ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

2.2-Transistor Bipolaire Modélisation

Exemples d'application

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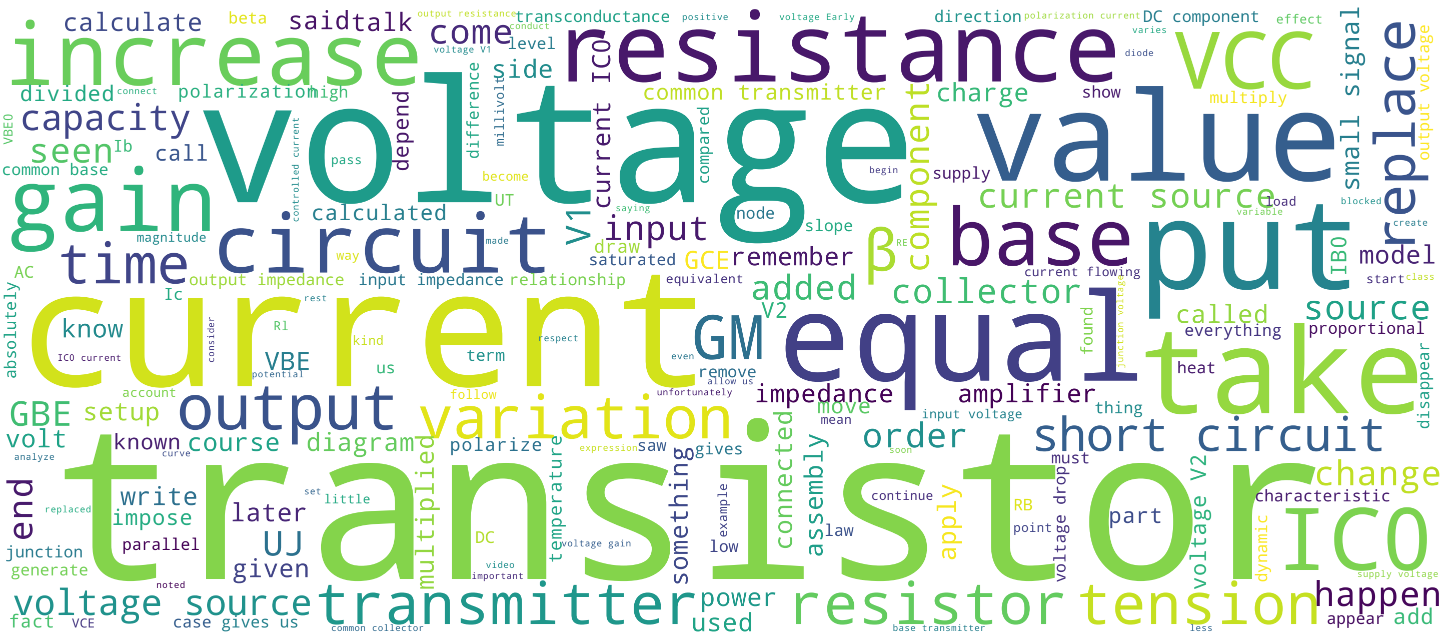
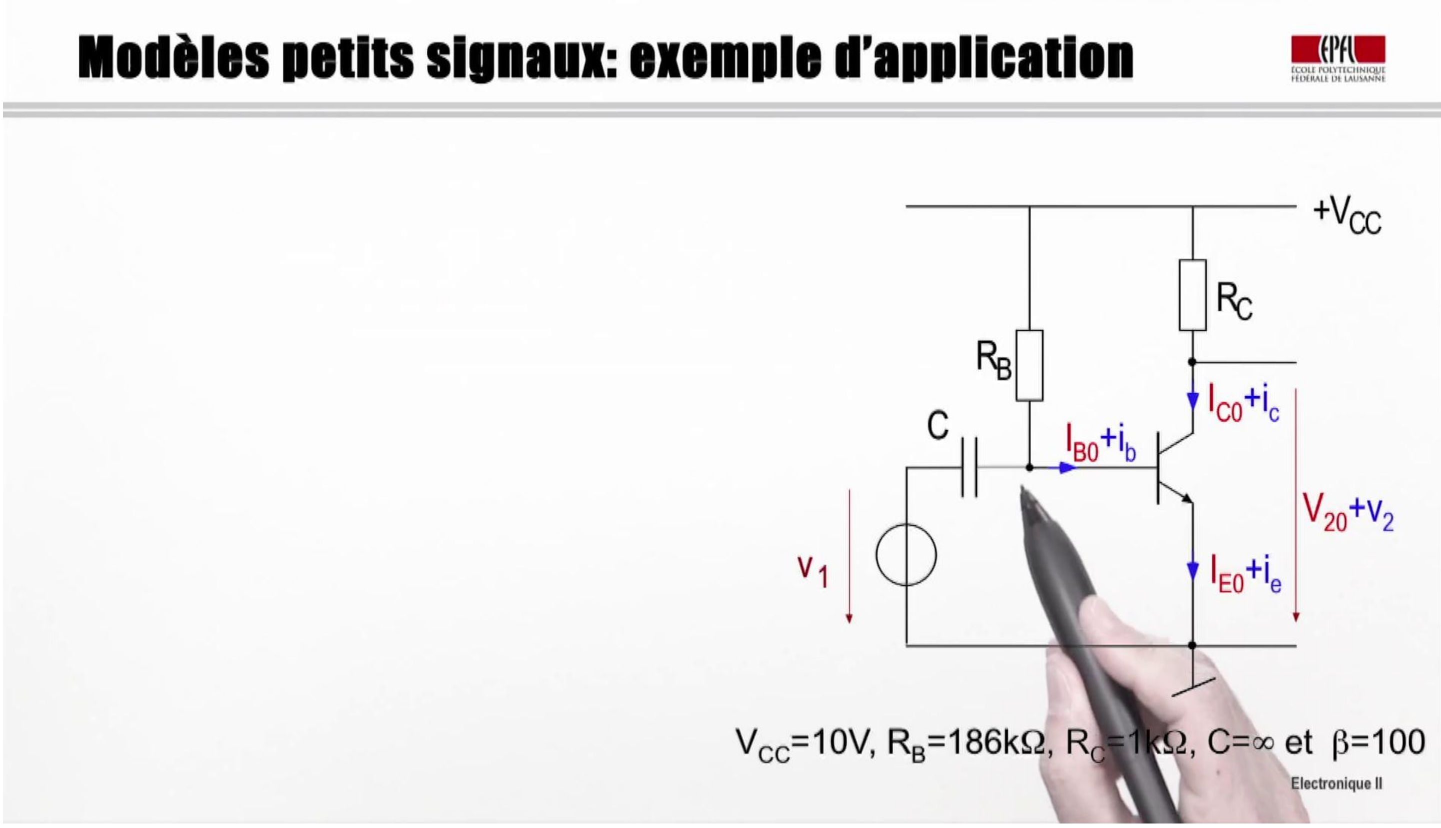


Video

EPFL

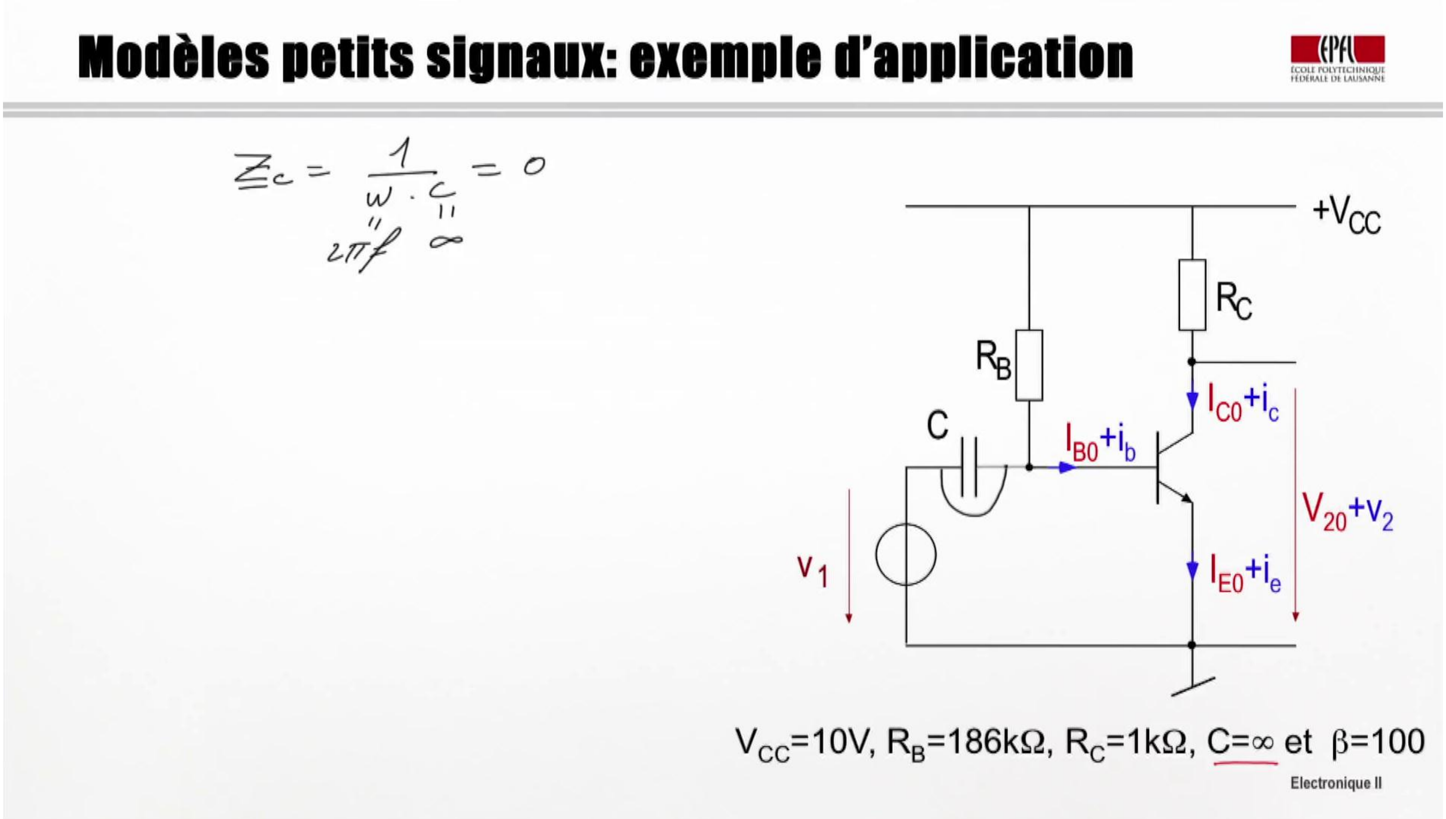


Now that the small signal model has been introduced, we will implement it in the context of a circuit. The purpose of this video is to take a simple example of a transistor where we will have to polarize it, of course and superimpose an increase on the polarization. Thanks to this, we can see what will happen with our transistor and how the small signal model is used once our transistor is put in a complete circuit context. The example of the circuit is as follows. We see out transistor here, and there is a supply. This is a voltage source VCC. I took a DC voltage source, I can of course draw it here if I want. I pull this here, and I just have to draw a VCC voltage source that will power all this. When I analyze my circuit, once I drew this, I'll point out the following. I take again the circuit now that I've cleared this source I added, and I notice that this voltage source, which is usually drawn like this without drawing it every time, we do not add it, that's why I deleted it. I put a transmitter that comes from the voltage supply to the base. I added a capacity here and I added a voltage that I noted in lowercase, I called it V1.

Notes

Summary

0m 04s

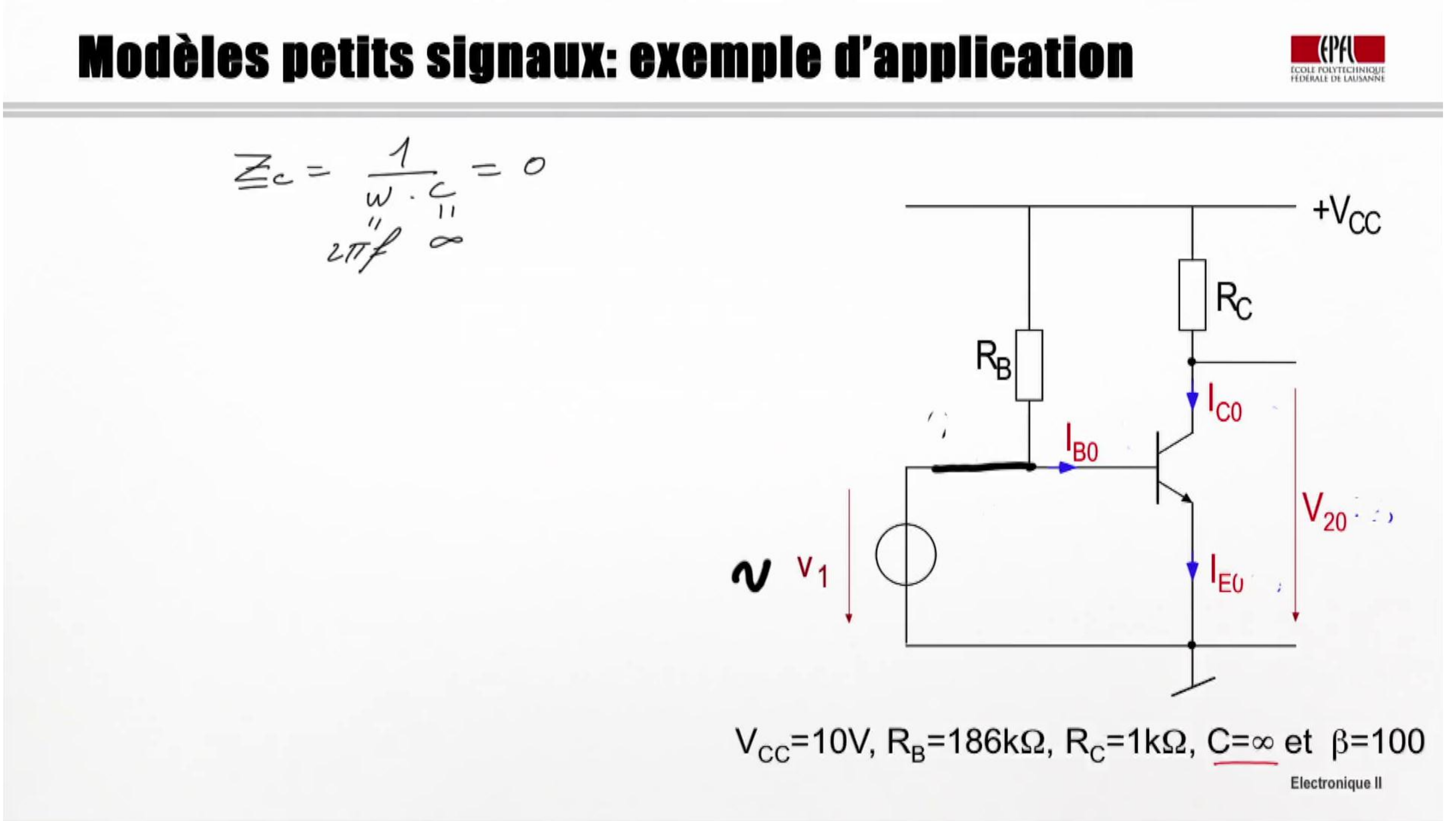


I added an increase source, or a source that will give me the signal through my transistor and I decoupled it by a capacitance. What is decoupled by a capacitance? We'll have a full lesson on what this capacitance is, but if you observe here what I just noted, I put C = ∞. You know that the capacitance value is extremely high and you say C = ∞, it is as if you were telling the impedance of my complex ZC capacitance, which is equal to 1 over the signal frequency, or the signal pulse which is 2πF, it's (2xπxF) which I inject times C, which will come from here an I put here it is equal to infinity. It's like I was saying that for all that is variable, all that has a frequency, the impedance is equal to 0. The capacitance behaves like a short circuit to all that concerns variations. For all we add here that has some variation, this capacitance acts as a short circuit. For everything that is not variable, it behaves as an open circuit. It means this circuit here, I can deal with it in two ways. If I want to deal with it in DC, so if I want to deal with it without injecting or rather keeping everything that is connected here, but not taking into account that I have here a variable source, I only have to remove this part.

