ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

3.1-Configurations petits signaux

Introduction

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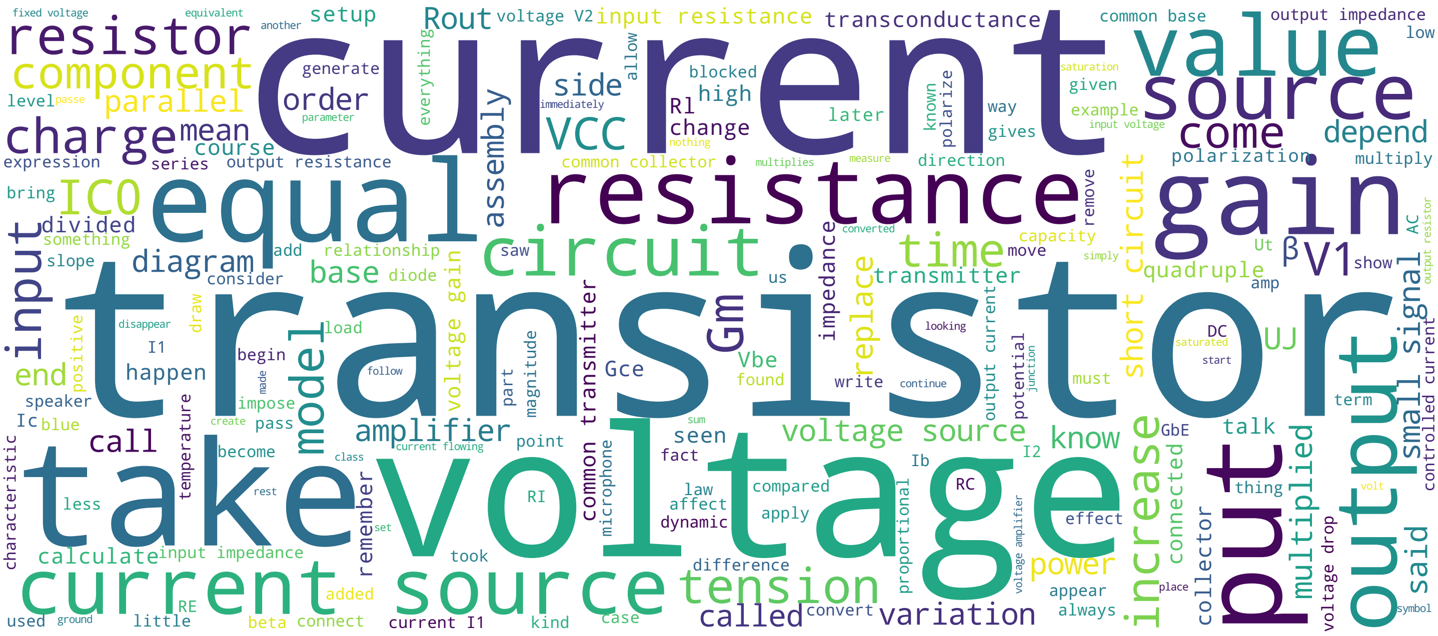
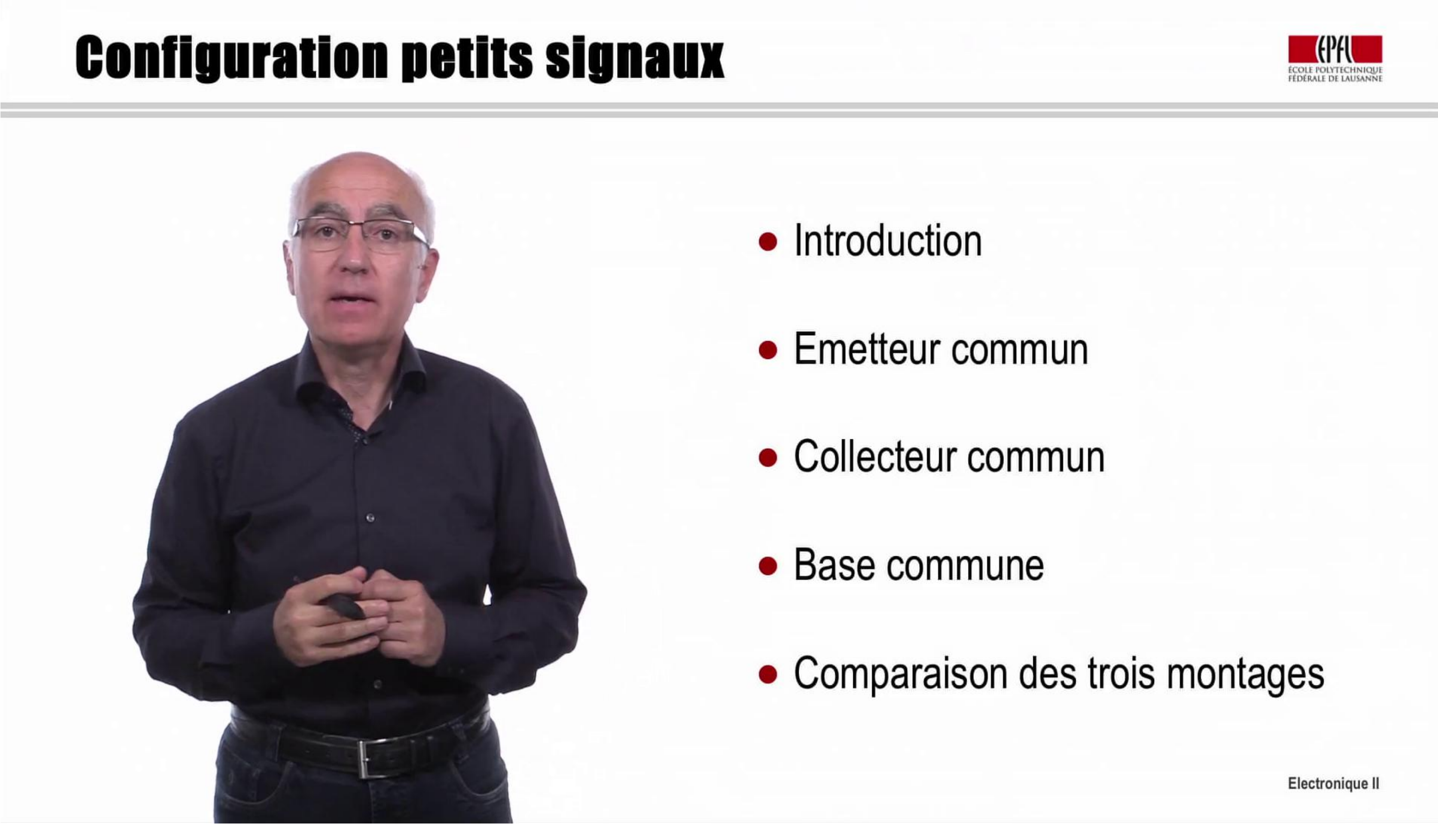


Video

EPFL

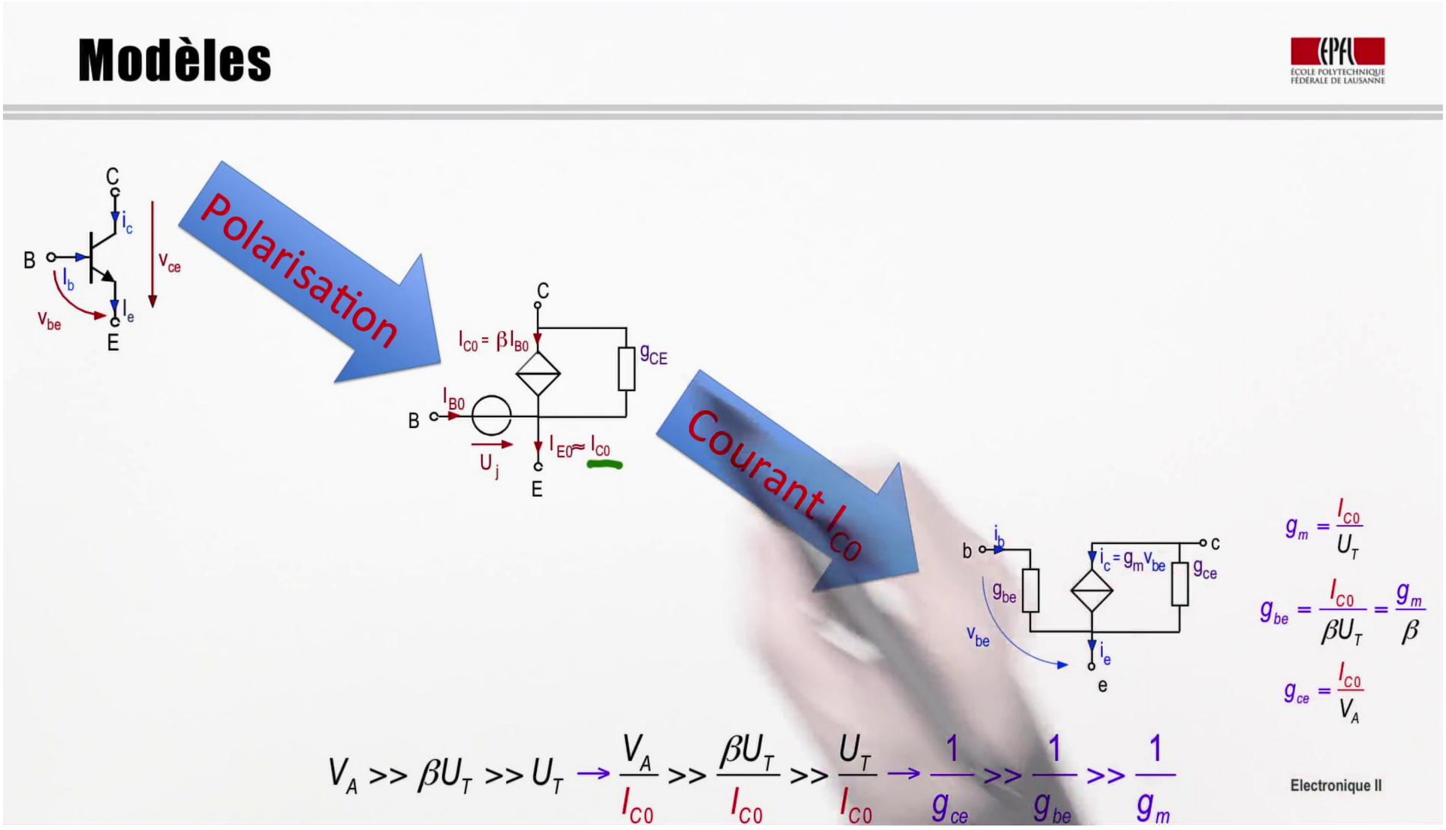


Good morning everyone, today we will discuss how we will use this small signals model which we have already derived from the non-linear characteristics of the transistor. So we have seen that once we have linearized our transistor, that is, we have simply polarized our transistor and we will take the slopes of the tangents on these characteristics, we get a linear model and the linear model is called small signals model.It is very powerful as a model because it's about components we know, when placed in circuit there is no non linearity. This means we will use three types of set that we called small signal configuration. You will see, we will take the transistor, we will take its model and we will turn it around its three terminals: transmitter, collector and base. And we'll talk about the common transmitter, common collector and common base. And we'll finish after with a global vision of the value of these three assemblies that will make the puzzle of linear electronic circuits.

