Foundation to Computer Systems Design

Indian Institute of Technology Madras

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Department of Computer science and Engineering

Module 1.2 CMOS Transistors and Gates

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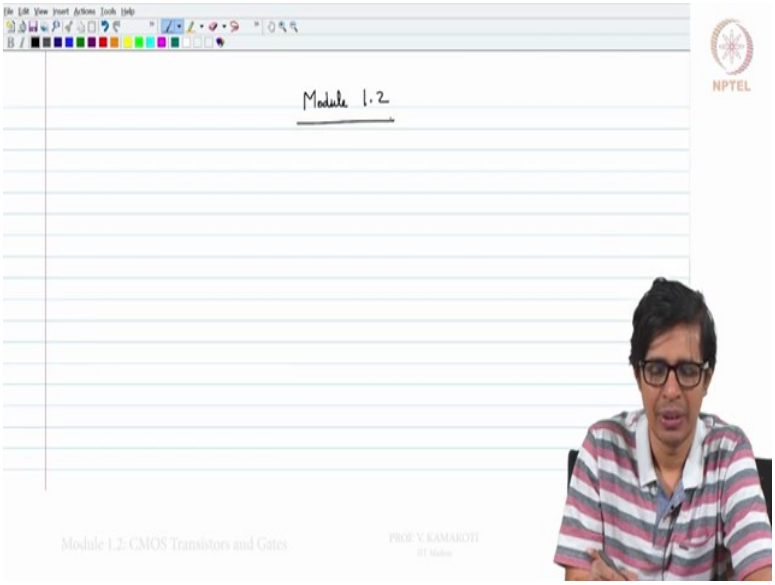

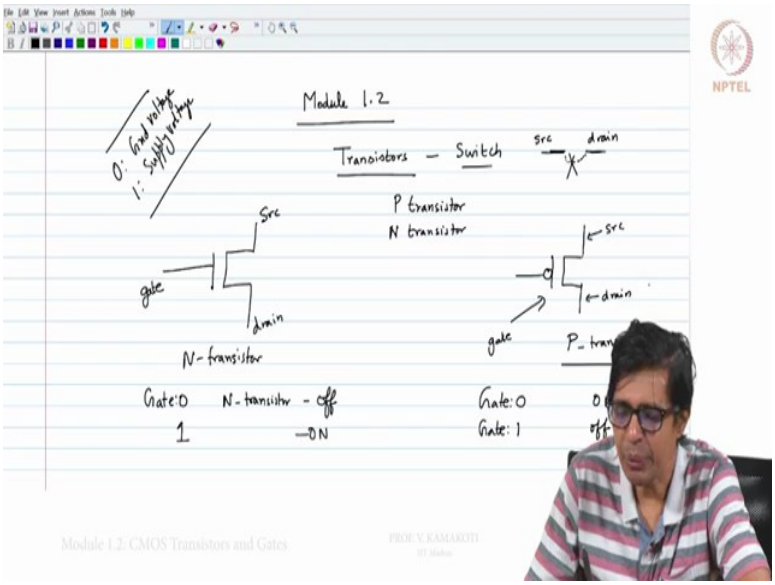

Module 1.2 we will be discussing the transistors in this particular module. What is a transistor? You would have studied this in your plus two physics for sure. Transistor for our understanding is nothing but a switch so what is switch if you so a switch basically connects one part of what you call as source to another end which you call as drain a which basically connects the source to the drain.

Right so when when the switch is on the source is connected to the drain then the switch is off the source is disconnected from the drain so this is the basic on off switch so the transistor essentially behaves as an on-off switch there are two types of transistors one is called a P transistor.

And another is called an N transistor as we have mentioned since the transistor is a switch the P transistor is symbolically represented like this where there is the source, there is a drain and there is a gate, there is call a gate which will close which will connect the source to drain when the transistor is on and which will disconnect the source to drain when the transistor is off.

So this is the P transistor please note that there is a small bulb circle here so this is the P transistor. There is another type of transistor which is called the N transistor it also behaves in a similar fashion so this also has a source this also has a drain and this also has a gate. The distinguishing feature between the P transistor and N transistor symbolically if there is no circle here in the entrance.

But there is a circle here so what is the difference in the functioning of the N transistor and the P transistor?. The difference in the functioning of the N transistor and the P transistor is when the N transistor when the gate is zero, N transistor is off that means the source is not connected to that (())(3:26) when the gate is one then the N transistor is on that means the source is connected to the drain.

On the other hand P transistor works exactly opposite then the gate is 1 gate is zero the P transistor is on while the gate is 1 the P transistor is off. What you mean by zero and one. Zero and one are the basically voltages the zero corresponds to what we call as the ground voltage the one corresponds to what we call as the supply voltage so the transistor has a supply voltage.

