Course name- Analog VLSI Design (108104193)
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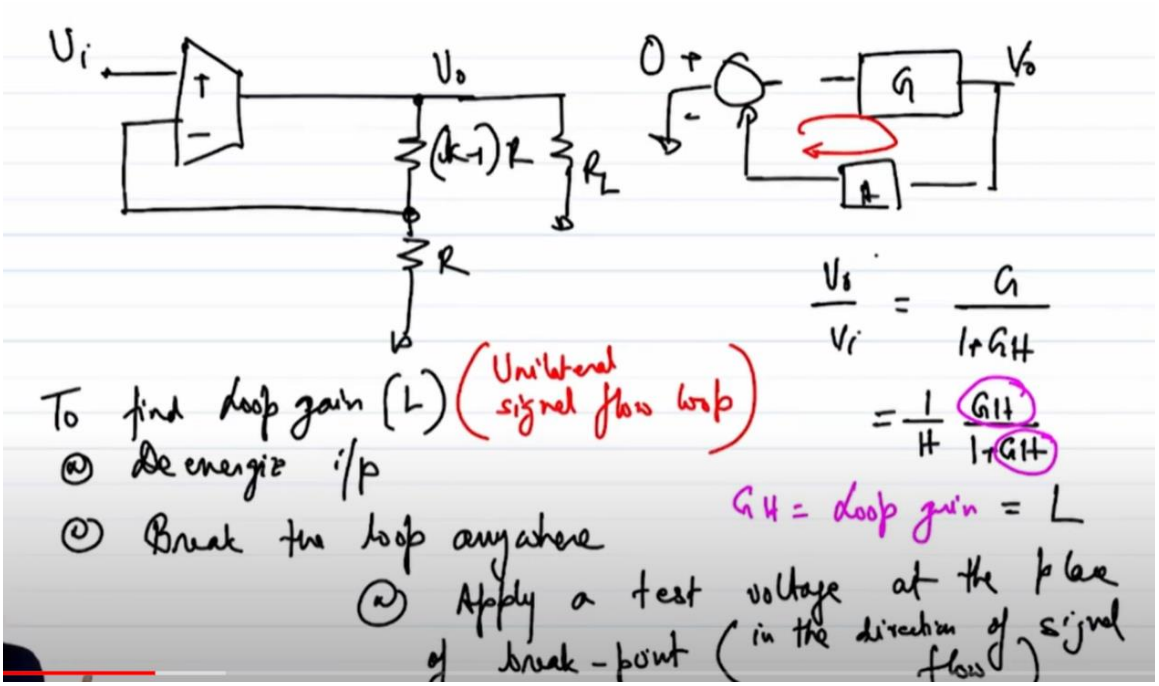
Week- 11
Lecture- 33, module-02

Now, welcome back. So let us do a formal treatment of what we just said. So, this is Vi, this is k minus 1 R, this is R, this is Vo ok. Let us say we have RL here. So, just in case of a negative feedback loop, we had G, we had H and we saw that what did we see? We saw that Vo over Vi was equal to G by 1 plus GH right, Vo over Vi is equal to 1 G plus 1 plus GH and if I represent this as 1 over H times GH by 1 plus GH right. So, we see that this stuff in the numerator and denominator that is which is multiplied by GH and GH right, which is essentially GH, this is often called loop gain right, GH is often called loop gain and loop gain is the property of the loop right.

So, loop gain is a property of the loop and how do we figure out what is loop gain right, how do we figure out what is loop gain? So, from this structure you can see that in order to figure out the loop gain what should we do? We should to figure out find loop gain. So, this loop gain is also often called L ok. So, to find loop gain L right, we can essentially do this, we can desensitize input, de-energize input right. So, this input goes to 0 ok.

Number 2 is break the loop anywhere right. So, I can break the loop let us say I break it here right. Number 3 is apply a test voltage or current, but in our case we are doing everything in voltage domain. So, we are let us stick to voltage apply a test voltage at the input at the place where you broke at the place break point and preferably in the direction of signal flow. So, why do I say this? Because ultimately your signal in this loop is flowing in this direction.

