Power Management Integrated Circuits
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Lecture - 27
Offset in Amplifiers; Real Life Analogy; Static Offset Cancellation

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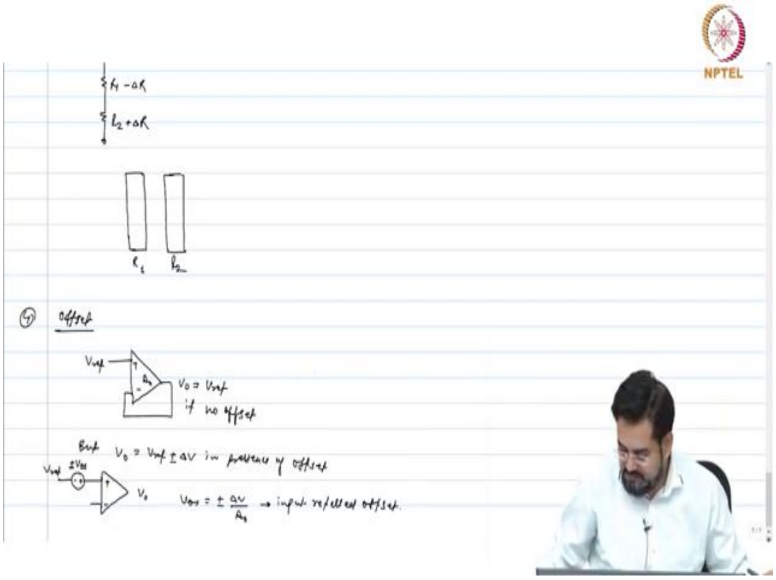

What is offset in your amplifier?

Correct ok. So, both definitions are correct. So, it is a just matter of how you explain it. So, if you are not giving any input means, not giving any differential input. So, when you short the 2 inputs means differential input is 0 and you expect a 0 output ok. So, 0 output in terms of when I say, when you say look at a 0 volt that corresponds to when you have a plus V dd and minus V dd. But, if you have a ground and V dd then you expect to settle at a mid voltage that will correspond to your 0 output in that case. So, I mean so when you say 0, it is not a absolute value, 0 means you do not expect anything that is it.

So, whatever it could be at a common-mode voltage, anything it could be 0 or any DC, depending upon how you provide the supply for your amplifier. So, which means if I do not short and I connect them in a unity feedback; so, in the unity feedback you expect your output to be same as input, but it will not be same, which means your, that will be that is usually called input-referred offset. So, whatever error you are seeing in the output, that will be divided by your gain and that will appear as a difference in the output, sorry input. So, that is your input-referred offset.

And, what does it cause? So, let us, let me just so, if this is let us say, V ref and I connect it in the unity feedback. So, your V out, V ref if no offset, ok, but V out equal to V ref plus minus delta V in presence of offset which I so, if I draw open loop, so, we represent it with a source, this could be plus minus V os V ref and this is your again V out. So, what will be this V os? Equal to plus minus delta V over whatever gain is here. So, that becomes input-referred, this is called input-referred offset ok. So, sometimes you may not have these direct input accessible, only output is accessible.

So, in that case you cannot tell how much is the input-referred offset, you can only tell what is the error in the output and that is what we actually require; we are interested in error in the output. But, when you design, it's actually the input-referred offset which is causing the error in the output and that input-referred offset comes from the mismatch between the two branches of your diff pair. So, I will give you an analogy with the simple, like a daily to daily life what we use.

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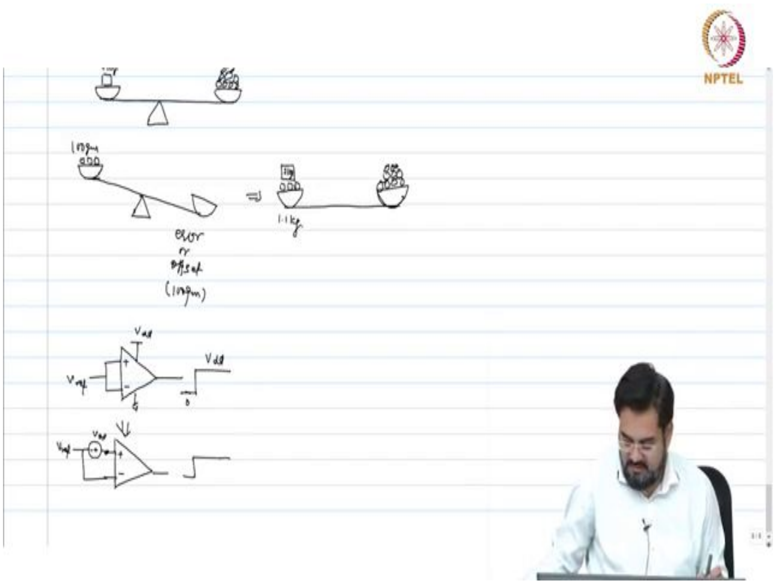