And there is supply voltage and there is a ground voltage so when for our understanding if I apply the ground voltage to the N transistor it gets off if I apply the supply voltage then its gets ON the exact opposite happens in the case of P transistor for you to quickly remember N transistor works normally.

Normally zero means off 1 means On, right so N transistor works in that normal fashion so P transistor works exactly opposite to it so this is how we can make a distinction in the functioning of the P transistor and N transistor. Now the (())(4:59) computer your mobile phone which has close to a billion transistor now has such transistors and the entire system is built out of these transistors very quickly we will see what is it that we can do?

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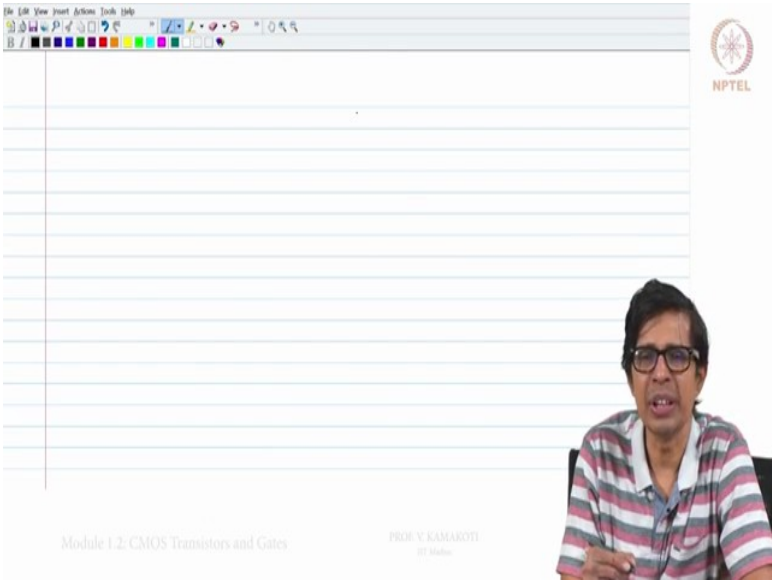

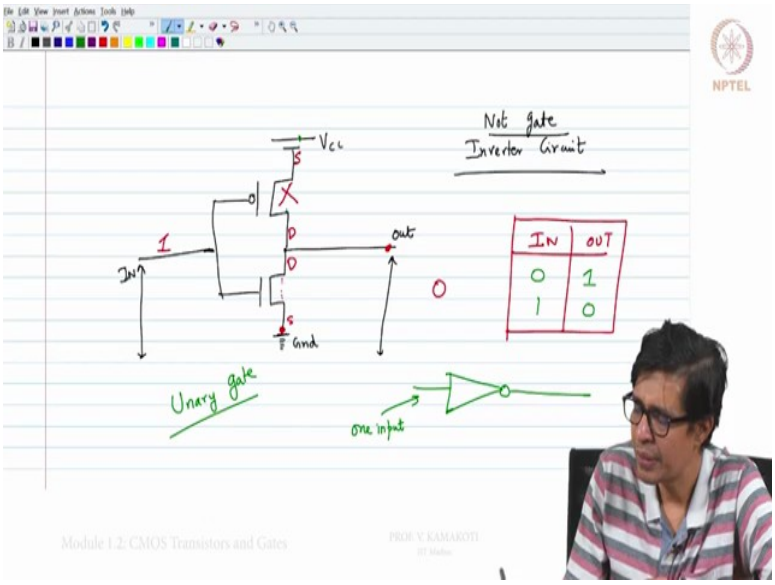

You have seen this N and P transistors right so I will now give you a simple circuit in which you give a zero you get one and when you give a one you get zero so this is called a not gate or an inverter circuit. So how is a not gate formed? Let us say how it is going to be I put a P transistor I put another N transistor and I connect them together this is the drain this is also the drain this is the source.

Now to this part I basically gave the supply voltage what you called as VCC and to this I put the ground it is the ground. Now I am this is the input I am giving to the circuit and which is the output I am going to collect out of the circuit. Now suppose I give of zero as an input when zero is applied to the P transistor what will happen it is switched on that means the source is connected to the drain when I give a zero to the N transistor what happens it switched off.

And that means the source is not connected to the drains so this is basically open so since this source is connected to this drain this means this is now short for all practical purposes we can view it as a short and this is open because this is this connector so this point and this point are the same so when I measure the voltage here what will I get this is VCC and this is (())(7:59) and the I get VCC that is one.