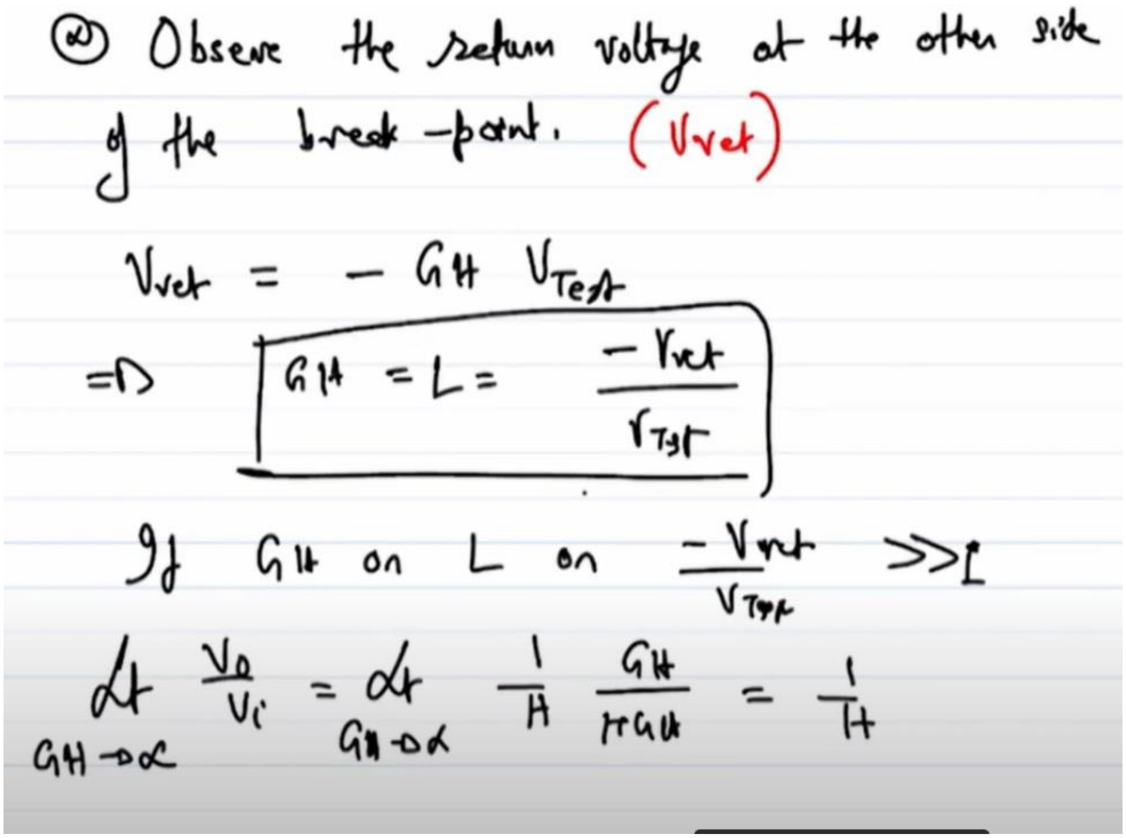
However it need not always be the case you can have multiple loops and the signals can flow you cannot always identify whether the signal is flowing from left to right or right to left there can be something that connects the signal from left to right or right to left right. So, the points that I am listing is only for a unilateral loop right. So, this is for unilateral loop or unilateral signal flow where its own signal is going from only one direction to



another if things go in other if you have multiple loops or you have multiple current directions then things can be can be slightly different ok. So, we should keep that in mind, but for the purpose of this course this is good enough. Then what should we do? Then we should apply a test voltage here in the direction of signal flow let us say Vtest right.