Notes

Summary

0m 04s

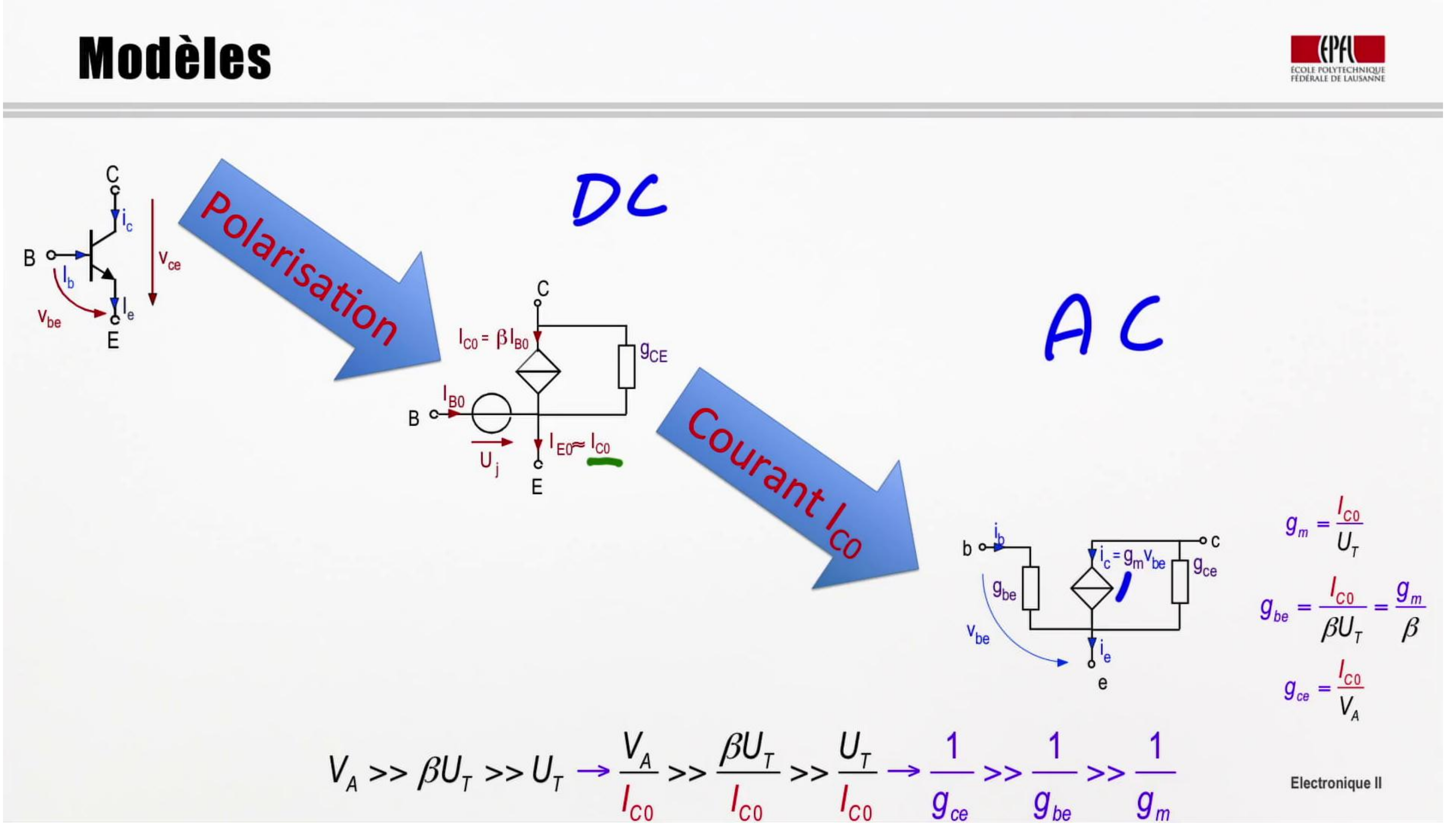


To begin, I will take again the transistor model. I put arrows that show in blue the small signal diagram and I have set vectors there that show a red color, which will first show that this transistor will all the time coexist an AC or variable so-called increments, which is drawn in blue and it will have fixed potentials who will be the polarization of this transistor. So when you take that component, we will make the first operation which is polarization. This polarization operation will be part of a specific chapter. Once we have polarized the transistor, that is we've managed to get this from our transistor, we managed to apply a fixed current called polarization current. And that's it our transistor will have a DC current that passes in both the base in the collector with the link we saw earlier through the β. And there we make the approximation to say, between base and transmitter simply we have a voltage drop that is called UJ junction voltage and is approximated at 0.7. So for the polarization operation we simply accept this model, but once this model is obtained we will move to this model. That's when the transistor is in AC mode. So here we are in the DC polarization and here it is in the use of what we call AC.

Notes

Summary

1m 10s

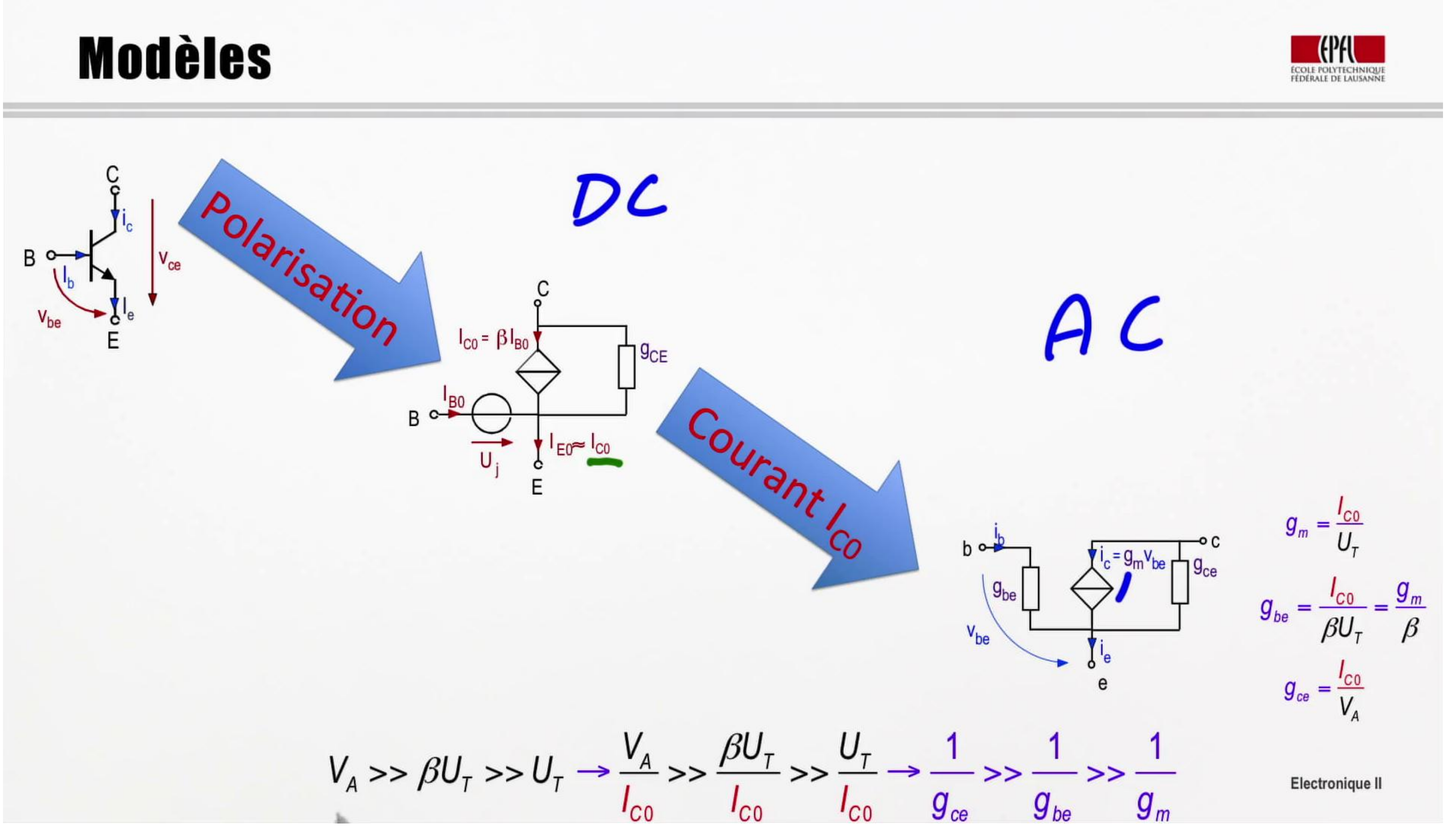


If your polarized transistor has an IC0 current that you applied yourself and you realize that you have analyzed the transistor and you know that it is not blocked or saturated and you have managed to ensure that during it use when Ic, in blue, Ib in blue and ΔVbe vary, that your transistor is neither saturated or blocked, you can remove this transistor in the diagram and replace it with equivalent small signals. This equivalent small signals was derived from non-linear characteristics. I remind you that we found your transistor, if you do a ΔIb / ΔVbe you'll find GbE. ΔIc and ΔUce, you find Gce and the transistor works like a transconductance, that is it checks the ΔVbe variation, it brings it to the output with ΔIc and we model it by a current controlled source and this controlled current source is this symbol here and we call it ΔIc or Ic which is equal to the transconductance of our transistor multiplied by the variation. Therefore was converted the voltage variation in a current variation, which is the role of the transistor. But this model is a model that represents only linear components. So we take this symbol and replace it by this and we will see later how we will change the rest of the diagram because it works in a world in which everything was derived.