So, this is your scale, weighing scale and let us say you go to market and so, we know that usually they have two plates ok; one for weight other side you put the object. This is a traditional scale, not the electronic scale which we use these days. If we try to explain in that term then it is not that simple, but this is a simplest. So, let us say you buy maybe 1 kg of apple or whatever. And what they do? They put a 1 kg of weight here and when both sides become balanced, that is the 1 kg.

But, here you go home and you have your own scale and you weigh that, instead of 1 kg its only 900 gram; there is a 100 gram error, you go back to the shopkeeper and tell, ok. You ask him to remove both the weights and apples you expect this, but what happened? His scale is doing this which means it had error of 100 gram, error or offset. So, it might be deliberate or non-deliberate you do not know, sometimes they deliberately do it ok, to cheat you so that they can instead of giving you 1 kg they will give you only 900 gram ok.

So, what can you do? Now, you know, you ask him, you gave me only 900 gram I asked you for 1 kg, either give me 1 kg or return my money ok. So, you will ask him, you weigh it again and you do this and keep putting smaller weights. So, error let us say 100 gram and you put a 100 gram weight here and then it, they will now, this is balanced out, correct? So, now, you put 1 kg of weight here again so, the total weight is 1.1 kg and now you get 100 grams extra apple effectively you are getting 1 kg apple because 100 gram weight extra weight has cancelled out your offset; the same concept we apply in the amplifier.

So, let us see how we do it. So, you have your amplifier, you are not putting any weight which means short this to, connect to V ref and look whether, where output is coming. So, if it has offset, it will go either high or low ok. If it's high which means your positive terminal has more weight compared to negative terminal and you have a positive offset here plus V s. So, instead of V ref that internal opamp terminal will see V ref plus some delta V os and it will go high. So, if this is V dd and this is ground, this is 0 to V dd.

So, what I do? If let us say it was 0 then your negative terminal or input has more weight compared to positive. So, what do you do? You try to introduce so, I know that there is a offset so, which means it has actually offset of V s V ref and this is your actually the if you look at internally this is what is happening inside not this plus minus ok. So, this is seeing V ref, but plus is seeing V ref plus V os and that is why it is going high. So, offset correction.

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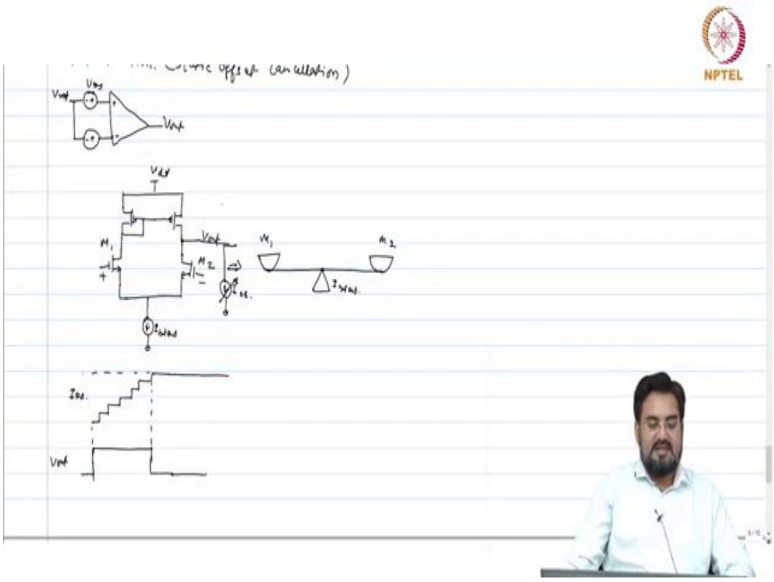

So, what we can do if we know that it has an offset of V os then I will introduce the same offset here, ok. So, both inputs will see the same voltage, that is the whole concept. So, how do I introduce the offset on the other terminal? So, I know offset is in which direction, now we try to increase the weight on the other side ok. So, how can you do that? So, we know the diff pair so, you can very well relate this to your that balance actually. So, you can call it M 1 M 2 and this is your I bias, this center ok. So, which means, I have to either change the size of M 1 or M 2 to increase the weight or add the current in the output.