So, if we do that what voltage will you get at V0? V0 will be G times Vtest. What voltage will you get at the other side of H? This will be GH times Vtest. What voltage will you get here? This voltage will be minus GH times Vtest. So, this voltage let us call it Vreturn right. So observe the return voltage at the other side of the breakpoint right.

So what is this return voltage let us call this Vif this voltage we call it as Vtest is voltage let us call it Vreturn. So, what is Vreturn? In the signal flow graph our Vreturn becomes minus GH times Vtest or in other words Vreturn or in other words GH or Loop gain is equal to minus Vreturn by Vtest. Ok. So, ultimately what we want? We want, we want. So, if GH oRL or minus Vreturn over Vtest is much much greater than 1 then V0 over Vi is almost equal to 1 over H right in this case 1 over H or if I have to write it more vigorously I should write limiting value of V0 over Vi when GH tends to infinity is limiting value of 1 over H GH by 1 plus GH which is equal to 1 over H.

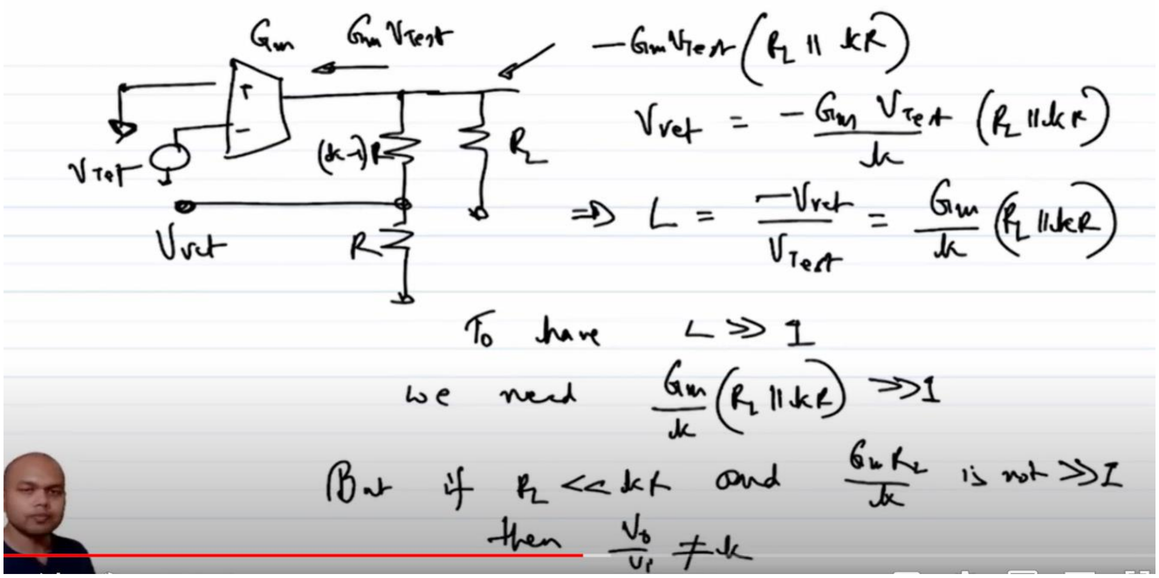


Ok. Fine. So, how does it make sense in our structure? In our structure what is the loop gain? So, if I have to use the same, same steps what is the first step? Desensitize the input correct. So, did I write it desensitize input or no? Yeah, deenergize input break the loop anywhere. Now I should also put a caveat you can in principle break the loop anywhere, but it is convenient to break it at the input to a high impedance node right. So, let me also write it down here, preferably at the input of amplifier right because you are not drawing any current right.

