Digital IC Design
Prof. Janakiraman Viraraghavan
Department of Electrical Engineering
Indian Institute of Technology, Madras

Lecture – 08
Drain Induced Barrier Lowering

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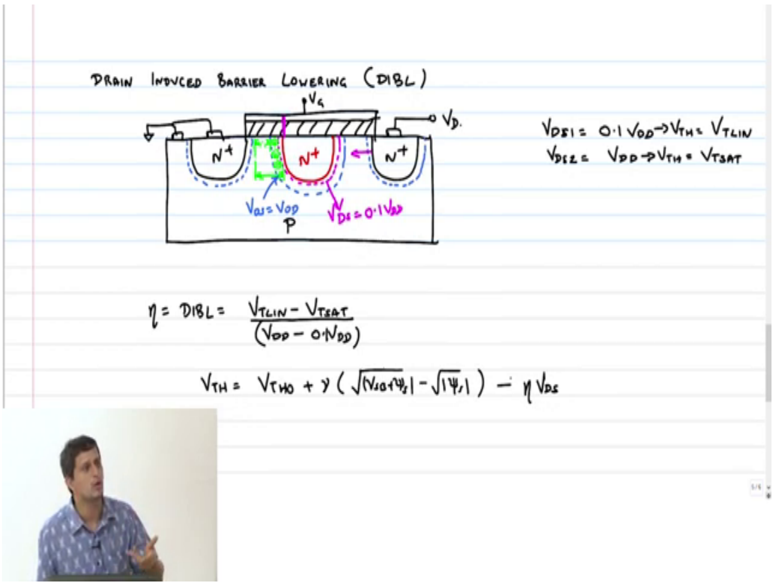

So, with that let me move on to the next short channel effect which is known as Drain Induced Barrier Lowering, DIBL, ok. So, this is the effect that I was talking about yesterday where because of this depletion region eating into your channel the threshold voltage also changes, ok. Now so, let us look at this N plus, N plus, P and this is my source, drain, body, grounding these two V G and my V D.

So, in a long channel device if I changed my drain voltage from say 50 milli volt or 0.1 V DD to V DD let us say there is a technology, where there is some V DD given to you. If V D 1 V

DS 1 equals 0.1 V DD and V DS 2 equals V DD and then I find out what the threshold voltage of this transistor is and how do I find out what the threshold voltage is I have to increase my gate voltage.

So, that surface potential is developed in whatever particular way right as per the definition right. Are these two threshold voltages expected to be the same or different? Same, if it is a long channel device you saw the expressions that we derived it had no dependence on V DS right which is quite understandable and the reason for that is of course, this depletion region sitting here, ok.

Now, this depletion regions width or length right or the depth of this depletion region is does not go far into the channel. So, therefore, it is negligible and the effect of this V DS is not seen on the threshold voltage. Of course, now if I bring this really close right and make a short channel device like this N plus, then this depletion region can look like this when V DS equals V DD, right and look like this if V DS equals 0.1 V DS, ok.

Of course now because this of course, by the way here my gate is only two here because it is a short channel device, I moved the dream from there till here short channel device. Now of course, it is true that because the depletion region has gone far into the channel, right. I have been able to generate some depleted charge carriers here already which means part of the channel has already got depleted because of my drain, drain voltage that I have applied, the gate has not yet done anything, ok.

Now, if I start ramping up the gate voltage the gate has to deplete only so much of the channel right, on the other hand if V DS was 0.1 V DD then the gate would have to deplete all the way till here right, there is more part of the channel that it has to deplete. Therefore which threshold voltage do you think is going to be higher 0.1 V DD, it has to do more work and therefore, that has to be.

Now, if V DS is very small, and V GS is fixed right let us say what region of operation is the transistor V DS is very small V GS is quite large linear region, right. Therefore, the threshold voltage corresponding to this region right V TH is called V TLIN, threshold voltage of the transistor in the linear region of operation and this; obviously, is called V TH is called V T SAT, for long channel devices V T SAT equal to V T LIN. But for short channel devices these two numbers are different and they are different because of the intuitive explanation I gave you and that is called drain induced barrier lowering, ok.

So, the DIBL coefficient is my V T LIN minus V T SAT divided by whatever my V DS whatever voltage I applied on the drain for the saturation read let us me let me call that V DD and this is 0.1 V DD, the threshold voltage gets altered because of this. So, the V TH will become like V TH naught plus gamma times root of V SB plus psi S minus mod psi S, right.

What should happen now, suppose I call this as eta how should this thing change, should it be plus should it be plus or we will put the sign later eta times V DS, right. Ultimately, it is a V DS the drain the drain voltage is inducing a barrier lowering right and it is barrier because the energy bands actually drop, lowering the barrier allowing more electrons to go through and all that. So, what should be the sign here, it should be negative; threshold voltage should decrease if my V DS increases, yeah.

Yeah, I am just saying that; no, what I am saying is by long channel definition itself all these changes are negligible. Of course it does happen what you are saying is true, but that eta coefficient will be so small that it will not really affect your value that is all, yeah.