So, if this is my output and this is plus, this is minus. So, I know I have a more offset on M 1 side that is causing your output to go high, I should make M 2 stronger. So, increase the size of M 2 that is a one way you can do or I know that this V out is going high. So, I can pull some extra current from let us say I will call it I os and this is a variable current. But, how do I know how much I have to add this current or how much if I have to increase the size of transistor, how much do I increase, how do you know? How did we figure out in case of balance?

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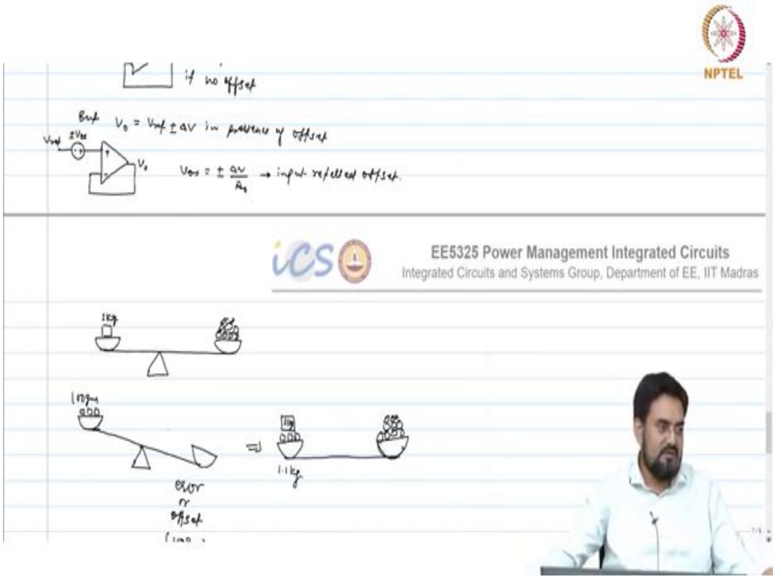

Initially you do not it is know it is a 100 gram error so, you have a small let us say 10 gram 25 gram whatever. So, you put a let us say 10 gram or 20 gram, you keep putting that unless direction is changed actually, this side gets heavier than that. So, when you put the last bit of this weight and this gets heavier then you know that whatever the previous weight you added and this it's lying in between. And, if you have a smaller weight you can start putting that and when it becomes completely balanced out ok. So, you keep putting the, adding this current I os unless your high becomes low, that will define, that is where you needs to stop. So, you do it digitally, this is your I os and if this is my V out which I know it was high ok.

Let us say this is the point where it becomes low, you freeze the I os here, ok. So, this will cancel out your, and the error in the offset will become, will depend what is your bit size or the step you are choosing. Finer the step you have, you can get closer to your desired output or offset equal to, close to 0 ok. What could be the second option? So, let us say I do not have weights, I do not have these weights, finer weights, I have only 1 kg and half kg. So, I cannot afford to cancel this way, is there any other way to cancel this? Just think again from this balance point of view, how can you do that?

Yeah. So, you can move the center actually.

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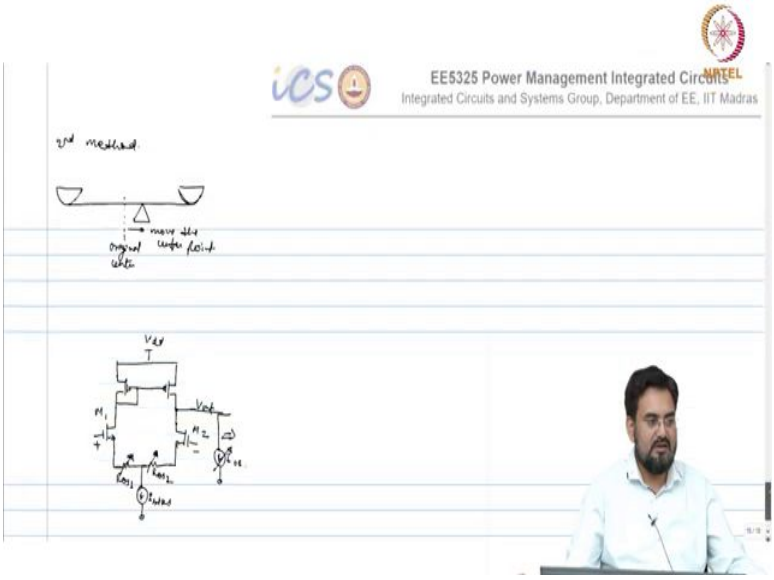

So, 2nd method so, we know the right hand side was heavier, ok. So, which side the center should go, left or right?

