Analog Electronic Circuits
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Lecture - 77
Intuition Behind the Dominant and Second Poles in a Miller Compensated OTA

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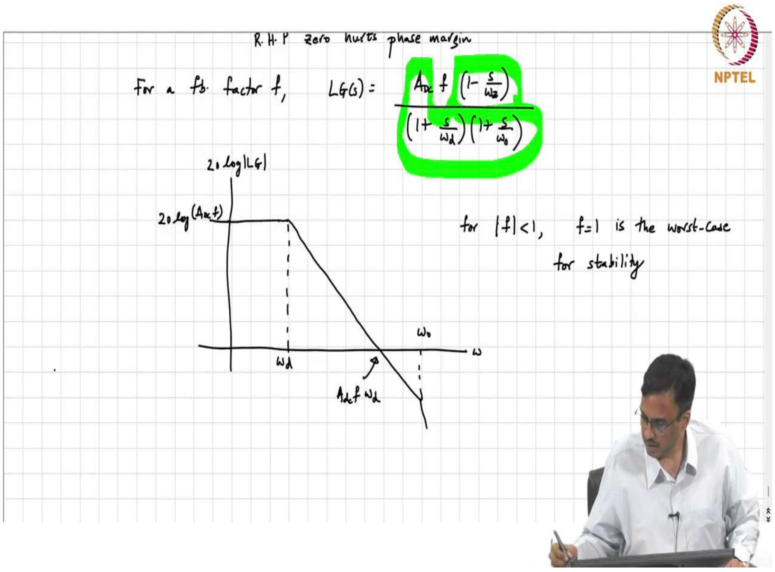

The next thing that I like to draw your attention to is you know the strange thing right. So, you look at the circuit there is g_{m1} g_{m2}.

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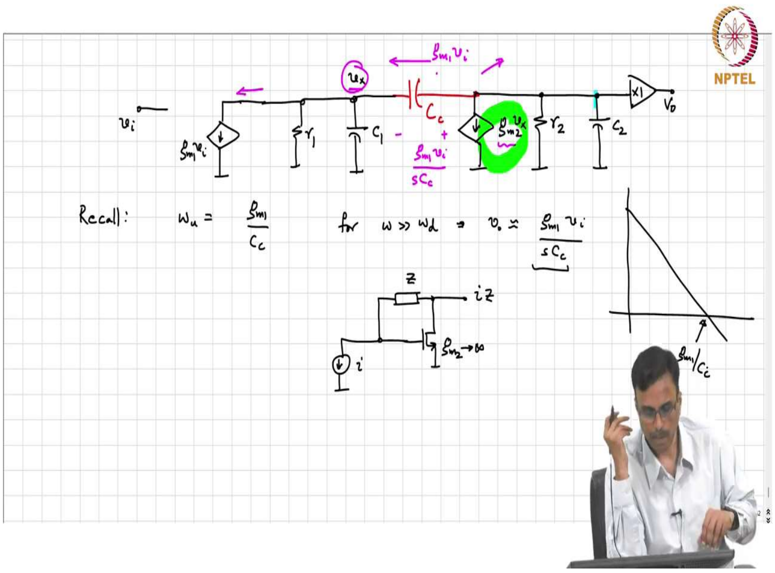

So, this basically you can see that there is g_{m1} g_{m2} you know all this all these you know 100 things here. But surprisingly the unity gain frequency is only dependent on so, this is g_{m1} v_i and this is r_1 the unity gain frequency is nothing but g_{m1}/C_c ok.

So, I mean an obvious thing is that you know you have this such a complicated circuit, but you know how come the unity gain frequency is such a simple expression there must be some intuition to intuition to this correct, right. So, the intuition is the following. So, at frequencies much beyond the so for ω much much larger than the dominant pole frequency correct where, is all this current flowing for frequencies much larger than ω_d, where is all the current flowing?

It is going through the capacitance, right. So, nothing is flowing through the resistances. So, I am going to delete r_1 ok, alright. So, all this current is going through the capacitance. The capacitance has got two parts one is C_1 the other one is the miller multiplied version of C_c. So, where is all that current flowing?

Student: C_c.

