Analog Electronic Circuits
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Lecture - 14
Introduction to Robust Biasing

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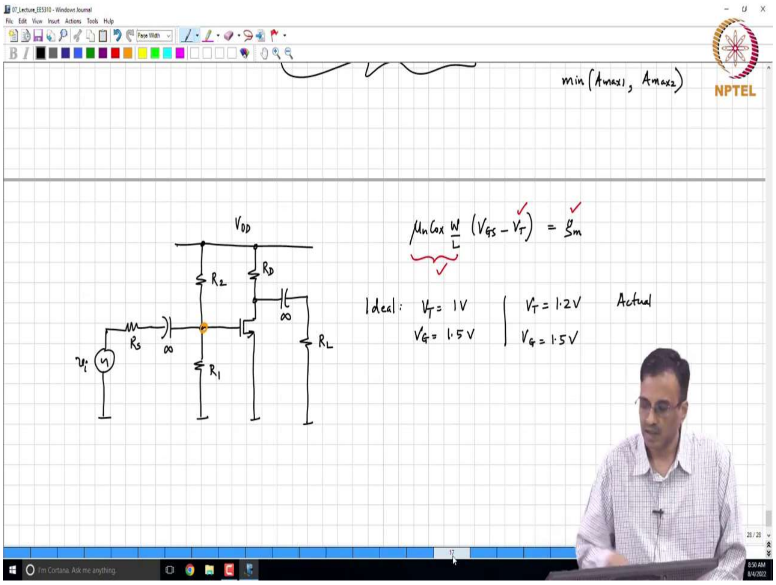

Alright. And these are the infinite Capacitors. So this is a perfectly valid design and then if you hook it up in the lab, it will work. Unfortunately, there are few problems. What are the problems? What do you think might be practical problems?

A capacitor we know I mean we cannot put infinite capacitors, we will put finite ones. And what I am referring to is basically the transistor itself, right. The transistor itself, remember, the properties of the entire circuit depend critically on the fact that the transistor is biased properly, right?

So, we have gone and you know let us say we want a certain g m, what are we going to do?

We know the properties of the transistor, correct. So, we know that let us say we know μ_n C_{ox} W/L and V_T. So, what are we going to do? We are going to basically say well,

μ_n C_{ox} W/L (V_{GS} - V_T) = g_m. So, we know this let us say. We mean we know what we want, ok. We know this and we know this. From this we go and calculate V_{GS}, that is needed to get this g_m. And once we know V_{GS} and we know V_{DD}, we go and pick.

I mean this is the reverse process, right. So far we basically found an incremental gain. Now, we say this is the incremental gain we want, that is what you do in a real design, right. Nobody gives you; I mean you know as an engineer I mean it is very rare that you know you will be somebody who will give you a circuit and say analyse this, ok.

It is more like, you know I want this to happen, tell me what I should do, correct. So, that is the design process. So, let us say we want to choose component values. So, that the gain is a certain value. We know the load resistor R_L and therefore, we know what the g_m should be, ok.

If you know the g_m and μ_n C_{ox} W/L and V_T, then we can find V_{GS}. Once you find V_{GS}?

Student: We can find R_1, R_2.

We can find R_1, R_2. And yeah and then you are done, alright.

Now, unfortunately it turns out that when a transistor manufacturer gives you a transistor, the data sheet only contains what are called nominal values for the transistor parameters. So, for example, μ_n C_{ox} W/L they will say, I do not know, maybe 400 micro amperes per volt square, right. It does not mean that if you take 100 transistors, all of them will have the exactly identical μ_n C_{ox} W/L. The same holds for the threshold. So, the threshold voltages of the devices are nominally, only nominally specified. They will change from that nominal value, ok.

Let us say the manufacturer told you V_T is 1 volt, but there is a spread. It is not uncommon to have maybe 50 millivolts, 100 millivolts change in the threshold voltage, right. Likewise, the same holds for the V_{DD}, correct. I mean all of you know that you know with all battery-operated devices, the voltage across the battery is very different when it is just freshly charged to when you go on discharging, right. And so, I mean, you cannot tell the user that you know my circuit is only going to work when the battery voltage is?

Student: 3 volts.

Is 3 volts, otherwise you know tough luck, you know your phone will not work, right, ok. The other thing is that this μ_n is mobility. All of you know that mobility is dependent on?

Student: Temperature.

Temperature, right. And you can say you cannot say well my phone only works in Paris, it does not work in the local Paris. So, right, ok because it is too hot, tough luck, that this kind of thing does not work. So, what we wanted to do therefore, as a designer your job is to make sure that I mean you know now saying my circuit must work for all V_{DD}s also is a bit too much, right. Then, somebody will say I will remove the V_{DD} and then you know then also it must work, right. So, obviously, that is a; that is another extreme. So, all that we must say is that for a reasonable range of variation of V_{DD} and temperature and V_T, you must make sure that the circuit works. Does make sense, alright.

So, for example, I mean you know let us take let us you know given that practical constraint, let us say we assume that the V_T is something, right. It turns out that the change in V_T is actually one of the most critical things.

Let us say we have gone and designed our circuit such that we assume that $V_T = 1$ volt, ok. And unfortunately, the transistor came back from the fabrication house and the V_D turned out to be not 1 volt, but 1.2 volts, ok.

So, earlier let us say the quiescent voltage, so ideally V_T was 1 volt and the gate quiescent voltage was 1.5 volts, alright. R_2 and R_1 and V_{DD} were chosen such that the gate voltage was 1.5 volts because we wanted a $V_{GS} - V_T = ½$ volt, ok.