Notes

Summary

1m 37s



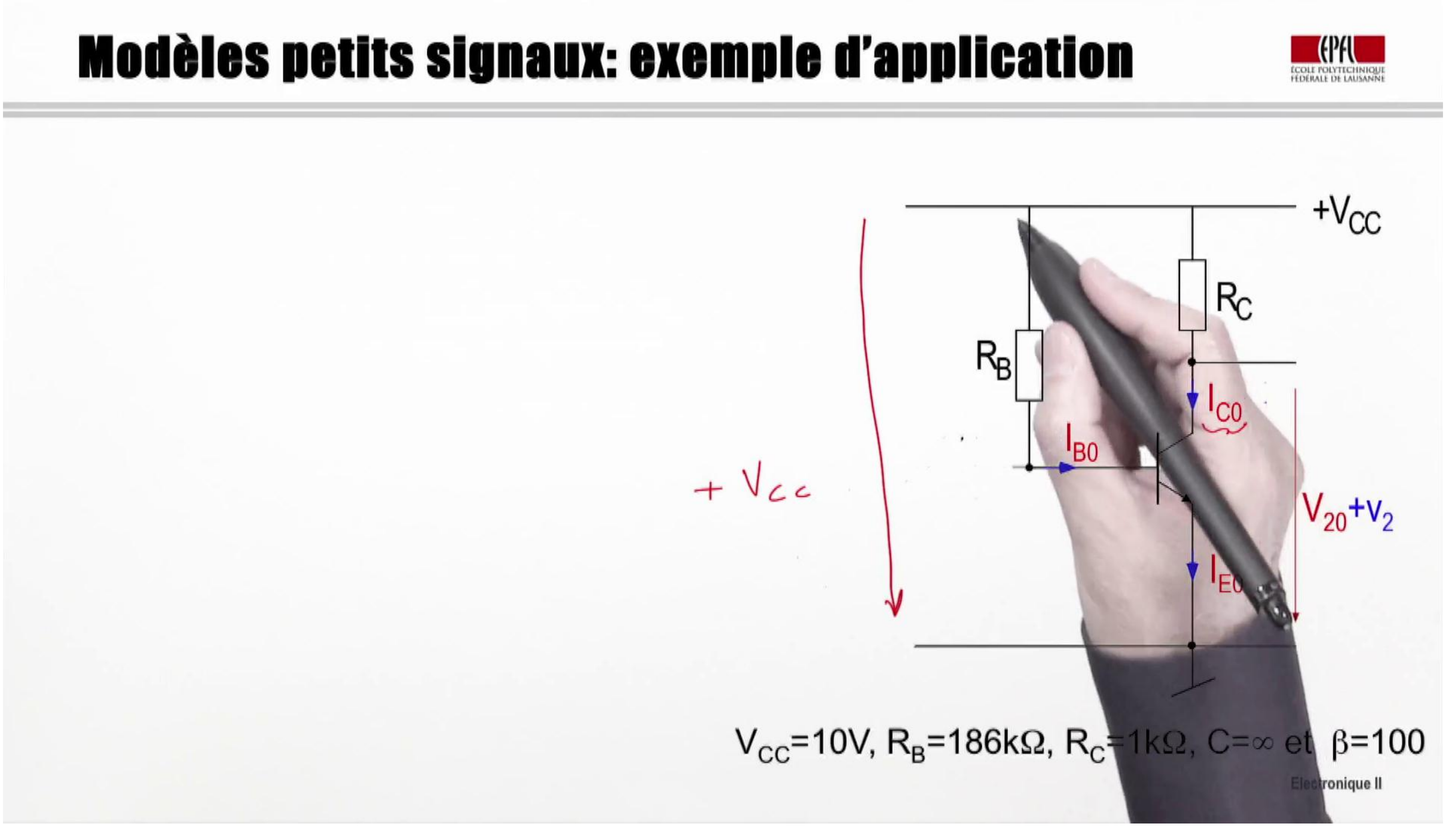
$Z_C = \frac{1}{\omega \cdot C} = 0$, $\omega = 2\pi f$, $C = \infty$

That part will disappear and there I have my circuit supplied, and of course this component here is not there. All these components that are here will disappear. So that, it will disappear in DC model, this will disappear in DC model and this too. So there are no AC variations, all this is due to to the fact that I used a capacity and it decouples variations. All that is variable, will pass through and otherwise I find myself with a circuit uniquely powered by a supply voltage and there is no DC component. All thanks to this capacity because the capacity is there to enable this source when this source applies a voltage variation to increase, something that varies in time, which has certain frequencies, when we talk of a sinusoidal voltage, its impedance here will be 0. It behaves as a short circuit, only when I have a voltage which varies in time and has been brought to a sinusoidal voltage to be able to speak of the impedance.

Notes

Summary

3m 12s

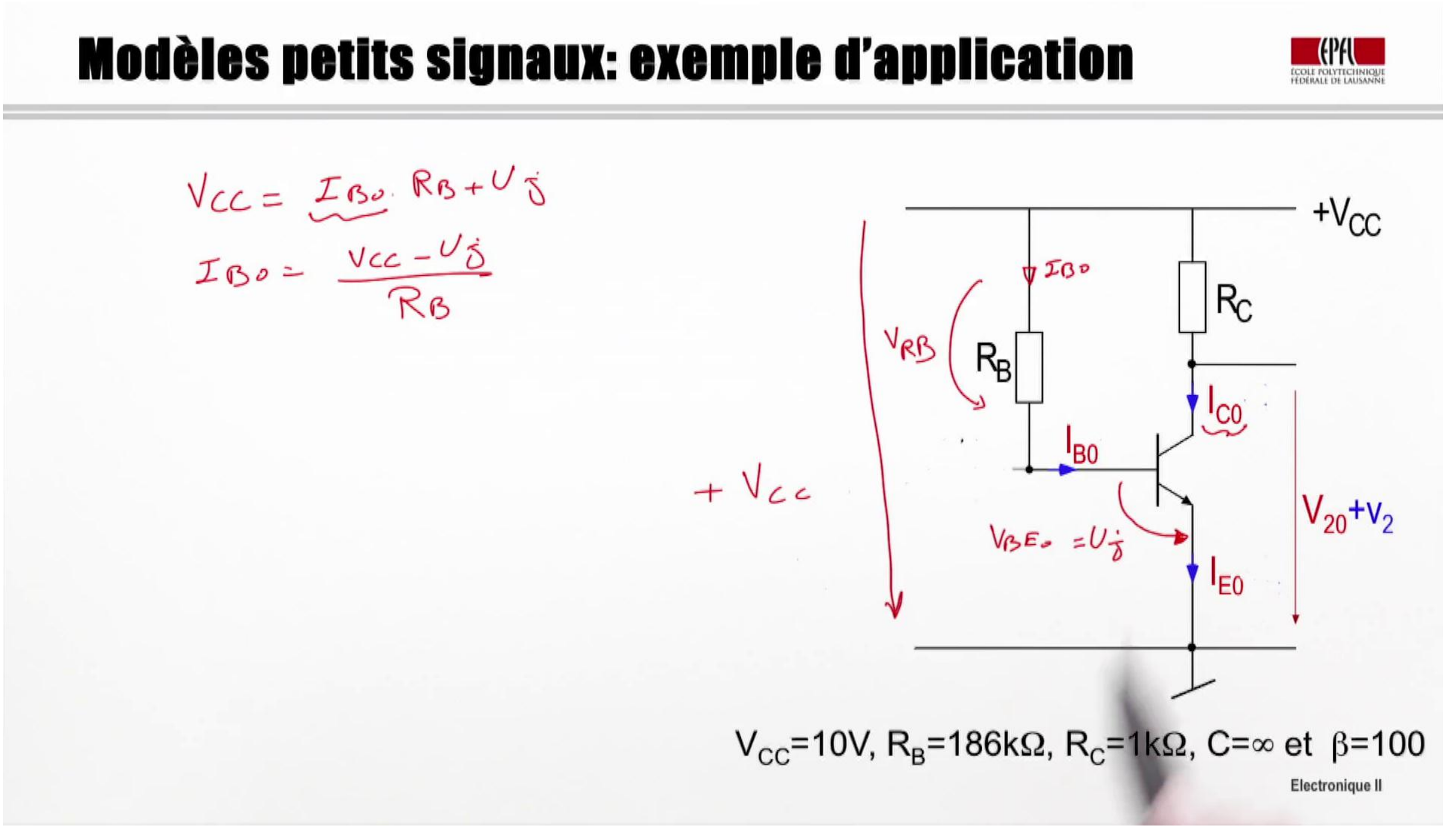


There you go. I would like to take my circuit and put it back in its DC use, that is to say, I will erase every where I have the capacitance. I'll just watch the DC model on what happens. It was said that here, we will look only at the DC components. I erase everything on AC, all this will disappear. I'll end up with a very simple circuit, which is this. All this is as if it did not exist, I can erase it, I do not see it. The V1 source that generates the AC signal will disappear. Here, now I have my polarization circuit. Observe this well, this is indeed a polarized circuit. What would i like to do, really? In fact, I would like to apply the Ic0 current. You will remember that the first step of the use. In reality, I would like to impose current IC0. Remember that the first step in the use of a transistor is to polarize it. This is a fairly known polarization diagram, not very much used, we will see later why, but rather didactic to explain that. We said we had a DC power supply, that is to say from here to here, I have a voltage +VCC. When you apply a voltage +VCC and you put a resistance coming from the base, you know that when your transistor will conduct, it will have a tension here if you use the simple model of the transistor that ignores the exponential.

Notes

Summary

4m 21s

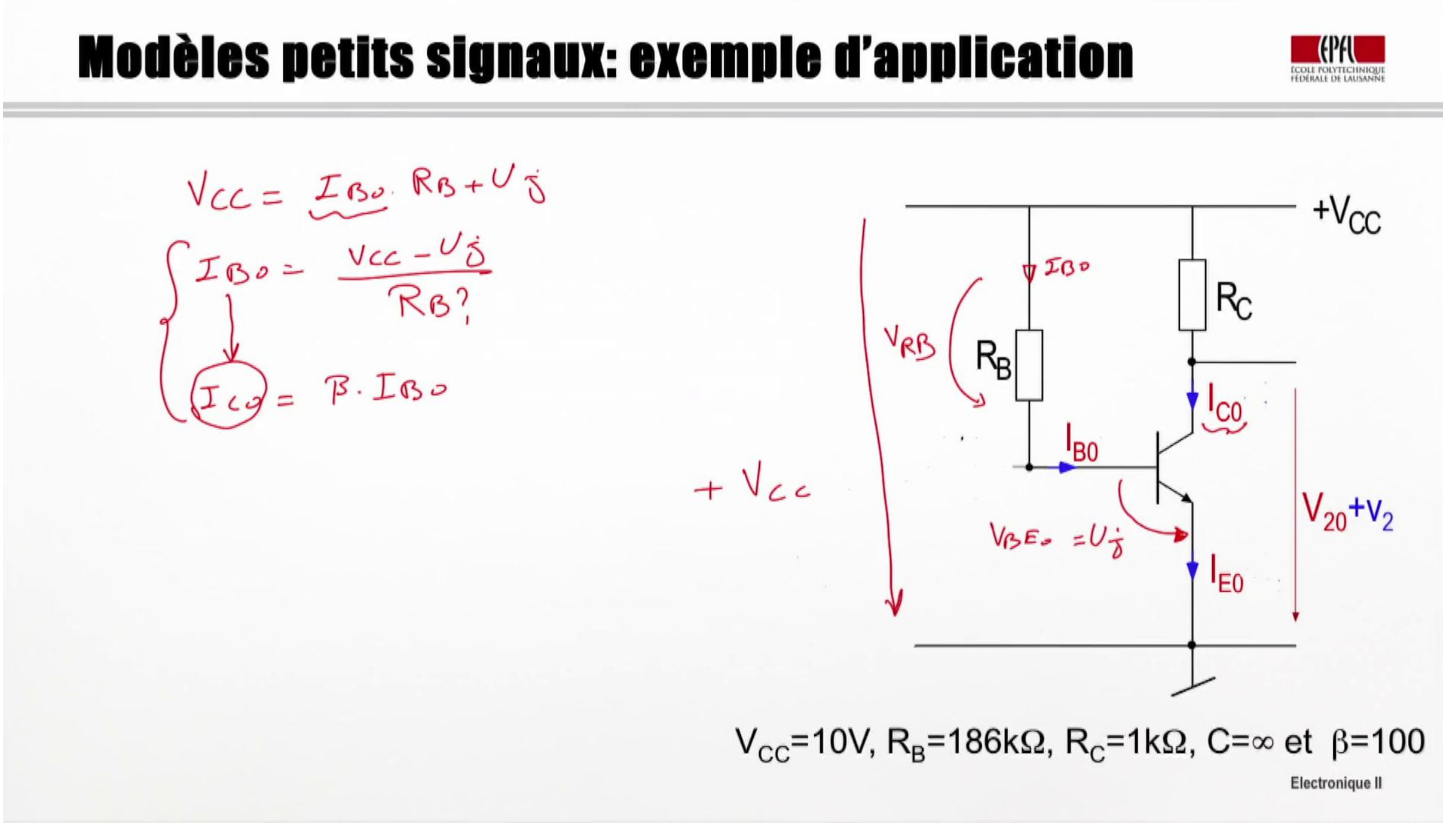


Remember that we said that during polarization of a transistor, we just use the simple transitor model, one that is linear by segment that will show me that here I have a junction voltage of the order of magnitude UJ, so VBE, or VBE0, will be of the order of magnitude of UJ. Obviously this value of UJ is an approximation. This is perfectly valid when we want to look at the polarization effect. So only in polarization do we have the right to use it. Because after the variable VBE, it will be injected by this voltage source that will perform a voltage variation between base and transmitter. If you start from that and you say IB0 passes by, the IB0 here and there I have a voltage which I called VRB which is equal to (IB0xRB), I can write that VCC, the supply voltage is equal to IB0 multiplied by RB plus UJ. And that is the voltage that is here plus this one. So I can easily extract my current IB0 which will be (VCC-UJ) divided by the resistor RB. Finally, the calculation element is the RB. It's up to you to chose RB resistor to apply IB0. That is not the objective, the objective is IC0. This allows us to determine IB0, but I know IB0 is linked to IC0 by the fact that the β of the transistor IB0 will give me this current IC0 so IC0 is known.

Notes

Summary

5m 56s

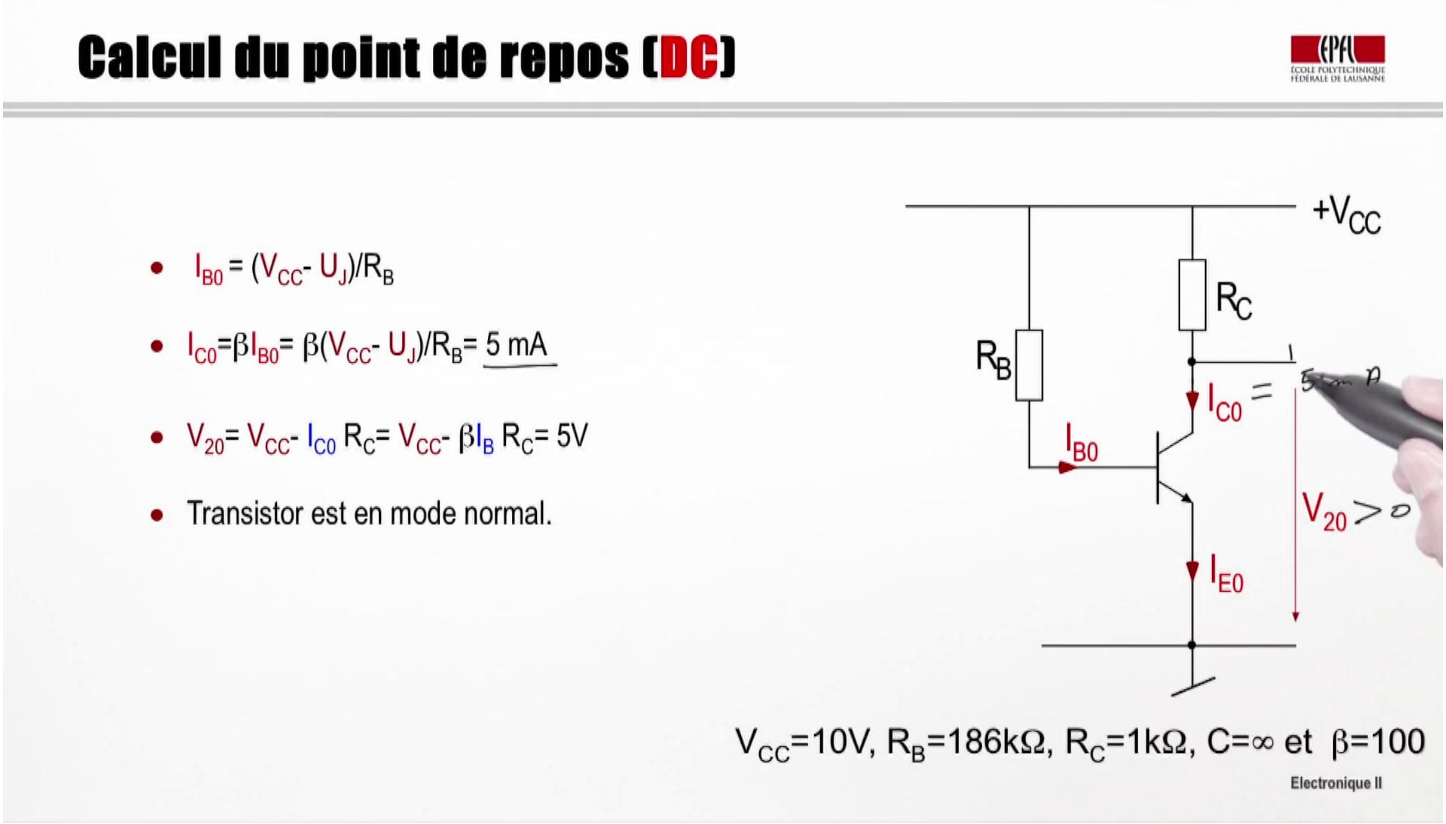


The β of the transistor is given, we have a β equal to 100. So the famous IB0 I have here will enable me to calculate IC0 once I decide the value of RB. These two relationships allow me then to size the RB resistor for an IC0 current. If you want to put IC0 to a value of 1 milliampere or other, we will calculate it later in this circuit. But if you want to impose a value here, knowing the β, you will find the IB0, you put the IB0 by its value here. VCC is known, UJ is of the order of 0.7 volts. You have to calculate the RB, so it is only RB we should extract from this once you imposed IC0. Actually, what I'm doing, I'm saying that I polarized my transistor, I have IC0. What is the current EVBE0 that will go through my transistor? We said we will not calculate it, it was approximated. But if you put it in the exponential law, you will need to have the real value of VBE0 which is quite close to this value, knowing that the law is exponential. Our transistor is polarized, our famous IC0 is known. What would we do then? Well this IC0 will overlay this IC0, and this IB0, the variation that will come from what I just erased. Let's see the values taking into account the correct calculation that takes into account the values that we have added. We put a resistor RB of 186 kΩ and the resistance RC = 1 kΩ.