So, this current is approximately g_{m1} v_i correct. Now, so, what is the voltage across C_c? g_{m1} v_i/s C_c ok, alright. So, remember for large phase margin what should g_{m2} be the large phase margin g_{m2} must be large correct, in other words if the unity gain frequency is much smaller than the second pole then g_{m2} must be very very large right. So, approximately what I mean so, if g_{m2} I mean in the limit g_{m2} is what let us say is infinity. So, what comment can you make about v_x if g_{m2} is infinite? It is 0. So, what is the output voltage?

The output voltage is nothing but v_x + the drop across the capacitor. So, basically this is nothing but the output voltage is approximately equal to $g_{m1}v_i/sC_c$ correct. So, you can think of it. I do not know how many of you still remember any of this stuff. Remember that let us say this is z if this g_m is very large. What kind of control source is this? It is a current controlled voltage source, what is the trans impedance?

It is z. So, basically this is i then this must be I_z. In this case what is z?

Student: 1/s C_c.

So, in this case so, basically the output voltage is g_{m1}/s C_c. So, what is the unity gain frequency of this transfer function? At what frequency does the gain go to unity? This basically this approximation is telling us that this is nothing but g_{m1}/C_c, alright.

Let me ask you some quick equations, right? So, let us say you know I have you know this two stage op amp and evidently let us say the phase margin I have is too much right, ok. I have a very large phase margin and consequently the bandwidth of the closed loop bandwidth is small, right?

So, if I want to increase the if I want to double the bandwidth right and I am not worried about the hit in the phase margin because I have so much of it anyway what are the what all can I do to double the bandwidth the unity gain bandwidth? I can double g_{m1} right or I can reduce C_c by a factor of 2. In either case you know the unity gain bandwidth will approximately double right and the phase margin will become 4, right. So, if you know if you want to restore the phase margin what should I do?

If I want to keep the unity gain frequency the same right which is double of what I had earlier, but the phase margin is; obviously reduced, if I want to restore the phase margin what should I do?

Student: Increase g_m.

Increase g_m. Does it make sense? Ok alright. So, the next thing that I like to talk to you about is, you know, the last thing that I like to mention with regard to this compensation is the following.

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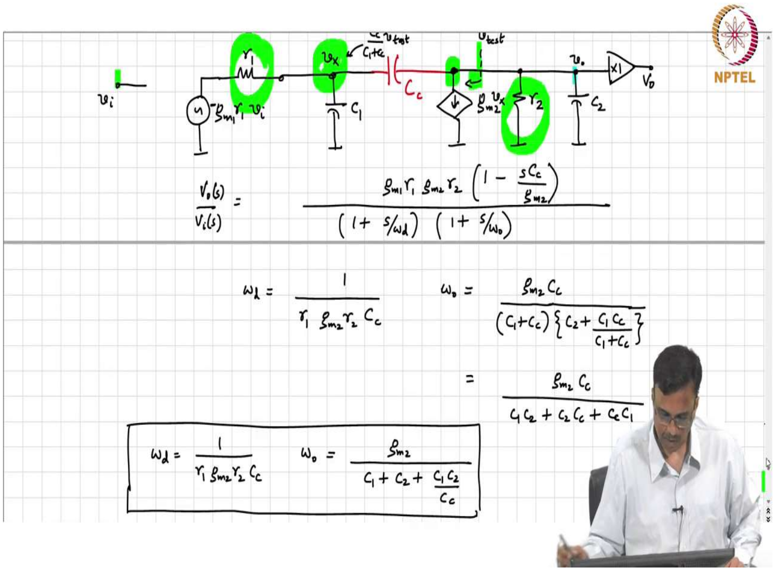