Notes

Summary

2m 53s

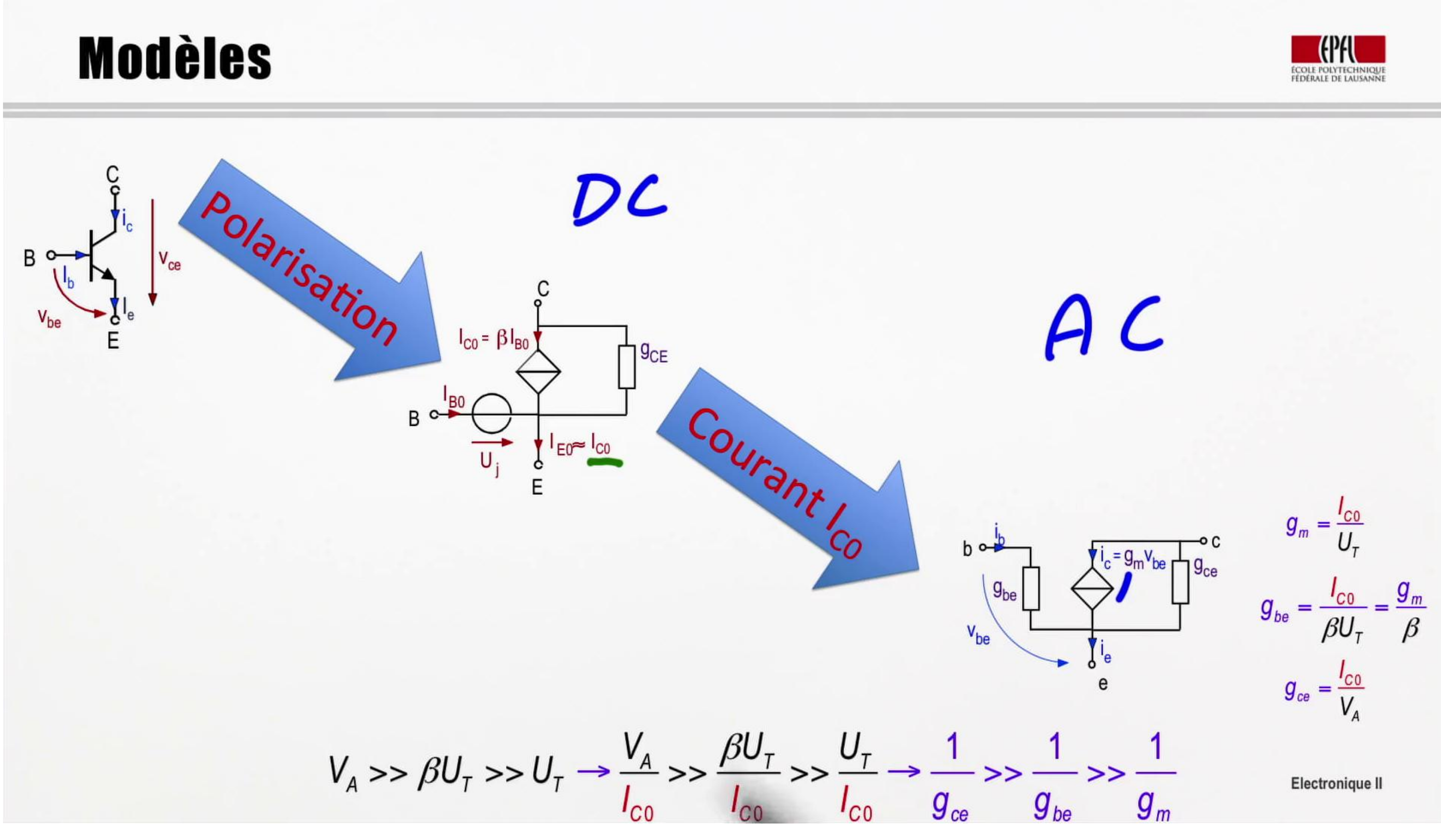


So just to remind you, wherever you have fixed voltage sources the derivative of a fixed voltage is zero, similarly if you have a fixed current source, the derivative of a constant current is equal to infinity. So if you have a fixed voltage source, you replace it with a short circuit. If you have a power source, you replace it with an open circuit. Now we come to the essential. The point is that the components that we derived, it is this Gm GbE Gce, their value is absolutely known. It depends on what is in red, which comes from this diagram here. This pattern then allowed us to fix IC0 and after looking at the other parameters. And these other parameters are related to the physical, it is not related to the circuit that you are making. The Va is this voltage here it is called the voltage early. Remember when extracted on the output characteristic Ic Uce, we found that there is a slope and this slope then affects the current source outside and it'll give you this conductance Gce or its inverse, it depends on whether you're looking at the voltage to current or current to voltage relation, it is equal, you can write Gce or 1 / Gce.

Notes

Summary

4m 36s

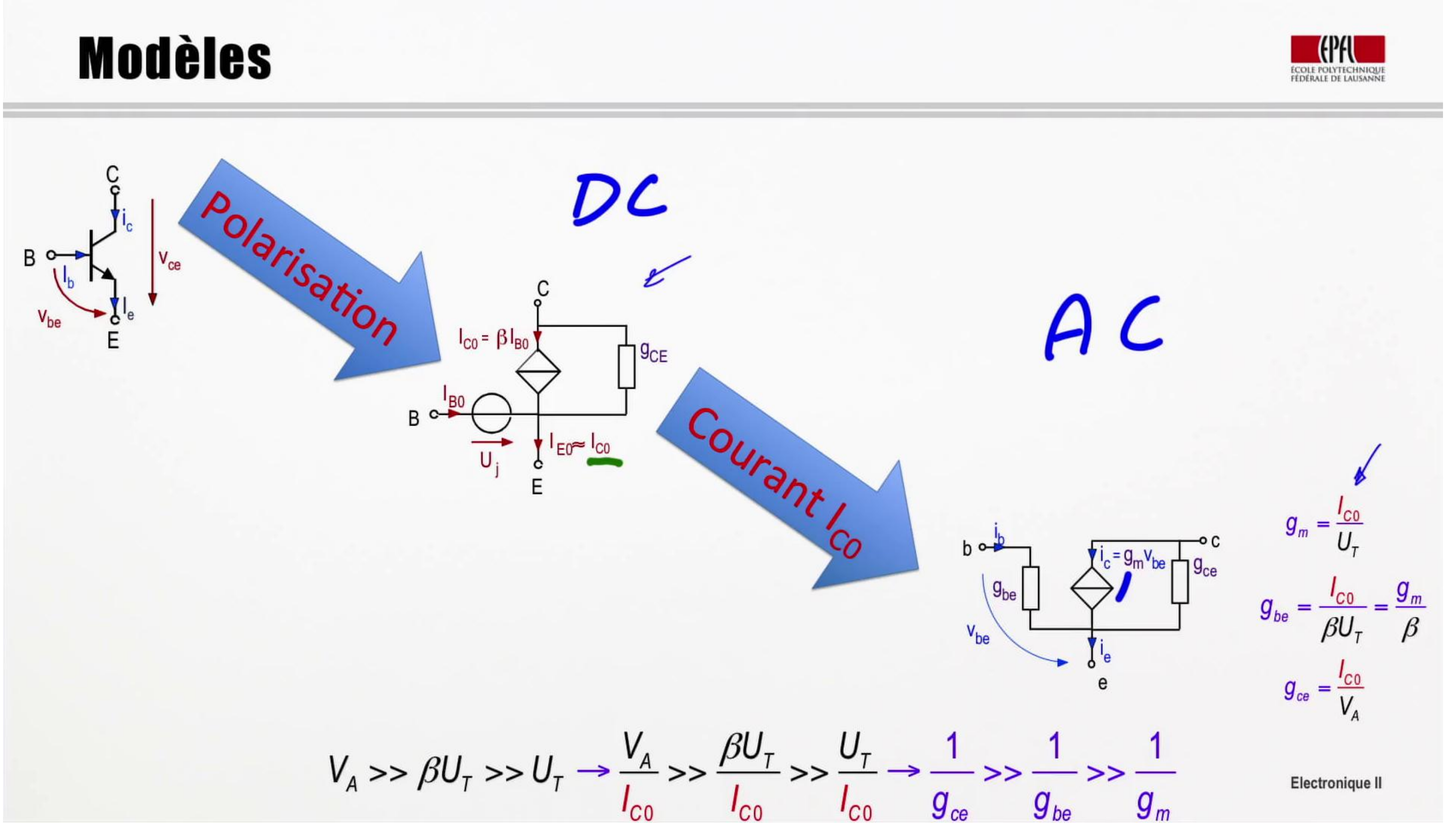


Now if you take Va and say "this voltage Early is of the order of a hundred volts " you take the voltage Ut, the voltage Ut is called the thermodynamic voltage, and this tension then is 26 mV at room temperature and you have the β of the transistor. So be aware that this is proportional to the device, the component that you have. The β is by fabrication that you get it, it's the manufacturer who has given you the β. The thermodynamic voltage is the laws of physics So that's 26 mV. This you have it by the manufacturer too. And look at this relationship. This relationship shows you there are three laws or rather three magnitudes and these three magnitudes are don't depend at all on your design it is Ut, 26 mV. Sure, if you have a β equal to 100 or 200, you have 100 to 200 times this Ut, so this term is more bigger than this, and if you take the voltage Early that is about one hundred volts, you will see that 26 mV.100 is significantly less than a hundred volts. Now if you normalize all these to IC0, IC0, IC0 you find what we saw here. So the voltage Va / IC0 is nothing that1 / Gce. The β value Ut / IC0 is nothing more than 1 / GbE and Ut / IC0 is nothing more than 1 / Gm.