So, now, this actually is not a good thing by the way ok, even though the threshold voltage actually comes down it means your current goes up you may think well that is a great thing, right. I can get more current out of the transistor, but this is not a controlled way of doing it and therefore, which also means that you will have more leakage which I will talk about later, you will have more leakage current which is again not a good thing. So, therefore, you have to do something to control this particular, control this particular phenomenon of DIBL.

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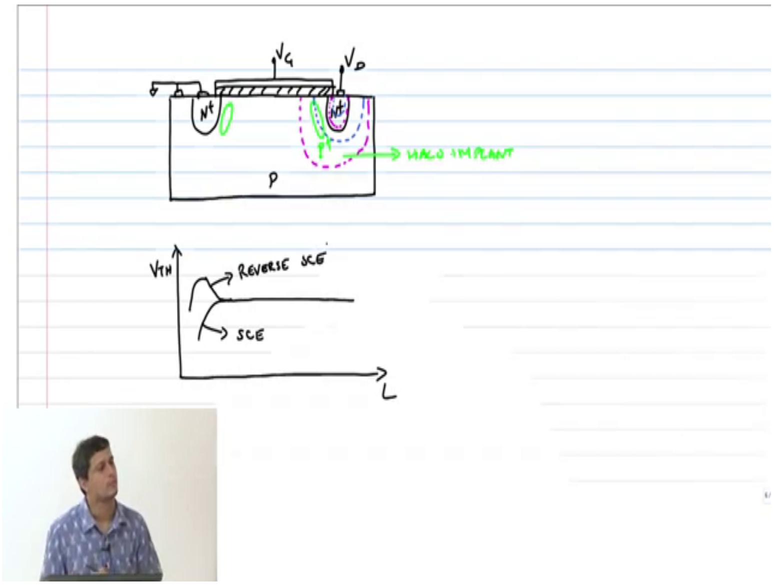

So, what do people do? So, we will go and invoke our p-n junction idea that we had discussed right, we discussed about three ideas; so, N plus, P again my gate and oxide and all that. So, what is the problem my problem was my depletion region was actually going into the channel like this and why was that happening because this is an N plus P junction. So, V D, V G sorry V G right body is grounded, V D is a positive voltage and therefore, that is reverse bias junction and that is going in.

Now, the problem is because it is N plus P, the depletion actually penetrates farther into the P then into the N plus, right. So, just think about this you add what is known as an P plus hallow implant here, this is the P plus hallow implant, ok.

Now, what will happen I apply v ds, but because this is P plus and an N plus junction now, the depletion region will penetrates further into the N plus than the previous case, right. So, effectively if this was my earlier depletion region that was formed now, it would simply come down to let us me just blue, it will come down to this because the P plus is there just near that diffusion region, right.

Of course, earlier if my depletion region in N plus was still here now, it will go in further, it will go in all the way to here effectively. So, what we are saying is it does not matter if you penetrate into the N plus region, do not penetrate into the channel that is the intuition behind a hallo implant, ok. Now, the question is it enough if I do this only on the drain side.

Why? Yeah.

Leave it, yeah. But the catch is physically if you look at this structure of a transistor, they are actually reversible terminals. In fact, unless if you give me just a transistor and ask me and give me two diffusion and say which is drain and which is source I will say I do not know you have to tell me what potentials you applied where that is what determines, what is the drain, what is the source current will always flow from a high potential to low potential.

So, therefore, the one on the higher potential for an NMOS transistor is the drain, the other potential is the source. Now, in in my circuit I could well reverse these two voltages have V D applied here and ground that end. So, therefore, I need to do this on both ends, structurally they are the same in a BJT for example, this is not how it is physically it is different. So, I cannot actually swap the emitter and collector, it is defined physically and in only one way whereas, for a NMOS transistor that is not true, ok. So, this now brings us to what is known as dependence of V T on channel length. So, if channel length is long what will happen to the V T? Yeah.

It is basically a constant, it will be like this. Now, which short channel effects coming in right basically which means that I am having this depletion region eating into the channel, then what will happen to the threshold voltage as I reduce the channel length, it has to decrease. So, this is what will happen. Of course, we have not captured this in our threshold voltage equation completely, ok. So, it is very complex and that is why that that model file that you saw yesterday had 54 parameters in there to capture all these effects, ok.

So, this is basically the short channel effect, now because of this hallo implant to avoid this DIBL we put some hallow and reach something, what should happen to the threshold voltage there you, it will actually go up because now the bulk is not just P part of it is P plus, right. So, the threshold voltage if you remove a threshold voltage it goes a square root of N a, that N a concentration has gone up in some regions, ok.

So, therefore, threshold voltage will go up this is called reverse short channel effect because of the hallo implant it will go up a little bit and of course, after that it has to come down because beyond the point if you make the channel length so, small your depletion region will start eating into the channel eventually, right. So, this is called reverse short channel effect or this is the effect of the hallo implant that we have put in the drain and source end of the transistor, ok.