what does y11 equal to 0 imply? What does y11 equal to 0 imply? It is it implies that I1 over V1 when V2 is equal to 0 is 0 right implies that what does it imply? It implies that in plain English when the voltage across port 2 is held constant right when V2 is constant right I1 is independent of V1 right that is what it means right. So, effectively what this means is if I have if I take this network hold the output port that is the port 2 with a constant voltage right and I apply certain voltage V1 at the input port and I observe this current I1 even if I change this voltage V1 I1 remains unchanged. What that this is the total voltage and the current that we are referring to right.



This is what this is what the actual meaning of y11 equal to 0 means. So, what will be what will be the current voltage characteristics of I1 and with respect to V1? So, if I sketch so this for y1 equal to y11 equal to 0 what does the current voltage characteristics of I1 and V1 look like? y11 equal to 0 means the derivative of I1 and V with respect to V1 is constant right. So, all it means is that the derivative of I1 which means that I1 is constant with respect to V1 and this is probably for V2 equal to certain V2. That is all this is saying nothing else ok. Similarly, if we turn our attention to we turn our attention to y12 what is our y12? y12 also should be 0 and what does y12 signify? y12 signifies the relationship between the incremental I1 and the incremental V2 or in other words this signifies small i1 over small v2 is equal to 0 right.

So, again similar to similar to the curve of y11 equal to 0 this will also be a straight line right that is all that is all we can conclude and this is for some particular value of V1 which is equal to let us say V1 ok. Similarly, if we turn our attention to y22 right so y22 equal to 0 what does it imply? It implies small i2 over small v2 is equal to 0. So, from which plot would I from which IV characteristics plot should I get y22? So, I should be plotting I2 versus V2 and again what should it signify? Same old same old like the like the other two it should also be constant right and this is for certain V1 is equal to V1 correct ok. And similarly if now if we turn our attention to the last parameter right so last parameter is y21 and I want y21 to be as high as possible right y21 should be as high as possible which means that which means that i2 over V1 should be as high as possible correct. So, what does it signify I mean what should I be plotting? I should be plotting I2 with respect to V1 and what does it mean when I say I2 over V1 should be infinity? All it means is that the slope should be the slope of I2 over V1 should be as high as possible right the slope of I2 over V1 should be as high as possible right.

Now note that all I have done is extrapolated the total IV characteristics from the slopes right I have not done anything else when I said when I assume the statement that I made here right the statement that I made here that when I1 y1 equal to 0 means that when V2 is constant I1 is independent of V1 right and we essentially do a straight line parallel to the x axis or parallel to V1 to signify that the slope is 0. Now note that it did not necessarily be that the slope has to be 0 everywhere right what does slope 0 mean? You can have let us say I1 you can let us say have an IV characteristics a generalized IV characteristics which has a characteristics like this quite possible. So, note that there are two places in this IV characteristics where the slope is 0 right had this been I1 and had this been V1 then I could have as well said that at these two points y11 equal to 0 right. This could as well have been another I1 V1 characteristics right. The note that the four characteristics that I have drawn did not necessarily be the only possible solution right.

