Course name- Analog VLSI Design (108104193)
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Week- 1
Lecture- 2, module-02

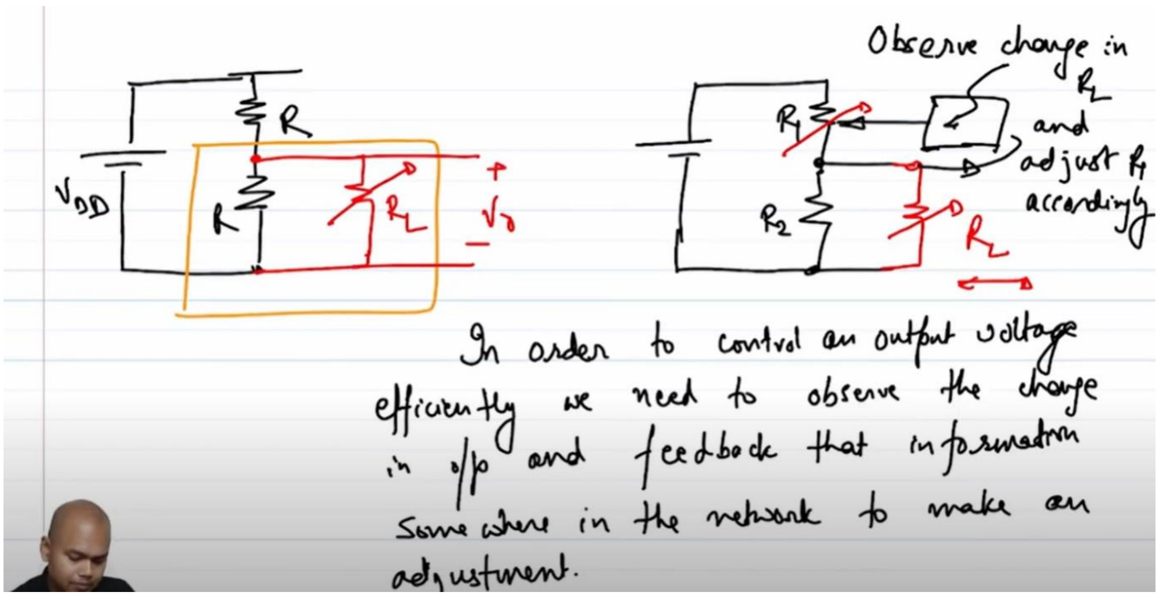
So, the another aspect that I was alluding to which is often used in designing constant voltage supplies is the following. Let me motivate the principle behind it and we will come back to the actual implementation of it at a later stage in this course, but the thought process is as follows. So, what is the main reason behind burning excessive power where we were trying to drive a resistive load? The main reason was as follows. The load was connected here. So, the main reason was as this resistance was changing, it was changing the effective resistance of this box. As that RL was changing, this was changing the effective resistance looking down, right.

The parallel combination of R and RL was changing the effective resistance with respect to the resistance that was attached on top of it, right. So, so as RL was changing, the division ratio, the resistive division ratio was also changing, correct. So, that is why, that is why it was being difficult to maintain a constant voltage at across the, getting difficult to maintain a constant voltage across this terminal. So, what did reducing R do? Reducing R sufficiently ensured that this division ratio becomes largely insensitive to RL, right.

If the division ratio is largely insensitive to RL, then it is not a problem, then I can always maintain approximately constant V0, right. So, therein lies the problem and therein also lies a potential solution. What is the potential solution? The potential solution is what if instead of using a fixed R, what if I say I will do this, I know that this RL is variable, right. So, let me call this one R1 and let me call this R2 for the time being. What if I also make, what if I also make R1 to be variable, right.

How we will make R1 to be a variable is a story for another day. But what if we make R1 to be also a variable resistance. If we can make R1 to be variable resistance, then it is probably possible to ensure that this division ratio of R2 parallel RL and R1 become unity or rather become half for all values of RL. In principle this is possible, but how if you have to do that, what do you need to do? Because note that this RL can change. If RL changes, I will have to ensure that the change, the information of the change of RL gets captured and then transferred to R1, right.

So, in principle we need a block, we need a block that can observe a change and feed that information into R1, right. So, what is this block supposed to do? This block is supposed to observe change in RL and adjust R1 accordingly. So, in other words, I need to feed back the information from the output that is from RL to R1. So, that is why negative feedback becomes our feedback networks become a very important aspect of analog circuit design in the context of controlling things, right. So, as we had, as I had mentioned in the introductory video, this lecture, this course will be as much about designing an amplifier as it will be about designing an amplifier from the perspective of negative feedback, right.



