ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

# 1.3-Transistor Bipolaire

## Résumé et exemples

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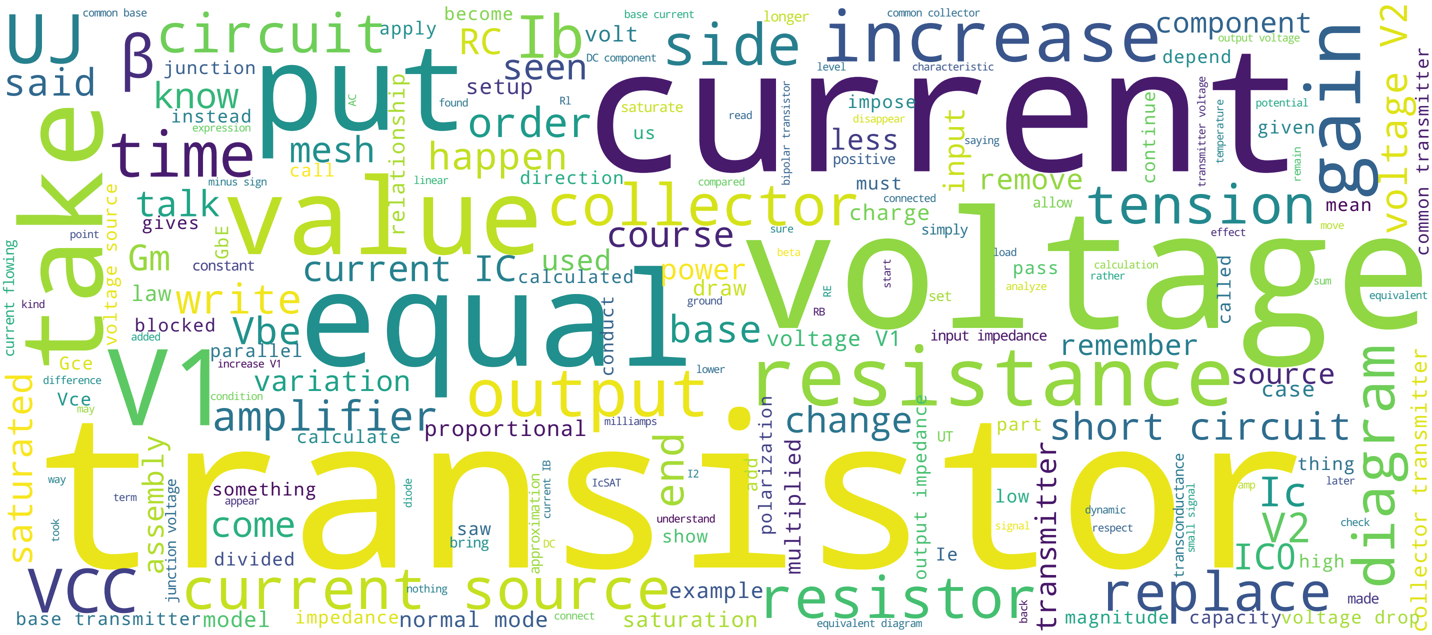
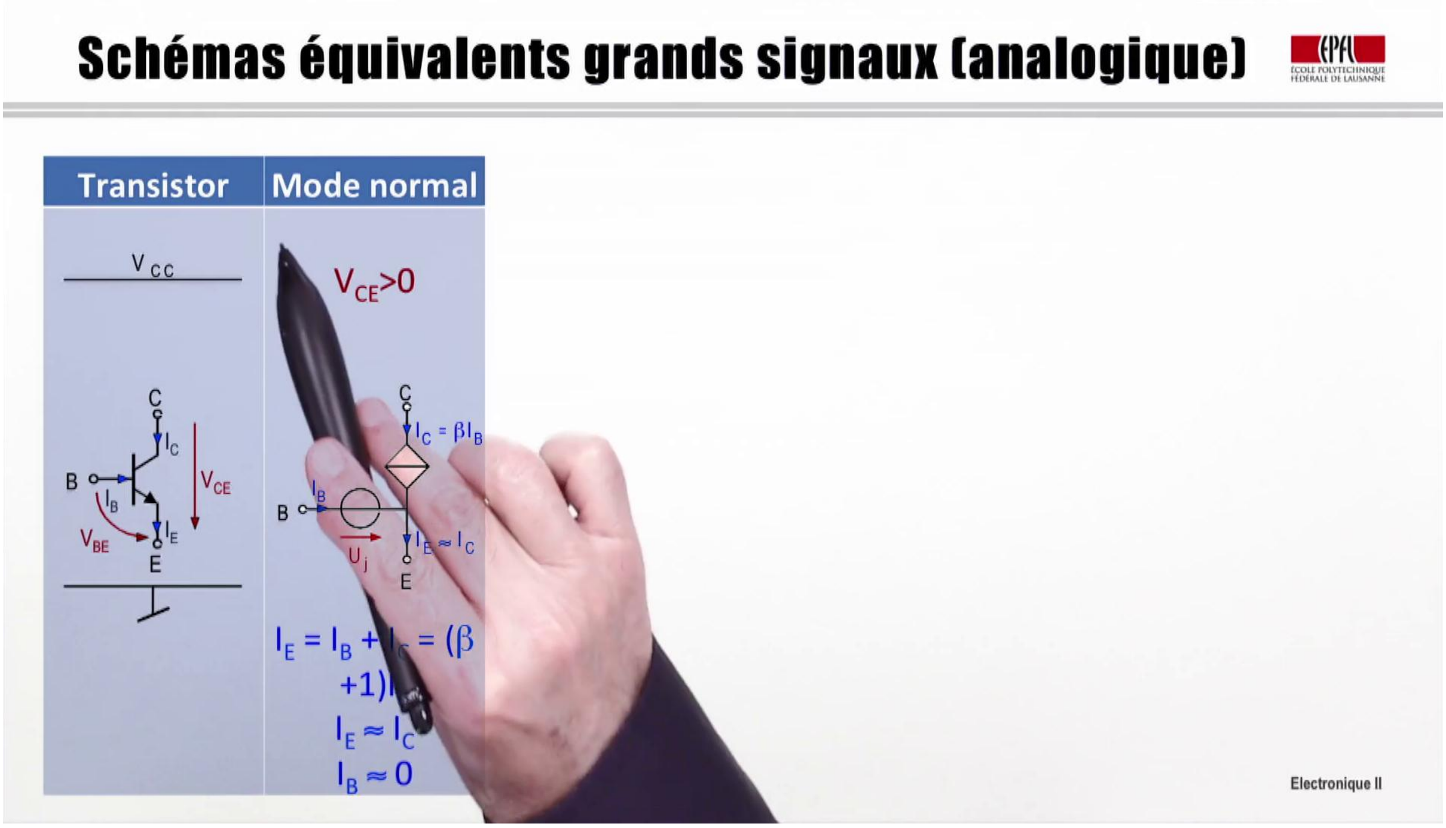