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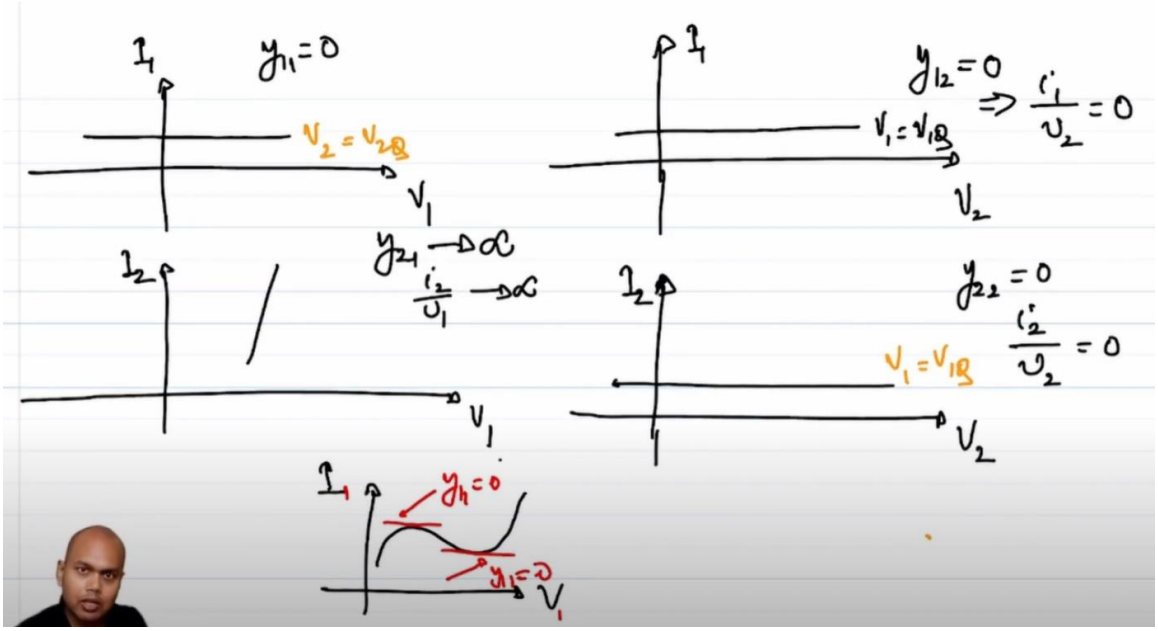
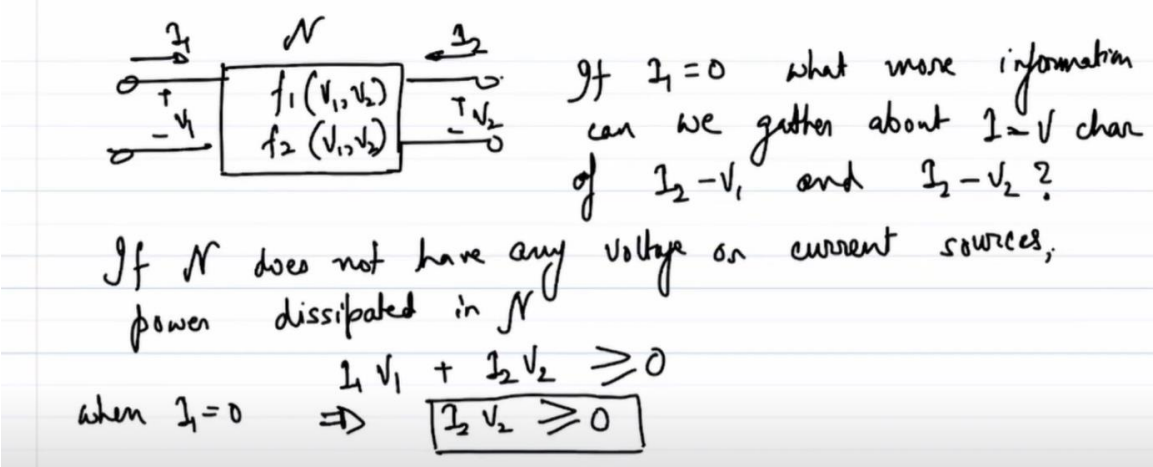
there can be many other solutions also why because we have simply extrapolated what we could have gotten from the slope and did not it need not necessarily be that the slope needs to be has to be constant right for all values of I1 and V1. So, that is something we should keep in mind right. Now with that disclaimer with that disclaimer let me now take some specific cases right. Now as it turns out right as it turns out this is just by the statement that I am going to make right now is based on the devices that we already have at our disposal right. So, as it turns out as it turns out in there are many devices in which in which I1 is close to 0 ok.