So, this is one of the motivations of why negative feedback is important that is in order to, in order to control an output voltage effectively or efficiently, we need to observe the change in output and feedback that information somewhere in the network to make an adjustment, right. So, because in principle, this is what we would like to do, hence in principle, negative feedback is something that we will be focusing on for a major part of this course, ok. So, we will come to a more formal way of introducing negative feedback, few lectures down the line, but let me concentrate on one more extremely important aspect that we will be covering in this course or we will be using in this course. It's extremely simple idea, we all know about it, but I would like to reintroduce it from the perspective of resistances and keeping and identifying which block can drive which load or which block cannot drive which load or you know, another way of saying the same thing is under what condition a particular block that you are designing will be able to drive a certain load or might not be able to drive certain load, right. We have already seen that example, we have already seen the example from the perspective of a resistive divider, but let us try to see another example.

Even though this is a very simple concept, right, we will be using it time and again throughout this course. So, it makes sense to go over it one last time, ok. So, let me try to convince you about this importance with a thought experiment. So, let us assume that I went to the, I went to the, I went to a electrical store, I bought a battery, ok. So, let us say I went to an electrical store and I asked for a battery.

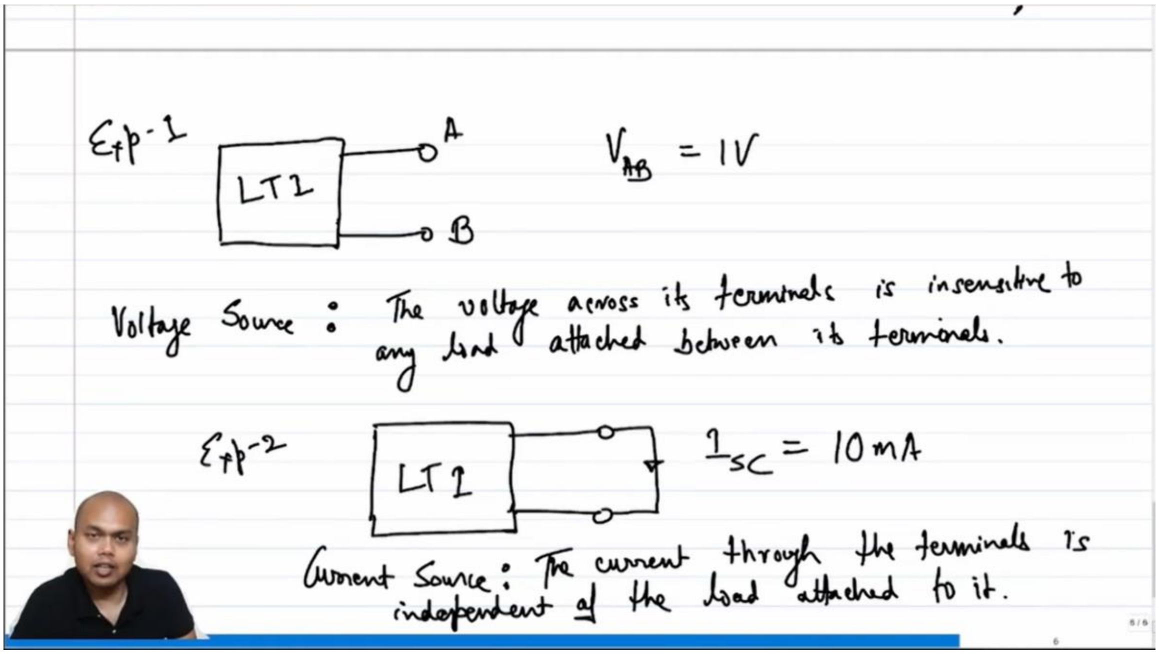
So, I got a box, I got a box, I do not know what is inside the box, I have been told that this is a, this is a battery and this comes with two terminals, ok. I am fairly certain that this is an LTI network inside, right. Let us say this is an LTI network inside, right, ok. So, what I do? I come home and I put a voltmeter between these two terminals. Let me say, let me mark these terminals as A and B, right.