Video

EPFL

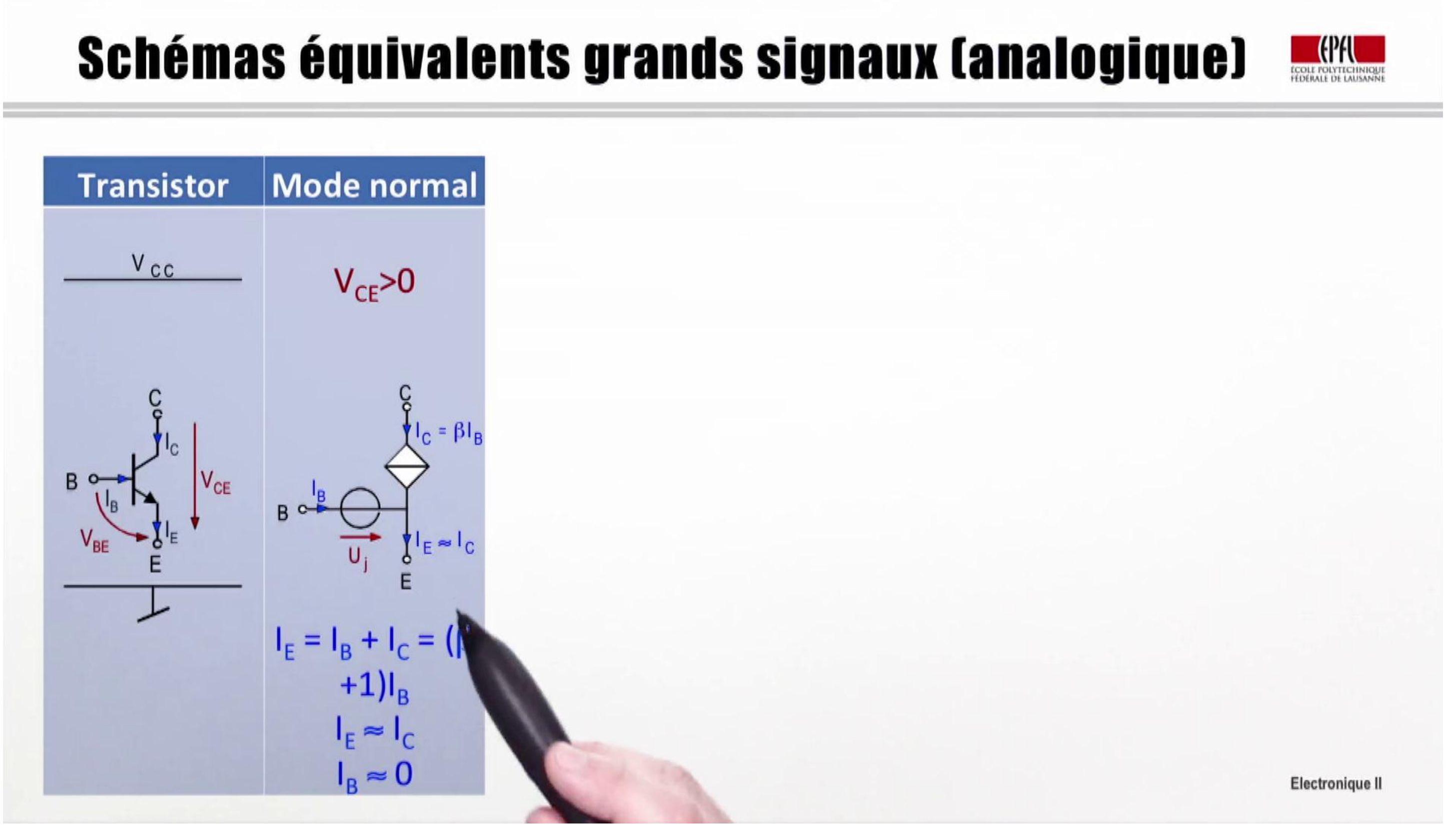



Well to end this introductory course on transistors, let's take a look on equivalent diagrams where we will propose a diagram that represents the transistor according to each mode of use of this transistor. So we have seen that there are three modes: blocked, the blocked transistor, if we simply remove it from the circuit, it will disappear, we will see how we replace the transistor when it is in normal mode and we will end by replacing a transistor with an equivalent diagram when it is saturated. These are equivalent diagrams called large-signal equivalent diagrams that will be useful especially for a transistor when it is used in the so-called "Analog" circuit. So that's the transistor symbol, I think now you understand, there is a junction voltage in the base-transmitter, there are three currents that fall within the three pings of this transistor so that the Vce voltage, we will make a focus on the value of Vce. Because as we have seen, the normal mode, is really when the transistor is in a world where it conducts, that is to say, we have the base-transmitter voltage which is a voltage of the order of magnitude of the junction voltage and the voltage between collector-transmitter is strictly positive.