So, this is some devices have this for all V1 right. This is again the fact of I mean this is again the characteristics of certain device ok. So, now if I get I1 equal to 0 for any V1 equal to V2 I need not bother about the top two plots right. If I do not have to bother about the top two plots then I can as well say that forget about them let us concentrate on the other two plots ok. So, what are the other two plots? So, again so if I sketch our if I sketch the two port network in a generalized form and let me mark these as V1, V2 as we have been doing throughout.

So, as it turns out I1 is equal to 0 right. So, let us say if I1 is equal to 0 what more information can we gather about port, IV of I2 versus V1 and I2 versus V2. So, this is the question that we would like to delve into next right. So, now going from this information to the next information right what we are saying what we are essentially saying is that let us assume the stuff inside this box right the stuff inside this box does not have any extra power sources right. So, let us assume if N does not have any voltage or current sources right.

If N does not have any voltage or current sources then you might say if I mean I am probably violating one of the original assumptions that we made I am not violating because I am not saying There can not be any other voltage sources right. So, the voltage sources the extra DC voltage sources can be connected to can be connected to port 1 or port 2 right we are taking a special case right. If N does not have any voltage or current sources then what do you think will be what do you think will be the total power dissipated in the network can we can we make a comment on the total power that is dissipated inside the network right. So, the power sources and the power dissipated in N can be represented as I1 times V1 plus I2 times V2 right and if since N does not have any power sources which means it is a passive network right it cannot generate a power on its own which means the power dissipated will always be positive right. So, this has to be greater than or equal to 0.



Now given that I1 is equal to 0 that is the assumption that we took or that is a that is something that I just that I just took out of the hat right then under the condition that when I1 equal to 0 right then your I2 V2 should always be greater than 0 right. So, let us let us take a note of it because this will give us some important insight into the IV characteristics from which we are getting Y22 and what are those insights let us see. Now what when we when we said that my Y22 is equal to 0 what did we say again what is Y22? Y22 is the slope of the plot slope of the characteristics between I2 and V2 and when we said Y22 equal to 0 all we are saying is that right there is some region there is some region in this I2 V2 characteristics where I2 is constant with respect to V2 right that is all we are saying this is for this is for certain value of V1 let us say V1Q right. So, this is for V1 equal to V1Q ok So, now now what do you think will happen right what do you think will happen if I extend this plot to the right and to the left right. So, let us I mean can you comment on the generic trend of this plot if I extend it to the left right.

So, essentially what I am asking is that can you comment whether this plot in principle can go to the second quadrant. I would like to draw your attention to the fact that we have already we have already come up with a constraint that I2 times V2 has to be greater than

equal to 0 right. So, we have already come with a constraint that I2 times V2 has to be greater than equal to 0. What does it mean? It essentially means that the product of I2 and V2 is always positive which means that I cannot get into the second or the fourth quadrant right. So, I2 V2 characteristics always have to stay between the sec first and the third quadrant right.

So, all this is saying is all this is saying is you might have a flat region of I2 and V2 somewhere in between some range of I2 and V2, but ultimately this guy has to draw right. Ultimately this guy has to draw. Note that it does not say anything about how it is supposed to drop right. It can drop like this, it can drop like this, it can do this, it can be anything. It does not really comment on how it is going to drop, but all it says is that this current has to change from whatever value it had to 0 and maybe it can go down into the third quadrant also if necessary right.