Notes

Summary

5m 53s



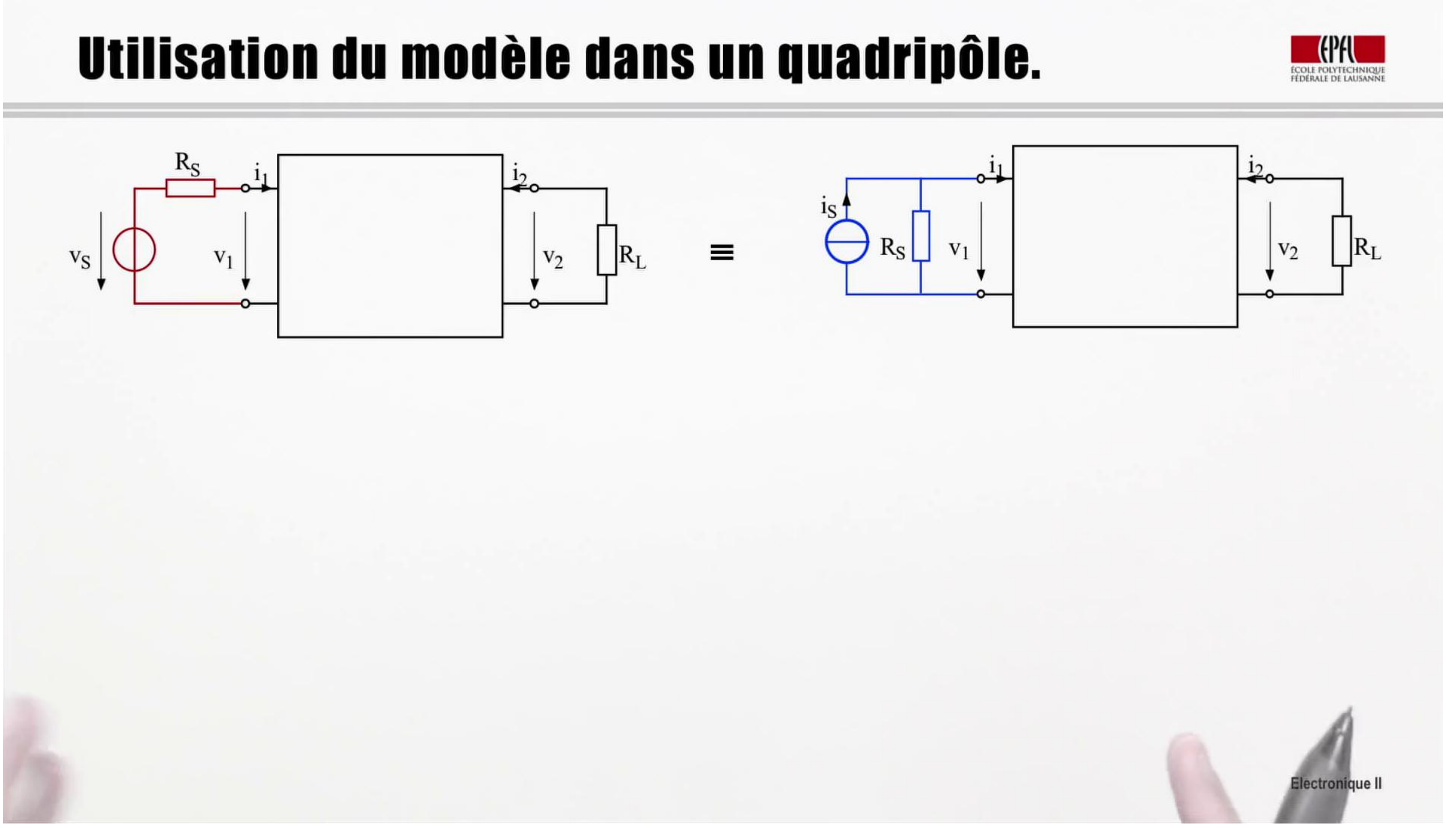
And that's it you have this relationship. So it is clear that in this small signal signals diagram, if you determine IC0 from this diagram, that's it, all the rest you can get them. So the ultimate aim is to polarize, to take the value and it is upon you to do so it's up to you to impose the IC0 value. But once you have this IC0 you have the Gm which is known, the GbE is known, and Gcu is known because the manufacturer gave the β and the Va, and you have the Ut. So if you look at this diagram then all these values are absolutely known. So you take this model, you put it in place in the global diagram of your circuit and you will solve a linear system as you learned in the basic lessons how to simplify or calculate a linear system. Then you were taught to do the next thing.

Notes

Summary

7m 25s

Utilisation du modèle dans un quadripôle.

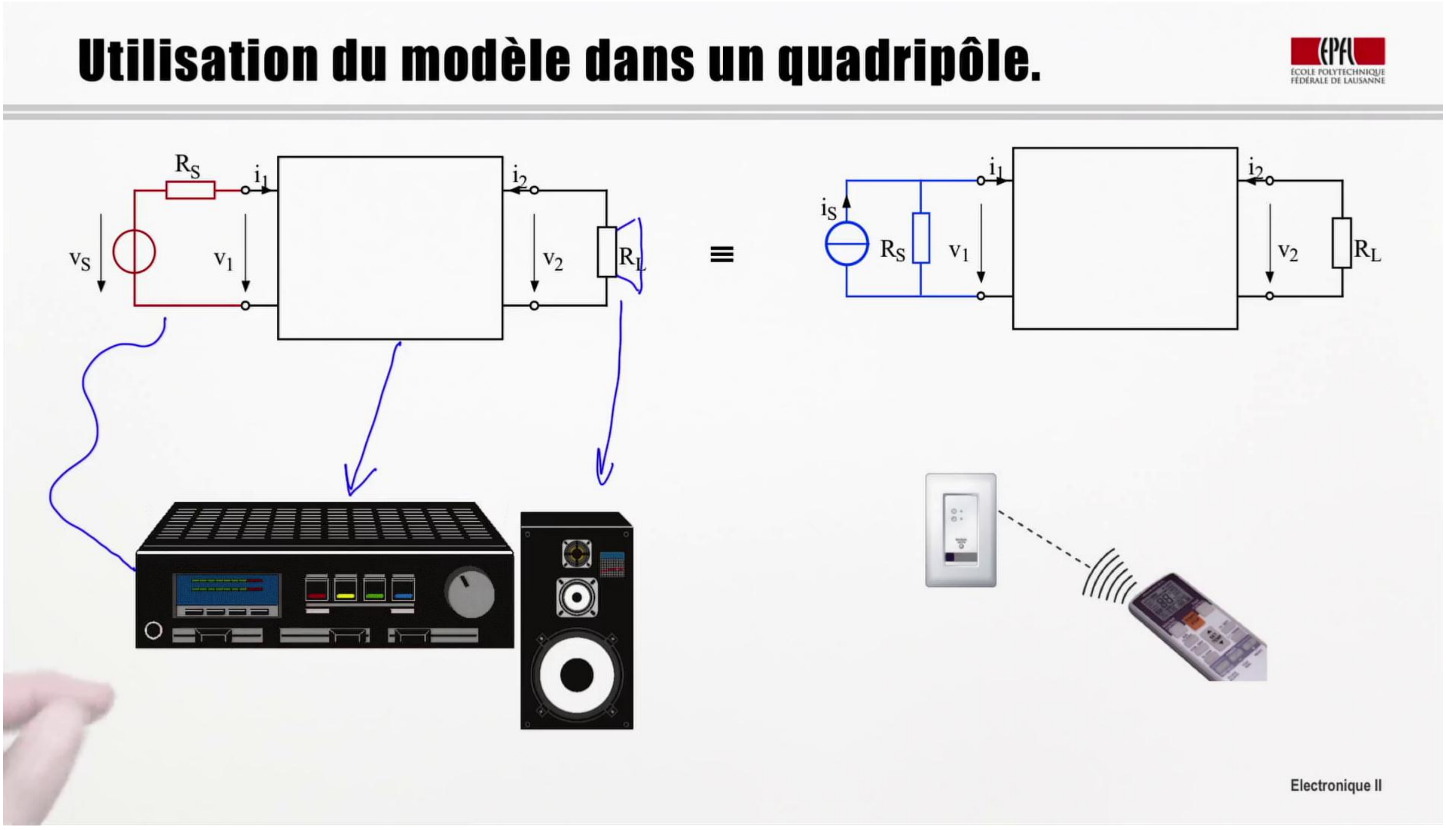


You were told "if you have a linear system that you put in a box, you call it a quadruple ". A quadruple is a black box, you have an input voltage and an input current, an output voltage and an output current. And you were told "your black box, when you apply a voltage to it at the input, it will transform it into a voltage at the output, similar to the current versus output current and you will connect yourself your charge and you will connect your own source. "If your source is a real source, it means that your source has a value of an ideal source, and there is a defect due to a series resistance, it depends on your source so there is a series resistor with it. And you were told that this same box, it can remain the same, but when you take it, you can see the source, you can transform it to its Thevenin-Norton equivalent. So a series of voltage source with a resistor may be presented by a current source in parallel with a resistor. If someone gives you a closed box and tells you "look at the entrance of your closed box, you have an equivalent resistance." If this resistance is known, this is it, you can absolutely know D1 and I1 and what happens if a current passes through your resistor, you can calculate the voltage drop in it.

Notes

Summary

8m 23s



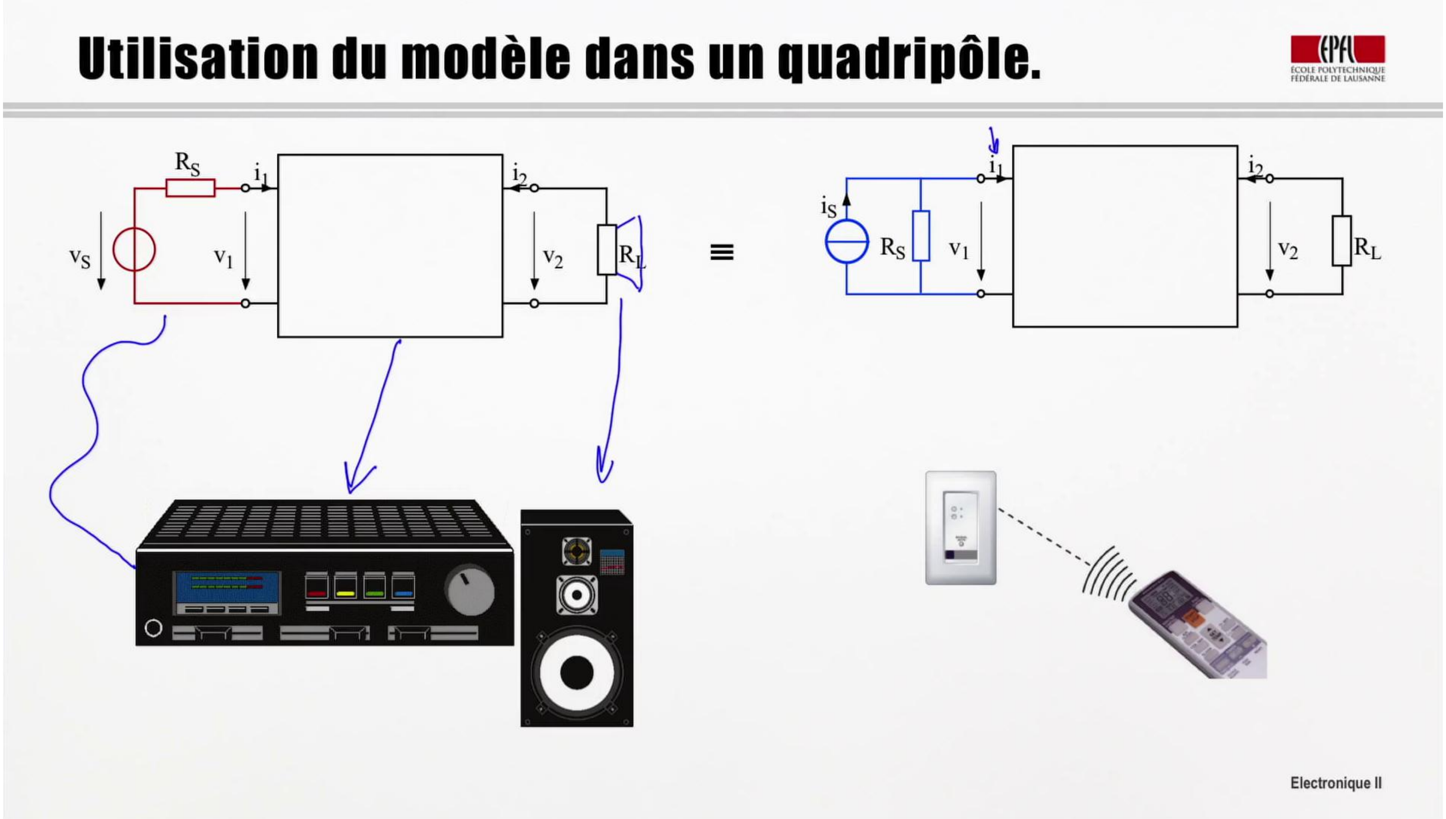
Like, if you know the Rl charge and someone tells you "there is a resistance that would be put in parallel ", called the output resistance, you have quite the ability to say "Rl will be parallel to the internal resistance that is here " same on the other side. And this Thevenin-Norton conversion helps to simplify the circuit and see it according to what we put as the source type. Now consider the same vision and go a little into practice to understand what that means. If your closed box is an amplifier, we will take the example of an audio amp, and if the load is a speaker, what you have here so it means that you have a voltage amplifier. Here you have a source. If that source is a cable that brings an audio signal and this audio signal is generated from a microphone or a digital file with analog output from an mp4 or mp3 code, what you want, so you have a signal here is going to arrive, the input resistance this is where there is a plug that is here. When you connect your microphone, your source what will this microphone show? It will show the input resistance, one that appears here. So anything that is like electronic inside come down to the input resistor.