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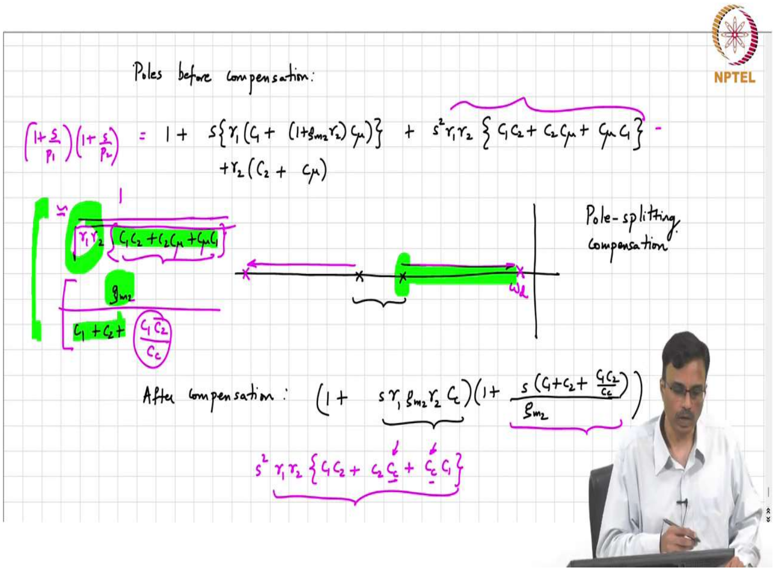

Remember that the poles before compensation for the roots of other roots of this polynomial 1+s $\{r_1 (C_1 + (1 + g_{m2} r_2) C_\mu)\}$+ $r_2 (C_2 + C_\mu)$ + $s^2 r_1 r_2 \{C_1 C_2 + C_2 C_\mu + C_\mu C_1\}$, ok, alright. So, both these poles will be on the left half s plane right and they will be comparable ok there will be alright. Now, after compensation what does this become? So, what is the denominator? $(1 + s\, r_1 g_{m2} r_2 C_c)$+ $(1 + s/\omega_o)$ what is ω_o? $g_{m2}/(C_1 + C_2)/C_c$ alright. So, what comment can we make about this pole in relation to these guys? This is the dominant pole. So, where is that pole going to be? It is going to be ω_d. What about the other pole? The other pole as you can see here is $1/g_{m2}$ if you look at the product of these 2 poles right. What is the product of the 2 poles after compensation? How did we get this expression? We basically said $r_1\ r_2\ \{ C_1\ C_2 + C_2\ C_c + C_c\ C_1\}$, right. So, if you look, what you call the coefficient of the square term, what comment can you make about the product of the time constants?

No, because we have introduced C_c, ok. So basically the product has decreased and it is only reduced by factor C_c or the product of the poles is reduced. The time constants have the product of the time constants has increased, right. But the product of the time constants has increased only by a factor C_c whereas, one of the poles is reduced by a factor C_c. So, the other pole basically is going to be much higher than is going to be much higher than the original poles that we have, ok.

Alright. Another way of thinking about it is basically if you think that these 2 poles are comparable right what is the you know if you assume these 2 poles are comparable this is nothing but this is nothing but let us call this let us call this expression $(1 + s/P_1)\ (1 + s/P_2)$.

So, $P_1\ P_2$ is basically $1/(r_1\ r_2\ (C_1\ C_2 + C_2\ C_\mu + C_\mu\ C_1))$. So, if P_1 and P_2 are roughly at the same frequency right then each one of them is approximately at this frequency ok. Now, whereas our second pole is at $1/g_{m2}$ it is basically a $g_{m2}/(C_1 + C_2 + C_1\ C_2/C_c)$. So, now what do you think? Which of these things is larger? See this is roughly of the order of if you take the square root of those quantities, it is roughly of the order of? If $C_1\ C_2$ and C_μ all of these are roughly the same order.

This is approximately of the order of r any of those parasitic capacitance. Whereas, this is of the order of g_m over you know those capacitors, I mean C_c is large. So, $C_1\ C_2/C_c$ can be very small compared to C_1 or C_2. So, all I am saying is that this term and this term are of roughly the same order of magnitude whereas, 1 by r what comment can we make about 1/r versus g_{m2}? Which is larger?

g_{m2} will be much larger. So, what comment can you make about the location of these poles versus the second pole after compensation? It will be much higher. So, basically you can see that the poles which were here earlier have now split one going. You know, becoming dominant whereas the other one goes higher right this is actually a very good thing because earlier when we did this dominant pole compensation, we said Well we will take a big capacitor and put it in parallel with one of the existing capacitors and one of the poles will move down correctly.

So, what is happening here though that is definitely by doing this Miller compensation there are two things have happened one they of course, one of the poles has moved very low as you would like, but fortunately the other poles also moved higher correct. So, therefore, making it you know a better situation as far as phase margin is concerned. So, some Miller compensation for this reason is also what is called pole - splitting compensation.