Course name- Analog VLSI Design (108104193)
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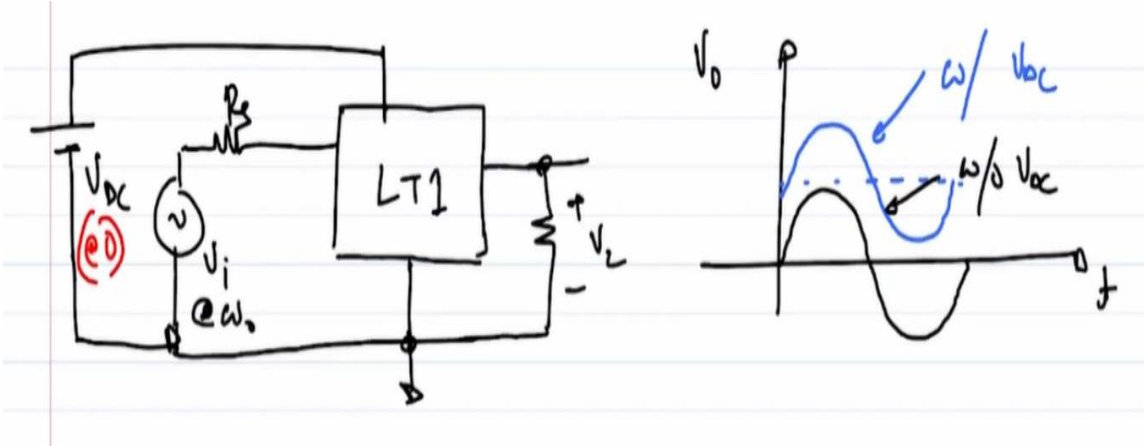
Lecture- 3, module-02

Welcome back. So, what is the fundamental reason why we are unable to get power amplification using an LTI network even though we have a additional power source. The main reason we are unable to get power amplification and this output terminal V2, power amplification of the sinusoidal source of Vin right of the sinusoidal source. So, we are unable to get a power amplification at V2 simply because, simply because what an LTI system does is LTI system simply pushes the sinusoid up by some DC term right. It does not really increase the amplitude of the sinusoid right. So, ultimately what we want we and if I have an LTI system, in case of an LTI system in the absence of VDC if this were my output right.

So, this were my output without VDC. In the presence of VDC this output essentially becomes something like this right. So, this is with VDC. So, the peak to peak amplitude or the peak the amplitude of the sinusoid or the peak to peak voltage does not really change.

Hence, hence the power of the signal at the output does not really change regardless of the fact that you have one extra DC supply or you might have a bunch of extra DC supplies right. So, what are we after? We are after a network which can increase the amplitude of the sinusoid itself ok, not only just shift the sinusoid by certain amount right. So, in essence what we are after is the fact that, is the fact that this term whatever be this term is alpha times Vp should get multiplied with something. So, that the amplitude of the sinusoid at the output itself increases. Now, why is another way of thinking about this problem is the fact that this LTI system is not able to transfer the power of the DC signal of the DC source to a frequency of omega not right.

So, this signal this source Vi is acting at a frequency omega not and what is the frequency of the DC source? What is the frequency of a DC source? The frequency of a DC source is 0. So, in other words what we are expecting? We are expecting the transference of the power from 0 frequency to a non-zero frequency omega not. If that happens, if that happens then it is possible to expect that the sinusoidal amplitude of the sinusoid will increase. If that does not happen then naturally the amplitude of the sinusoid cannot increase and as we know from our basics of LTI system right from basic circuit theory courses, we know that an LTI system does not cause any shift in frequency of a signal. Since an LTI system does not cause any shift in frequency of a signal, no power from this DC source can be delivered to a frequency of omega not ok.

