Course name- Analog VLSI Design (108104193)
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Welcome to Analog VLSI Design, this is lecture 1. As we had seen in the introductory video, in this course we will almost exclusively focusing on designing an amplifier. Now, this is a course for electrical department or electronics department. So, when we talk about amplifying something, we are essentially talking about amplifying an electrical quantity, right. So, what is the most familiar electrical quantity that we can amplify? Obviously, we can say that let us start off with voltage, right. So, when we are planning to design an amplifier, the question is are we planning to design a voltage amplifier, right.

What do I mean by that? So, let us assume that I have a voltage source, let us assume I have a voltage source V_{in}, let us further assume that it has an internal resistance Rs, right because no voltage source comes with zero internal resistance, it is always a real life voltage source, it is always accompanied by an internal resistance, let us call it Rs where S stands for the source. And let us say there is a load resistance RL, right. What are we interested in? Are we interested in building a block and put it in between Rs and RL such that after we connected this block, the voltage that will develop across RL, right, let us call it V_0. Are we interested in building a block? Let me just put a question mark here.

So, are we interested in building a block such that V_0 is equal to Av times V_{in} where Av is greater than 1, right. So, are we interested to build this? One might say that if we have such a block, we might as well call it a voltage amplifier, right. Can call this a voltage amplifier. So, is the course about finding out what is the stuff inside this box which can give us voltage amplification? Now some of you might turn around and tell me that, hey, what is so only about voltage in electrical domain, we have another quantity that we are equally interested in that is the current. Can we make a current amplifier, right? Why are you partial about amplifying voltages, right? So, you will also be right.

So, let us say that I have a current source, let me call it Iin. The current source is again accompanied by an internal resistance Rs and I have a load resistance RL. What should I, so is the course about building this box inside such that the current I0 that will flow into RL, right, I0 is equal to some proportionally constant Ai times I in such that Ai is greater than 1. And if this is realizable, if we have been successful in realizing this, we can call this current amplifier. And you will be right, right? Thus, if we are able to realize the box on the top, we can say that that box is a voltage amplifier.

If we can realize the box in the bottom circuit, then we can say that the box acts like a current amplifier. However, in this course, we are neither interested in designing a voltage amplifier nor a current amplifier. What we are interested in is the following. We are interested in building a box such that if I put this box in between the load and the source, if I put this box between the load and the source, then the power delivered to the load, right, so the power delivered to the load Pout, right, should be greater than the power that I am extracting from the source. In other words, if the power that is going in is Pin and the power that is getting delivered to the load RL is Pout, we are interested in finding out this box such that Pout is equal to let me call some proportionally constant Ap and it is Pin where Ap is greater than 1.

This course is focused in designing this box where the output power is greater than the power that is that I am extracting from the source. The source might be voltage source, the source might be current source, it does not really matter. All we are interested in is to deliver an output power which is greater than the power that we have extracted from the source. And why is this relevant? This is relevant because there are several applications which demands this. For example, the most common application that you might familiar with is that of a microphone and a loudspeaker.

The volume that comes out of the loudspeaker is much much stronger than the decibel level of the volume that is a decibel level of the signal that is going into the microphone, right. Similarly, there is a power amplification that is that has happened. It is neither a voltage amplification nor a current amplification. Let me try to Convince you with a concrete example of what I mean. Let us take the example of a humble transformer.

I am sure you have gone through or you have encountered an ideal transformer in your basic electrical engineering courses, right. So for example, you have let us say I have this again this non-ideal voltage source and I have this load resistance RL and I put this transformer in between and let me mark this transformers turns ratio as 1 is to n, right. What is a transformer? An ideal transformer is nothing but all we need to know for the purpose of this discussion is an ideal transformer is the following. If this is V1 and I have a turns ratio of 1 is to n, the other terminal will be the voltage across other terminal will be n times V1, right. And also we know that if I have a load resistance RL connected to the secondary of the transformer that is on the right hand side of the transformer in this case, it that load resistance gets reduced by a factor of n squared obviously, if n is more than 1, ok.

So, these are the two things that we need to keep in mind in order to solve this problem, ok. So, what are we interested in? I am interested in figuring out what is V_0. So, what is V_0 over V_{in}? We are interested in, we are interested in figuring this out, ok. So, how should I go about figuring this out? So, we know that the resistance looking in that is Rn for an ideal transformer in this case will be RL over n squared, right. So, if I remodel, if I remodel this circuit, right, if I remodel, redraw the circuit like this, so this becomes Pin, Rs and a resistance of value RL over n squared.

And if I mark these voltages as V1, this voltage becomes V1, ok. So, what is V1? V1 is nothing, but the current that is flowing into this loop that is V_{in} over Rs plus RL over n squared times the resistance RL over n squared, ok. So, if that is the case, if this is V1, what will be V_0? Now, if I switch our attention to the circuit on the top, I know V1. So, what will be V_0? From the transformer action, we know that V_0 is n times V1 which is equal to V_{in} times n times RL over n squared divided by Rs plus RL over n squared, correct. So, if I multiply both the numerator and the denominator by n squared, what do I get? I get V_0

over V_{in} is equal to n times RL by n squared Rs plus RL, ok.

So, if I rewrite this here, so V_0 over V_{in} becomes n times n times what? RL by RL plus n squared Rs, ok. So, let me redraw this circuit, redraw this circuit, V_{in} press, ok. So, if RL is much, much greater than n squared times Rs, what happens to V_0 over V_{in}? In this case, V_0 tends to n times V_{in}, right, V_0 tends to n times V_{in}. So, this acts as a voltage amplifier, right, from the definition that we started off with, right. If I take you back to the definition that we started off with in few minutes back, it seems like a simple transformer is able to satisfy this condition, right, ok.

Only one might turn around and say that hey this is limited because this is true only for certain ranges of RL, the RL has to be much greater than n squared times Rs, if that is the case, I will, I might get voltage amplification, but nonetheless we are getting voltage amplification, correct. However, note that we are not interested in these type of amplifiers because you cannot get power amplification out of a transformer, right. If you are not convinced, what I would like you to do is pause the video here and try to find out what is Pout over V_{in}. In other words, what I am asking you to do is to find out what is the power delivered find Pout over Pin, where Pout is equal to the power delivered to RL, right. So, which is effectively you can say that V_0 squared average over RL and what is Pin? Pin is equal to the total voltage V1 and the total current I1, the multiplication of V1 times I1, the average of that, right.

So, you can assume Pin to be equal to $V_p\sin(\ _0t)$, right. You can assume this and try to figure out what will be Pout, what will be Pin and what will be the ratio of Pout over Pin and we will continue from there. Thank you.