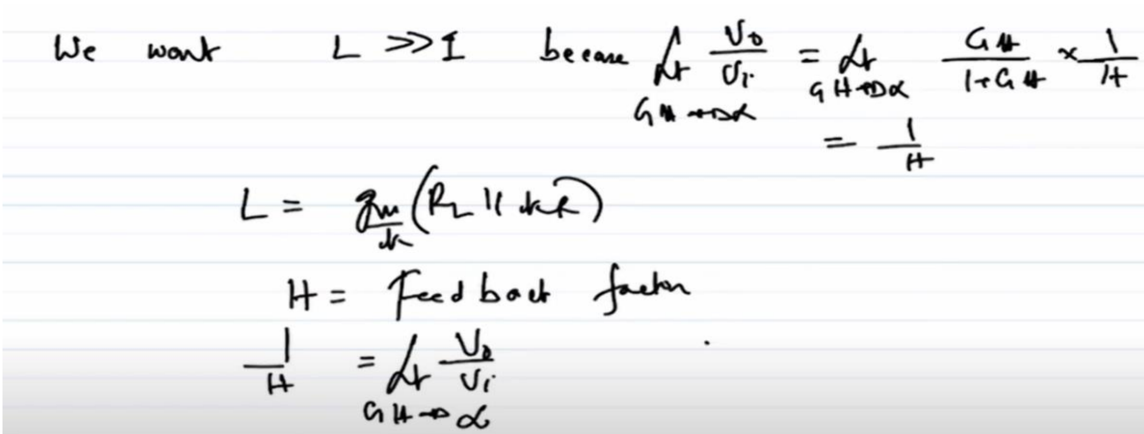
So by breaking the loop there you are not disturbing the, you are not disturbing the loop operation to some extent right. So let us break the loop here and apply a test voltage and this voltage will be Vreturn ok. This is gm which no mind you gm is the equivalent transconductance of the differential amplifier ok. So, now if this is Vtest what is this voltage? What is this current or rather what is the current that is going dragging in? This is gm times Vtest. So, what is this voltage? This voltage will be minus gm times Vtest times RL parallel kr correct.

So, what will be Vreturn? Vreturn will be 1 over k of this because it is a voltage divider. So minus gm Vtest by k times RL parallel kr which means what is loop gain L is minus Vreturn over Vtest which is gm by k times RL parallel kr right. So in order for our Loop gain loop to work properly right. So to have L tends to infinity oRL has to be much much greater than 1 we need to ensure gm over k times RL parallel kr is much much greater than

1 right. So if we can ensure this we are good, but if RL for example if RL is much less than if RL is much less than kr, but if RL is much much less than kr and gm RL by k is almost is not much much greater than 1 then obviously our V0 over Vi will not be equal to k correct.