Notes

Summary

7m 39s



This is exactly what I just noted, but with numerical values. We applied an IC0 current of 5 milliamps, really, it's how we say it. We just polarize a bipolar transistor with a constant current equal to 5 milliamps that will cross our transistor permanently. Do what you want, as soon as you plug these values, supply it, you will have this equal to 5 milliamps. You will end up with 5 milliamps divided by IB0 that will give you something. But before going further, we must at all costs check that the UCE voltage is raised from 0, from this transistor, we give a value with what we just calculated which guarantees that our transistor is not saturated. For it to be blocked, it could not be blocked, it is in conduction because it has a current going through, but I must be sure that this is positive. Generally, we will see it later, we try placing it in the middle of the dynamic, that is to say, if it's supply with a voltage what we call the supply rail between 0 and VCC, we must try to place this potential almost in the middle of this range here. Why ? Because this voltage will rise up to VCC, it will drop to 0. If it gets to VCC, the transistor will block. If it gets towards 0, the transistor is saturated.

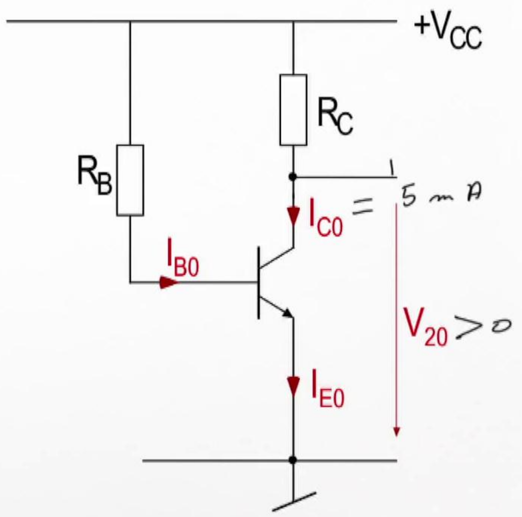
Notes

Summary

9m 20s

Calcul du point de repos (DC)

- $I_{B0} = (V_{CC} - U_J)/R_B$
- $I_{C0} = \beta I_{B0} = \beta(V_{CC} - U_J)/R_B = 5\ mA$
- $V_{20} = V_{CC} - I_{C0} R_C = V_{CC} - \beta I_B R_C = 5V = U_{CE0}$
- Transistor est en mode normal.



V_{CC}=10V, R_B=186kΩ, R_C=1kΩ, C=∞ et β=100

Electronique II

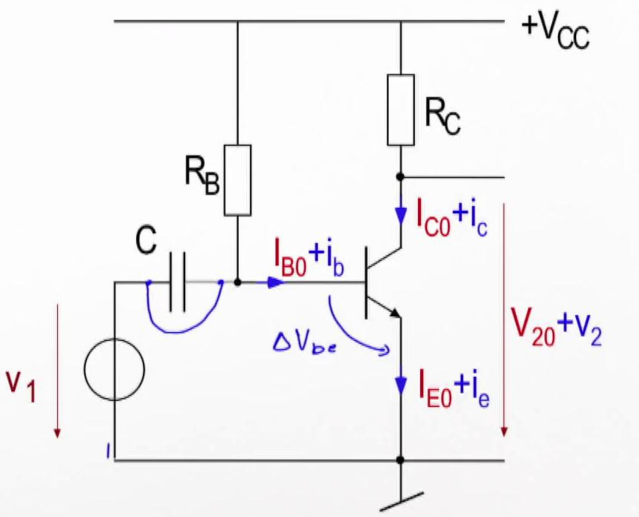
When V20 is 0, and this is what will happen to it because remember, when you put a variation here this tension will then move with. It will go up to a maximum of VCC, it will come down to a minimum to 0. It will give you what would later be called the dynamic. I think now is not the time to talk about it, what is most important to me is to find that the UCE of this transistor is at rest, therefore the UCE0 which is V20, is equal to 5 volts. So 5 volts is not equal to 0, so our transistor is not saturated. Very good. Our transistor is neither blocked nor saturated, I can put my transistor in normal mode. It is an essential verification to be sure that what I'm doing with my circuit later would result in a circuit that will enable the input and output voltage, in the case that the variation of the output current be linear.

Notes

Summary

10m 49s

Modèles petits signaux, Modèle AC



V_{CC}=10V, R_B=186kΩ, R_C=1kΩ, C=∞ et β=100

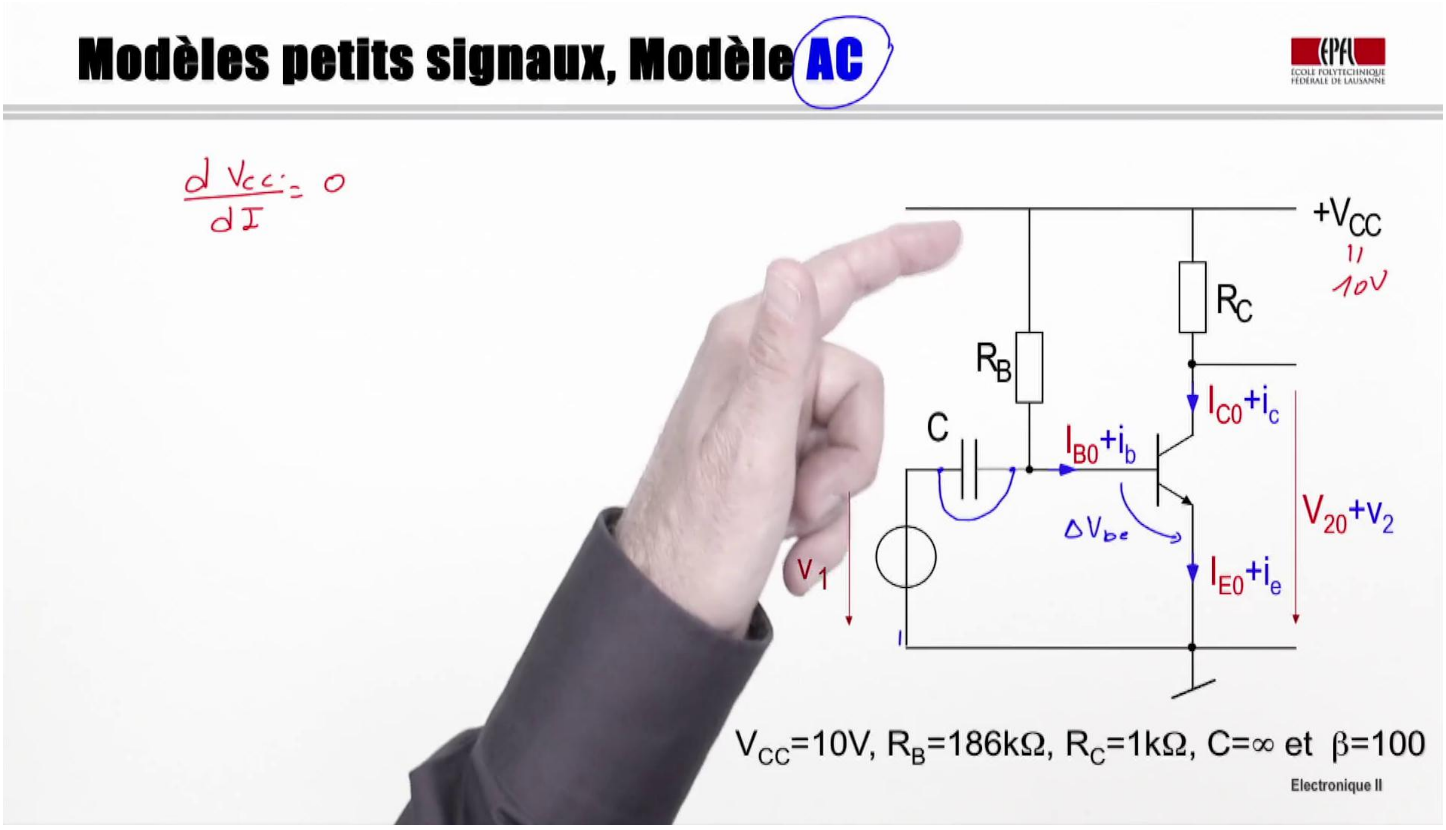
Electronique II

I now take again my diagram once I have added the capacity C which is there to couple AC component that is here. I am indeed interested in this AC component that will be generated by the AC source that was added here. But of course, this AC component is superimposed on the DC component we just calculated just before. Before getting here, I calculated the IC0, IB0, IE0 and V20. Now I just plug my source and I ask my capacity to create a short circuit and couple all the variations that come from this node here towards the other node to bring back the variation caused by this source here to the VBE voltage, which is of course a ΔVBE or a tiny VBE which describes the change in the VBE. Any variation of this voltage will generate a variation of this current through the transistor effect, So through the transconductance we had seen before. All variations of this voltage will conduct a current flowing here which is the base current. I will be able to remove my transistor and only observe in AC what happens with this circuit. Most important in this model is that it is a model which is based on the fact that I have derived the nonlinear law of my transistor to replace it with this small signals model that we had done before.

Notes

Summary

11m 51s

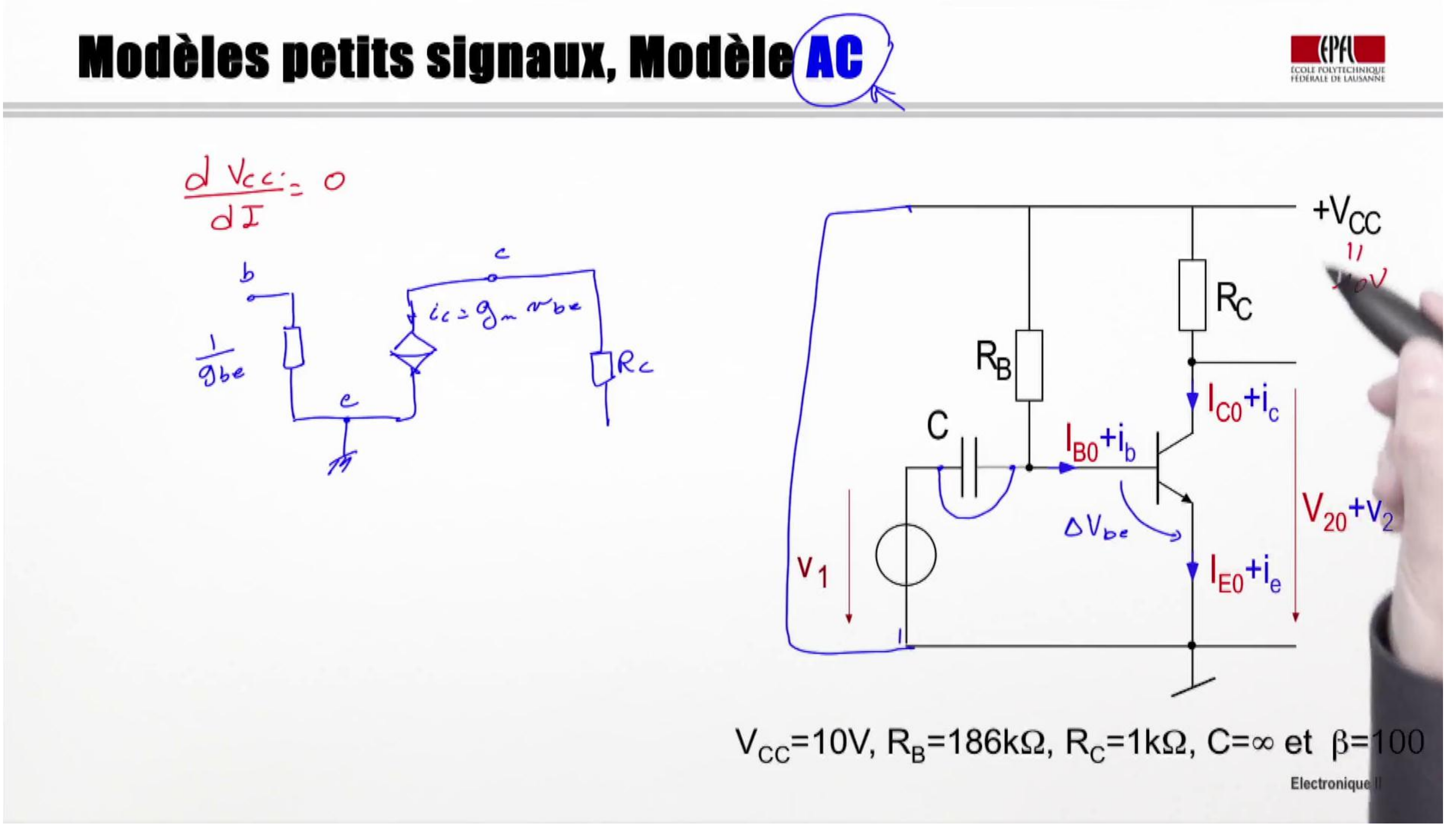


We said that any ΔVBE change will give me a current proportional to (GMxΔVBE). Same for the impedance that I see here, it is a kind of a resistance, there is here 1/GBE which is proportional to a voltage variation: ΔVBE = 1/GBExIB. If I applied it to the transistor and would like to remove from this diagram my transistor and replace it with its model which is represented by a resistor, a controlled current source, I have to do it for the rest of my circuit. And for the rest of my circuit, I have a constant voltage here. A constant VCC voltage is equal to 10 volts, it remains constant. You can take what you want as current of this source, it has no value on the supply voltage of 10 volts. If you are looking for what is the derivative of this tension DVCC divided by the change in current, well there is nothing that varies, it gives you a 0. This voltage source is none other than a short circuit because a zero impedance gives you a short circuit between this node and this node here. And that's what will allow us to take all the diagram and say: as the voltage source is constant, the derivative with respect to the current does not vary. So this node here it is the same as that in the diagram I'll draw.

Notes

Summary

13m 25s

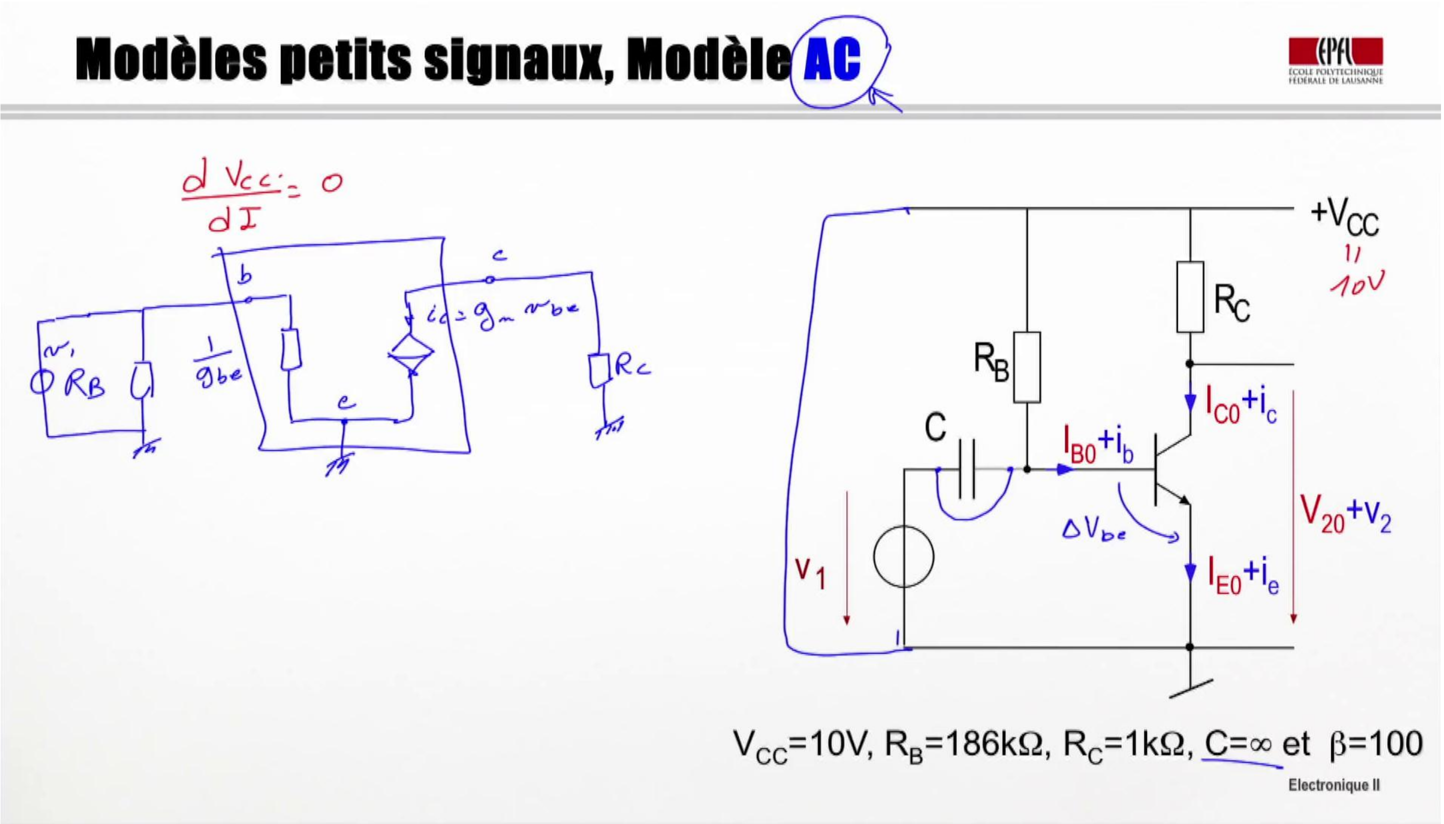


The capacity is a short circuit because its value is infinite. So, its impedance is zero. The transistor, I remove and replace the transistor with the model we had seen before. The resistors remain as they are. So a DU/DI gives a resistor RB and the same here. That's it, I have all it takes to remove this diagram and replace it with a diagram where the source of voltage becomes, in an AAC model, an earth short circuit. I don't have any more variation here. The transistor, when I replace it, I have to replace it between the base and transmitter using the famous 1/GBE. We can write GBE or 1/GBE it's up to you to know whether you talk about a resistance or a conductance. At the exit, you have a power source that will give you a current ΔIc where Ic = GMxVBE. And now, here you have the transistor with its model which is base-transmitter-collector. So this, this and this. And the resistance you have here will come upon the collector of your transistor. It is the resistor RC. I'd like to see the transmitter. The transmitter is connected to earth, very well, it is linked to earth. The resistor is connected to +VCC. But as a constant voltage source, its derivative is zero, I have to replace it with a short circuit.