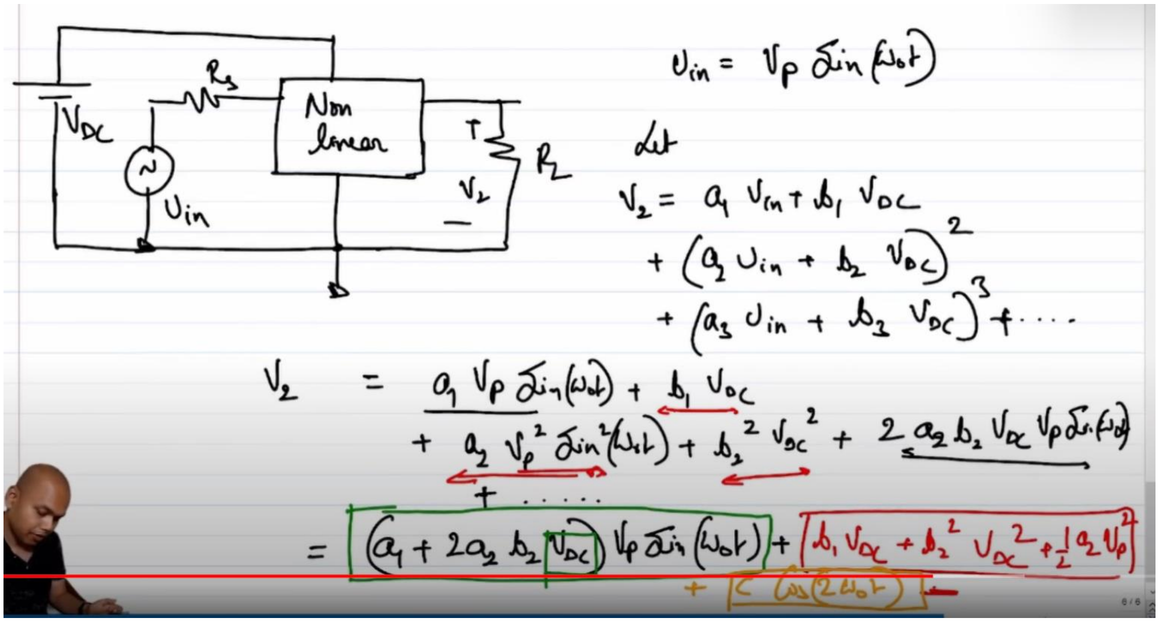


So, what is the, what is the, what is the solution then? The solution is you cannot use an LTI network. If you have an LTI network you will not get any transference of power from your DC source to any port or across any load that you want ok. So, what happens if you if this network is not LTI? let's say this network is non-linear right. So, what happens if this network is non-linear? let's say this network now is non-linear. Is it possible? The question we are asking is, is it possible now for transference of the DC power to a frequency of omega not? Let's see.

let's say this is VDC again, this is Vin, this is Rs, this is RL. let's say Vin is Vp sin omega not t and note that this is a non-linear network. Since this is a non-linear network we cannot use superposition. Unfortunately, we cannot use superposition which means we will have to take the effect of both the sources into account simultaneously. Now, a generalized form of a generalized solution for any non-linear network is not possible.

So, what we will say is that let's again take an, take a, take an approximation and say that let's assume this non-linearity is a polynomial type of non-linearity right. By that what I mean is if this is my port V2, V1. So, if this is my port V2, let's say the output voltage V2 is related to the sources Vin and VDC as follows. let's say, let V2 be equal to a1 times Vin plus b1 times VDC plus a2 times Vin plus b2 times VDC whole square plus let's say is a3 Vin plus b3 VDC whole cube and so on right. So, let's say this is a generic polynomial type of non-linearity the values of a1, b1, a2, b2, a3, b3 and so on and so forth can be dependent on the type of non-linearity that we have within the box ok.