I put a voltmeter between these terminals and I observe, right, I observe VAB under this condition is equal to 1 volt, right. Then can I conclude from this observation that this is indeed a voltage source? I obviously cannot, right, because what is the property of a voltage source? A property of a voltage source is that, so what is a voltage source? So voltage source, the major property of voltage source is the voltage across its terminals is insensitive to any load attached between its terminals, correct. This we all agree, right. So, how does the statement that I just made any different from the observation that we have made? The observation that we have made is for an open circuited load, right. We have not really tested out whether the voltage source is whether this stuff that I have bought from the market is actually a good voltage source or not because I have not put any resistances across its terminals, ok.

So let, then what I did was I said I could not find any resistance lying around. So what I did, I went ahead and shorted the terminals A and B, right. So what I did, I experiment 2, right. So this is, this is experiment 1, I do did this. So let us say I do an experiment 2, experiment 2, I go ahead and do this.

Again same network, I know this is an LTI network. What I did, I went, I go ahead and short these two terminals and I observe this current and I call this IAB or let me just simply call it ISC, it is a short short circuit current, because it is ISC, I say I observe that this is equal to 10 milliamps. Now from this observation can I conclude that this is a current source that supplies a current of 10 milliamps. Again obviously I cannot conclude this from one's experiment because what is the definition of a current source, what we understand by current source? The current through the terminals is independent of, is independent of the load attached. If it has to be a current source, then the current through the terminals has to be independent of the load attached to it.

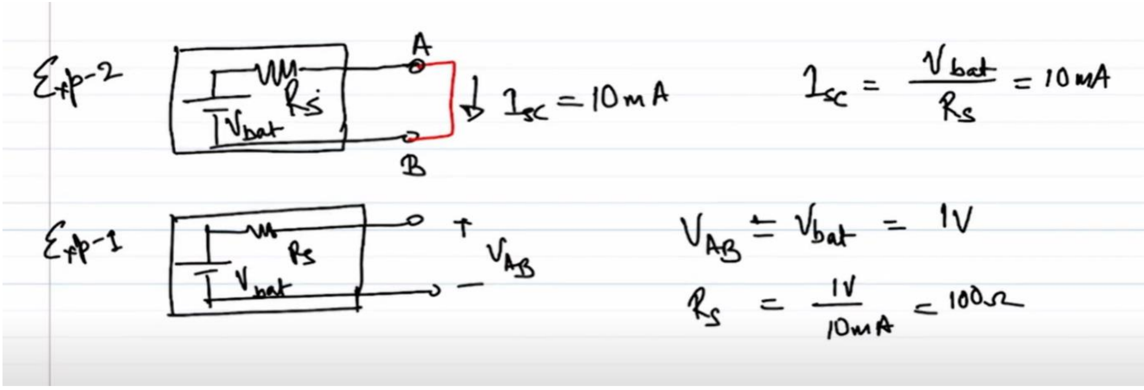
Now mind you I have not attached any load, I have just simply shorted out. So from these two experiments can I conclude that the stuff that I have bought from the market is, is it a good voltage source or is it a good current source? Actually I cannot conclude either, because I have some missing information and what is the information that is missing? Now we all know that, we all know that if this were a good voltage source right, if this were an ideal voltage source, then what would have happened if I had shorted the terminals A and B? If I had shorted the terminals A and B, I should have seen an infinite current right, an ideal voltage source does not have any internal resistance right.



So let us assume this stuff inside my LTI box is an ideal voltage source. If this were an ideal voltage source and I did the experiment too by shorting these two terminals, this is A and B, what would this current have been? This Isc would have been infinity. However, what do I see? I see a limited current, the current is limited to 10 milliamps.

So what can I conclude? I can conclude that this is not an ideal voltage source and the fact that there is probably a resistance associated with the voltage source. So there is a resistance Rs associated with the voltage source right, correct. Since I have a resistance Rs associated with the voltage source, the short circuit current is instead of Isc, the short circuit current is 10 milliamps. So now what is 10 milliamps? This I have a battery, what is 10 milliamps? 10 milliamps Isc is Vbat by Rs which is 10 milliamps. What is Vbat? From where do I know Vbat? This was experiment 2 right, this is experiment 2.

What was experiment 1 telling us? Experiment 1 was telling us that if this contraption was open circuited and I was measuring this voltage Vab correct, I was getting Vab to be equal to 1 volt and what is Vab in terms of Vbat? Because the current that I am drawing is 0 because of open circuit, my Vbat Vab is equal to Vbat which is equal to 1 volt.