Notes

Summary

15m 03s

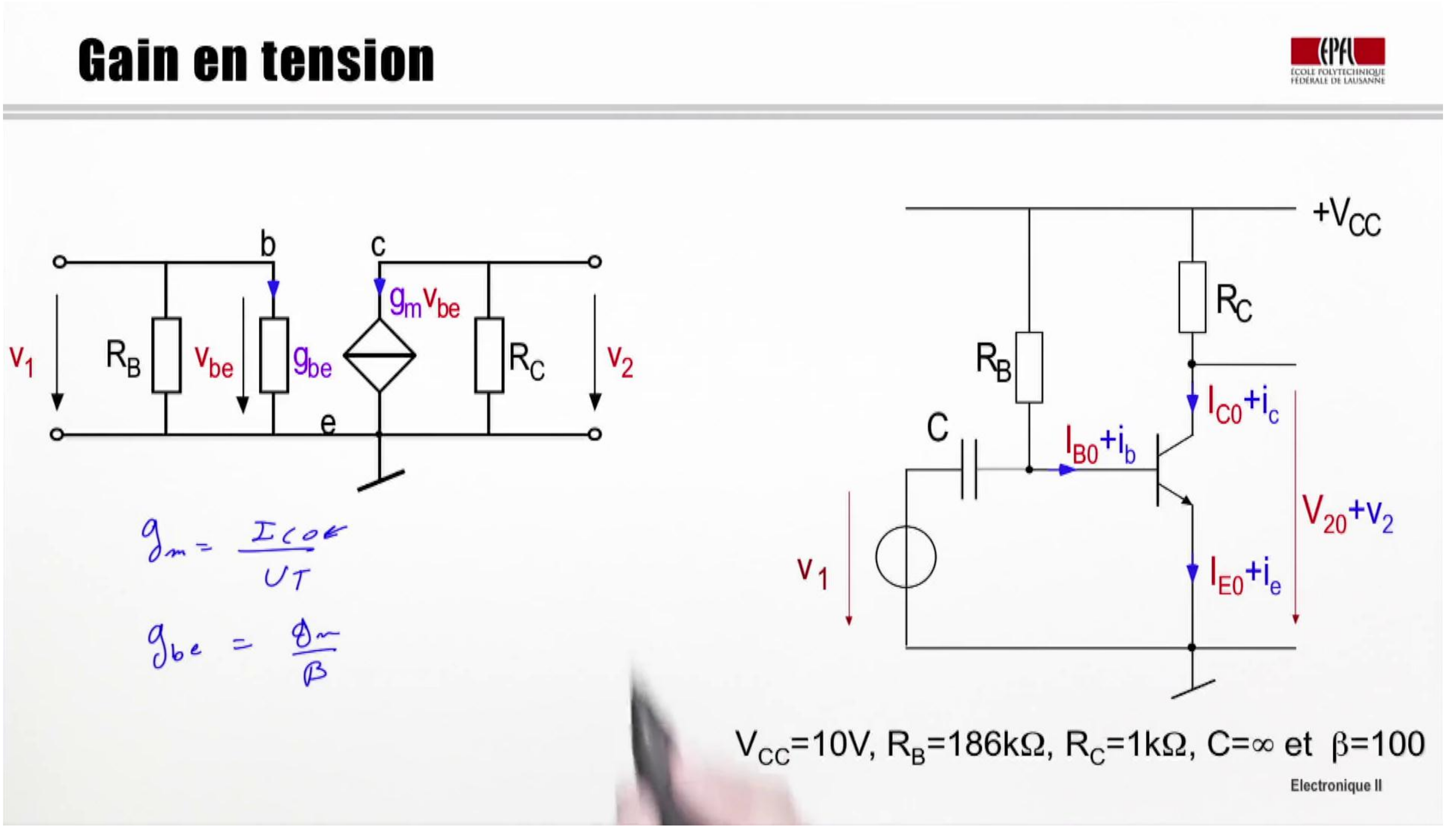


This is a resistance equal to 0. A voltage source doesn't have any resistance. The voltage does not vary depending on the current variation so you will end up with a resistor also connected to earth. RB is also connected to VCC. Therefore the same, RB will appear here and you'll connect a capacity that has a short circuit because of it and you will get the voltage source V1, here. That's it, you are applying V1 between the base and the transmitter, and it is this source which must have a very small growth value, less than UT, which will controls the change here. And you have all the DC components that will be the rest point. Whenever there is change, we go from this rest point and we will change the output current in regards to the variation of this voltage source V1. And here you have the equivalent of what we just saw as with a complete diagram with a circuit. When it was modeled in AC where the voltage sources are replaced by short circuits, our transistor is replaced by its small signals model and we end up with an equivalent diagram, which is this.

Notes

Summary

16m 53s



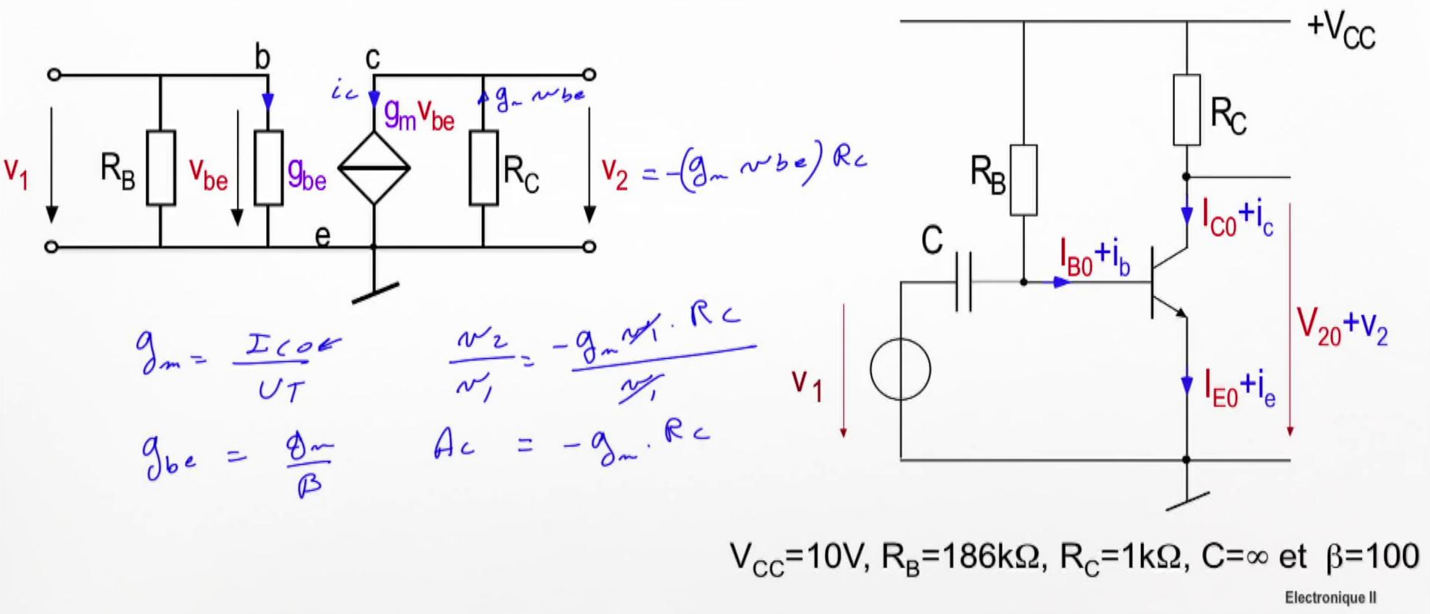
Now we can see all this a little more clearer and represent what we have just saw earlier: the RB resistance, RC resistance, the controlled current source and the conductance at the input, or the resistance at the input. And here's the transistor as we have seen. It's amazing, because we have a completely linear circuit. We forget this, we do not see anywhere content components, why? Because they are hidden in GM and GBE. If I want to write the value of GM, I would have written Gm = IC0/UT. If I want to watch the current, or rather the GBE, I just have to write it's GM/β. I absolutely have the value of GM and GBE, because IC0 divided by β gives me the current IB and I have all that is needed in there, everything is known. As long as we calculated the IC0, we found 5 milliamps you put this value here. UT is known, so you have the transistor GM value. You take the GM, you divide by the β you find the GBE value and replace it by its value, the RC resistance is known, the RB resistance is known and that's it, you have a voltage V1 and have a voltage V2. But the voltage V2 is very easy to write. This voltage V2 is this current here which is this tiny Ic which is equal to GMVBE passing in this direction.

Notes

Summary

18m 12s

Gain en tension

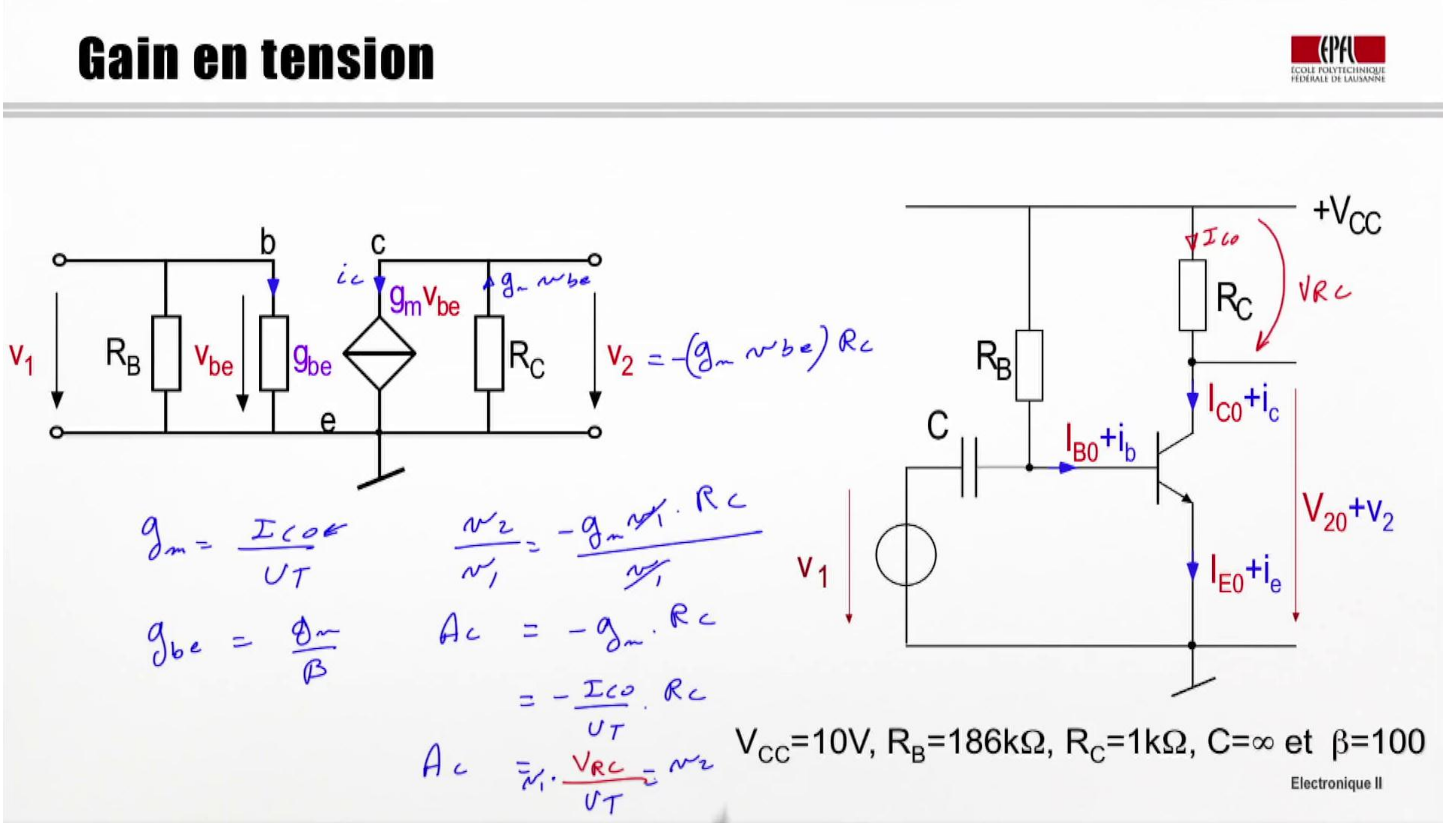


That is the GMVBE which multiplies the resistor RC. Therefore, V2 = -GMVBE. It is a current flowing through a resistor. It will generate a voltage by ohm's law which multiplies the resistor RC. That's it, the output voltage is directly proportional to the variation of the input voltage V1 and VBE because VBE and V1 is the same thing, multiplied by the GM which gave us this current. The current was converted into a voltage by passing it through a resistor, it become an output voltage. If now you want to watch what happens like the relationship between V1 and V2, you just do it. V2/V1, it's called a voltage gain, that is to say, we took V1, it was multiplied by something to give us V2. This is something, it is what I will write here. V2 is the -GMV1 which is VBE, the same thing multiplied by RC divided by the V1 here. V1 will simplify, it gives me a gain equal to -GMxRC. And now, you just made a voltage gain with a minus sign to say that there is a phase difference. If you apply a sinusoidal input voltage, you find a 180 ° phase shift in respect to the voltage that you see at the output. It was converted to a voltage V2 that appears from here to here or from here to here, but it's the same thing.