Notes

Summary

0m 04s

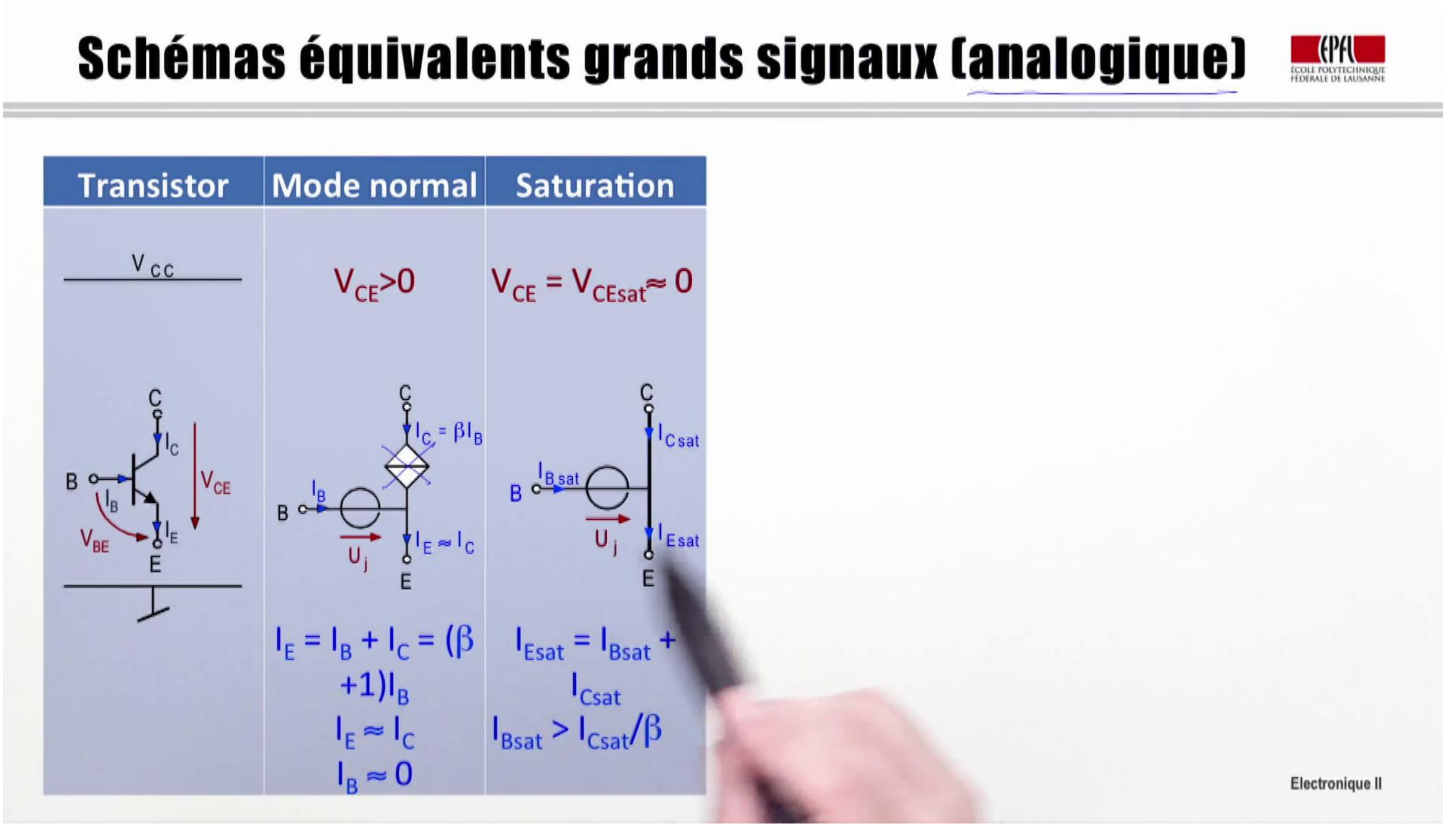



If we were able to verify that the transistor conducts and that this voltage stays positive at this moment, it is possible to remove this symbol and replace it with an equivalent diagram which is the following. We replace the voltage between the base and transmitter by a voltage, or a source of voltage, called Uj, it is an approximation. And now we have the famous transistor effect, that is to say, the famous transistor effect, the transistor behaves as a current source where the current flowing in the collector, which is drawn into the collector, will go out through the transmitter, it is proportional to β x IB, which will draw a small Ib current in the base that would be multiplied by β and this is the diagram we might simply... if someone tells me, your transistor conducts and you verified that the collector-transmitter voltage is positive, you remove this pattern and then you replace with this instead. And I just repeat to say, when a transistor with low power, in normal mode, which draws a current IC, we can simply do this approximation that the current IC+ IB that will give the current IE, here you write like that, and you replace the current IC by βxIB and you bring to light IB, you will find that it is β + 1, we can neglect the 1 relative to β which is usually very, very big.

