Analog Circuits
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Module - 01
Lecture – 03

Now, what can we do in order to obtain power amplification, it is very clear that the source of signals of interest that cannot be the only source that is applied to the circuits, because then what you get out of the network will definitely be less than what you put in. So, there must also be an additional source of power that is you have some relevant inputs signals, let say v_1 or v_{in} and there must also be an additional source of power. So, somehow the power must be greater than the power that you put in from the relevant signal source. Now, this is quite common at least even if you do not understand how things work you know that an amplifier works with a battery or with some source of power. So, you have this public system in your class room and so on, they are plugged into the mains I mean that is so that they can draw some power from the mains. The actual signal is let say coming from the microphone, so the output power that goes into the loudspeaker is more than what comes in from the microphone. And how does it do that it actually draw some power from the, and converts it into additional power in the loudspeaker.

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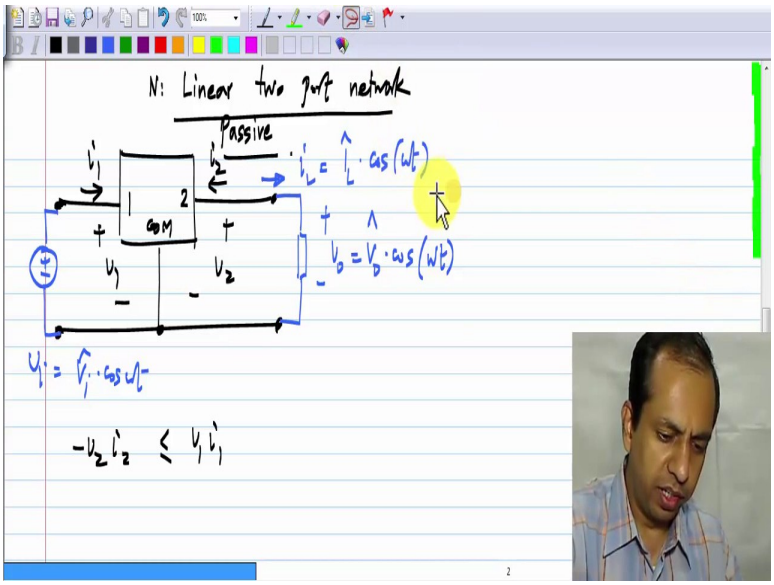

What it means is the following. Let me again take a two port network and let me assume that N is the linear two port network. Now, I said that I will have a source of signal and another additional source of power. So, to distinguish between the two easily, I will consider the signal source to be a sinusoid of some frequency and additional power source to be DC. Now this is the quite common case, but it does not have to be the additional source can also be a sinusoid but the most simple form the most commonly used form is where the additional source of power is DC, so that is what I am going to consider. So, that is by input v_i is some peak value $v_{i'} \cos(\omega t)$. So, by the way, this is not just a linear two port network, it is also passive. So, now the output is a sinusoid of the same frequency because it is a linear network,and for simplicity I will assume that it is in the same phase. It does not matter if it is or if it is not.

Now, again I have a single independent source in the circuit. So, this we know it cannot give you any power gain, but I am just going to go through it. And this current that is going into the load will be some $i_{1'} \cos(\omega t)$. We already know that defining the port variables like this $v_1 i_1$ and $v_2 i_2$, $v_2 i_2$ which is the output power is less than $v_1 i_1$. So, this circuit cannot give you any power gain at all. Now, what we can do is to add an additional source of power to this circuit somewhere,it can be anywhere; it does not matter. The same argument will apply, but remember this network is a linear passive two port network.

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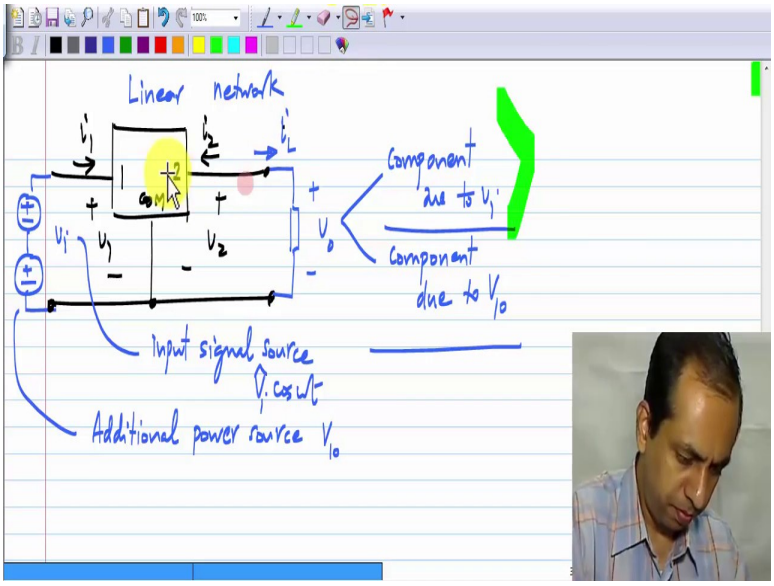