Notes

Summary

20m 00s

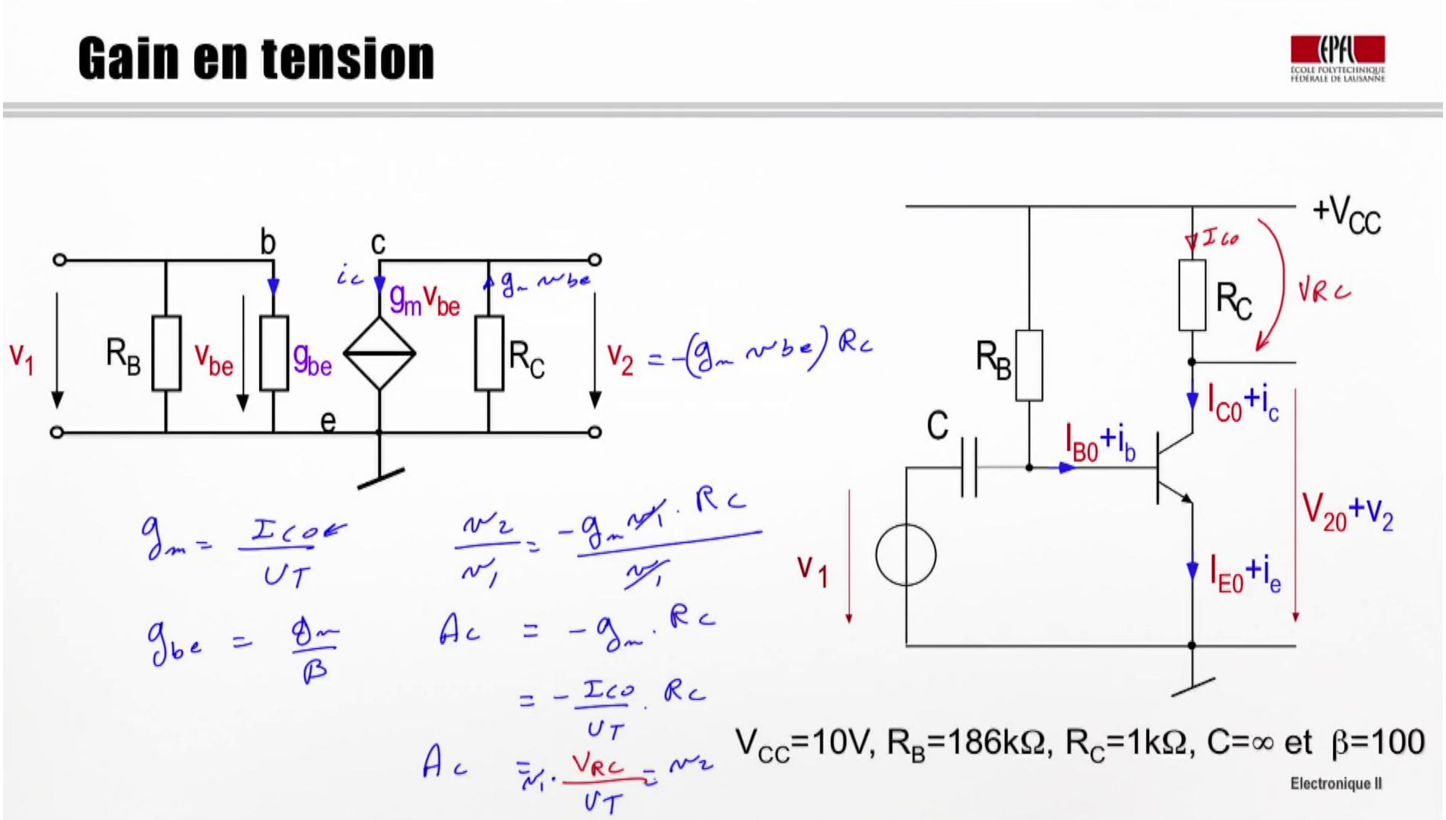


Why ? Because in AC mode, these two are short-circuited. You remember it, it comes here, so whether you see the change here or here, it's the same because it's the same voltage V2. And that's how we determine what is called gain in voltage and we have seen that we just completed a voltage amplifier: we apply to it a voltage V1 and it gives us a voltage V2 and the voltage V2 is multiplied by this. One has only to calculate the value of this which is (-IC0 / UTxRC) and here I will write IC0xRC too, it is nothing other than this. That's the IC0. And that, is the RC so, the voltage you see here, I'll call VRC, well it is the voltage I will even write in red because it's a DC component, it is VRC/UT, the thermodynamic voltage. So we see that we made a gain which will multiply, that will give me the voltage V2. When I multiply this by V1 multiplied by the DC component that I see here, I divided it by thermodynamic voltage of 26 millivolts at room temperature, it gives me V2. Look at the power of polarization, it's really IC0 that did everything. So the IC0 you imposed here, the resistor value you selected, the DC component we chose that's worth 5 volts, you remember, it was calculated.

Notes

Summary

21m 49s

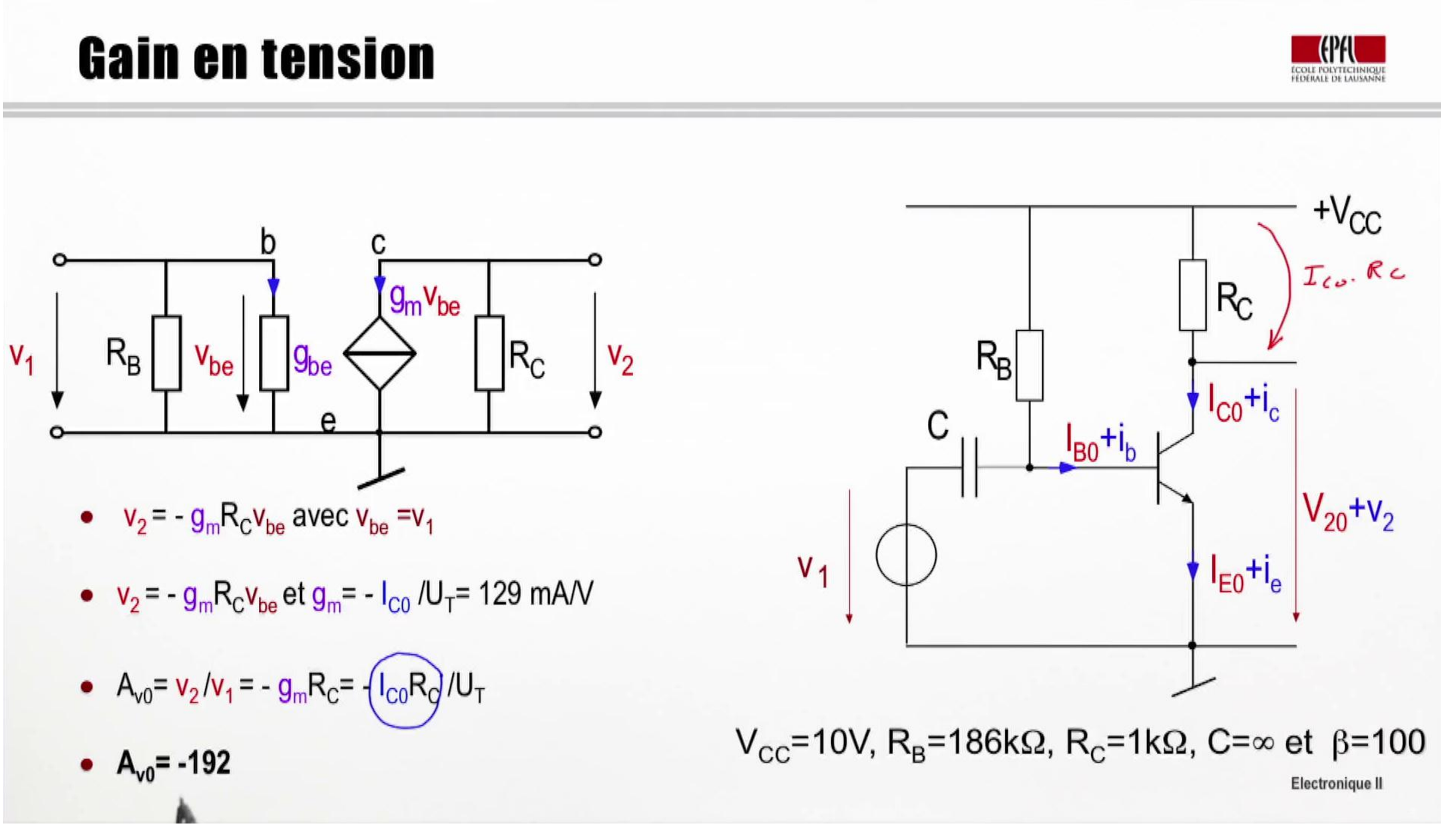


This, it gives us the VRC = 5 volts, we found that it is equal to 5, here we have 10 volts so we are left with 5 volts here. That's 5 volts divided by 26 millivolts, you multiply it by any changes here, you'll find it at the output. So this is what will allow us to do what we'll later call the function of a common transmitter with a based polarization diagram by a base resistor that brought the current IC0 to become fixed in applying an IB0 current to the input.

Notes

Summary

23m 27s

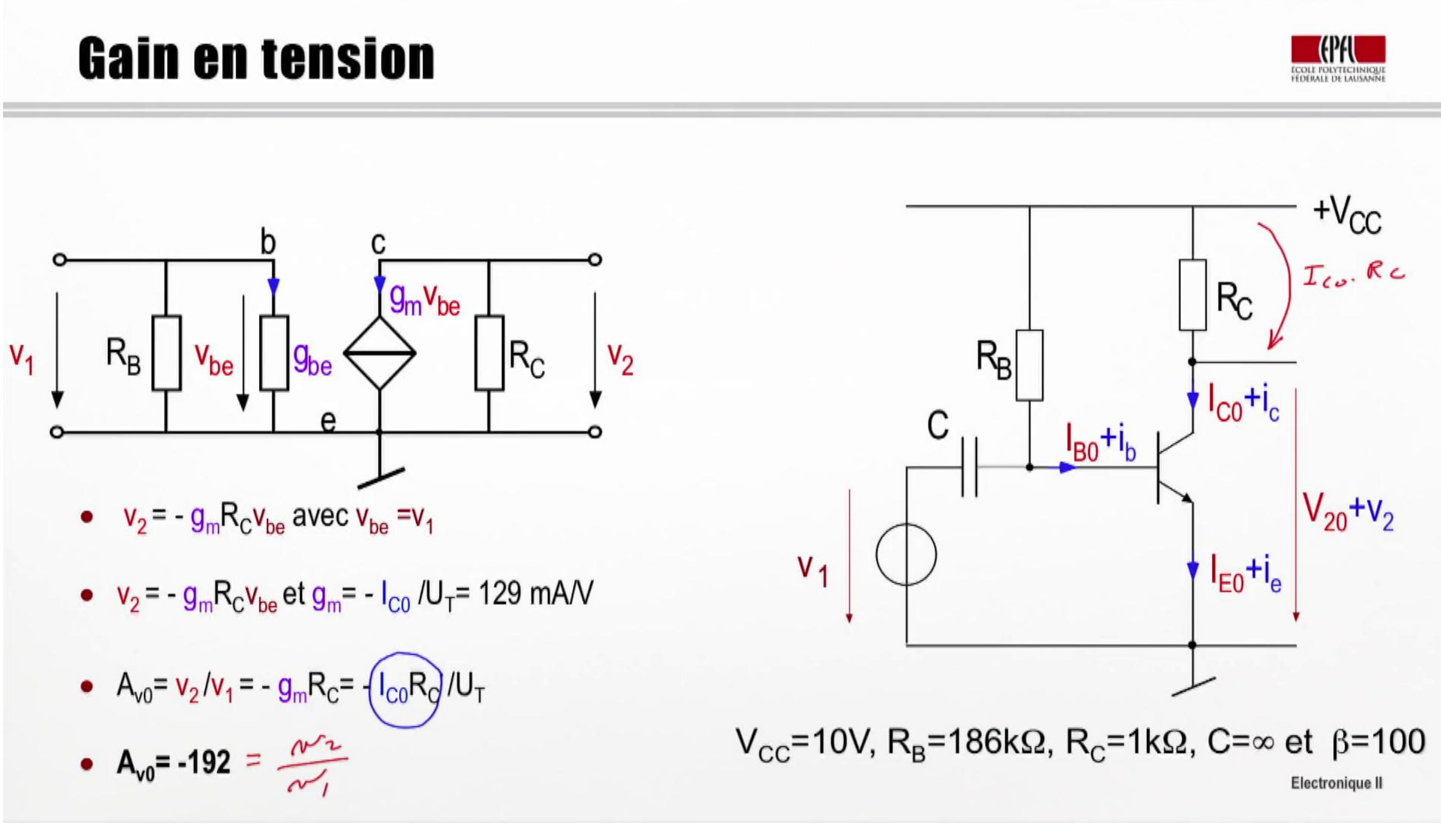


Here is the same diagram, a little clearer, written now with the values we obtained. The GM transconductance, if I take into account values calculated, it will give me 126 milliamperes per volt. So I have a numerical value of this GM. The gain, the same calculation that I showed you, I remind you it is -GMRC. We saw it and I repeat it a second time, because this, to calculate it, it's much faster to see it: it's that, as soon as you take a diagram like this and you put a resistance, you apply a current in there, you're going to end up with the voltage drop here and this voltage drop is this term. So that's IC0xRC. So we have not yet applied anything yet, we simply imposed IC0 and had a resistance of RC loads and we will find it in this application, well in this application or in any other application, gives us a value once divided by UT, it gives us directly the gain and we will find that the gain is 192 or one hundred ninety-two, if you are in Switzerland or if you are in France or elsewhere, you would have said maybe 192. With a minus sign in front, so you end up with a ratio between the output voltage divided by the input voltage, if you multiply by a gain V1 equal to 192, you get an output voltage that is significantly higher than the input voltage.

Notes

Summary

24m 02s

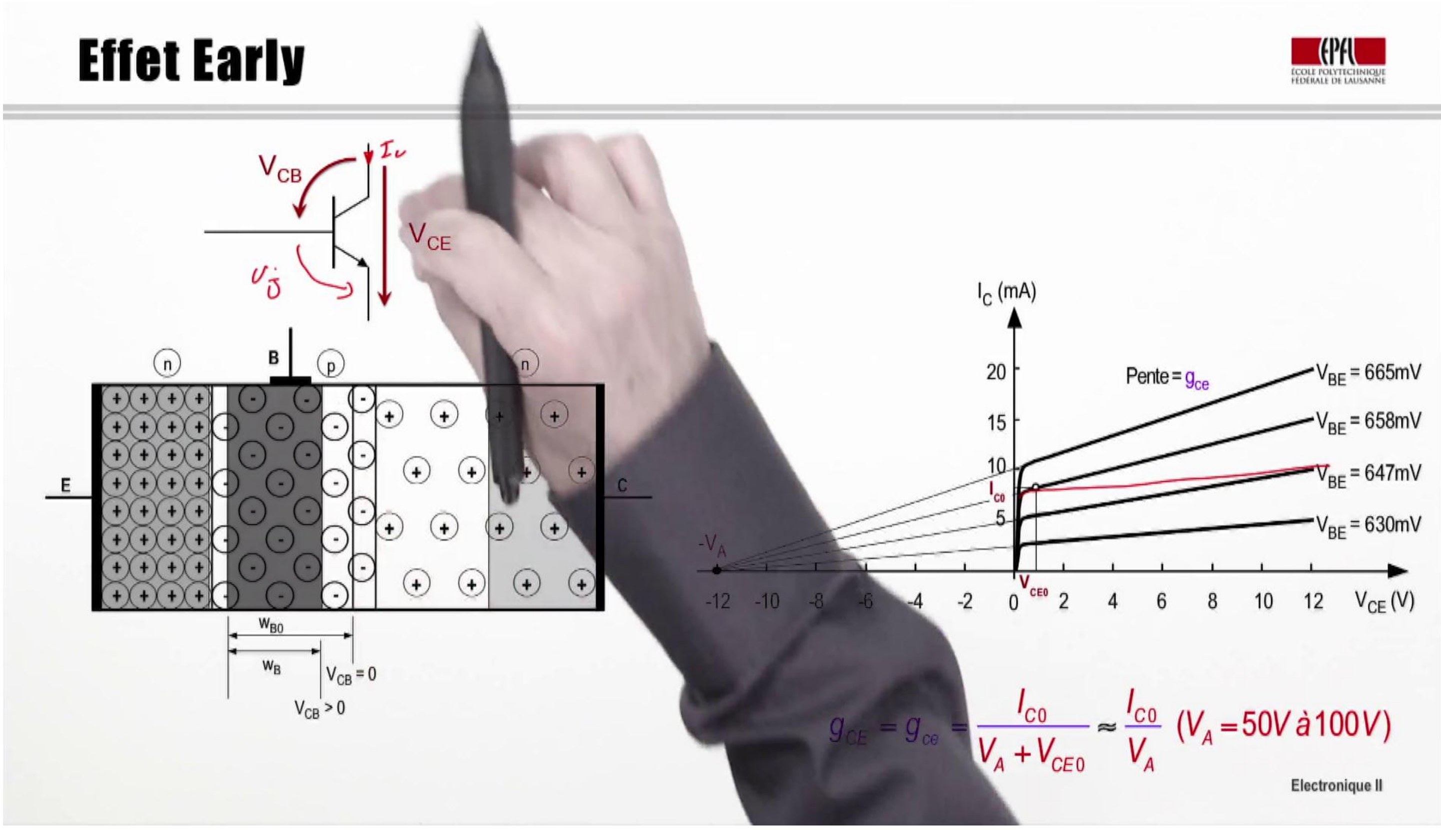


That's how we calculate the circuit and replace the transistor, we replace the voltage sources. All that is continuous becomes a short-circuit to earth in an AC diagram. And the transistor takes the linear diagram we extracted in the first part of this course.