Notes

Summary

1m 19s

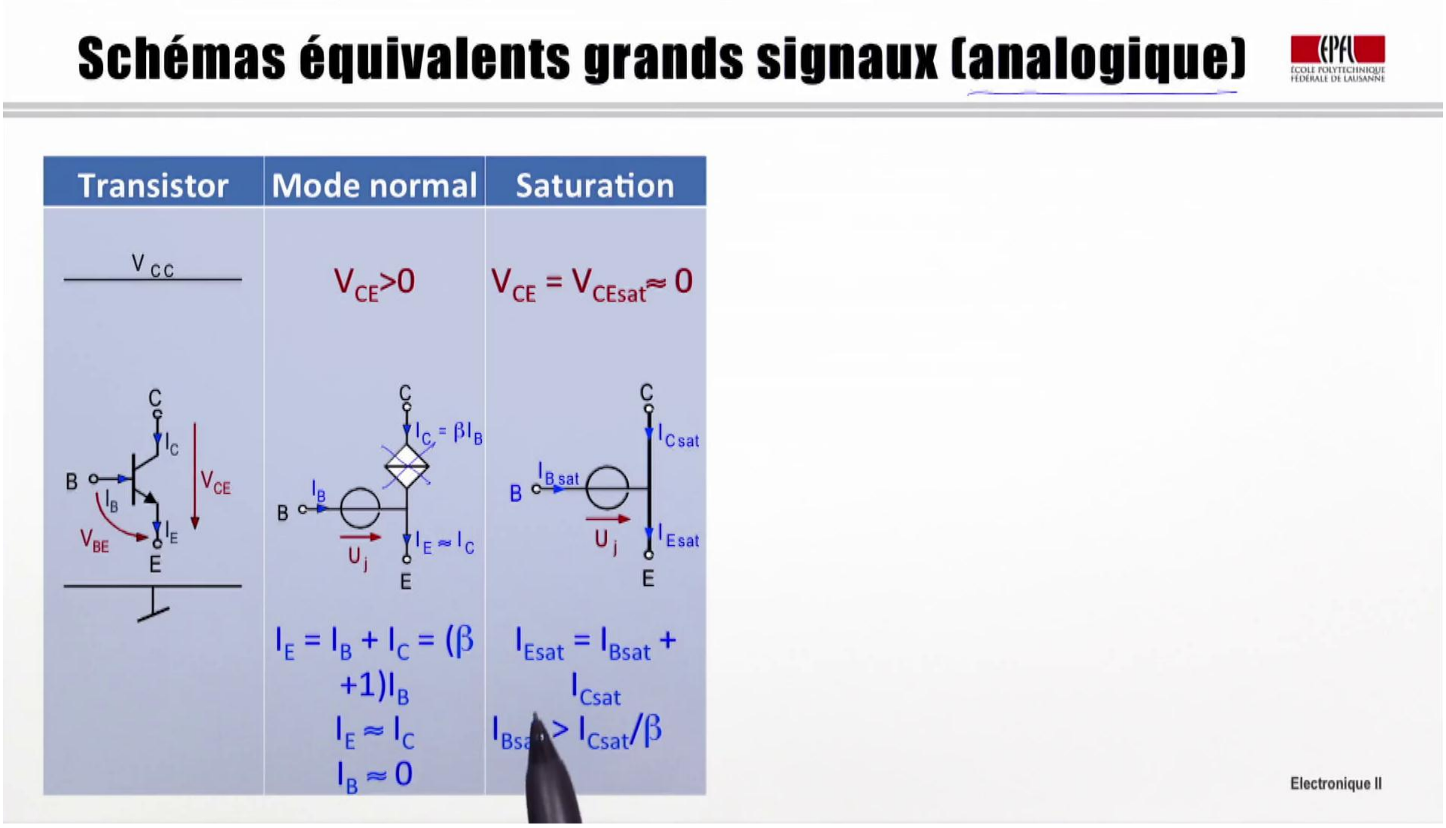



So we can always say that Ie approximately equals Ic, it is as if we're cancelling the base current, this is what we're saying, this current is almost negligible, so it's approximated by one current approximately equal to 0. That is the normal mode. It focuses on Vce. We will now focus on VCE again, but this time, when Vce is equal to 0. When your transistor is placed in a circuit, we will see just now how we get to saturate a transistor, you apply a collector-transmitter voltage, I mean, you apply because it's the user in his circuit that brings the transistor to saturate and the voltage between the collector-transmitter is equal to 0, that is to say the current source, it will disappear and the transistor will become a real short-circuit as a collector-transmitter and there, there is no longer the transistor effect that we are interested in in the analog circuit, that is when the transistor operates as a current source. And you will end up with a short-circuit between the collector and transmitter, there is no longer the current source effect, so we can not say Ic = β x Ib, you are dependent on a diagram. And this diagram we have the transistor conducting, therefore, the junction voltage remains the same.