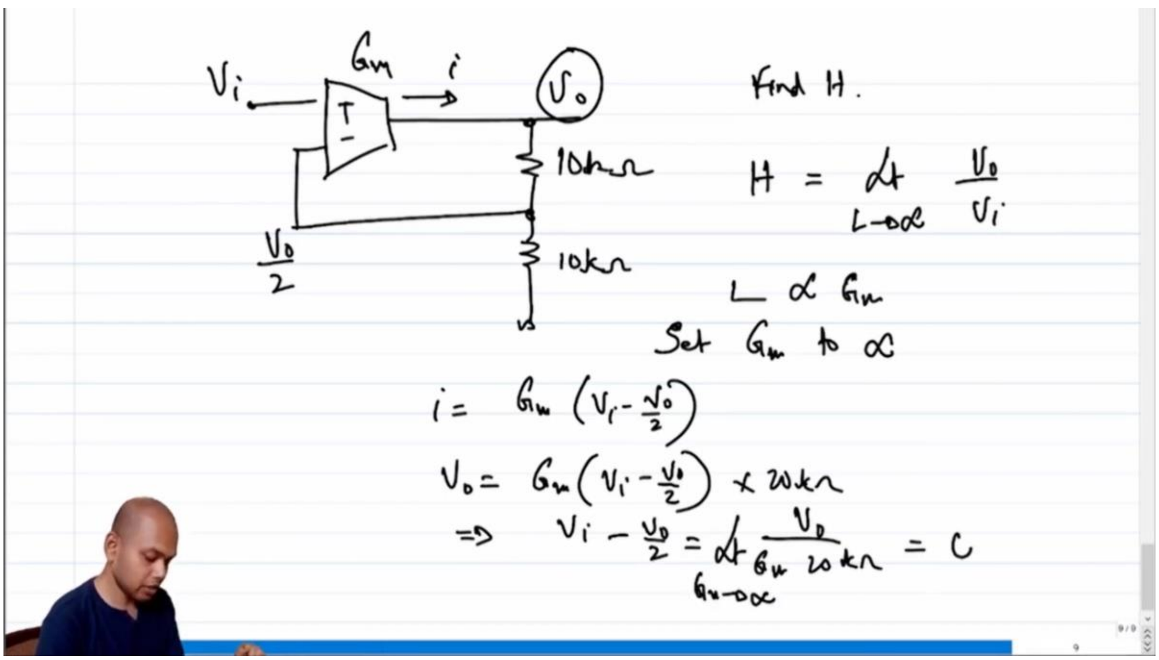
Because ultimately what are we looking for? We are looking for we want L to be much L to be much much greater than unity right. Why? Because V0 over k because what is V0 over Vi? V0 over Vi is 1 by H GH by 1 plus GH and limiting value of this guy when GH tends to infinity becomes 1 over H ok. So in our case in our case L is equal to gm times RL parallel gm by k times RL parallel kr right. This is GH and what is h? H is a feedback factor and how do you ascertain what is H experimentally? So how do you ascertain? So to find H assume L tends to infinity correct. So in other words H is equal to V0 over Vi when GH tends to infinity or rather 1 over h.



1 over H is gm feedback factor when gm tends to infinity. So if I give you this network so

if let us say you if I tell you that this is network and let us say this is 50 ohm or rather 50 k this is 10 kilo ohm this is 10 kilo ohm. What do you think is h? Find H what will be h? So what is h? H is limiting value of V0 over Vi when L tends to infinity right. So what is loop gain? How do you figure out loop gain? We know that loop gain is proportional to gm right because that's the everything gets multiplied by gm moment you go through the loop. So to find H so set gm to infinity correct and then do our calculations if gm tends to infinity what happens right.

So this is V0 this is V0 this is this is what this is V0 by 2 correct because your voltage divider right. So what is this current? This current is this I is what I is gm times Vi minus V0 over 2 correct. Where is this I going? This I is going and creating a voltage and going and going into the two resistances 10 kilo ohm and 10 kilo ohm which are in series right. So V0 is essentially I times 20 kilo ohm. So this is V0 is gm times Vi minus V0 over 2 times 20 kilo ohm right.



So in other words Vi minus V0 over 2 is equal to V0 by gm times 20 kilo ohm. Now limiting value of this guy when gm tends to infinity is what? This is 0. Which means what? Which means V0 is equal to twice Vi correct. So which means what is h? Oh I made a mistake sorry.

So this is 1 over h. So what is h? So H is therefore H is 1 over 2 correct. So to find H you set the error amplifier whatever is the whatever is the amplification factor right proportional to in this case the the transconductance is the is corresponds to the amplifier. So you set gm to infinity and you find out V0 over Di whatever you get is 1 over H right.