So when I apply a zero to the circuit I basically get a one. Now let us go and apply a one to the circuit when I apply a one the N transistor is switched on that means the source connected to the drain while the P transistor is switched off so this is open so this point as you see is

equal to this point because this is close and this is open. So when a measure the voltage across this what we get is ground because these two are same.

So I get clown voltage which is zero so when I apply a one I get a zero. So now this is not gate where in this is the input and this is the output when I apply zero I get a one when I get one apply zero this is represented by the symbol in digital electronics so this is how a not gate is built out of a simple inverter. Now let us built so this is basically a unary gate.

Because it has 1 input this has only one input now let us built something which is a binary gate.

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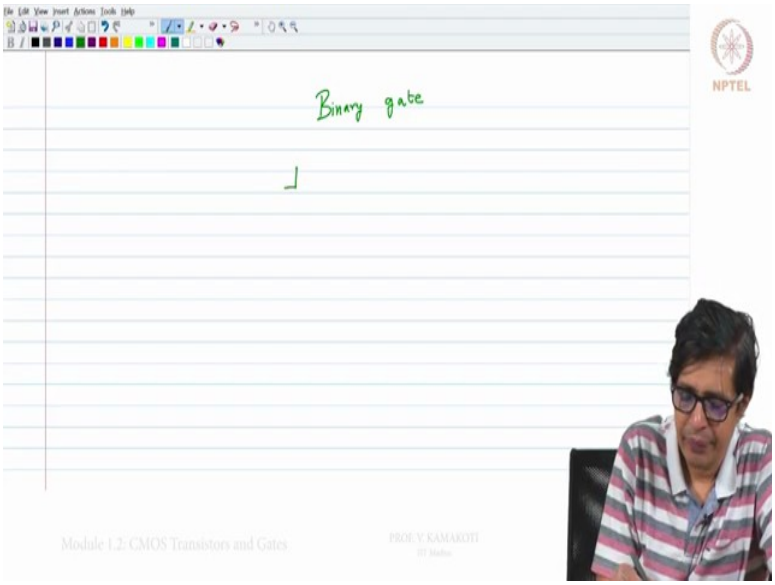

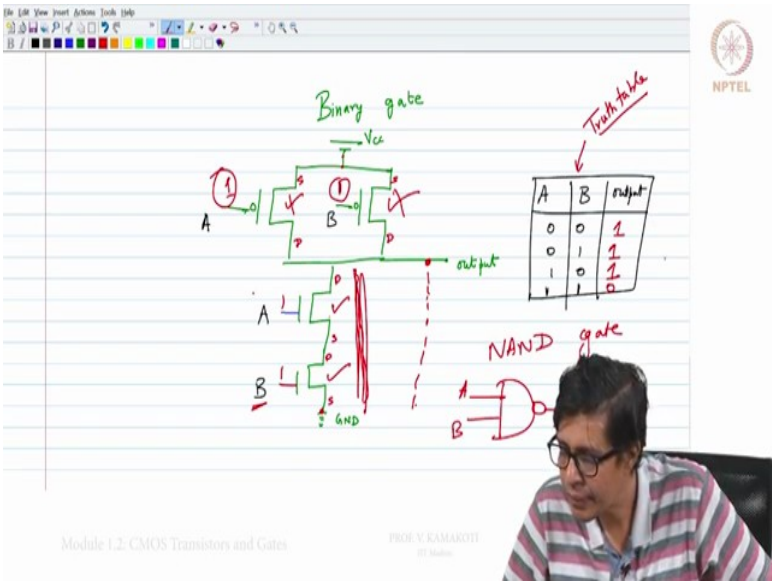

I put one P transistor here another P transistor here and I put two N transistor here so let us let me just this is ground and this is ECC and this is output these are the inputs this is A and B the same A and B are given here also now let us see so what are the different inputs I can give for A and B so I can give a zero or 1 for the each so these are all the probable com these are all the possible combinations.

I can give a zero zero, zero one, one zero and one one so these are all the probable comb possible combinations for A and B so let us see zero zero, zero zero, zero zero the same A is

given here same B is given here, right when zero is given this is on this is also on that means your source is connected to the drain while this is off and this is off these being N transistor given zero there after pins these are disconnected.

So when I look at this point since both of them are connected this point and this point this point are the same right because these are essentially for all practical purpose it is behaving like a short. Because this are open close these are on that means source and drain are connected so when I apply the when I measure the voltage here what I see is one now let us go for to the next step.

And say I am applying zero one, zero one what could happen this on this is off this is off and this is on. So now what happens since this is off that means source is connected to this source is not connected to drain this whole circuit here as you see since this an a N transistor is off this whole circuit as you see here is off is this connected so this is open while since this is on though this is off there is shot from VCC to this output so when I measure the output here output at this point here since this N transistor as you mark is off.