Which means what? Which means my Vbat is 1 volt and my Rs is 1 volt by 10 milliamp which is 100 ohm. So essentially, so essentially the stuff that I have bought from the market is this is 1 volt 100 ohm and this comes inside my box ok. I have gone to the market to get an ideal 1 volt, but we ended I when I came back I came back with this contraption right. So now is this a good voltage source or is this a good current source? How can I, how can I, what can I infer from this? I will argue that I cannot infer anything from this information.

Why? Because whether this is a good voltage source or a good current source depends upon what resistance am I planning to drive. Let me elaborate. So, if I connect a resistance RL, if I connect a resistance RL what is the voltage Vab? Vab is 1 volt times RL right RL plus 100 ohms. Let me replace this, express this in terms of the internal resistance of the of the battery ok. So, under what condition this Vab will not change regardless of the values of RL right.

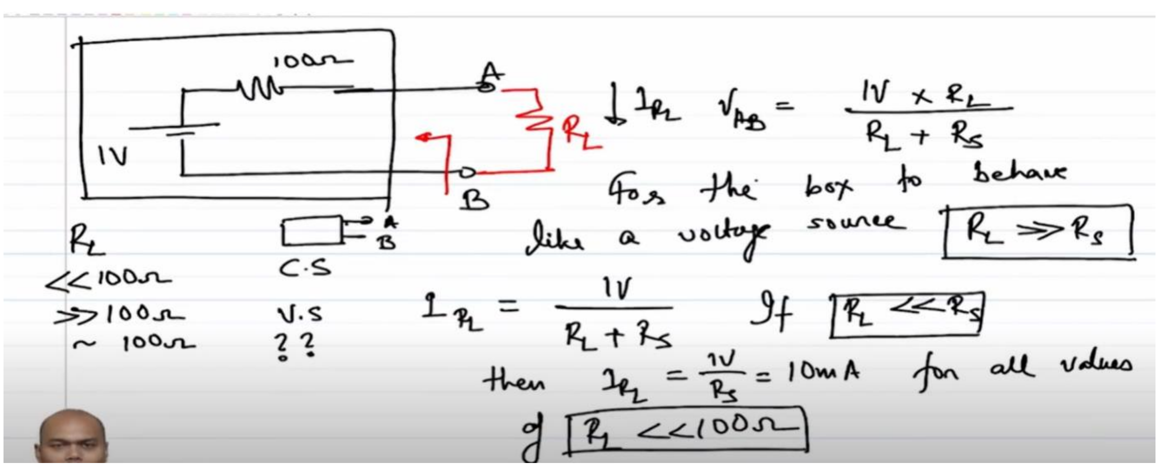
What is the definition of a voltage source? Let me take you back to the definition of a voltage source. The definition of a voltage source is that thing that is insensitive to any load that is attached between its terminals. Now, there is a load RL attached at the terminal. However, my Vab should not change if this pair supposed to be a voltage source. So, for voltage source for the box to behave like a voltage source, what should I, what should get satisfied? We should ensure that that those ranges of R, RL for which RL is much much greater than Rs right.

For these ranges of RL my contraption inside the box will behave like a voltage source right. So, if you satisfy this, if you use this box to drive those values of load, rather if you use this box to drive load, load, load resistances which are much greater than Rs which in this case is 100 ohms, then this will behave like a voltage source right. Your output output voltage is will remain insensitive to the change in, change in RL. Now, can this block, can this box behave like a current source? So, what should I, what should I, what should I try to see? I should try to see what is the current right, what should, what is the current through this, through this load right. So, what is the current IRL? My current is 1 volt divided by

RL plus Rs right.