Notes

Summary

2m 54s

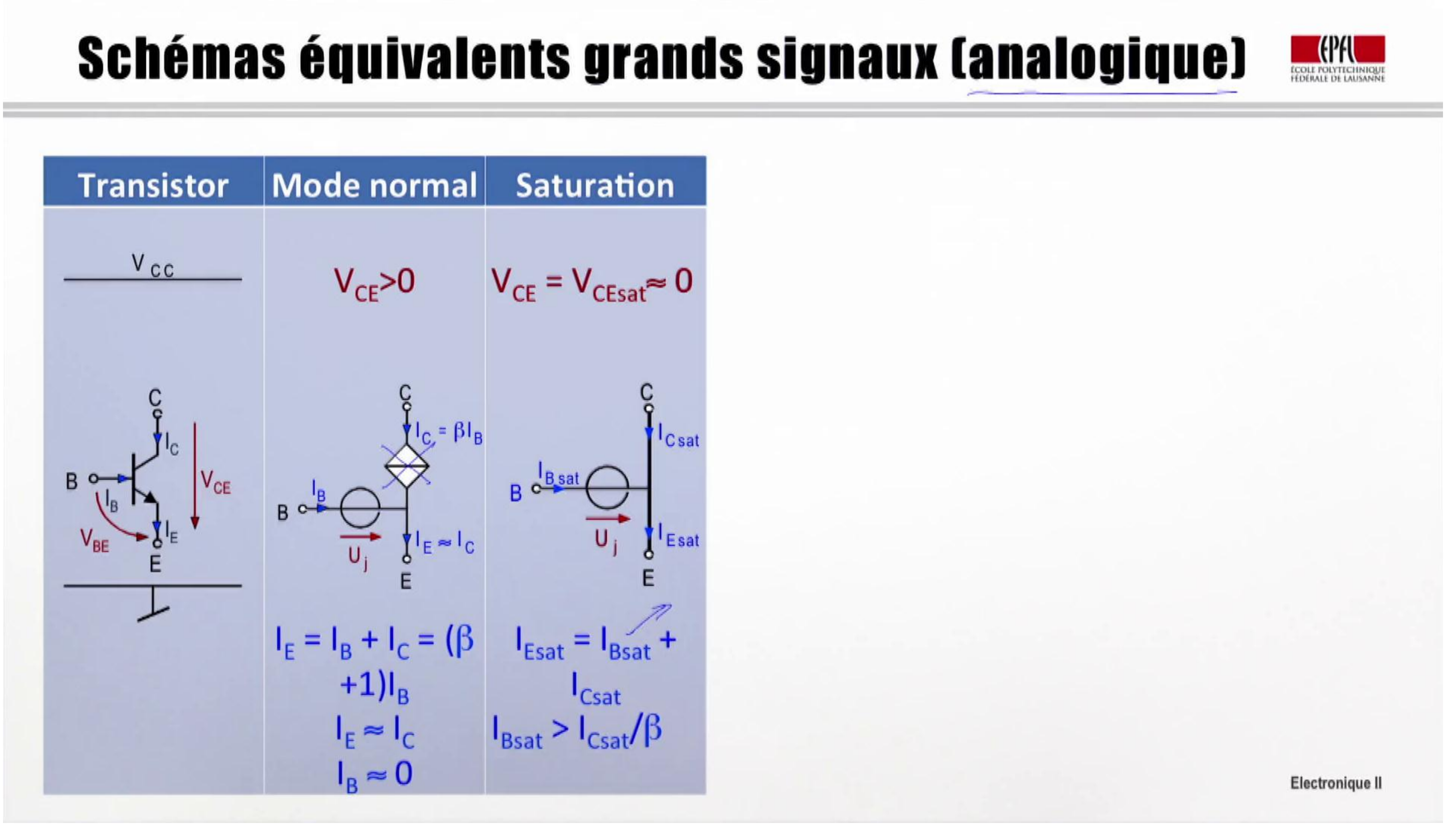



The collector-transmitter is a short-circuit, it is replaced in this model by a short circuit, so if you check if Vce = 0, you remove your transistor, you replace your transistor by this diagram you see here. And then you end up with a link that will tell you clearly, as here, Ie is the sum of Ic + Ib, the two currents enter by the two pings, exit through the transmitter, besides the arrow here indicates the current leaving the transistor and you see it here, but the fundamental difference is that you can not write this relationship. So you are to say it is Ic, we add SAT. We're out of power source, there is a current that may be proportional to a saturation current that we'll see how we calculate it later, but then the more critical is IbSAT. As the relationship has disappeared here, so we can not say that this IbSAT is linked to Ic. And Ic is a constant current, or a current controlled through a power source, you can increase IbSAT, remember that here you have a junction that... a diode. And this diode, the more you increase the base transmitter, the more the base current will increase and we talk of IbSAT. So you will end up with an IeSAT that will be proportional to IbSAT that, it can increase.

Notes

Summary

4m 17s

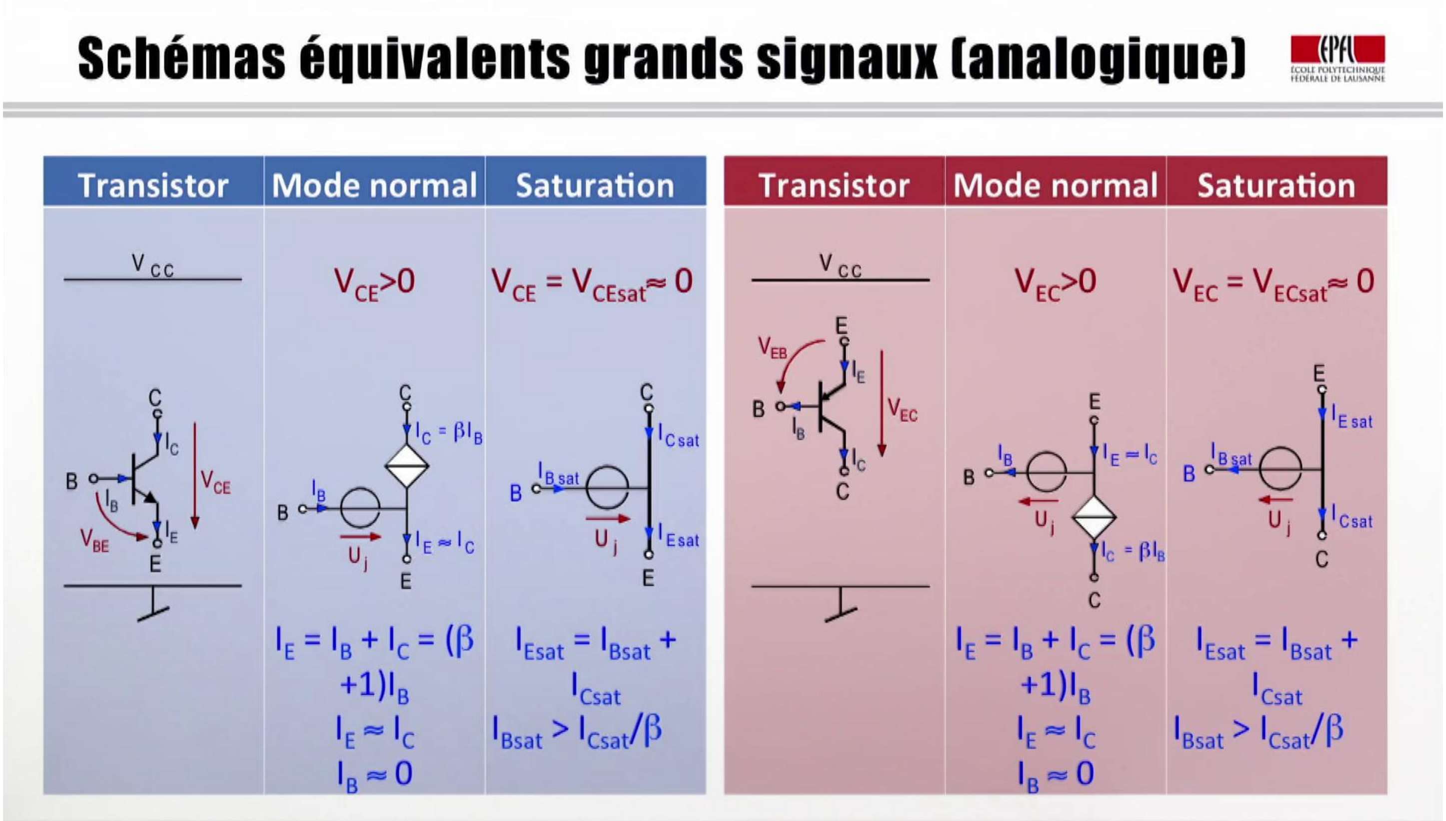



So that current can increase, another current IcSAT will add itself, this current, we will see that it will be quite limited often by a resistor, so you will have a current that is no longer proportional to IcSAT. And you must be very careful, if by chance you continue to increase this current, you may damage the base-transmitter junction, because you're going to apply to it a current which increases with voltage that remains on an exponential curve of the order of Uj, so the dissipated power in the junction will be of the order of U multiplied by IbSAT, but if IbSAT increases, the power increases and you can click the base-transmitter junction, which often happens when we increase, or go into saturation, and the base transmitter voltage wraps up, or increases. What I just explain here is absolutely valid for a PNP transistor, that is why we do not spend time showing the PNP and NPN, because if I take the same thing and I now apply it to a,PNP transistor, I find myself with a transistor, I take the symbol, instead of talking of Vbe as junction voltage, given that the current enters the transmitter and it exits through the base and leaves through the collector, this is the opposite direction of what you see here, well I speak of a Veb voltage.