Notes

Summary

25m 36s



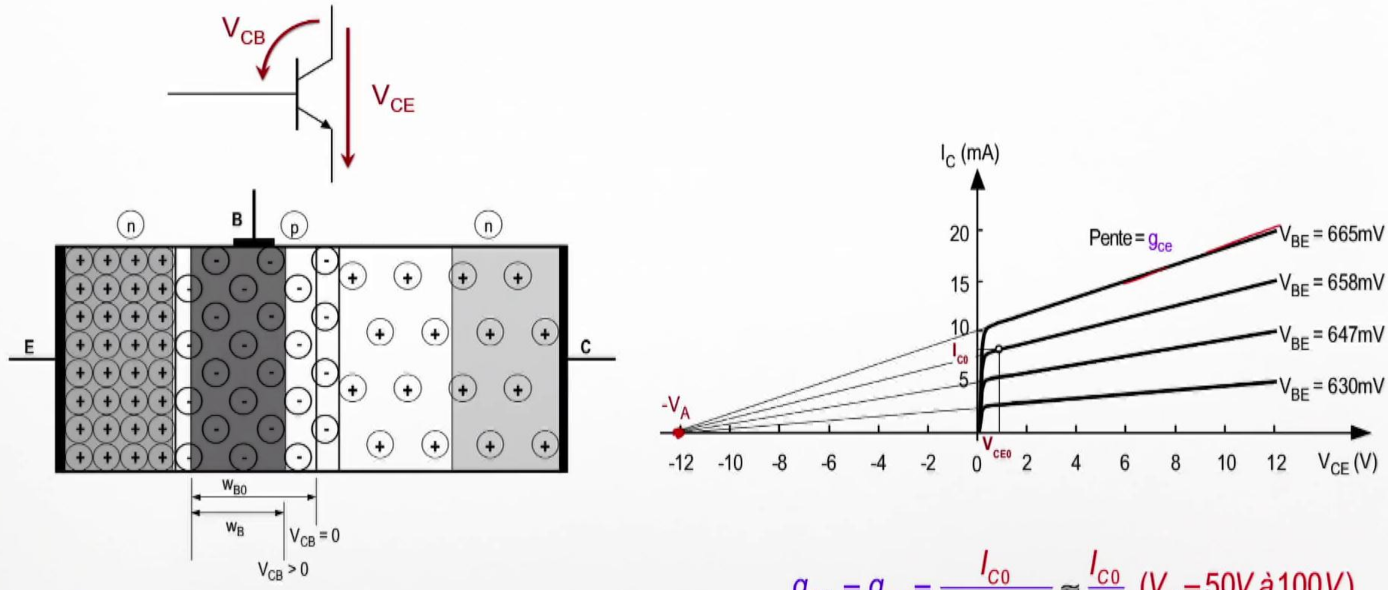
I want to finish this video with transistor imperfections we had not seen until today. We have always considered that the current and voltage in a transistor, so if you want to see the current change with respect to voltage, we said that it is an ideal current source, it's like we had a curve that was like this. And unfortunately this is not the case. In a transistor, there is a phenomenon that occurs such that, you remember when the transistor was presented as a sandwich in which there is a synoptic diagram to show that there is a base, there is a collector and a transmitter and we are in between the two. So it turns out that when the transistor you polarize the collector-base junction and you increase the voltage. So in other words, the more you increase the voltage VCE, the more the junction or collector-base voltage increases with it. Why ? Because this tension, it is almost constant, it does not move, it is of the order of UJ. The VBE0, when the transistor conducts, it will give you VBE value, the junction voltage. So every time you increase this voltage here, given that it was constant, so the latter, increases with it.

Notes

Summary

25m 53s

Effet Early



$$g_{CE} = g_{ce} = \frac{I_{C0}}{V_A + V_{CE0}} \approx \frac{I_{C0}}{V_A} \quad (V_A = 50V\ \grave{a}\ 100V)$$

Electronique II

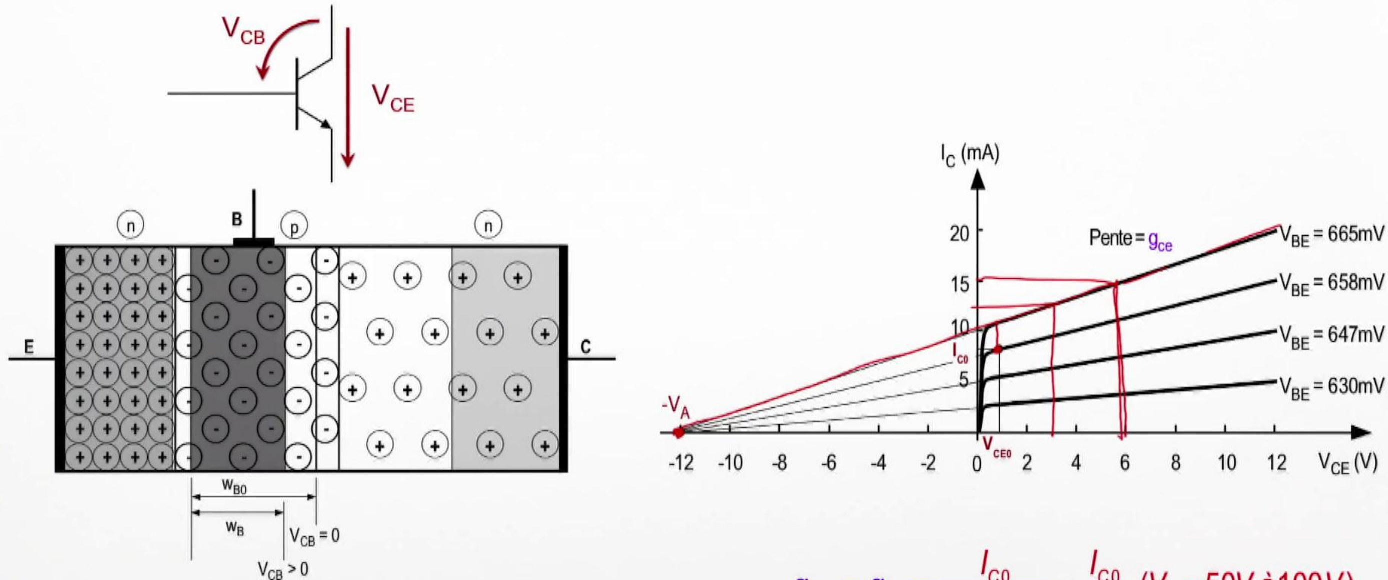
And when you increase it like this, what happens is, there is a depression region in the PN junction that will increase with it, from this side. So it munches part of the base and we talk of the active part of the base, it becomes increasingly low when the collector-transmitter voltage increases with it. In reality, what happens is, when this tension increases, it increases with it because it is equal to this plus this. Therefore it increases with it and when it increases, your base becomes smaller. When the base increasingly becomes small as an active area, the combination of the electrons that takes place in the base or holes, depends on whether you have an NPN or PNP transistor, makes sure that the base current, it reduces with it. Therefore, the collector current, will follow it: if it increases, it increases with it, or if it reduces, it reduces with it. So it will take you to the slope shown here. So, I'll delete this red line and you can now see that the output characteristic has a slope and all these tensions, sorry, all these slopes here meet at a voltage called the voltage "Early". And this voltage Early, it is noted as a voltage VA, it is negative because, when you pull this line here, it will join in a point and when you see the slope of the line here.

Notes

Summary

27m 17s

Effet Early



$$g_{CE} = g_{ce} = \frac{I_{C0}}{V_A + V_{CE0}} \approx \frac{I_{C0}}{V_A} \quad (V_A = 50V \text{ à } 100V)$$

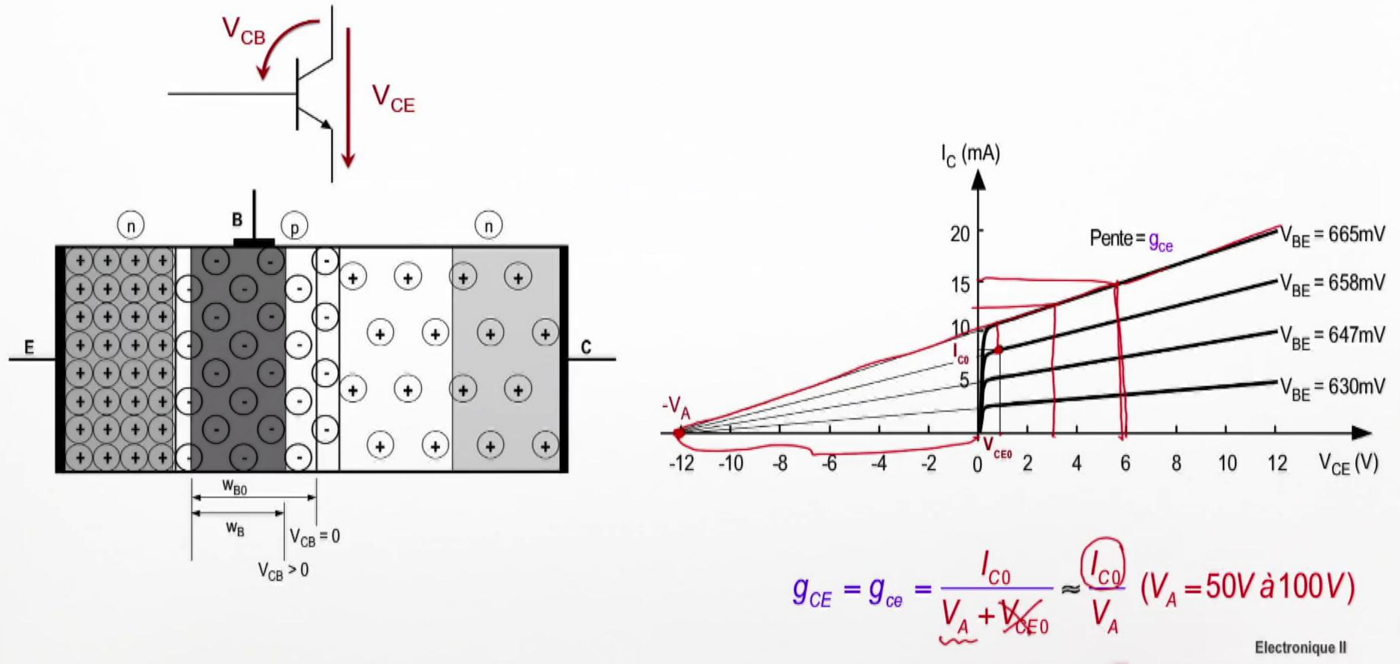
And if you take your transistor, you polarize it by applying a given IC0 current, therefore, suppose you put a current IC0 that's equal to six milliamps... sorry, excuse me. If you put a current that's here and you put a VCE0 voltage on your transistor terminals, if the VCE0 voltage drops, you will end up with another current, and vice versa. What will happen is that this slope, it will have to change the behavior of your transistor between the collector and the transmitter. If we look at this triangle here. So I'll try to draw it better. So if I look at this triangle and then I look at a polarized current IC0 VCE0 and I look at what's happening with the VCE voltage when the voltage increases, or decreases, I'll find myself with such a similar triangle. Here I have two triangles that are similar, from here to here, I have VA. From here to here, I'll end up with a VCE0. And from here to here, I have the original polarized current before there was a bit of dynamic on the terminals of my transistor. So I can write that the slope I see here, if I am here, or here, or here, it depends on this IC0 divided by the voltage Early which is from here to here, plus the polarization voltage, whether this or this or this.

Notes

Summary

28m 47s

Effet Early



$$g_{CE} = g_{ce} = \frac{I_{C0}}{V_A + V_{CE0}} \approx \frac{I_{C0}}{V_A} \quad (V_A = 50V \text{ à } 100V)$$

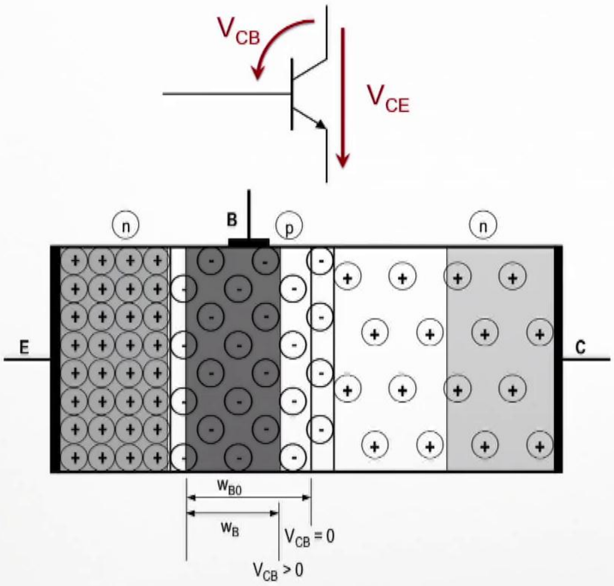
So it gives me IC0/VA+IC0. The voltage VA is high enough, the supply that we use in low voltage transistors, may vary between 5-15 volts or 20 volts. Therefore, when we compare a voltage of a hundred volts that depends on your transistor, so that's something that is reflected in the characteristic of the transistor, this is something you're given. So the voltage Early, you can consider the voltage Early and neglect the polarization voltage you get with regard to this Early voltage, which will take you to an output conductance that will be an approximation of IC0 divided by VA. That's how we calculated it. So again, we are left with the polarization current IC0 divided by a voltage that we should give you, or you should be able to measure it in a transistor when you trace its output characteristic. What we do often is: we measure, we change the VCE0 voltage and we look at what's going on with the IC0 current and we extrapolate the slope and it allows us to calculate the voltage VA when drawing this line until we get to a current IC = 0 so we can find the voltage UA, otherwise the manufacturers will give it to you. And we found that it is mainly the polarization current and a value given by the manufacturer, which is determined by your components.

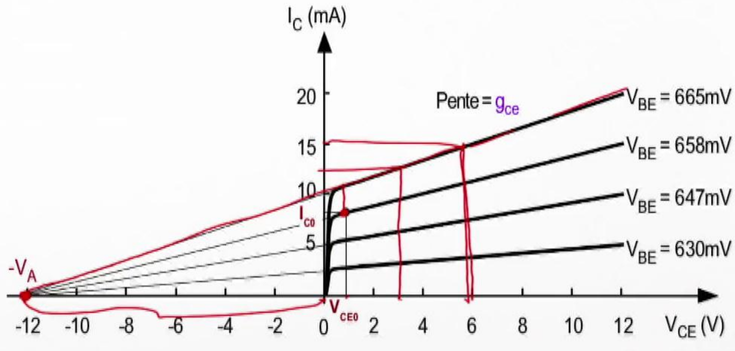
Notes

Summary

30m 21s

Effet Early





$$g_{CE} = g_{ce} = \frac{I_{C0}}{V_A + V_{CE0}} \approx \frac{I_{C0}}{V_A} \quad (V_A = 50V \text{ à } 100V)$$

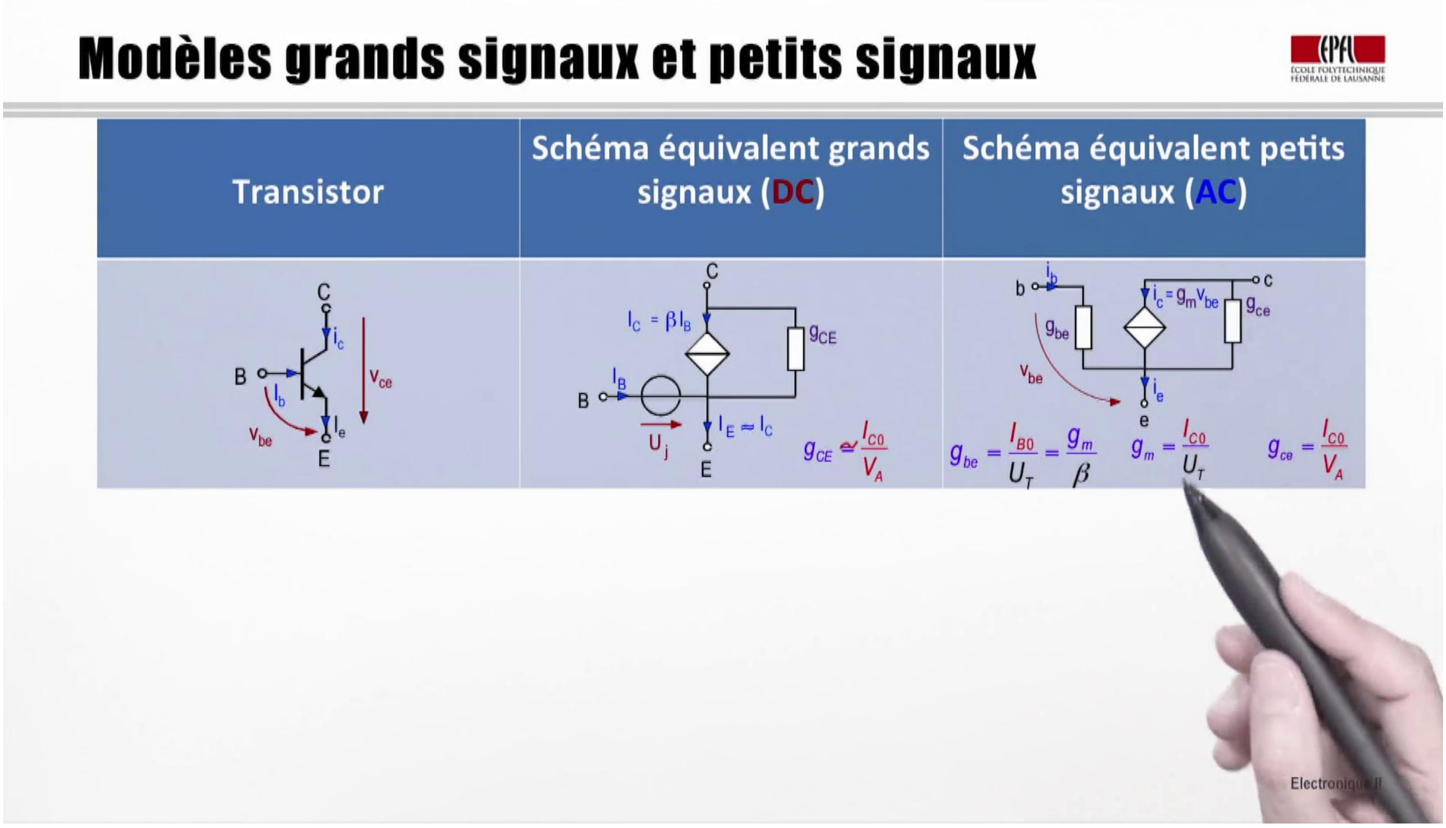
Electronique II

So again, it is you who will decide and it is because of your polarization current that will give you a conductance output or a resistance output.