Now just for illustration sake let me assume that the additional source of power is something connected in series with the input source. So, this is the input signal source,and the additional source of power let say is another source that is connected in series,and let say it has the value of v_{10}.So, now we will have some v_o, and some load current;and this will have a component due to v_i, and also a component due to v_{10}. All I am saying is that both of these sources will have some effect on the output voltage,so that is a very general statement very obvious. Now, the question is if the power in the load, due to the input source v_i ,because this is the signal source, this is the source that has useful information. So, as I said I call this $v_{i'}$ cos(ωt). So, the component due to v_i in the load, if it has more power than what is being fed from the left side, what is being delivered by the input source. And the answer is it turns out that it cannot and the answer is very simple, because this is a linear network superposition applies.

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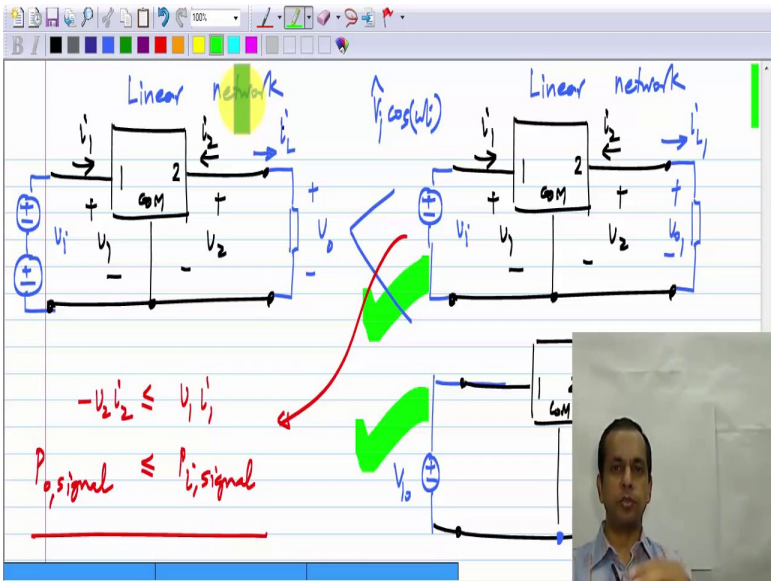

What does it mean, let me copy this over,it means that the solution to this can be obtained by superposition. And what are the two conditions,two conditions are one in which only v_i is present and one in which only v_0 is present. This is the load,so the solution to this can be obtained as the superposition of this where we have only v_i applied to the network, and this where we have only v_{10} applied to the network,this is because of linearity. Now, clearly the output voltage in this case, let say v_{o1} and the load current v_{L1} are only due to the signal v_i. And the output voltage in this case, let say v_{o2} and i_{L2} are only due to the dc source v_{10}. So if you compute the power, that is

contained only in the signal component; like I said v_i is $v_{i'}$ cos(ωt) both i_{L1} and v_{o1} will be sinusoids, and their product is the power. In this case, we already know that minus $v_2 i_2$ is less than or equal to $v_1 i_1$, so the output power due to the signal component is less than or equal to the input power due to the signal component.

So, what it means is the following. If you have a linear network, even if you use an additional source of power you cannot have an output power in the signal component that is more than the input power in the signal component. You surely have an additional output power, because the voltage across this for instance if you consider this load as a resistor, the voltage across this will have component from the input source as well as the DC .So, there will be additional power in the load for sure, but that would not get translated to power in the signal component, because by linearity you can analyze the circuit with the signal and the dc separately. And we will assume that the signal is sinusoid, so the signal component of the power will only come from this one and the dc component of the load power will only come from that one. So, even if you add an additional source, you are not going to get a higher output power at the signal component; you will surely get higher power in the load, but that would not be at the signal component.

Now,it is a very obvious and you can do the analysis yourself, this is not the only way to provide an additional dc source. You can be provided using a third port, but by linearity exactly the same thing will happen. You can always decompose the linear network into a different circuit in which only one is source activated at a time. So, you can activate only the signal source at a time, you can activate the dc source at a time; and from this, you will conclude that the power in the output at the signal component will be no different from if you have only the signal input. So, the whole idea was if you have only the signal input, the output power will be smaller than the input power. So we thought we will add an additional source of power, let say we stick a battery somewhere, but that is not going to help if the circuit is linear, because once the circuit is linear then whether you have two sources together or acting separately, the effect of each source will remain the same,that is what is meant by superposition.