Notes

Summary

9m 54s

Utilisation du modèle dans un quadripôle.

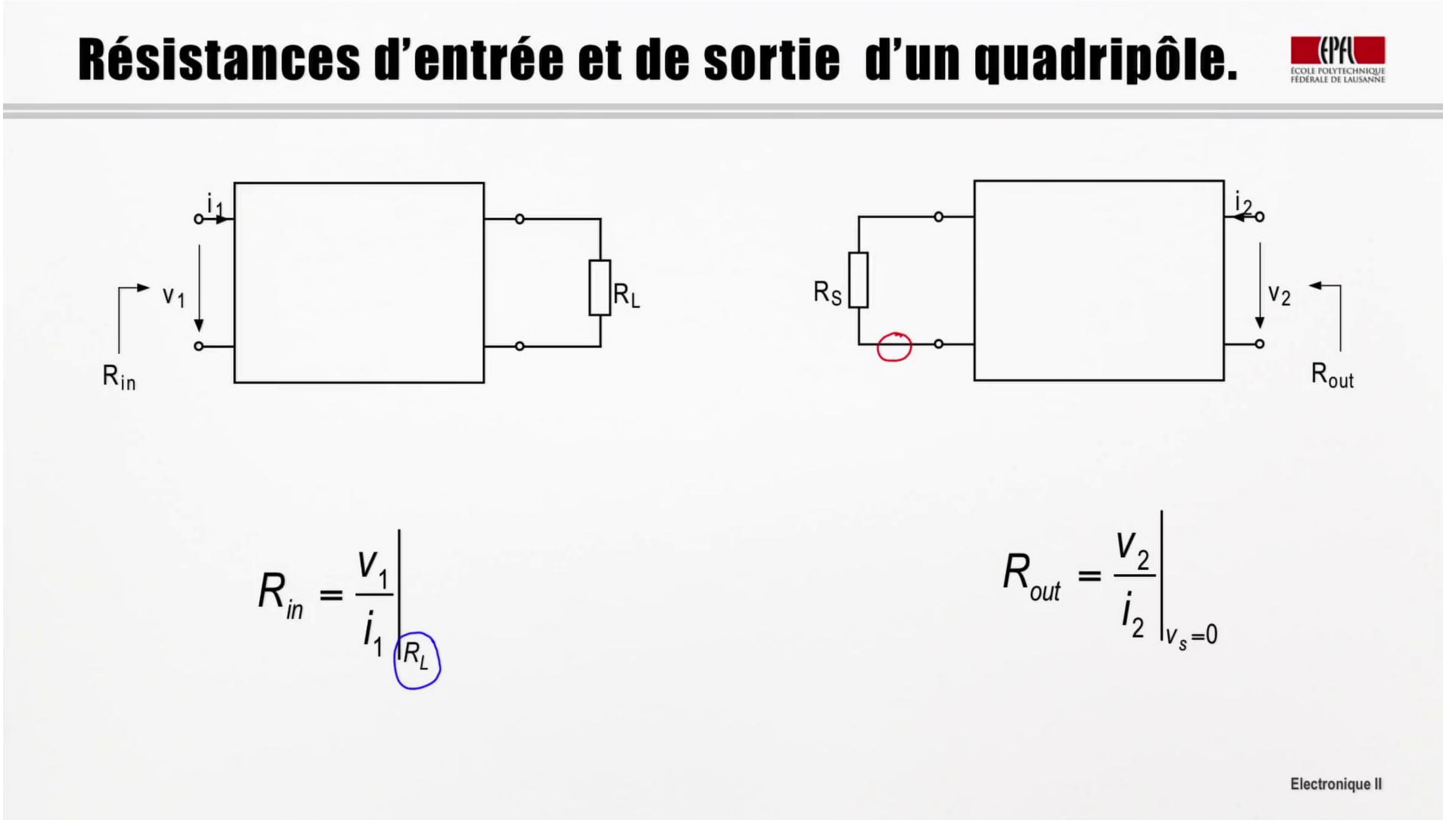


Same here you have this speaker that would come with an output resistor. We can take another example here. When you transmit from an infrared transmitter, it will send a light in the infrared band and here you have what is called a transresistance, we'll see later, that is, the light will be converted with a diode into a current. So you have here a current I1. This current I1, you put a transistor circuit that is a quadruple, that's it, at the output you can read the data that is sent in coded light, converted into a current to an output current and this output current sent to a resistor, becomes a voltage. So it's up to you if you want to take a voltage, convert it to voltage and we talk of voltage gain, if you have a current you want to convert voltage or current, and we will talk here of a current input, a current output, a current input, voltage output. Or the same, we can put a voltage input, a current output. So all these are conversions which we know how to do very well because there is Ohm's law that facilitates the transition from one to another.

Notes

Summary

11m 22s

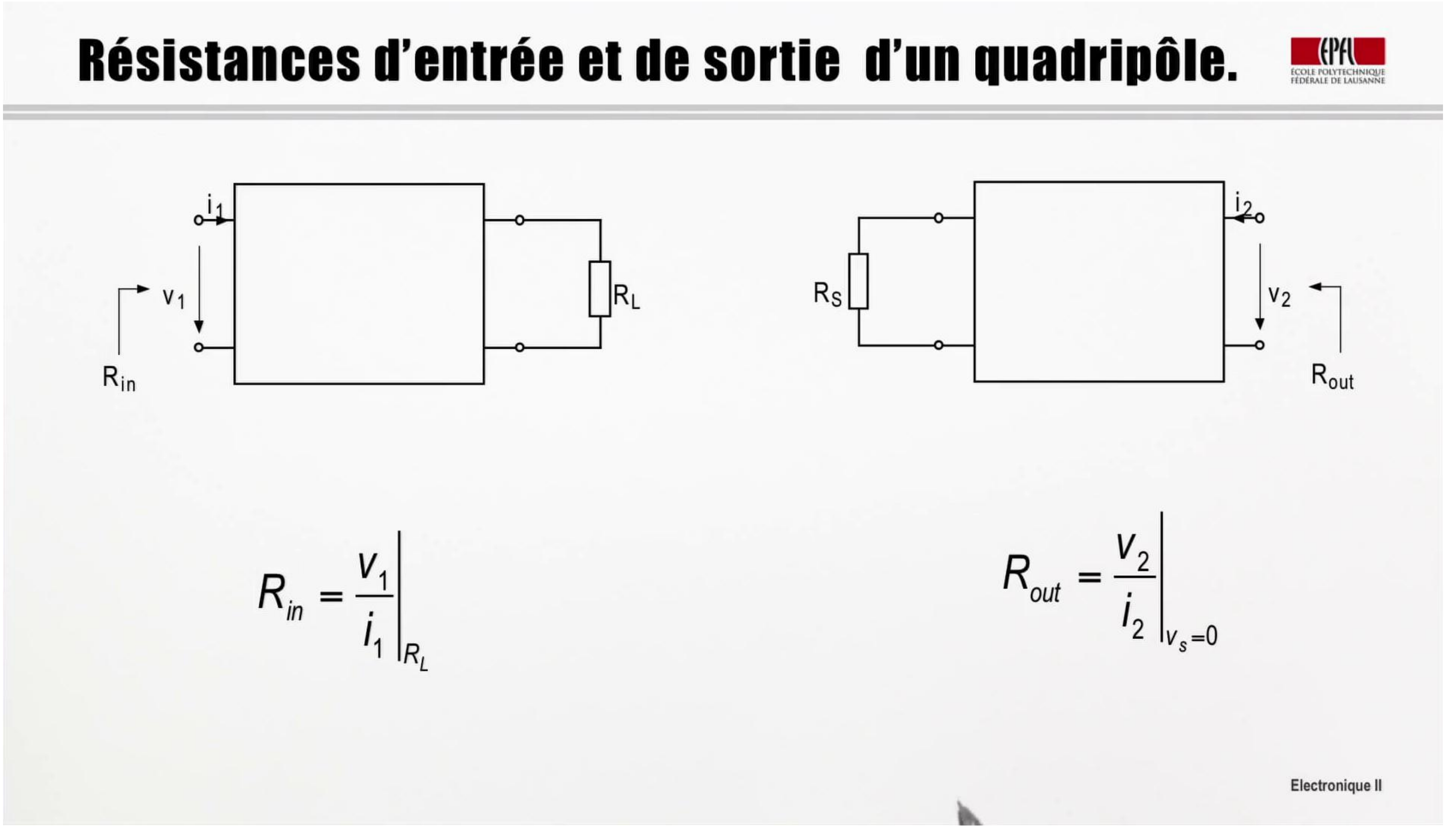


Our quadruple that we see here and we said it comes down to the input by an input resistor and at the output by an output resistor, the relationship that describes the input resistance defined like this: if you want to calculate the input resistance that appears here or measure this input resistance, you have to create a relationship between V1 / I1. But to properly measure Rin, you must keep your charge. So if there is an audio amp, you must keep the speaker connected, if the speaker is connected, your speaker keeps its impedance, everything will depend on what is inside, because sometimes the speaker can affect the input resistance. So when you put that and we say "with RI", it means your quadruple, you must keep your resistor at the output when you measure the ratio between V1 and I1, that's the definition of the input resistance. The output resistance, it is set to a source zero, so you remember a while ago, we had a voltage source which supplied our signal to our amplifier. Here when we say the source, it should be canceled, it is as if you are going to erase this source, So it's like this.