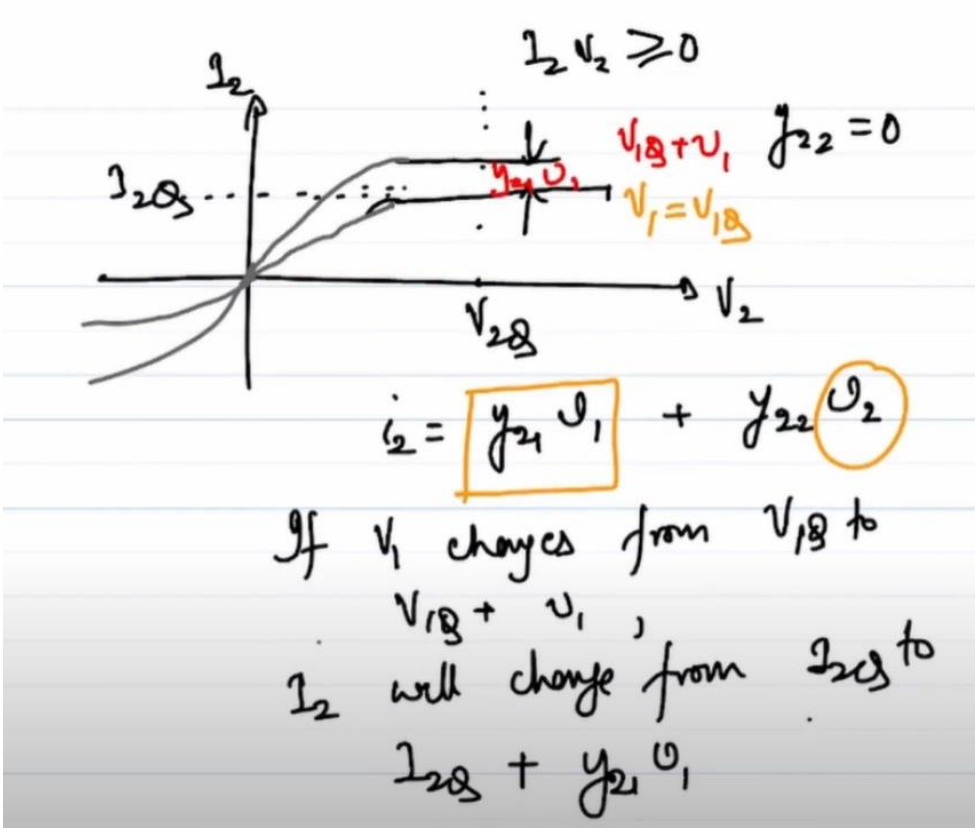
That is all that this is telling us ok. So, now let us say that I have changed this voltage V1 from V1 cube to V1 cube plus delta V1 right. So, if I have changed this voltage let us say from V1 to V1 cube plus small v1 what comment can you make about current I2. Let us say this current I2 here is I2 cube right. So, what comment So, what comment can you make on the current I2, Icube, I2 will it be the same I2 cube, will it be a different I2 cube, what do you think? In order to understand this we will have to go back to see what happens if what happens to I2 if V1 changes right.

That is what we have done here, that is what we are asking correct. So, incrementally what is the relationship between I2 and the port voltages I2 is incrementally I2 is Y21 V1 plus Y22 V2. Now, if we are concentrating on a particular value of V2 let us say V2 cube right. If we are concentrating on a particular value of V2 that is V2 cube then what is small v2? We are not changing V2 cube, if you are not changing V2 cube and we are trying to figure out what will happen to the current V1 changes what is small v2? Small v2 is essentially 0 right. So, delta V2 is 0 which means small v2 is 0.

So, which means that this current I2 is going to change by this amount. So, this will be the delta I2 right. So, if V1 changes from V1 cube to V1 cube plus V1 I2 will change from I2 cube to I2 cube plus this change which is Y21 times V1. And what you think Y21 is or the desired Y21 , is the desired Y21 is a large value right. So, for small changes in V1 we would expect we would expect this curve to shift upwards assuming Y21 is greater than 0 right.

So, which means that this curve will shift upwards and this change will be Y21, this change will be Y21 times V1. And similarly this curve will also have to somehow nose dive into 0 and maybe go into the third quadrant. Now note that again how it will go to the third