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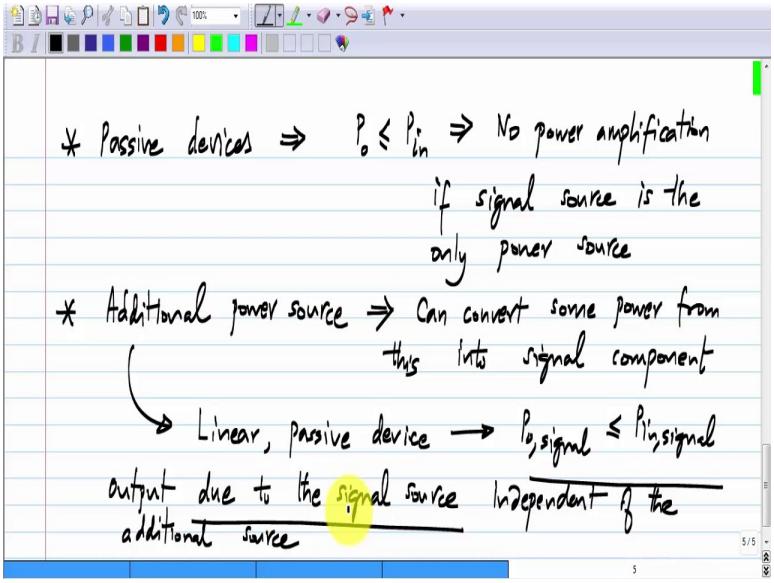

So, to conclude passive devices means $P_{out} \leq P_{in}$, so which means no power amplification if the signal source is the only power source that is if you have box with an input and an output, and the input consist only of the signal source, the output power has got to be less than what is being delivered by the signal source. So, the next idea is, an additional power source. Now this you know by experience, you know that all your electronic gadget work with the battery. Why is that because you need amplification and you need an extra source of power, so that when you get a small signal, you can augmented to with the power from the battery,so that is the general idea. Although you do not know exactly how it is work yet, the idea behind this is it can convert some power from this into the signal component,but this also does not work if you have a linear device and of course all devices are passive, then the output power in this signal component is going to be less than the input power in the signal component.

This is because with a linear network, when you have two sources that is the signal source and the additional power source, there is no effect on the output because of the signal source just because you connected an additional power source. This is very easily seen when you decompose it into superposition with each source acting by itself. So, whether the additional sources is there or not, the output because of the signal source will be exactly the same. This will be independent of the additional source. So, you cannot use a linear device for amplification.

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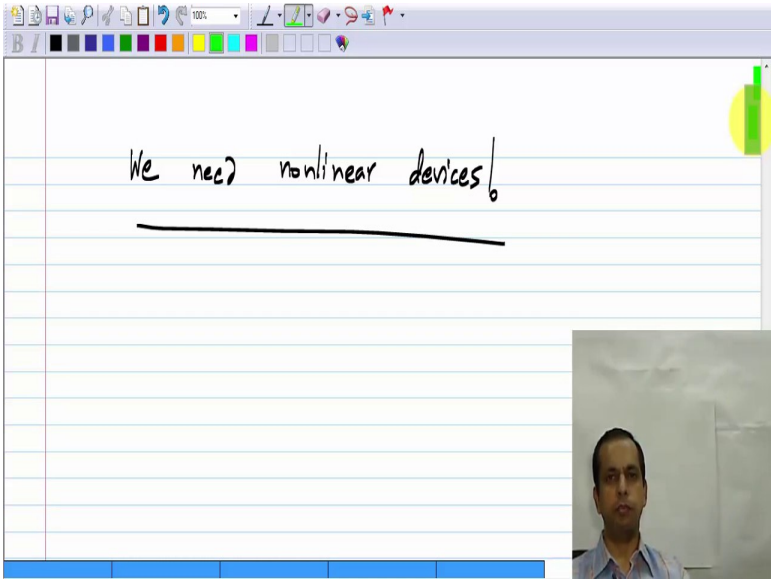

So, the very important conclusion is that we need nonlinear devices. Now, some of you may have already been expose to the transistor or other amplifying devices, and you know that they are nonlinear. It is not arbitrary, it is in fact something that we need if you have only linear devices, you could never get any power amplification. It is only with nonlinear devices that you need power amplification. Now, this also gives you very good motivation for studying analysis methods of nonlinear circuits, and understands them properly and so on. So, those things we will see in the following lessons that gives you motivation to study nonlinear devices and method to analyze the nonlinear circuits and so on. Although they are more complicated than linear circuits,because without nonlinear devices, we cannot have any amplifiers; and without amplifiers, we cannot have any of the wonders of the information age because it is with amplifiers that you can build all the wonderful analog and digital circuitry that are all around us.