Notes

Summary

31m 52s

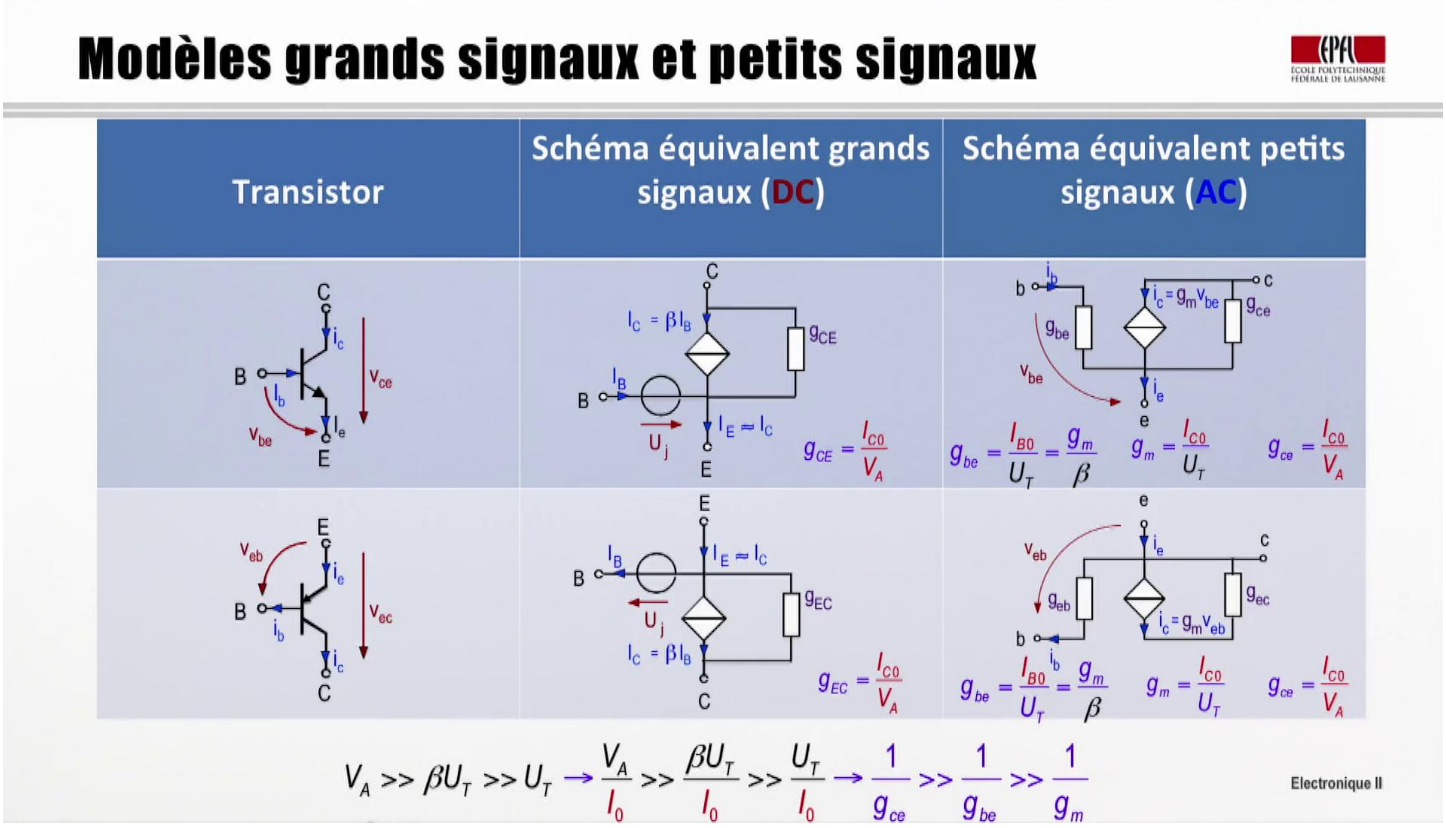


We will now change the pattern of our transistor taking into account what we just observed. Therefore, there is an additional defect. Remember when we analyzed the large signal patterns, we talked about the DC model of the transistor? We said a transistor can be replaced by a source of controlled current when working in DC, we replace the base-transmitter voltage by a voltage drop of the order of UJ, we replace the collector current with the β of the transistor given by a manufacturer multiplied by the base polarization current, which gives us the IC0. And there is an output conductance we call and multiply by the base polarization current, which gives us the IC0. And there is an output conductance called GCE, which is IC0/VA. Here, I should have put approximately equal, because we just saw that we have neglected the voltage UCE0. The small signals model that we derived from this transistor is this. And, in this small signals model, we need to add the output conductance that adds itself. So earlier, we did not have this, we simply said the transistor behaves like a resistor equal to 1/GBE between the base and the transmitter and a controlled current source.

Notes

Summary

32m 02s

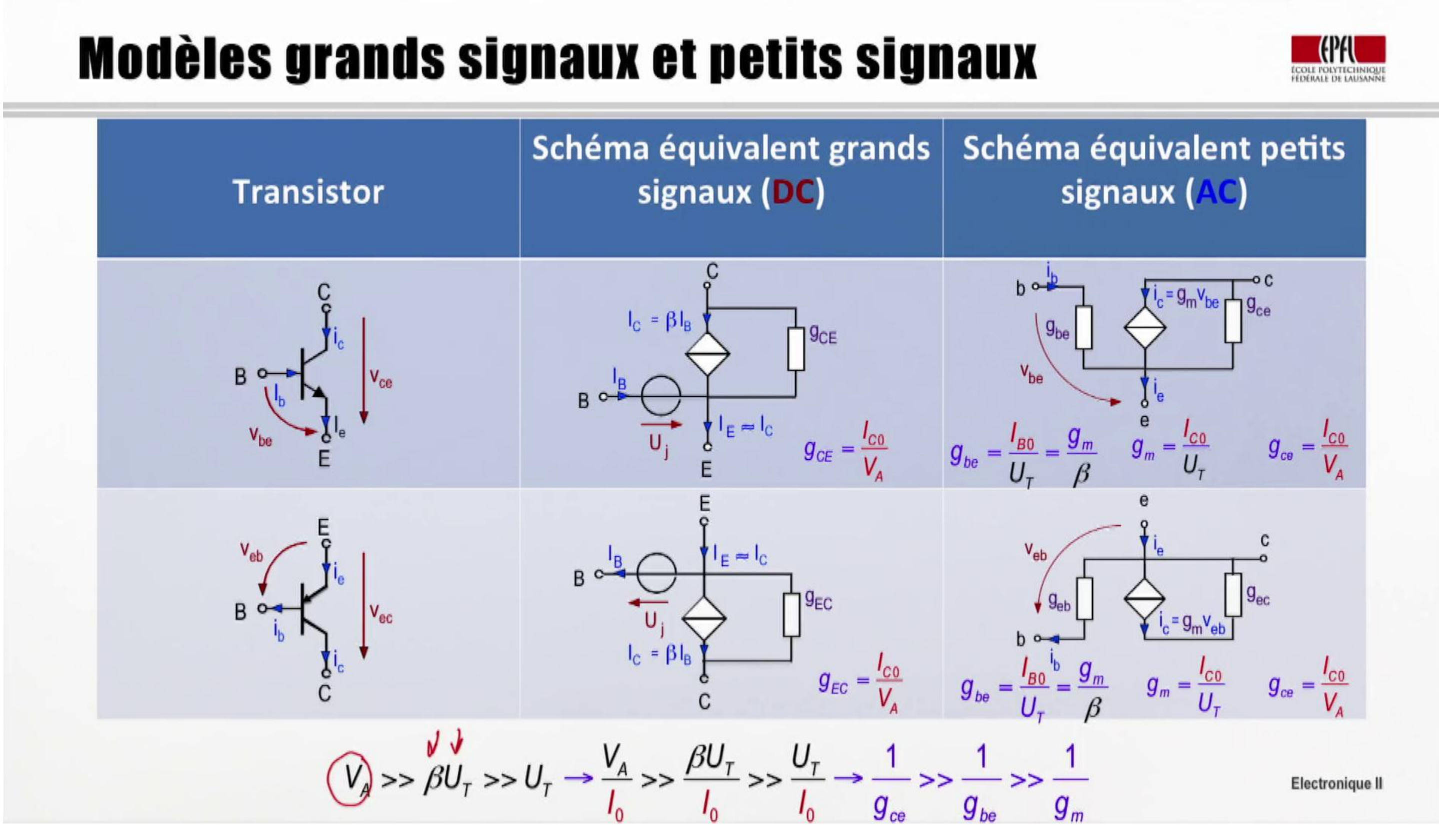


There, I have to take into account the output resistance that appears, which is 1/GCE and I have to add the value of 1/GCE. So, I end up with the values that we had calculated and I added the GCE. So, look carefully: IC0, IC0/β, which is IB0 and IC0. So everything is related to the choice of this polarizing current IC0. As soon as you set it, you can calculate GCE, GM, and GM GBE and it will give you all this model with numerical values which is proportional to your IC0, why? Because VA is given by a manufacturer. UT is 26 millivolts. β is given by the manufacturer of your transistor, everything is known and its upon you to get IC0. So this is the most important task of a designer when he polarizes his transistor, what is the value of IC0 that he would put in his transistor. So it comes from this model here. When calculating IC0, it is when we are in DC mode and that is what will give us the value we spread here and immediately we have the different values. Here is the diagram of NPN and PNP. So here, there is absolutely no difference between this and this. There are really the same expressions found here. I noted below conditions and would like to emphasize on them.

Notes

Summary

33m 13s

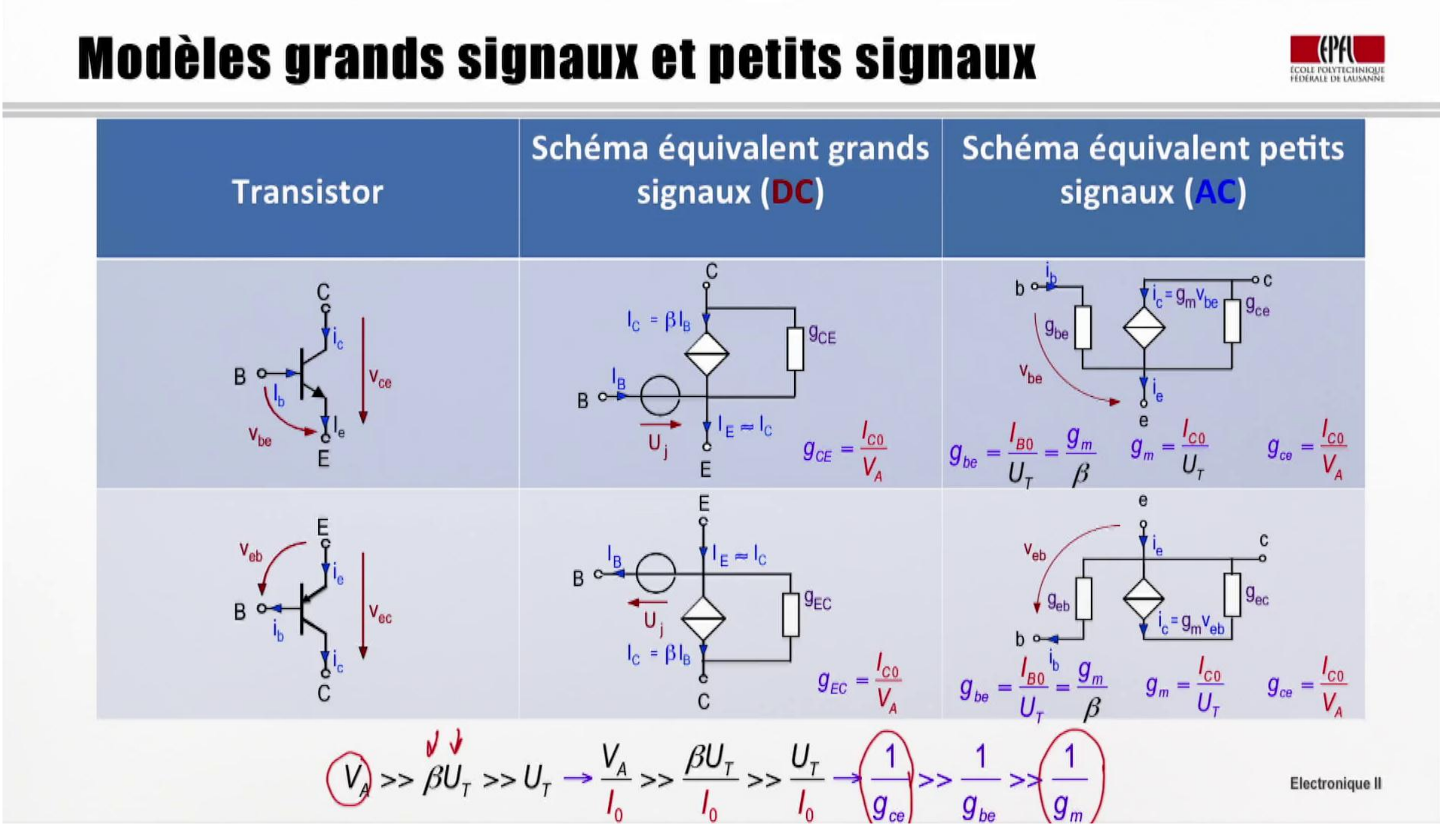


If you look at that GBE = IC0 / βUT, in other words, GM / β. GM is IC0 / UT. GCE is IC0 / VA.We said VA is known, β is known, UT is known. So all these things are known. In practice, we assign values to VA where, we know that it is between 50 and 100, or even 120 or more. β, for a low power transistor, or rather low voltage and low power, is of the order of 100 to 300. UT is in the order of 26 millivolts at room temperature. So, this relationship makes sens. UT is 26 millivolts, it is significantly lower perhaps 100 times this value, it is clearly less than something, Don't forget that these 26 millivolts here multiplied by 100, it's still well below a hundred volts. So if you look at this relationship here and you try to write 1 / GCE, 1 / GBE, 1 / GM, you will end up with this: 1 / GCE is VA / I0, this is a resistor. this, it's a resistor. It's also the unit, it will give you as a resistance 1 / GM, in terms of units. So you're going to say I0, I0, I0, it divides all these. So you may well say: VA is more than β UT, what we just got here and this relationship is valid. So this brings us to this reflection: it will be in gold this relationship when we go into practice.

Notes

Summary

34m 40s

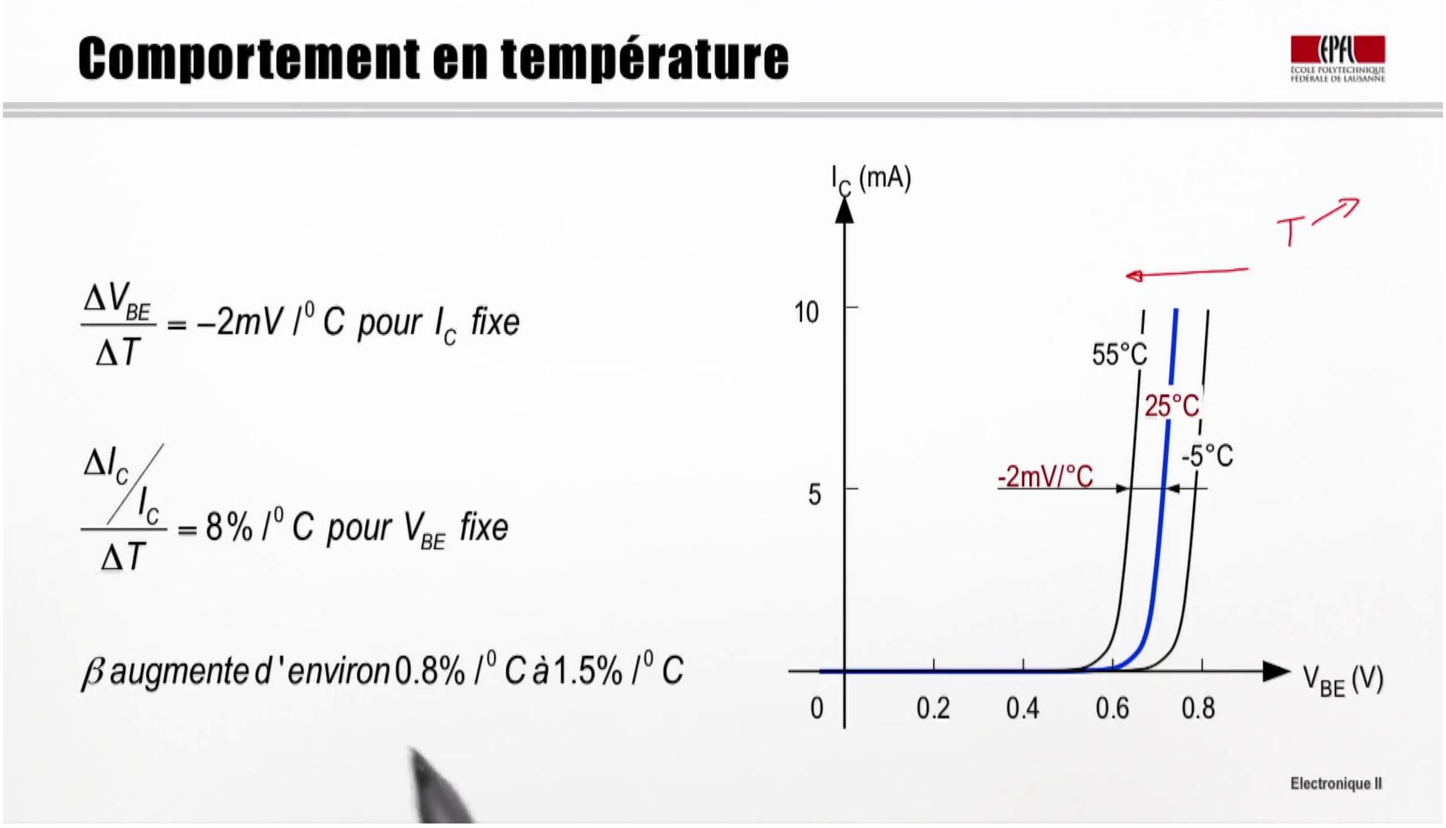


Because you will see later that this is what will allow us impedances, to see the impedances at the accesses of our set ups and we are discovering that 1/GCE is much bigger than 1/GBE it is much bigger than 1/GM, and that's a fact, it is a reality! And later, our set ups, they will be based on a reflection, on this inequality where a designer must know that the lowest is always 1/GM and the highest, is still 1/GCE. And it's with this decision, the 1/GBE, is between the two. But that's a high resistance. This is a low resistance in value and this is a resistance between the two. And this is what will determine, during the designing, what setup to use and we will see it in details later.