Notes

Summary

12m 35s



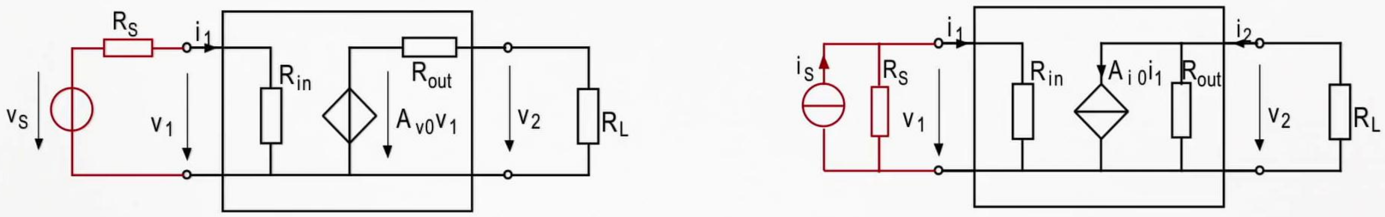
In other words, you are not at all in the process of implementing an increase, so if you have connected a microphone, you must do everything not to make noise, not to generate an AC signal at the input. So the source is equal to 0, that is, there is no AC voltage source, but you should keep your microphone connected, that's what requires the fact that the internal resistance of your microphone should be plugged in, but you must not increase or rather apply a sound source for your microphone to generate an AC signal and affect the output, so it cancels the source, but we keep the source connected so the input impedance of the source, if ever the output resistance depends on the input resistance, we would see it in the expression that appears in place of Rout. So after we'll have Rin, we will have Rout, and here we know exactly what the impedances are at the input and output of such a quadruple. So this concept is a basic concept that we all know, and with that, we will go further to see how we put a transistor diagram inside and how are we going to use it.

Notes

Summary

14m 04s

Modèles du quadripôle



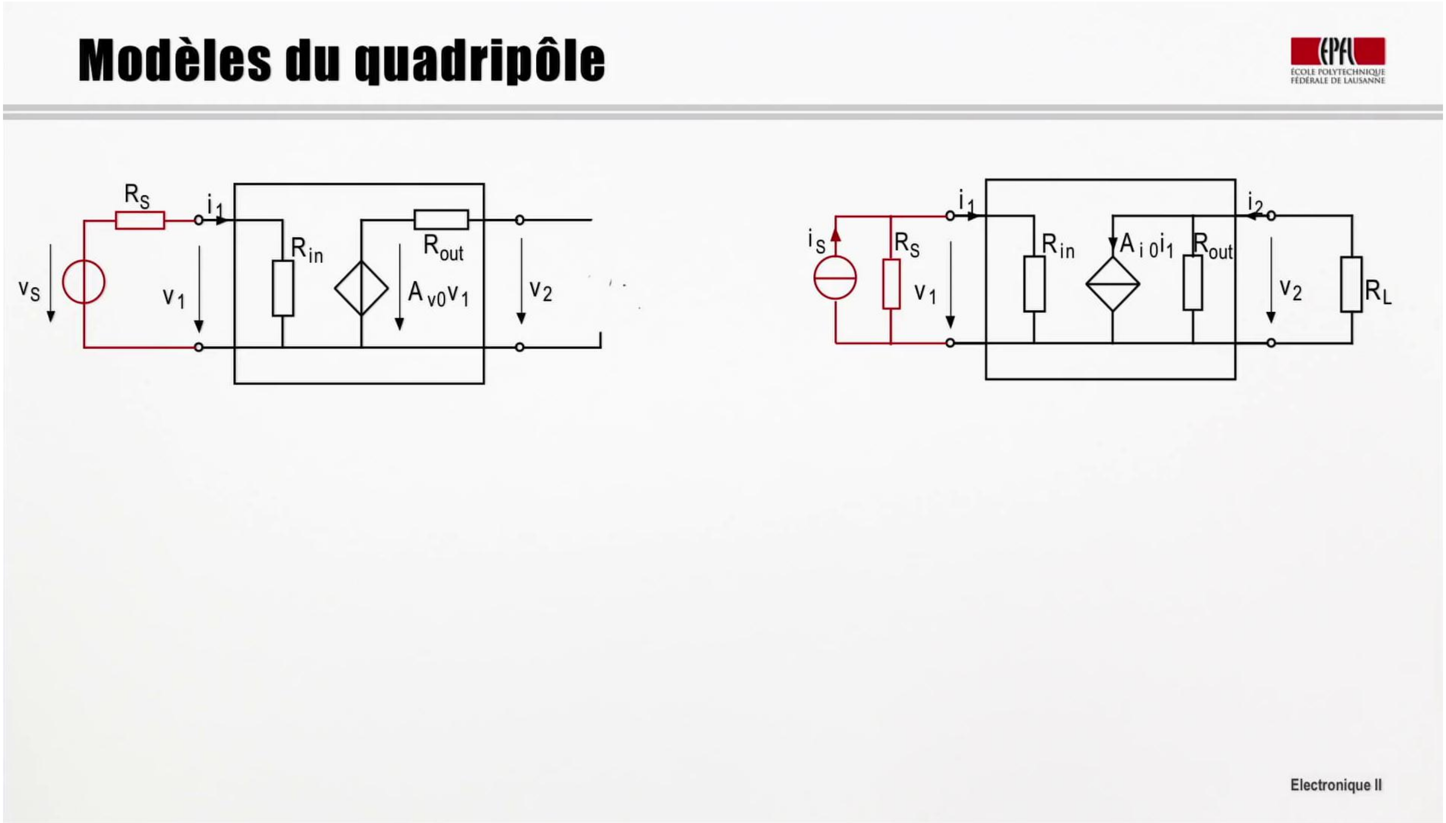
Electronique II

If you take the quadruple, you can break it into different types depending on what you want make of your quadruple. If you take the earlier example when I gave the example of the audio amplifier, I said there is a voltage V1 and a voltage V2, I also said "I would like to take V1, multiplied by a gain and send it back on a speaker. "You remember, when it's about an audio amp, so it is a voltage amplifier. A voltage amplifier is an amplifier that takes power and multiplies it by a gain, so it is very convenient to present a voltage amp like this. The input resistance, which we had already set, the output resistance we had already defined are not here. Now I take a controlled voltage source, the V1 voltage I see here, it is multiplied by a voltage gain. So it is with that you use to increse or reduce the volume of your amp, so you are increasing or lowering the gain of your amp, and this is a way to represent a voltage amplifier quite adequate for voltage amplification. So if you remove the resistor R, that is to say, you look at it it's empty, we remove this, So I remove all this it's empty, then the output resistor does not affect it at all, there is no more current flowing here,that is, the voltage V2 is what I see here, it is called the open circuit voltage.

Notes

Summary

15m 19s



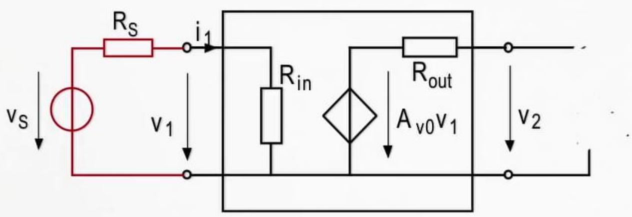
Now I take another way to present, you see what we have here, a voltage source in series with a resistor, I can well replace it with a current source in parallel with a resistor, so this Thevenin-Norton transformation, this duality exists. So I can take it and use it like this, it's a current amplifier. I would like to take the current I1 I generated with a current source which is not ideal, with a parallel resistor with the source, I1, I multiply it by a gain, then I'm interested in what we call the current amplifier. We'll see it later, we will see later we will make voltage follower in whic the gain V2 is equal to V1, but I take I1 and multiply it by a gain, and i refer it to the output, i transform it into another current which is much larger, and I call it current amplifier. So it is more convenient to use a controlled current source that describes that the current I1 is multiplied by a gain which I call Ai that I find at the output affected by the output resistor. So this resistance is always the one that was determined before.