Student: The center should go towards the right direction (Refer Time: 16:20).

This was your original center. So, move the center point, correct and you decide where to move when they are balanced out correct. So now, go back to this. So, how can we move the center? Both are at.

Student: You can keep the bias currents.

Bias current is common, how can we change the bias current? Yeah. Size of the transistor or adding a resistor here. This is the technique we most often use and this is variable. The reason we use this technique, because when we already talked about the placement of M 1, M 2 you try to match them ok. So, matching, which means the offset is very small, not that large. So, you cannot further break those pieces into a very smaller pieces, there is some limit there. If you make the transistor too small then that is smaller transistor will have larger error actually.

Because, whatever the non-idealities in the process are, they are fixed, if you have a delta l and delta width, whatever the change in length and width ok, that is fixed it's an absolute change. So, when you have a smaller length or width, in terms of percentage, that will be huge actually. So, that is why we do not prefer to make the devices too small. So, we do not touch the devices M 1, M 2 once you have laid out in a proper manner, we just use this offset resistor too. So, this will effectively, this is called actually source degeneration where you change the gm of your transistor so, it will reduce the gm.

So, it will make the M 2 so, it is a positive side. So, it should be put here. Usually, put on the, in the both direction because we do not know which one where is the error, in left or right. So, depending upon which side the error is you try to change one of the sides uh, resistor. And so now, this so, if this is R os 2 and this is R os 1. So, as long as they are same, your center point is at the mid, but when you have a difference in the two; that means it's moving in one of the directions and that is what it does actually and the value of offset is nothing but.

So, we know that half the current is flowing in both half of I bias; so, whatever value you choose multiply it by half of the bias current, that will be the offset. And, since these currents are in like a microamp and kilo ohm resistor will give you very good accuracy, like you can achieve 1 to 2 milli volt accuracy, even less than 1 millivolt with this, ok. And, by keeping the resistor size still large, order of kiloohms because your bias current is very small, ok. Because, designing a very low value of resistor order of ohms on-chip is not easy; I mean you use a metal, but kilo ohms of resistor comes from like poly, mostly poly resistors.

And, if you are using let us say 10 ohm or something, using poly, its size becomes fairly huge, because width height needs to be very large. But, kilo ohm will take very low area and you can easily do it without any problem.

Student: Can we use different high level metals because if we (Refer Time: 20:31) increase the metal layer, the resistance will reduce.

Yeah, resistance will reduce, but we do not prefer it, its order of kilo ohm, that is what I am saying. If you require order of ohms you do that ok, but in this case you know your bias current is order of microamp. So, you do not prefer to use metal resistance here because your area will be bloated. So, you should try to use high resistivity, sheet resistance which is mostly the poly actually. You have diffusion resistance also, but those are not very accurate compared to this poly resistor, ok.

Metal resistances you use for sensing purpose and those, but not for general use, general purpose use ok. So, that is the one way and you apply the same technique. So, what we do, instead of I os now, it will become R os.

R os 1 or R os 2 this guy. So now, I am not adding any current here, but I am adding offset resistors and keep increasing one of the resistor depending upon whether your output is high or low and wait for the output to go low and freeze the code there. So, it is done digitally again and, but this is only one-time calibration that is why we call it static offset cancellation, static offset. So, static offset cancellation and major portion coming from the process and your mismatch due to design and layout so, that is our mainly static parameter.

So, it will correct most of your offset, it may bring down by 80 or 90 percent, still you may have a 10 20 percent left due to dynamic variations. Dynamic variations means your supply voltage is changing, your temperature is changing ok. So, with the temperature, so, whatever weight you have selected to cancel the offset, that weight may vary with the temperature or if you have a V dd that may again cause some variation in the weight, ok. So, in that case you use a dynamic offset cancellation, but for regulator purpose, we already know that we do not require a ADC kind of accuracy here.

So, most of the time you do not employ the dynamic offset cancellation, only you live with the static offset cancellation, only one-time that is it.