Notes

Summary

36m 30s

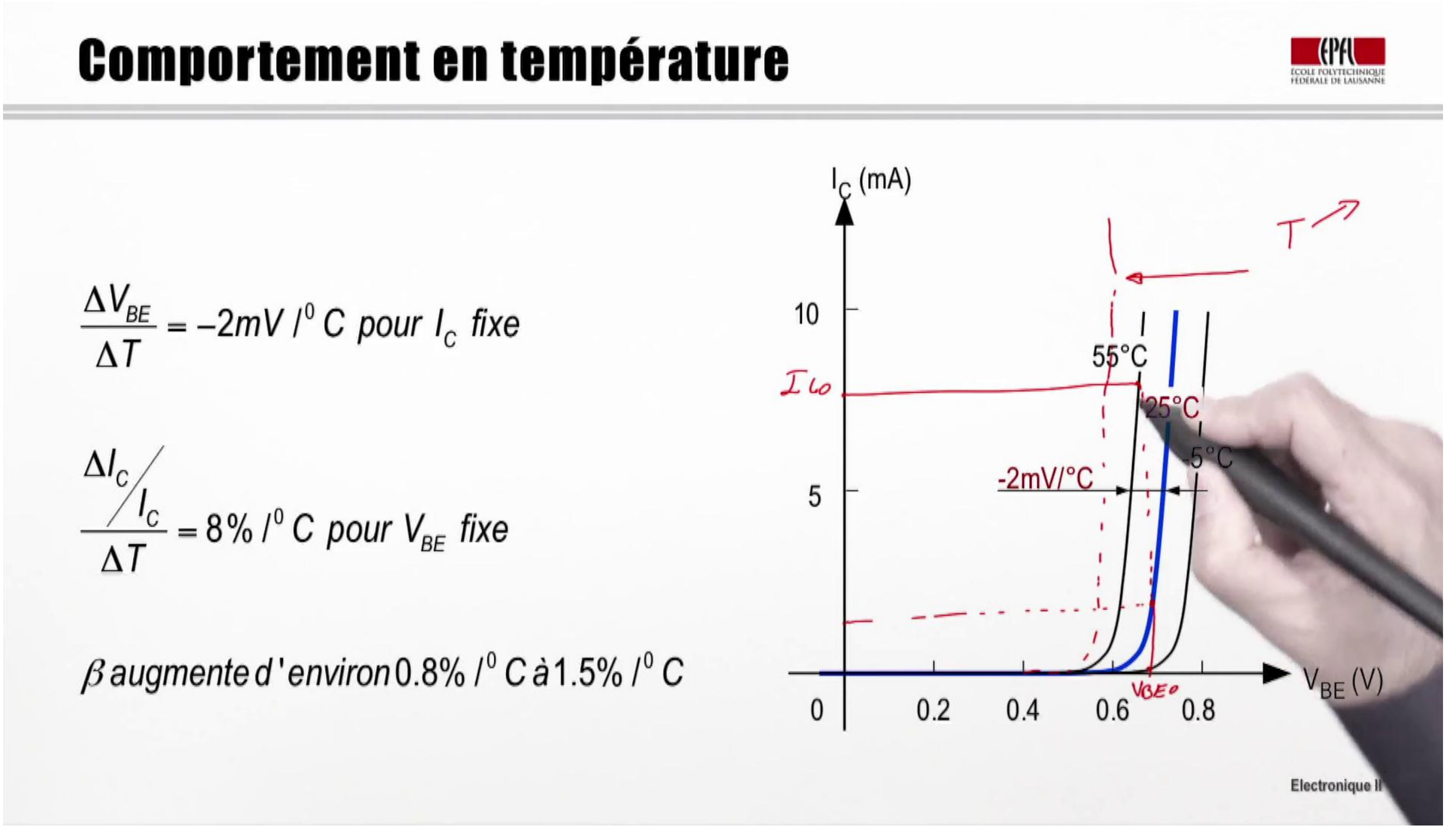


One of the transistor imperfections is its temperature dependence. I take the exponential law of the ICF2VBE transistor. Unfortunately, I say unfortunately this feature here moves in this direction. Therefore, it moves like this, when the temperature increases. So when I am -5 ° I am with a feature that is here. It begins to heat, to become hotter. The transistor is in a usage condition that makes it heat, or it has a warm atmosphere inside or close to a car engine : we start when it's cold, it's -5 ° at a certain time and the engine begins to heat, then it continues to heat and unfortunately it is mutating, its characteristic moves in this direction when the temperature increases. This will leads us to a drift in temperature, a temperature change ΔVBE/ΔT, ΔT of - 2millivolts per degree centigrade, which is a value pretty well controlled, correct enough, that we even use to make a thermometer by measuring the difference of temperature, by measuring the variation of the voltage ΔVBE. Same for the β, the β of the transistor varies with the temperature variation. This is of the order of 0.8% to 1.5% with the temperature.

Notes

Summary

37m 19s



I would like to emphasize this: it is excluded to consider later, because of this drift in temperature that moves the temperature like this, that we will one day apply on a transistor a constant VBE voltage. Because, if you apply a constant VBE on this curve here, look at your transistor, if it's cold, it is in a condition where it is -5 degrees, it is almost blocked. There is no current flowing through it. The same transistor, if you want to apply a voltage VBE0 and that will apply a current IC0 which is here. If you apply it at a temperature of 25 °, it will give you a current IC0 which is here. If, suddenly, the transistor heats by an external condition, suddenly, the current passing through it increases. You will see later that the power dissipated in your transistor is proportional to this current then multiplied by the VCE. So if you want to multiply this IC0 that just increased, not because of you or because of your set up, it is because of this transistor characteristic which moved: it is at 5.55 °, it further heated a little more, this curve will continue to decline, to move in this direction. And same for the current which will increase in your transistor.

Notes

Summary

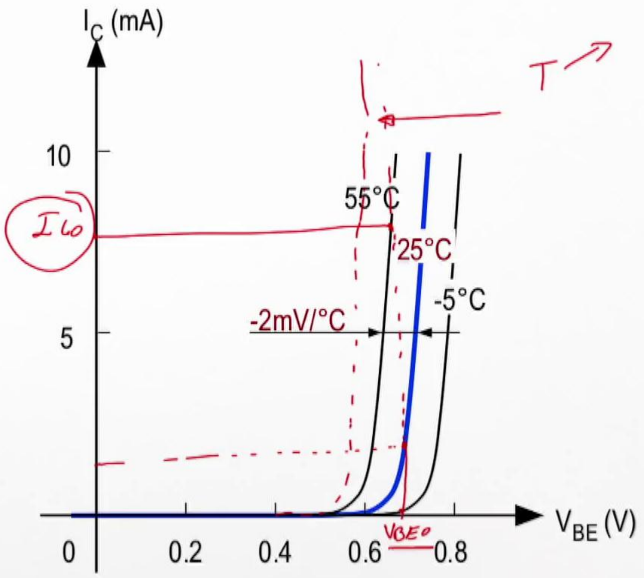
38m 58s

Comportement en température

$$\frac{\Delta V_{BE}}{\Delta T} = -2mV/^0C \text{ pour } I_C \text{ fixe}$$

$$\frac{\Delta I_C / I_C}{\Delta T} = 8\%/^0C \text{ pour } V_{BE} \text{ fixe}$$

β augmente d'environ 0.8% $/^0C$ à 1.5% $/^0C$



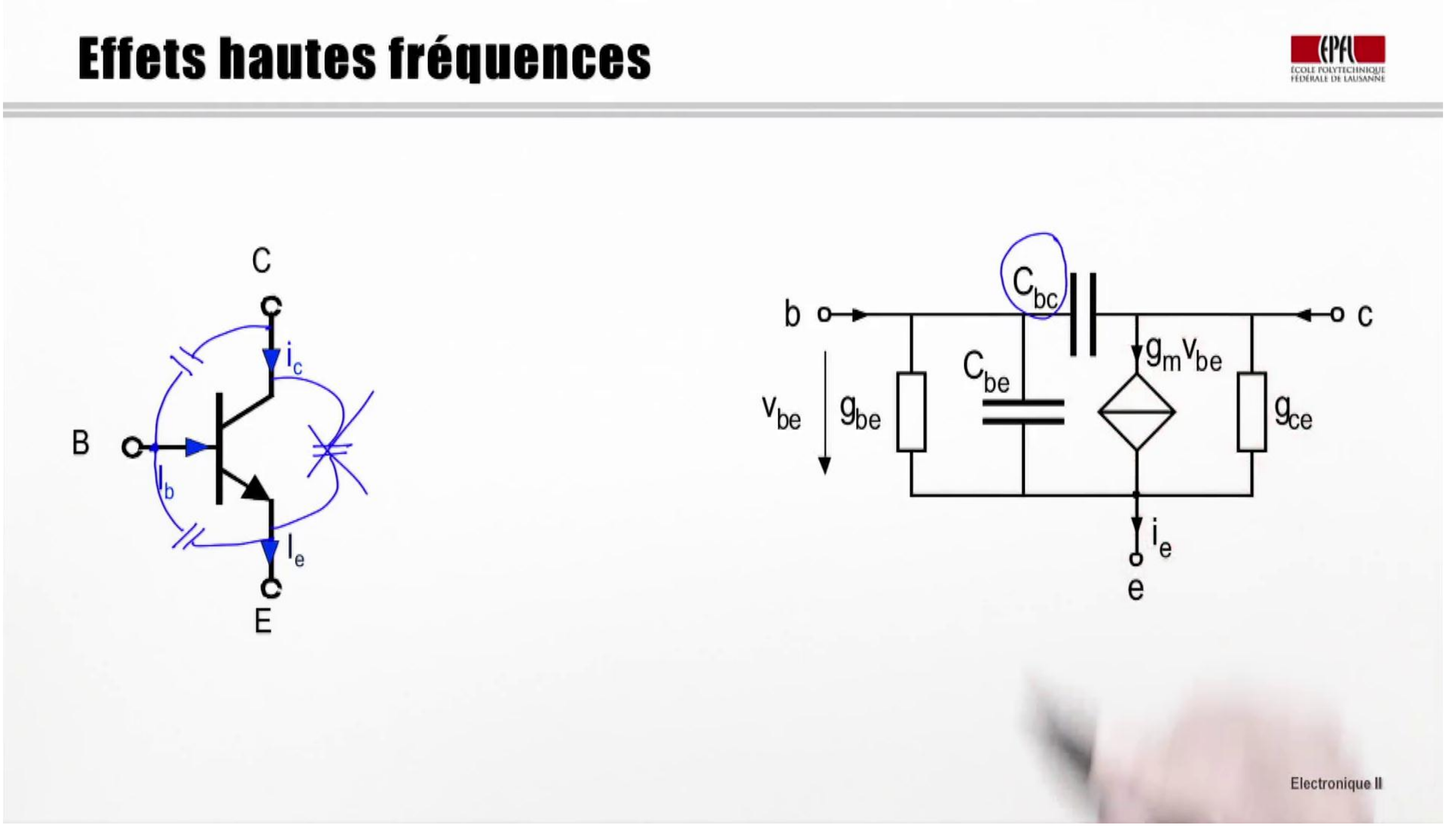
Electronique II

Therefore, the more the characteristic moves, the more the current increases, the more the power dissipation increases and your transistor wraps. So it will heat up itself because of this effect. So it is absolutely out of question to one day play with the VBE0 by imposing it. Generally, we apply the current IC0, but we will have the time to see it in detail later.

Notes

Summary

40m 34s



And to finish this video I would like to show a second imperfection, or third imperfection of the transistor due to the fact that your transistor, until today, has been shown as if there is no capacity. This is not true: your transistor has a parasitic capacity. It is not visible, it is part of the transistor, the junction itself, the housing and other things that will impose a capacity between base and collector. Same, there is one between the base and the transmitter. Same, there is one between the collector and transmitter. Therefore, between the three ping transistors, there is a parasite component of capacitive nature that is added. I have not added to the small signals diagram this ability here, because it is one of the lowest. We can induce it if we make a bad circuit and we put two wires of the collector and transmitter and we create a parasitic capacity. I should have added it here, but I have not added it compared to the other two. I added that of base-transmitter I added that of base-collector. You will see later, the most dangerous is this one. The base-collector capacity, it often connects the input to the output.

Notes

Summary

41m 02s

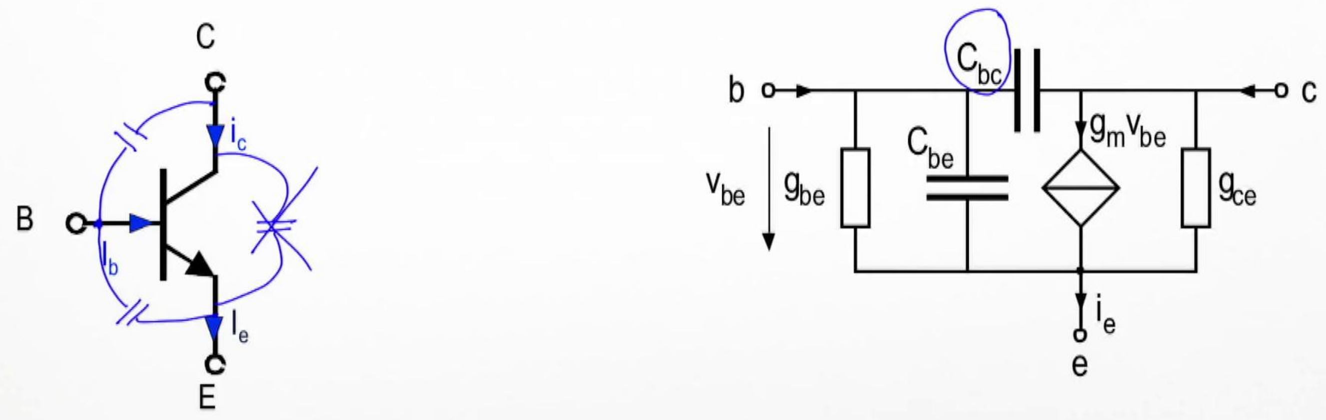
So your signal, which is supposed to change a voltage to generate a current, can go through this capacity right out and it will give us what we call in the control jargon, a 0 of transfer function therefore, a short circuit between input and output via this capacity. I would just mention that to end with this capacitive coupling phenomenon that can be created by parasitic capacities which are associated with the components and at the encapsulation of your device, or sometimes in the way it is connected in a circuit. In conclusion, with what we have just seen, we just put the transistor in a diagram. We have seen that we begin by polarizing it with a constant current and it is through this constant current we will be able to calculate all the small signals parameters of your transistor and you can replace your transistor by the famous small signals diagram, called the AC diagram. And I remind you that, as soon as we talk of AC diagram everything that concerns constant voltage source turns into short circuit, it's like a zero resistor. And I have not mentioned all the current sources.

Notes

Summary

42m 13s

Effets hautes fréquences



Electronique II

And of course, it will be replaced by an infinite resistor, that is to say, you simply remove it from your circuit and you will end up with a completely linear diagram, which contains resistors and current sources. As we are used to dealing with linear circuits, we will be able to solve it and it will allow us to go further with transistor based linear applications.

Notes

Summary

43m 29s