Now, you know the transistor comes back from the fabrication foundry, the V_T, you thought it was you designed your circuit assuming it was 1 volt, unfortunately it is now 1.2 volts. So, what happens to the gate potential now?

I have replaced the transistor, what comment can we make about the gate potential?

The gate potential, the gate does not, I mean that that potential divider does not know anything about the transistor, right. The gate potential still remains?

Students: 1.5 volt.

1.5 volts. So, what has happened all of a sudden?

The g_m which was μ_n C_{ox} W/L times ½ volt has now become 0.3 volts, right. And therefore, the trans conductance is reduced. As a consequence, what comment can you make about the incremental gain?

Incremental gain is changed, right and not only that the swings also will change, ok. So, you can see that this is quite a disruption, right. Likewise, I mean and this is just merely with the threshold voltage change. If the supply voltage changes by 10 percent, again you know a common thing in all electronics is that all your circuits must work. The circuits that you design must work with plus minus 10 percent change in the supply, ok.

And please do not confuse this with the variation in the battery voltage. The battery voltage will change from you know 4 volts to 2 and half or 2.7, ok. That is a much larger change. There are already circuits there which make sure that in spite of the battery voltage changing the voltage that is going to all your ICs on your cell phone, they are all very well controlled.

In spite of the battery voltage changing by a large amount. In spite of that all circuits are to be designed to have plus minus?

Student: 10 percent.

10 percent or maybe plus minus 5 percent depending on chips R. But the reason for that is even if you apply the nominal voltage at the pin of the chip, right internally that voltage is going to be routed to a whole bunch of circuit blocks. And they will always be I R drop along that path. And therefore, the voltage will drop, ok.

So, your circuits internally must work, and are often designed to be compliant with ±10 percent. So, if the threshold voltage changes and the supply voltage changes, then you can see that you know what you thought should work will no longer work as intended because the key problem being that the operating point of the transistor is?

Student: Changed.

Is completely modified, alright. And the root cause of the problem as you can see is that this the equivalent of this battery here, I mean remember as far as quiescent operating point is concerned all these are irrelevant, right. And this is nothing, but what is that input network doing all that it is doing is generating some bias voltage and applying it to the gate.

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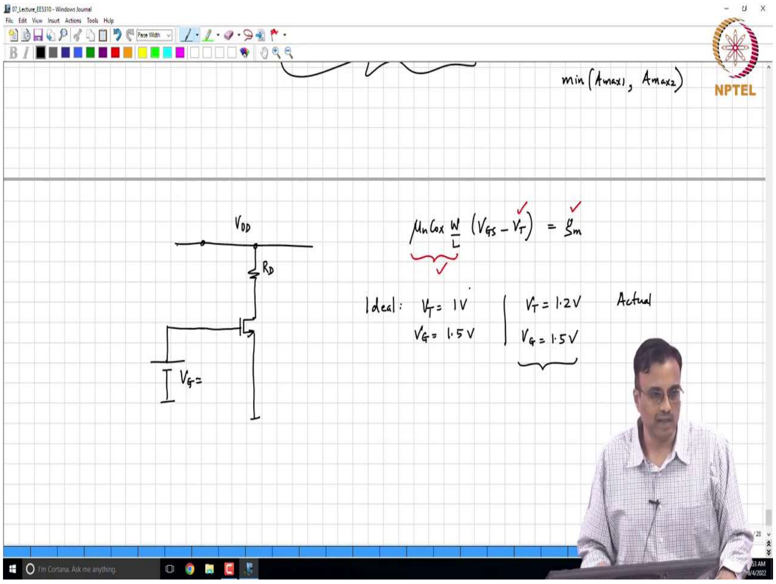

And the root cause of the problem is that this battery that V_G is a dumb battery. Does it know anything about this?

Student: Transistor.

About the transistor, right, ok.

If the transistor's properties have changed the battery does not know that the threshold voltage has changed. And therefore, it continues to give the same old voltage it was giving earlier, alright.

What we therefore need is within codes an intelligent battery which will somehow figure out what the V_T of the transistor is and give that appropriate voltage. For example, what should have been the battery in this case?

Students: 1.7.

Yeah, 1.7, correct, ok. So, in other words, we would basically need to be smarter than we are now, ok. And most of the time you know whenever you might say that how is it that you know the device engineer you know that is his fault, I mean how can he basically say the threshold voltage is 1 volt and give me something with 1.2 volts, ok.

You can say that ok, but then there will be a smarter guy who comes around and says I will work with a device with whose properties win, alright. So, the saying that the threshold voltage variation should not be this large is not an option because when you manufacture something there will always be variations, ok. So, what should we do? Therefore, it figures out a way in which one can change that bias voltage in a way that depends on the actual threshold voltage of the transistor, right? And fortunately, you know as I say when God closes one window, he opens another, right, it turns out that yeah when you manufacture a million devices, right. The threshold voltage of these devices may not be equal to the nominal voltage. But all of them will be equally bad.

On an IC, right, I mean you thought that your nominal threshold voltage of the transistors you build on an IC is 1 volt, but it turns out to be 1.2 volts. But if you build it turns out that on a chip if you build 100 transistors, it will turn out that the threshold voltage of all the 100 transistors is 1.2 volts, ok.

So, I mean they are like Siamese twins, right. They go through the same processing all through. So, basically, all the transistors will be bad, but they will be just, they are all donkeys, but they are all identical donkeys, right, ok. So, you can use one donkey to figure out what the properties of the donkey are and then go and use that medicine for the other donkey.