So this entire part here as you see is out it is disconnected to the ground so the VCC is connected to the output so when I measure the signal at this part across this output you basically get a one. The same things happens when I apply one zero, one for A and zero for B note that the N transistor to which B is connected is off now though the A transistor is on where since they are in series this entire part of this N part is disconnected while the P transistor to which A is connected is off.

Because we have given one here but B transistor is on because we have given zero so the VCC there is a path between VCC to output so when I measure the output here so you get VCC now this one now let us take the last part which is one one when you put one one both these A and B that both the P transistor to which A and B are connected they have no disconnected because they are given one to each.

And they are P transistors so P transistors is again one (())(15:32) and both the N transistors are on because we are given one both the N transistor are on so that means so the output spot and the ground. Ground just connected to the output because this is for all practical reason this entire path that I am shading here is going to be a short well there is no connection between VCC to output.

So what happens is when I measure this it gives me a zero so this is a function which takes 2 inputs and give us me a output this gate is called a NAND gate. And this is given by the symbol even A B and this is the output. The behaviour of this NAND gate is basically described by this table they says that if you give these 2 inputs this is the output and for every combination of this input it gives output.

So what we see here this is called the truth table of the NAND gate. Similarly, if you go to the previous one this is the.

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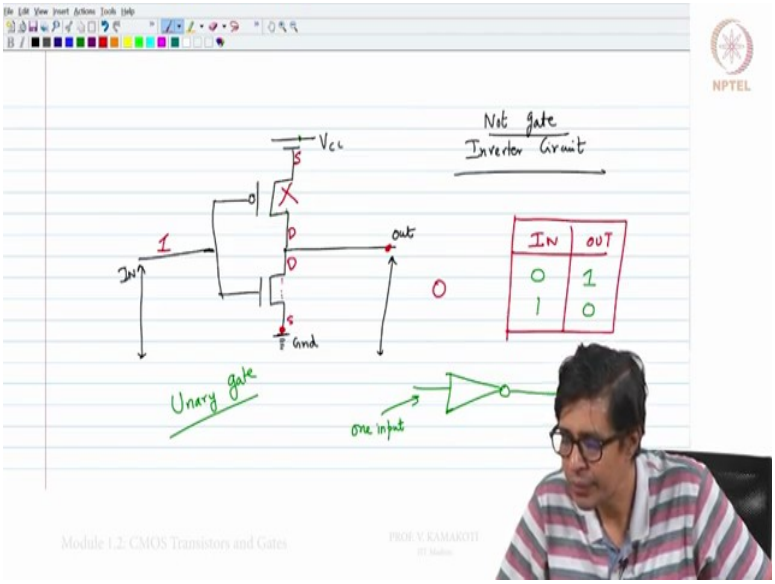

This is the truth table for the not gate right so what we have.

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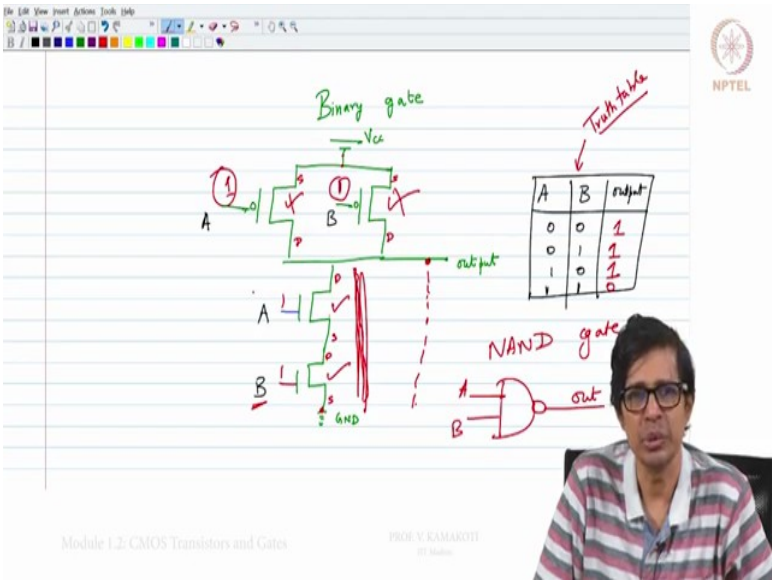

What we have seen in this course in this particular module on point two is a word transistor and how we can use transistor to built basic gates now the entire system is now built using this kit specifically in this course we are going to build entire computer using this NAND gate and we will see how it is going to happen. Thank you!