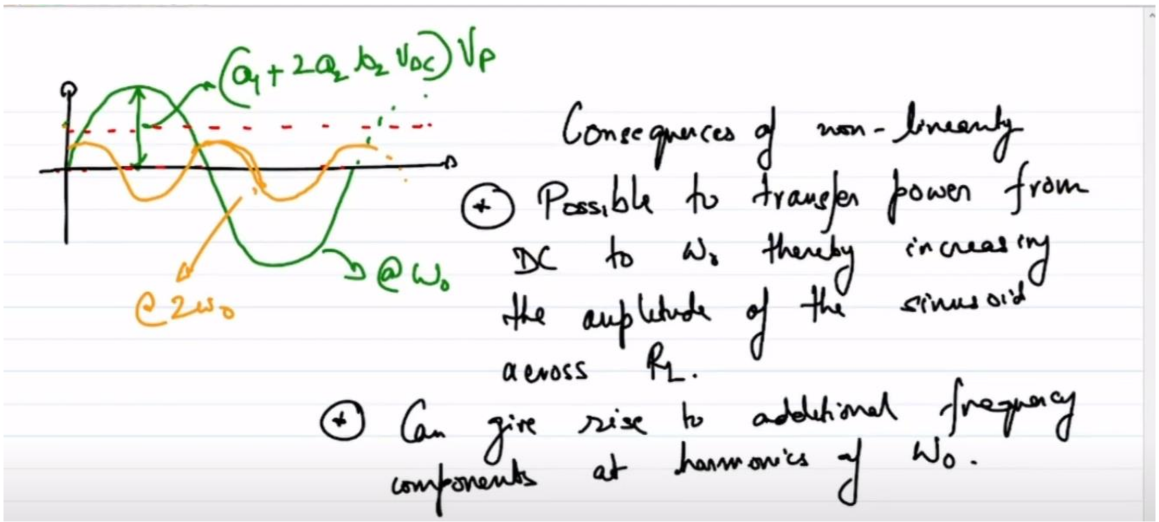
So, this was essentially an expansion of V2 right. So, this was V2 not the power, power is obviously average of V2 square over R right. So, V2 be equal to a1 Vp sine omega not t plus b1 VDC plus a2 Vp square sine square omega not t plus b2 squared VDC square plus 2 a2 b2 VDC times Vp sine omega not t and plus so on right. So, I am for the purpose of gravity, I am ignoring the higher order terms right. It will just help make the point by making the algebra simpler ok.



So, let me ignore the higher order terms if I do that what do I end up with let me collect all the similar terms together. So, what do I get what are the terms for sine omega t the first term here and I have this term here. So, I get a1 plus 2 a2 b2 VDC Vp sine omega not t plus there will be a DC term and the DC term will be this, b1 VDC plus this square VDC square plus, there will be once we expand this sine square omega not t will be, will be half of right, will be half of a2 Vp square right and you will have another sine 2 omega not t right. So, we will have another term all this plus some constant times cosine 2 omega not t right ok. So, now if we stare at this term if we stare at this term what do we see? We see that there is this there is this nice term over here which is proportional to sine omega not t but it is appended with a1 plus a2 b2 VDC.

Now, interesting thing is that VDC makes an appearance in the amplitude of sine omega not t right, VDC makes an appearance in the amplitude of sine omega not t which means that now if you have a non-linear system it is possible to increase the amplitude of the sinusoid because of this cross multiplication that is happening because of the presence of non-linearity and hence it is possible to increase the amplitude of the sinusoid in other words we can also say that it is possible to transfer the power from the DC source to from 0 frequency to omega not t ok. So, what are the other terms? The other terms this is a DC this term that we see here is DC right. So, this is the DC and this is, this is a and this last term here is either is a cosine or sine at twice the frequency right. So, your output now right, your output now what is the output look like? Under these conditions your output will look like you have a DC term right you have a DC term. So, let us say this is the DC, DC level what do you have else what else you have you have you have a sinusoid more importantly you have a sinusoid whose amplitude is a1 plus 2 a2 b2 times VDC right that VDC factor is important.

So, essentially you have a sinusoid whose amplitude is how much a1 plus 2 a2 b2 VDC 2 a2 b2 VDC times Vp because Vp initially, but now it becomes a1 plus a2 plus 2 b2 VDC and you have another term another co-sinusoid signal right. So, you have another co-sinusoid signal of double the frequency right. So, essentially your this co-sinusoid signal excuse me I need to sketch it properly. So, all these terms I am sketching individually. So, the sinusoid should have been at a 0 mean right once we add them up then we can shift them together.



So, this was the DC and the cosine sinusoid will be something like right. So, what are the consequences of non-linearity? The consequences of non-linearity are Its possible to transfer power from DC to omega not, thereby increasing the amplitude of the sinusoid across RL right thereby getting more and more power and second another unintended consequences is can give rise additional frequency components at harmonics of omega not, right. So, this is this frequency is at 2 omega not the intended frequency is at omega not we are able to get an amplification of the intended frequency, but at the cost of introducing an unintended frequency component also right. So, a non-linearity is good and is bad in some ways right. So, there are many things in life which are good in small doses, but not so good when you keep repeating it in larger and larger doses.

This is one such example you cannot do away with non-linearity we need non-linearity to get power amplification. However, along with it also comes a small or negligible or non-negligible it depends signals along with the power amplification we get signals of different other frequencies which we do not want right. We do not want signals as 2 omega not when we have provided a signal at omega not ok.