Notes

Summary

5m 39s

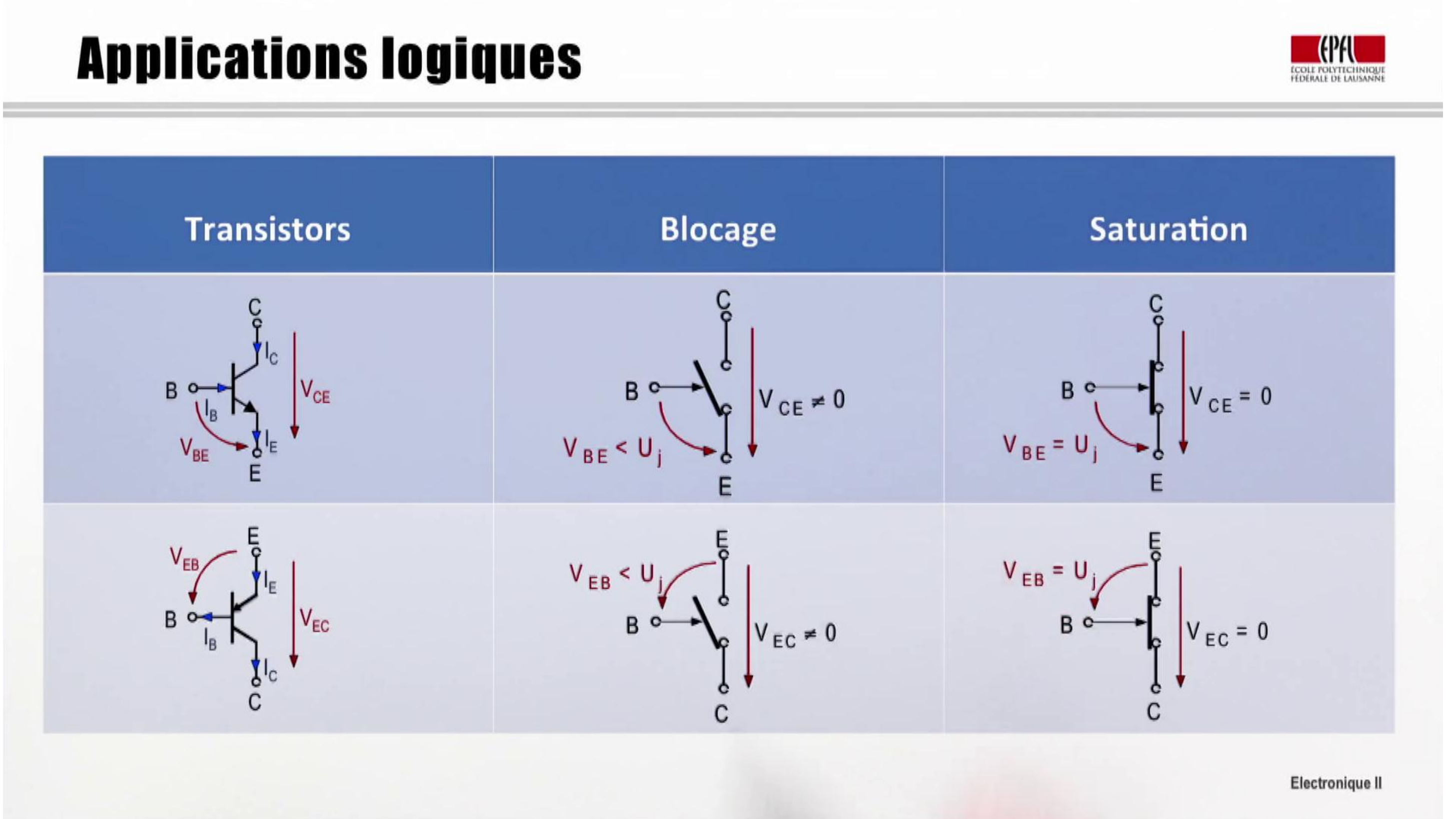



I have to continue after, when I talk about normal mode, it's the same condition, but instead of saying Vce must be positive, this time I must say Vec must be positive. And saturation is the same, because here it is equality with 0, then I reverse the direction of arrows in this transistor, which always leads me to exactly the same rules that I apply. As well here and there you find the same laws, you invert the direction of the vectors base-transmitter, transmitter-base and as for the current direction, and the same for output currents therefore the current of the collector-transmitter and voltage between transmitter and collector. There you go. So we will not talk all the time of duality between the two transistors knowing that this transistor is just a transistor whose laws are the same, but simply the directions of voltage and current are different.