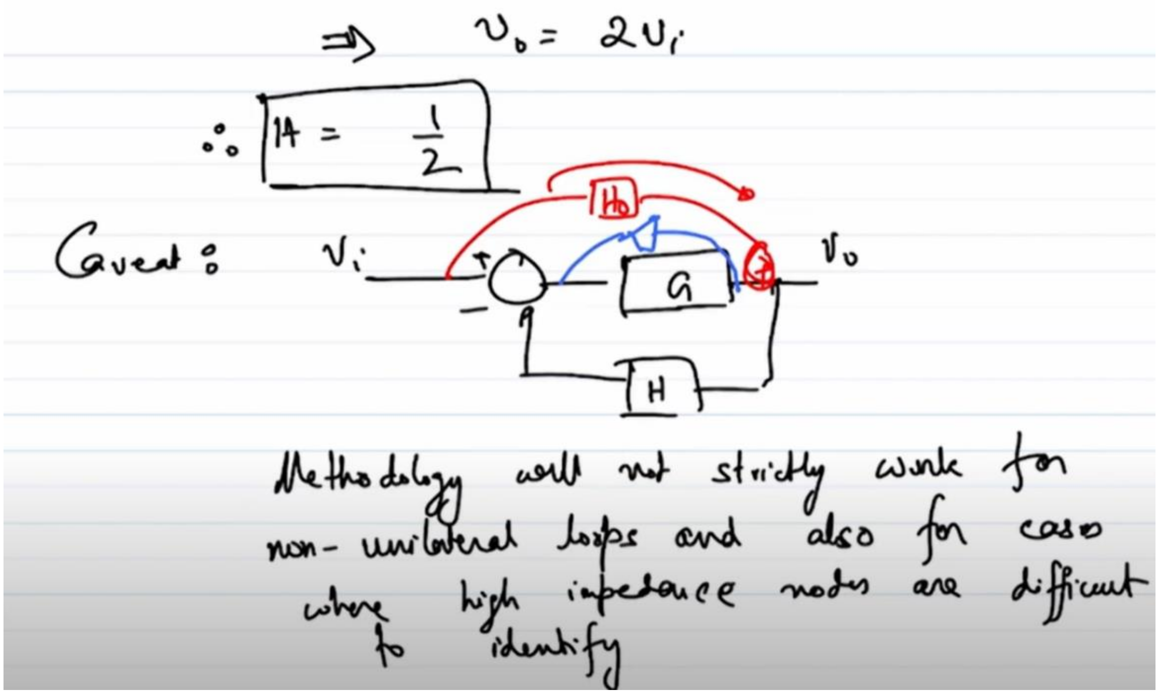
So in order to find loop gain what should you do? You break the loop desensitize the input and you apply a test voltage and see whatever comes back. The ratio of whatever comes back to whatever test voltage you applied negative of that becomes a loop gain.

So in order to figure out the whole structure of negative feedback loop you need two things you need to find out loop gain and you need to find out h. So so with this simplistic format we can figure out both experimentally both what is what is the loop gain and what is the H and we can go ahead and do our analysis right. But note that there are some caveats to this. The caveats to this is as follows. The loop has to be so I should the caveat the caveat that we that we should be mindful of are the following.

One of the caveats is the loop has to be of this has to be of this form right. Loop has to be of this form but it need not necessarily be that all loops can be extracted expressed in this form correct. So it can as well be the loop can have some some transfer function from input to output directly. It's quite possible. It need not necessarily be that the loop is unilateral right.

So it's quite possible that there is a there is a signal flow from output to input right. So if these are the cases it need not necessarily be the input impedance of at the point that you are breaking is infinity right. So if these are the cases right so we'll have strictly speaking the structure that we talked about or the signal flow that we talked about will not work right. However if we are smart enough and identify a part of the loop where the signal flow is kind of unilateral right then we can probably break the loop there and apply it as voltage. And for most low frequency applications unless you are going to like 2 gigahertz for most low frequency application this is this is sufficient right.

So Gaviat is methodology this methodology will not strictly work for bilateral loops or non-unilateral loops and also for signal flow in multiple loops and also for un- directions. That's the same thing like and also for cases where high impedance nodes are difficult to identify right. Why do I say so? Because ultimately what did we do we broke the loop somewhere here right. We broke the loop at the input of the error amplifier right. So what happens if the input of the error amplifier also has a resistance R.



So in that case this methodology will strictly not work but a modified version of this method methodology is going to work right. So in this course we'll not get into that we don't have the time and the bandwidth to get into those details. But the circuit that we'll be dealing with in this course will have places to break where this where the simplistic GH kind of methodology will still work. So we will stick to that right. Thank you.