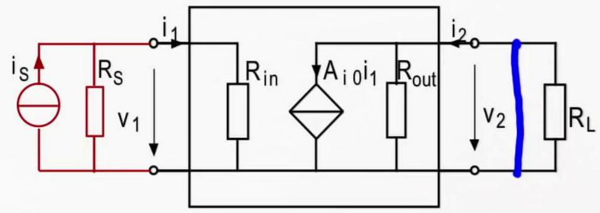
Notes

Summary

16m 56s

Gain en tension & gain en courant





Gain en tension à vide

$$A_{v0} = \left.\frac{v_2}{v_1}\right|_{R_L=\infty}$$

Gain en tension avec charge

$$A_v = \left.\frac{v_2}{v_1}\right|_{R_L} = A_{v0}\frac{R_L}{R_{out}+R_L}$$

Gain en courant sortie court-circuitée

$$A_{i0} = \left.\frac{i_2}{i_1}\right|_{R_L=0}$$

Gain en courant avec sortie chargée

$$A_v = \left.\frac{i_2}{i_1}\right|_{R_L} = A_{v0}\frac{R_{out}}{R_{out}+R_L}$$

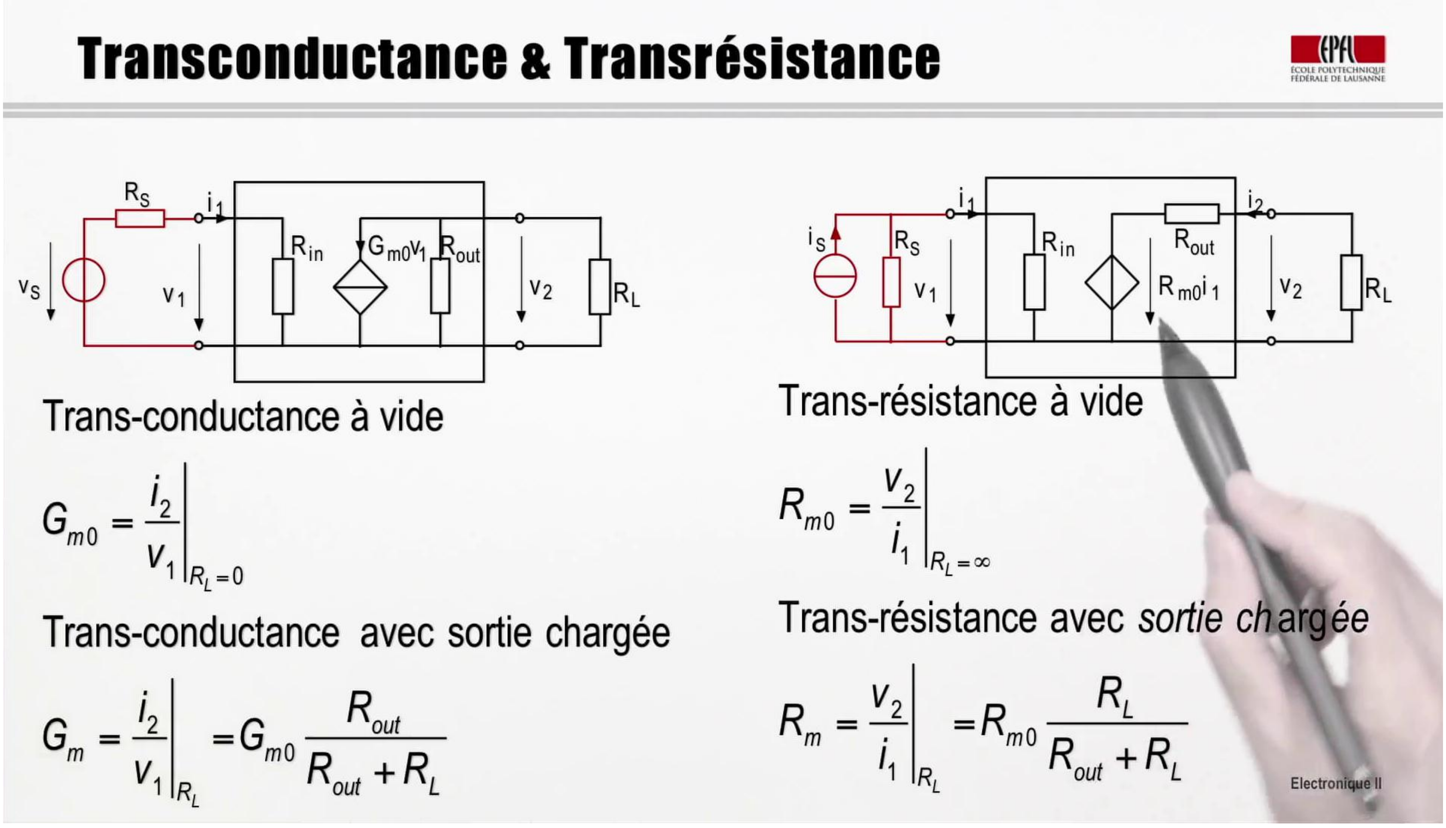
Electronique II

So looking at the behavior of this view, I see it with the voltage gain and the current gain is the equivalent diagrams of a quadruple presented in one way or another. I speak of the open circuit voltage gain is when my resistor that I had connected here has dissappeared, so that's resistance, I'm make it disappear, here I'm talking about the open voltage gain, it is when RI is equal to infinity, which is the case now. Here, when I look for a current amplifier, what I call the short circuited output current gain, it means I take the output and I create a short circuit, so i put zero resistance in parallel with RI and I will cancel RI and Rout. So you see your current source I2 is equal to Ai0 multiplied by I1, that means the current that is generated by your current source here is the current you see in the short circuit, it's how we could measure this current source. So when you talk about open circuit voltage gain, you remove the charge, you end up with the voltage V2 that is generated by it, is equal to this voltage source, your Rout does not affect it, likewise when you look at the short circuited output current gain, Rout and Rl will disappear and you will end up with only Ai0, that you'll measure, so you find directly your gain which is the ratio of this short circuit current divided by this input current.

Notes

Summary

18m 05s

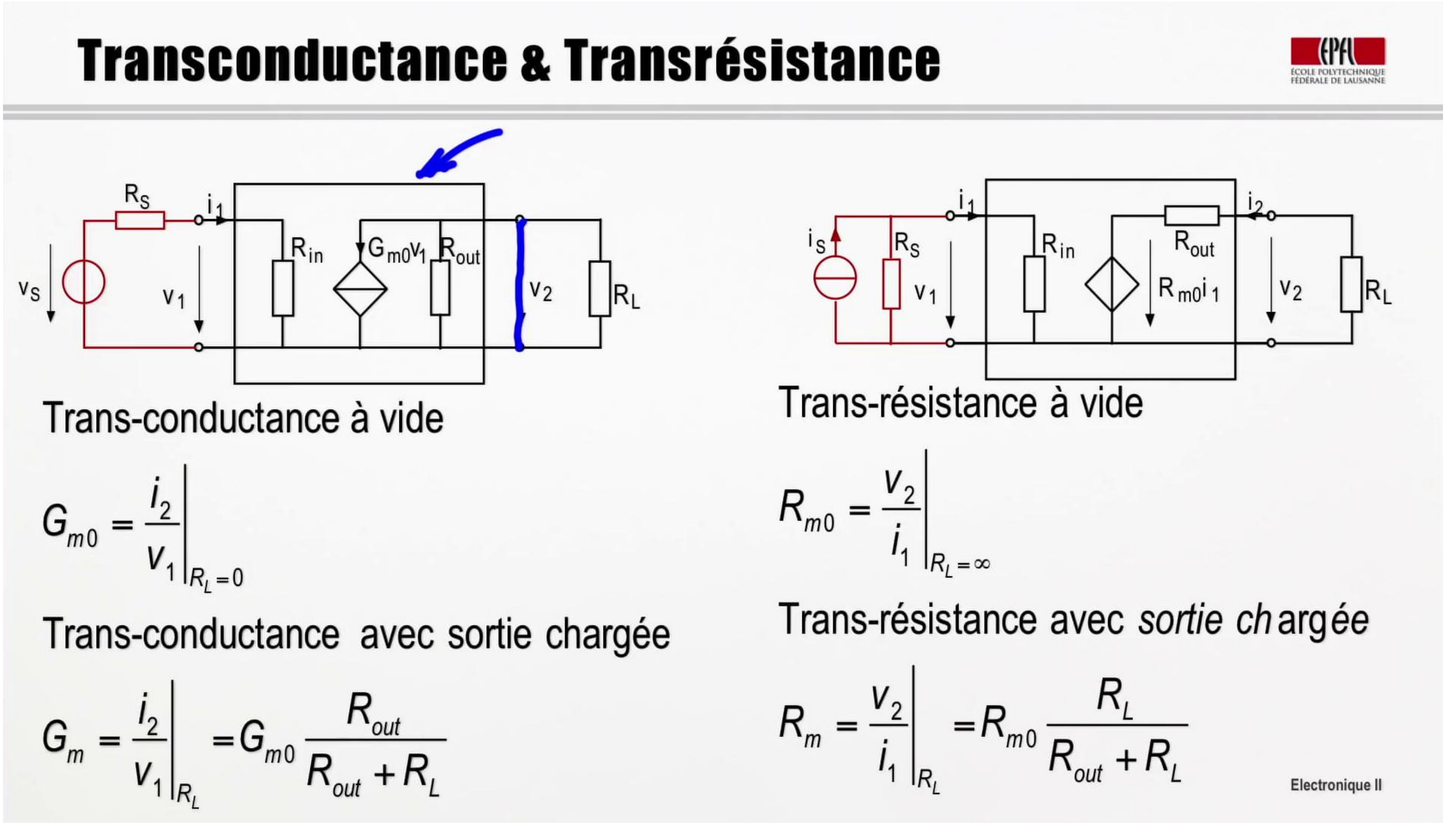


Now if you do not do that, but you charge your circuit, that is, you return to this situation, you put back RI and put RI here. There you have a resistive voltage divider, so your divider, you have a voltage source which sees two resistors Rout and Rl. So it's as if you took the voltage gain that we have here, and you multiply it by two, the division ratio RI divided by the sum of the two, as noted here, and it allows you to immediately see the gain V2 / V1, called voltage gain with charge. Same when you add here Rl in parallel with Rout, that's it, you take this here and you have to multiply it by the current divisor which is formed by RI in parallel with Rout. And now two terms for two configurations. A configuration called transconductance and another called trans-resistance. Transconductance means, you put V1 here you want to convert V1 into a current that is equal to the transconductance multiplied by this voltage, So we want to convert voltage to current, look it is a controlled current source here, controlled by what? By voltage. We call it transresistance,you took a current at the input and turned it into a controlled voltage source by the current.

Notes

Summary

19m 46s

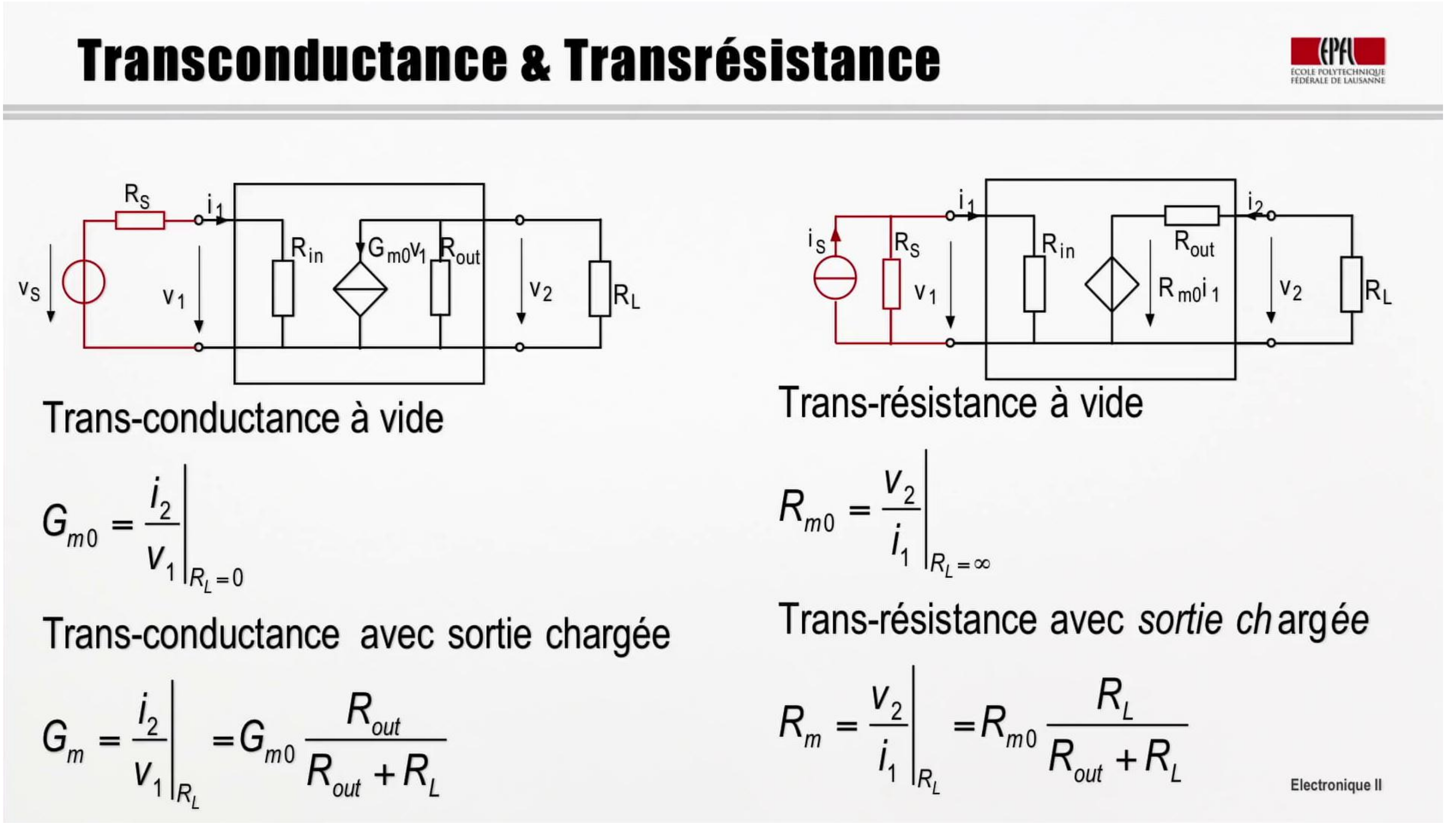


That's each variation of this current changes into a voltage which is equal to this value that you'll have to calculate, called transresistance, Rm0 which multiplies this. Same here, each change in voltage is multiplied by this Gm. What we will overuse later in this course is this diagram here, and you will see that the transconductance diagram is indeed the electronic component we made with the transistor. The transistor itself is a transconductance, we said that already, we will repeat it. It'll take your voltage and convert it into a current, that's it. So if you measure in short circuit the output, if you take the transconductance and you want to see if we have current here, if you pass it through a short circuit, this current here, is exactly the gm0 V1, V1 which is a current and it's called transconductance, you are absolutely measuring the transistor effect by the Gm of the transistor. If now, you look at what will happen with your Gm when you remove the short-circuit that I just added, and you put your charge, you just need to multiply it by the ratio of these two resistors that we added.