Notes

Summary

7m 04s

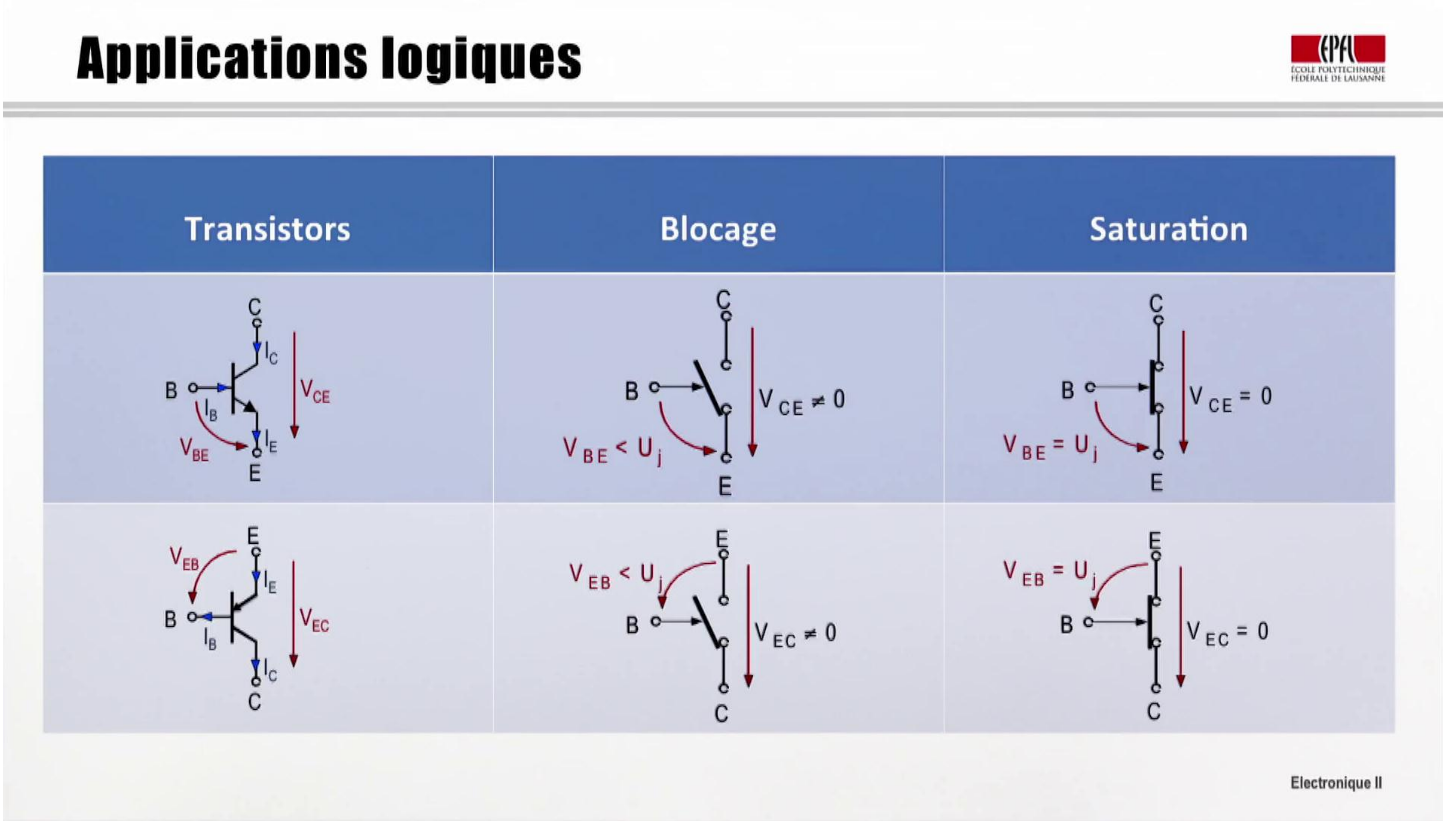



The bipolar transistor could be used also in logic circuits. Here, we will talk of the transistor in the blocked state and the saturated state. We have seen that saturation can happen to this transistor and it behaves with a short-circuit, rather there is a voltage between the collector-transmitter equal to 0. So it's like a closed switch. It is said that there is a short-circuit between collector and transmitter, it is equivalent to say that the collector-transmitter voltage is equal to 0 and when one locks the transistor, the transistor is simply where you can remove it, if the Vbe voltage is lower than a voltage junction, your transistor is completely useless. You can remove it from your system, so it is symbolized by an open switch. So then, as we talked about NPN transistor, we can also talk of the PNP transistor. And we end up with the same thing we had presented just before, instead of saying Vbe, we say Veb and as for the ec voltage instead of saying ce but the modes of operation do not change. We block a transistor by applying a voltage less than J, we saturate it on the condition that its output voltage, we circulate a current in a way that the collector-transmitter voltage drop stretches towards 0 and the transistor behaves like a closed circuit.