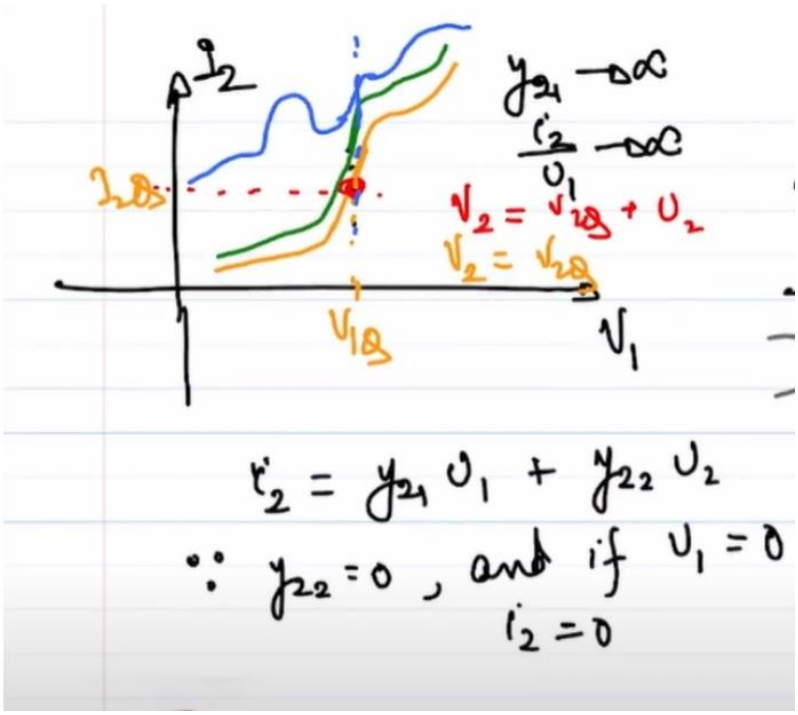
quadrant we do not know, but all we know is that it will go ok. Similarly, if I now further if I decrease if I decrease V1 from V1 cube to V1 cube minus some small delta this entire curve will shift to the shift downwards and we will have the we have the same mechanism ok. So, now let us shift our focus to the other curve the last remaining curve.



So, this is I2 V1 and we are saying that Y21 tends to infinity. Again Y21 means small i2 over small v1 tends to infinity which means the slope of i2 slope of the curve defining the relationship between i2 and v1 has to be very high right infinity means vertical line ok. So, which essentially means that all we are saying is around for let us say for some fixed V2 like V2 equal to V2 cube and let us say around some operating point V1 cube the curve needs to be very steep that is all we are saying right. Does it say anything what will happen if I deviate from V1 cube? It does not it does not say anything if I the wish list does not say anything if I deviate from V1 cube the wish list only tells us that if we all we know is that all we need is a is a is a is a place in the IV characteristics of i2 versus V1 where the slope is very high. It does not say what the slope needs to be if I deviate from that particular operating point right.

So, which means that it may it may as well be right. So, it may it may as well be that this goes like this right it may as well be that this goes like this right. So, can you now can you comment on what will happen like in case of in case of the plot on the right if I change V2 from V2 plus V2 V2 from V2 cube to let us say V2 cube plus I go from this. So, let me

mark this. So, let us say this curve is like this and we we change V2 from V2 V2 cube plus an incremental V2.



So, what is going to happen? What is I2 incrementally? My I2 is Y21 V1 plus Y2 to V2 right. If we are not changing V1 Q that is we are sitting on V1Q and we have changed V2 and I want to see I want to see what is going to be the what is going to be the change in I2 if I change V2 right. What is what is our Y22 right. My Y22 is 0 right. So, since Y22 is 0 and if V1 equal to 0 that is we are talking at we are sitting at a fixed V1Q then I2 will change in I2 will be 0 right.

So, your I2Q will still remain as I2Q right. So, this was I2Q. So, even with change in output voltage V2 this current will not will not change and it will remain exactly where it is ok. But note that note that this slope this curve will have the exactly same Y21 as another curve let us say which is shifted upwards, but having the same slope as V1Q as the as the as the orange line or maybe another curve will just come something completely crazy, but as it appears around V1Q has the same slope and goes something like this. All three of them will have the same Y21 because the Y21 has been evaluated by the slope at V1Q.

Now, if V1Q changes right if you bias your if you bias your network with a voltage which is different from V1Q is quite possible not even possible with the sketches that I have made you can see that you will have a completely a different value of Y21 ok. Thank you.