Course name- Analog VLSI Design (108104193)
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Now, we will come back, we just now saw that starting from first principles and some assumptions, some incremental assumptions, some exact, some assumptions which we just blew out of a hat, we could come up with a desirable IV characteristics of a two-port network, which can give us amplification of power, right. So now, as it turns out, as it turns out, there are two-port network, there are devices, right, which can be, which can be arranged in this form of two-port networks, which have characteristics similar to whatever we just plotted, right. A case in point is a device called MOSFET, right. So, as it turns out, if we, inside this two-port network, we assume that we have a MOSFET and we can further assume that one terminal of the MOSFET is shared between the input and the output and we denote this terminal as V2, denote this terminal as V1 and denote this current as I1 and denote this current as I2, right. Don't bother about the particular symbol as of now, but if we simply denote these currents and voltages as I1, I2, V1, V2 as shown here, as it turns out, the I1, V1 characteristics, even if before sketching the I1, V1 characteristics, let me simply write that I1 is equal to 0 for all V1 and V2. This is just how the device is, ok.

So, that makes life pretty simple, if since I1 is equal to 0, right, so Y11 is equal to 0 and Y12 equal to 0. So, we do not have to bother about different slopes at different operating points, right, as far as the input characteristics is concerned, right, as far as the slope between I1 and V1 and I1 and V2 are concerned. However, I2 is governed by this following equation, simply say that this is equal to some constant beta times V1 minus some constant Vth whole square, right. This is as long as V1 is greater than equal to Vth and V2 is greater than equal to V1 minus Vth.

So, this is just how the current equations are, right. So, if I sketch the I2 versus V1 characteristics, right, what will I get? So as long as if I, let us say, I mark out every point Vth, all these characteristics is saying is that above, as long as V1 is more than Vth and V2 satisfies this condition, right, V2 is greater than V1 minus Vth, then if I keep increasing V1, right, I should get a parabolic slope, parabolic looking curve, ok. What happens, this is for let us say certain V2q, V2 equal to certain V2q. What happens if I, so this will have to also ensure that V2q is greater than equal to V1 - Vth for all range of V1 that I have plotted it with, plotted the curve for, ok. So, what happens if I change V2, what happens if I change V2 from V2 equal to V2q plus small V2? What do you think will happen if we follow the equation that we have just sketched? Note that this equation is independent of, this current I2 is independent of the voltage V2, right.

So whatever happens at V2 will have no bearing on the current I2, which means it will follow the same curve, ok. So as long as these two conditions are met. What about the output characteristics of I2 versus V2? What is this equation telling you? This equation is telling you that for certain V1, so V1 equal to V1q, right, I will have certain I2 and the value of I2 will be say I2q which is equal to beta V1q minus Vth whole square, ok. And this value will be constant as long as, as long as what? This equation is telling you that for certain V1, so V1 equal to V1q, right, I will have certain I2 and the value of I2 will be say I2q which is equal to beta V1q minus Vth whole square, ok. And this value will be constant as long as, as long as what? As long as V2 is, as long as V2 is greater than V1 minus, this is V1q minus threshold voltage, right.

So at smaller values of, as you decrease V2, right, as you decrease V2, maybe at some switch or some point here, you meet V2 equal to V1q minus special voltage and the boundary of the V1q. The validity of this equation is, is this, is this line where V2 is equal to V1q - Vth, ok. So, what happens if I increase V1 to V1 equal to V1q plus small v1? What happens then? Will I2 change? Surely, I2 is going to change because now I have a new V1, right. So I2 will increase to a different value and what will be this increase? This increase will be equivalent to the increase that you, you plug in that new V1 into the, into the current equation, right, you plug in the new V1 into the current equation, and you will get an increase. Or in other words, if V1, if you assume that the V1 is small enough, if you assume the V1 is small enough where you can neglect the higher order terms, that is if you expand this quadratic, if you expand this whole square term, you will get a square law, you will get a, you will get a square term, you will get a linear term, you will get a constant term, right.

So if you assume that the quadratic terms are small enough to be neglected, this increase, increase in I2 will be how much? This increase in I2 will be Y21 times V1, right. And again, what will be the range of validity for this flat line? This will be L, this new V1Q plus V1 minus Vth, right, okay. Now note that this equation does not tell us anything about what is going to happen, what is going to happen below V2, below the condition where you breach this limit of V2 to be greater than equal to V1 minus V, right. As it turns out, as it turns out, there is also a nice flow from expression for that. But I mean, even if we, even without going there, we know that this is going to, this is going to somehow dive, somehow dive into and go to 0, right.

That is all we know at the moment. We do not know the exact equation which will result in this diving, right. But we know that it will, it is going to, it is going to go to 0, okay. So even before, even before moving on, let me make couple of very important points here. As it turns out, these, this IV characteristics that we have sketched here are particular to a MOSFET.