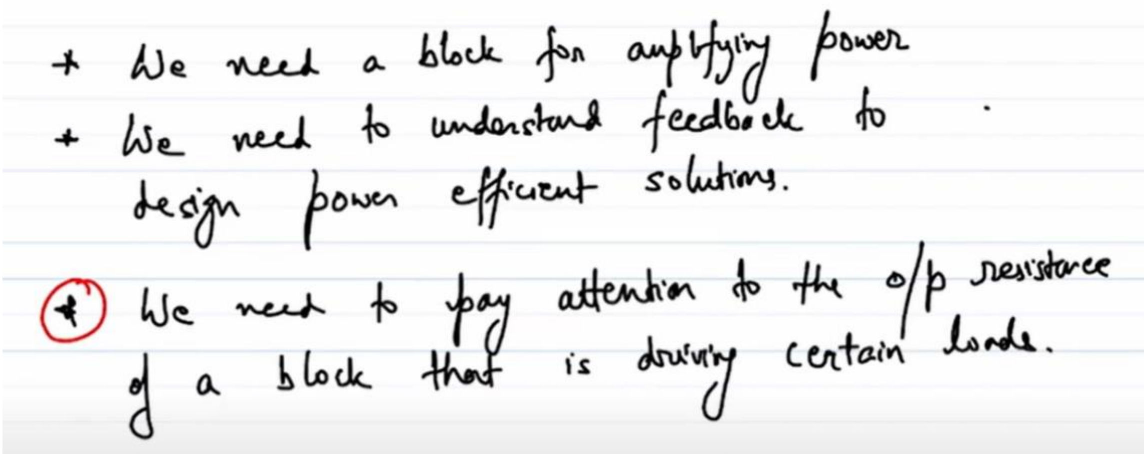
And what is the definition of a current source? The definition of a current source is that contraption whose output current is insensitive to the change in any load resistances right. So, under what condition this output current is independent of RL? This will be independent of RL under the condition that. So, if RL is much, much less than Rs right, then IRL is 1 volt by Rs which is 10 milli amps for all values of RL which is much less than 100 ohm. And hence under these, these ranges of RL right, under these ranges of RL this box will behave like a, like a current source right. Note that the same box, the same box I went to the market and asked for a voltage source, but the same box is can behave like a voltage source or like a current source depending upon the range of load that you are trying to derive right.

So, in other words if I mark the range of RL right, so if I say RL is much less than 100 ohm this behaves like a current source right. RL much greater than 100 ohm my box behaves like a, this box behaves like a voltage source, but if it is in around the range of if RL is of the order of 100 ohm then, then this is neither a voltage source nor a, nor a current source right. In that range both the currents through RL and the voltage across RL are dependent on the load resistances. So, now if you are somebody who is in charge of designing the box that will be the, that will be our job in a different context, we will in a different context that is something that we will be doing throughout the course, we will be in charge of designing the parameters inside the box. What is the first question that you should ask? The first question that you should ask is that ok fine you have asked me to design some block, maybe some amplifier or maybe some regulator, but what is the load that I am planning to drive because it is dependent on the performance of my block will be dependent on what am I trying to drive and what is this dependent on? It is dependent on the Thevenin resistance that I am seeing at the output of the block right.



If I know what is the Thevenin output resistance of the block that I have designed or the block that I am planning to design, then I can make a quick and dirty approximation to figure out whether this block will behave like a voltage source or will behave like a current source for the ranges of load resistance that have been provided to us or it might not behave either like a voltage source or a current source. So, this also becomes important when you are debugging a circuit right. When you are debugging a circuit and you see that your output voltage is changing when it is not supposed to change or it is your current is changing when it is not supposed to change, what is the first thing that you should go and check? One of the first things that you should go and check, you should go and check whether the Thevenin equivalent resistance at the output of your block is either very high or very low depending upon with respect to the load resistance that it is driving and it depends on what you are trying to make right. So, what is the conclusion of whatever we have been focusing on for the last two lectures? Essentially these last two lectures where a motivation behind all the things that we will cover in this course right. So, what was the first motivation? The first motivation is we need a block for amplifying power.

Second is we need to understand feedback, design power efficient solutions. And what is the third thing? We need to be we need to pay attention to the resist output resistance of a block that is driving certain loads right. So, these are the three bedrocks right, these are the three bedrocks of this course or rather you can say that these are the three targets that we need we plan to be we plan to get comfortable with as the course progresses. The final one, this one is super important right, we will be using it day in and day out right. So, because we need to pay attention to an output resistance of a block or for that matter some equivalent resistance of a block or for that matter Thevenin output or Thevenin resistance of a block we need to we need to brush up our basic circuit theory problems on figuring out resistances of a block.



So, what I will do is I will post an assignment in the first week which will be a refresher of figuring out output resistances or rather resistances of different types of linear time invariant circuits right. You can you can go through them and this first lecture will this first assignment will be a will be a refresher or a revision of the concepts that we already know right from our previous experiences of dealing with basic circuit theory right and we can then take it forward from there. Thank you.