Notes

Summary

21m 26s

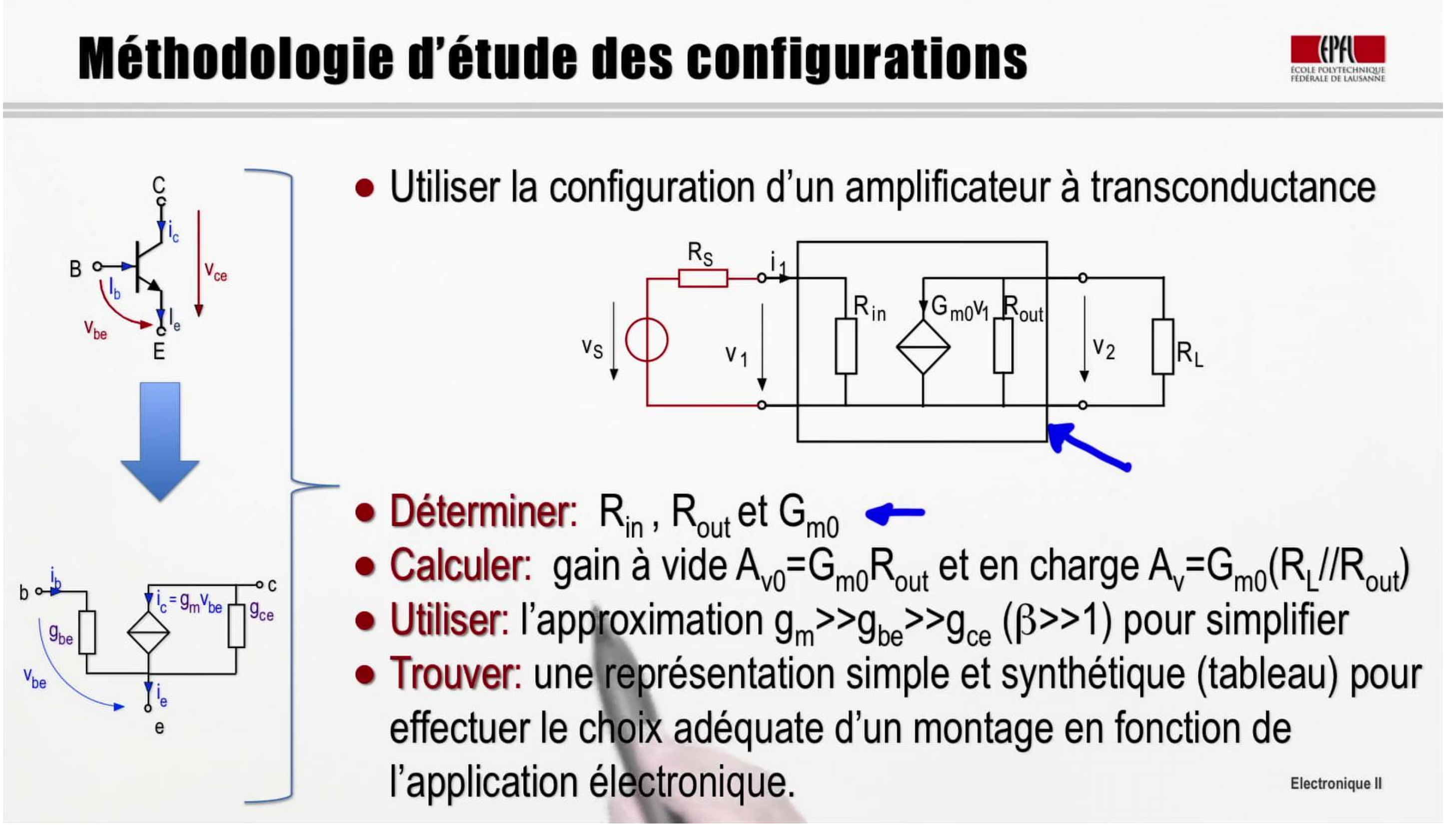


Same in a transresistance, we first begin by eliminating Rl therefore it is removed, we make it infinite, and here we are watching the voltage here, which is equal to this here. And the transresistance with a charged output, i connect the resistor and there are two resistors which form a resistive divider and the divider here, you simply need to calculate V2 considering Rl resistance ratios divided by the sum of both. So I repeat, this is the diagram in which we will all come back to all the time, and it is with that we will learn how to take our small signal configurations and convert it into an equivalent diagram of this, and you will see, it will always pass by calculating Rin, Rout and gm0.

Notes

Summary

22m 46s

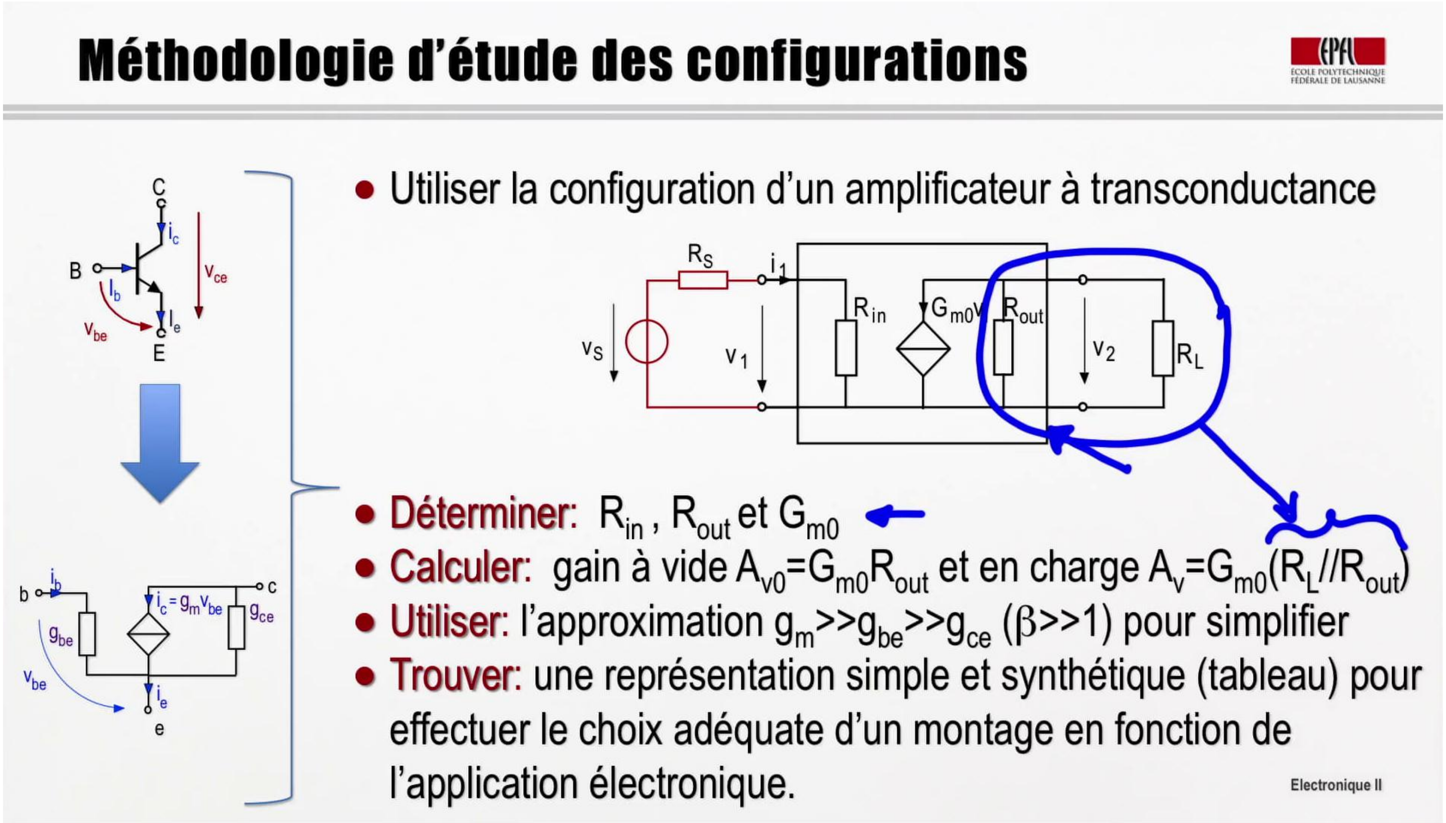


I will summarize what we just saw. We showed that the ultimate goal is to generate the equivalent of what is called a quadruple. In this quadrupole, we would l ike to see something that looks like a Rin, Rout and a source of open controlled current, we have gm0 which multiplies the voltage and converts it into a current, that is the vision we would like to have every time we have a transistor with a symbol, which we converted a transistor into a small signals diagram, we placed it in a circuit, you will see immediately what follows thissmall signals model of our transistor, it will enable us to calculate Rin, Rout and lGm0. So we begin by calculating these three parameters. Once we have that, we qualified our quadruple, we take our quadruple and place it with a source and a charge. We can calculate the charge gain, the ratio V2 / V1, which is always equal to Gm times the output resistance, and that once you have connected an external resistor Rl, just put Rl parallel with Rout and imagine that you have a current going through the parallel setting of the two, look at this, you have Rout and Rl in parallel, and you have a current source that begins in these two resistors, the equivalent resistance is this and the gm0 is the short-circuit transconductance you'll find here.

Notes

Summary

23m 33s



You will find expressions in which it will have settings that are here. You will find Gm, GbE, Gce or 1 / Gm, 1 / GbE, 1 / Gce and inevitably, you remember we have always done approximations that allow us to say the least is Gce and will become increasingly large until we get to the Gm or the inverse, 1 / Gm is the smallest after 1 / GbE, and then after 1 / Gce which becomes the largest. And finally, at the end of this week we will make a summary of what we'll later call small signal configurations with basic editing, and you will see, we will have a very synthetic vision, we can even fit it in a table that will show us that with three base set ups, we get to solve everything in linear circuits, and this is the goal of the end of this chapter or the end of what we are seeing in the series of videos we are watching this week.

Notes

Summary

25m 15s