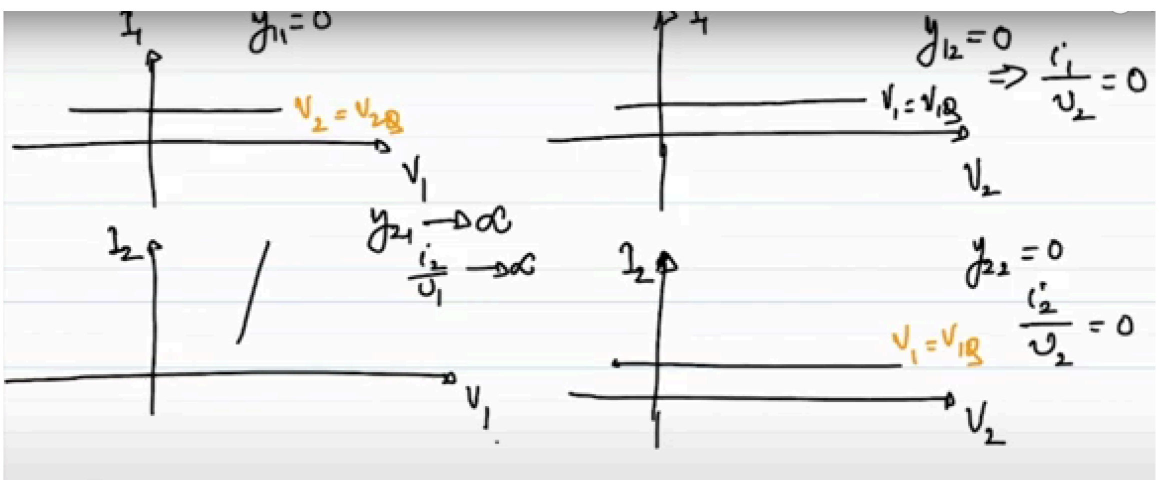
But note that the IV characteristics that we arrived at, right, the desirable IV characteristics that we arrived at are not particular to a MOSFET. That is particular to any device, right, that is particular to any device that has, that you can make, that you can, that you need to make an amplifier, right. So if you go down the history, and you will see that before MOSFETs, there were BJTs, right. BJTs are still present, they are still used, but not as widely used as BJT, as MOSFETs. But however, still there are BJTs whose input-output characteristics look almost similar to the whatever we see here.

Even before BJTs, there used to be vacuum tubes, right, whose input-output characteristics again, looked almost exactly what we came up with from scratch. Tomorrow, if there are new devices, you will see that you have FinFETs, get all around devices, gallium arsenide, gallium arsenide, and so on and so forth. All of them fundamentally have similar IV characteristics. So, it is not a coincidence that all of them have similar IV characteristics. In fact, the story goes the other way round.

The logic goes the other way round. What is the logic? The logic is in order to get an amplifier which can amplify power, we need these type of, we need devices which have these type of IV characteristics. Now as a circuit designer, if you lay down the law and say that I need these kind of devices which have these kinds of or rather I need devices which have these kinds of IV characteristics, then you go to your, then we go to our device colleagues and ask them, hey see, this is what we need to get a power amplification. Can you make a device and give it to us? They say sure enough, not only one, we can give you different flavors of devices whose IV characteristics look like this. Now note that the devices that I named before, right, right from vacuum tubes to BJTs to MOSFETs to Gallium Arsenide FETs, JPETs and pinFETs and so on, all of them can have completely different underlying physics, can have completely different transport phenomena as to how the current flows inside the device, right.

However, for the purpose of designing a circuit at the level in which this course will concentrate on, you do not need to know how the transport of current or how the transport of the electrons or the holes inside the devices take place, right. All we need to know is the, is the, is the underlying IV characteristics. Now note that these underlying equations of the IV characteristics will also depend on the type of, type of devices that we are, that one is going to use. However, however, they will look similar, they will look, they will look similar in terms of their incremental properties will look similar and what will they look like? They will look like Y11 will be close to 0 or exactly 0, Y12 will be close to 0 or exactly 0, Y22 will be close to 0 or exactly 0 and Y21 has to be very high, right. If you do not have these properties in a device, you cannot make a good amplifier.

Now as it turns out, all the devices that we talked about, right, are also three terminal devices. However, you can make a two-port network with a three terminal device also, right. So, all these devices are three terminal devices, and they have input output characteristics which are, which mimic, which mimic the conditions that we have been discussing till now. In this particular course, we will deal solely with MOSFETs and we will from the next class onwards or from the next lecture onwards, we will concentrate on the operation of a MOSFET under different conditions, under different operating conditions, like what happens if I increase V1, what happens if I increase V2, what happens if I decrease V1 or decrease V2 and what are the particular governing current voltage equations that we need to, that we need to deal with, but in doing so, we should not lose sight or you should not lose sight of the fact that if tomorrow you are given a different device, right, you should not throw up your hands and say I did not study, I did, I mean, the course that I took was only on MOSFETs, so I cannot, I cannot design circuits with these. You should, what you should imbibe is the thing that you should take away from this course is the fact that the first thing that you have to do is something somebody gives you a device is to, is to plot the IV characteristics and see whether in some portion of the IV characteristics are you able to satisfy those four conditions, right, simultaneously, right.



So you should be able to satisfy the conditions of Y11 should be equal to 0 or close to 0, Y12 should be equal to 0 close to 0, Y21 should be as high as possible and again Y22 should be close to 0 or equal to 0, right. As long as the new device that you are encountered with satisfy these four conditions, right, you should be able to make a decent amplifier. Now the details of when the current voltage characteristics change from the idealized case will depend on the device physics or on the, which in turn governs the current voltage equations. Then at the second order level, you need to know the exact current voltage equations which are going to affect your design, right. But as long as you know, as long as you know what your expectations are and the fact that the device that you are dealing with meets your expectations, you should be able to design an amplifier.

And from the next lecture onwards, we will concentrate on designing one such amplifier, right, using MOSFETs. Thank you.