Notes

Summary

8m 05s

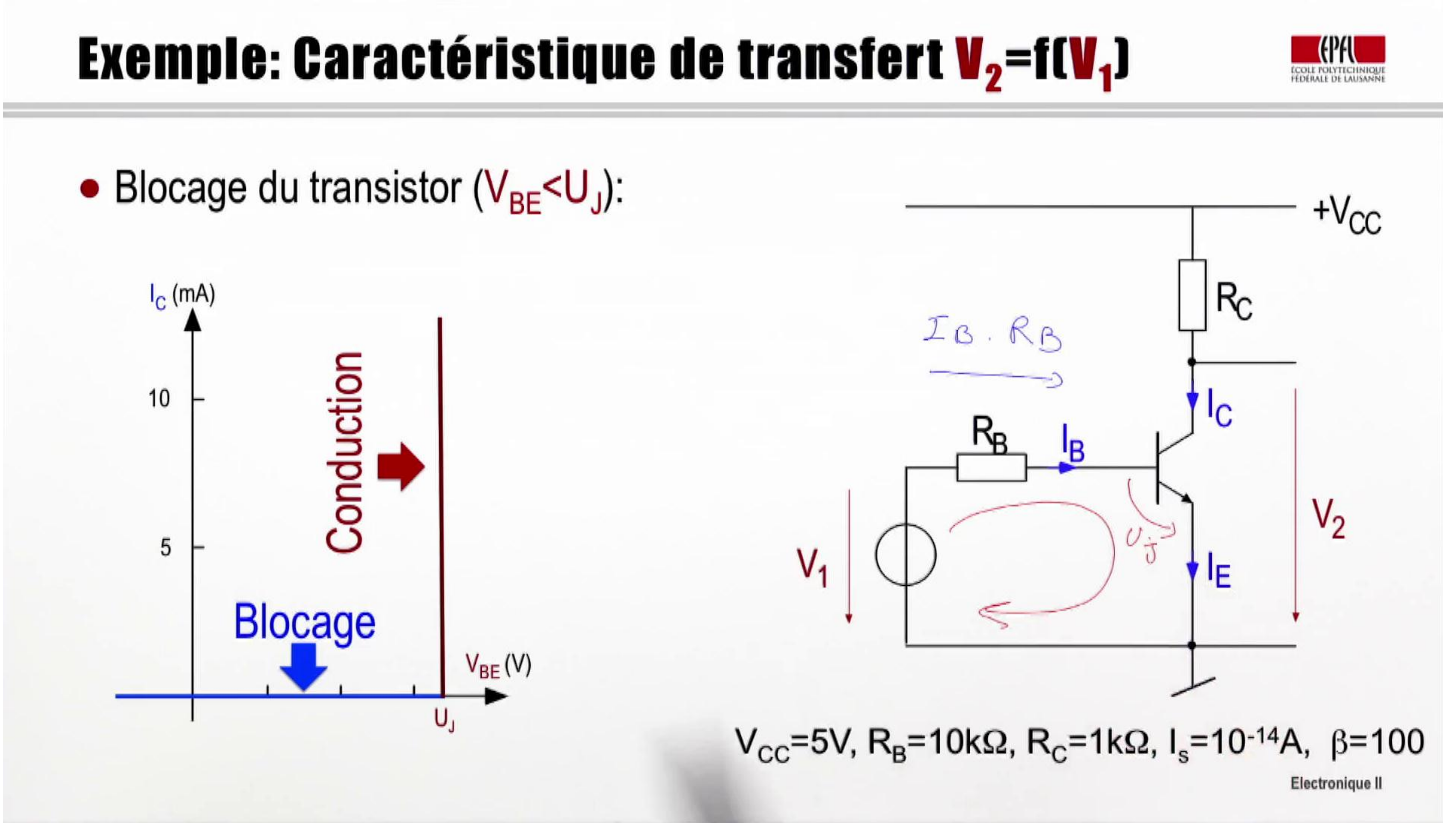



And it allows me to use the bipolar transistor in digital applications. So we may have logic gates, besides the bipolar transistors were the sources of the TLT gates transistor logic transistor, before the MOS transistor came to replace it to make logic circuits that are much more efficient. Why ? Because in this case, there is a current base and in the MOS transistor, there is no base current, therefore the control voltage is sufficient to close, or open, an MOS transistor. However here, when closing a transistor, so when we stand here, it continues to draw current as we had seen before. And that is a current that is wasted. It serves no purpose, there is a power loss in keeping the transistor closed.

Notes

Summary

9m 25s

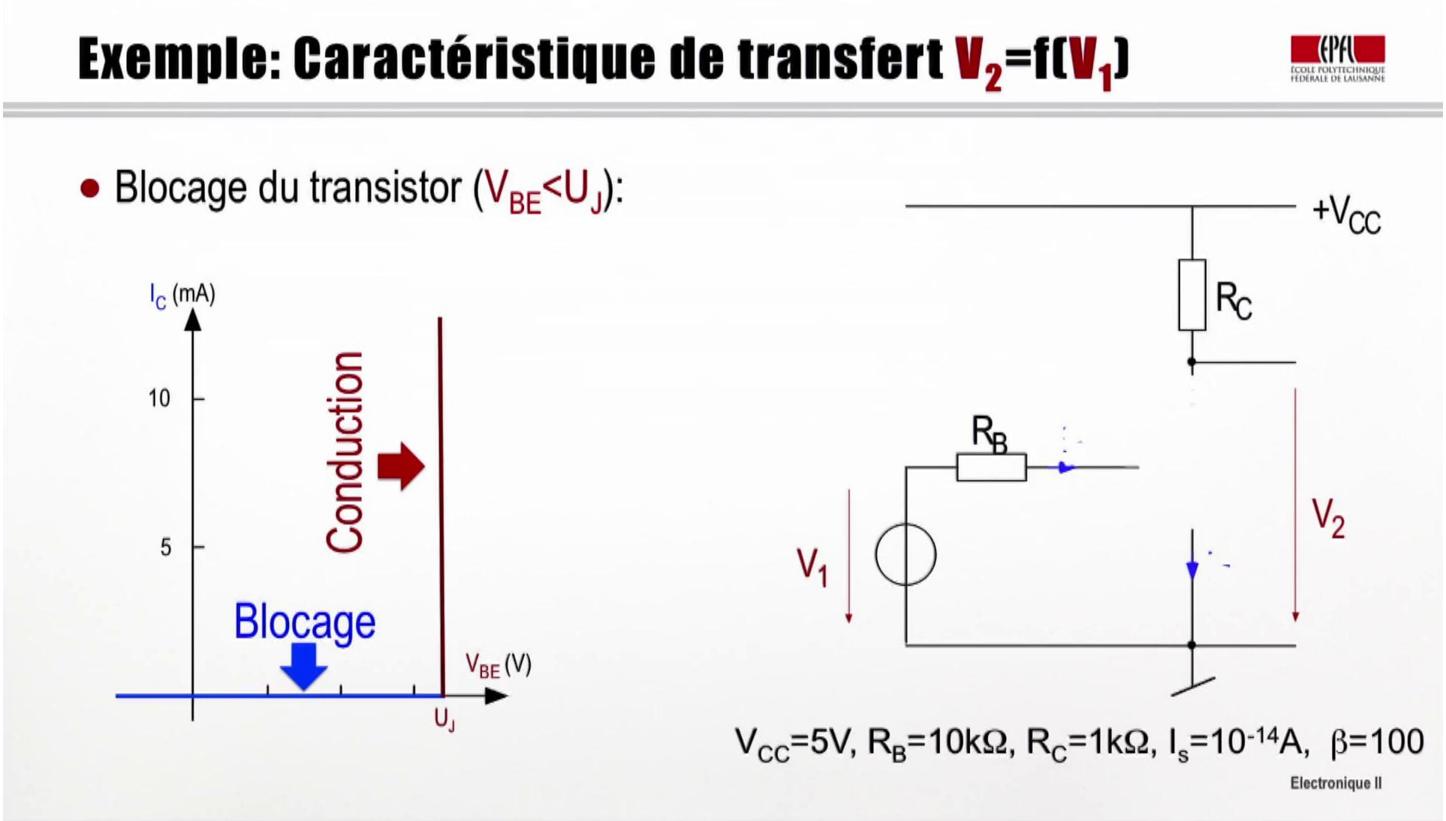



To end this week's classes, I would ike us to look at an example. Through this example, you'll see that we will master the three modes of transistor uses and show that a transistor, in a diagram, may be blocked in normal and saturated mode. And all this is related to what we put as resistance. For example in this diagram, I have put a resistor in the collector and I put a resistor in the base. The transistor, when it is used in the so-called large signal model, we had this approximation here. We said, when we want to mention the exponential law of a transistor, it could be approximated by blocking, or conduction. So if you take the mesh that is here so this mesh here, this one here, you'll see that the voltage V1 is equal to the voltage which is there, which is Ib x Rb to which I add the tension here and this, we will approximate it to Uj. It was this approximation, so I can easily in this mesh which is created by V1 = RbIb + Ube, since here I have a linear law, so this is Ohm's law and there is an exponential law. This exponential law, if the transistor conducts, put Uj, if the transistor blocks, well this voltage, I mean, it is not an Uj voltage it is the Vbe voltage.

Notes

Summary

10m 14s

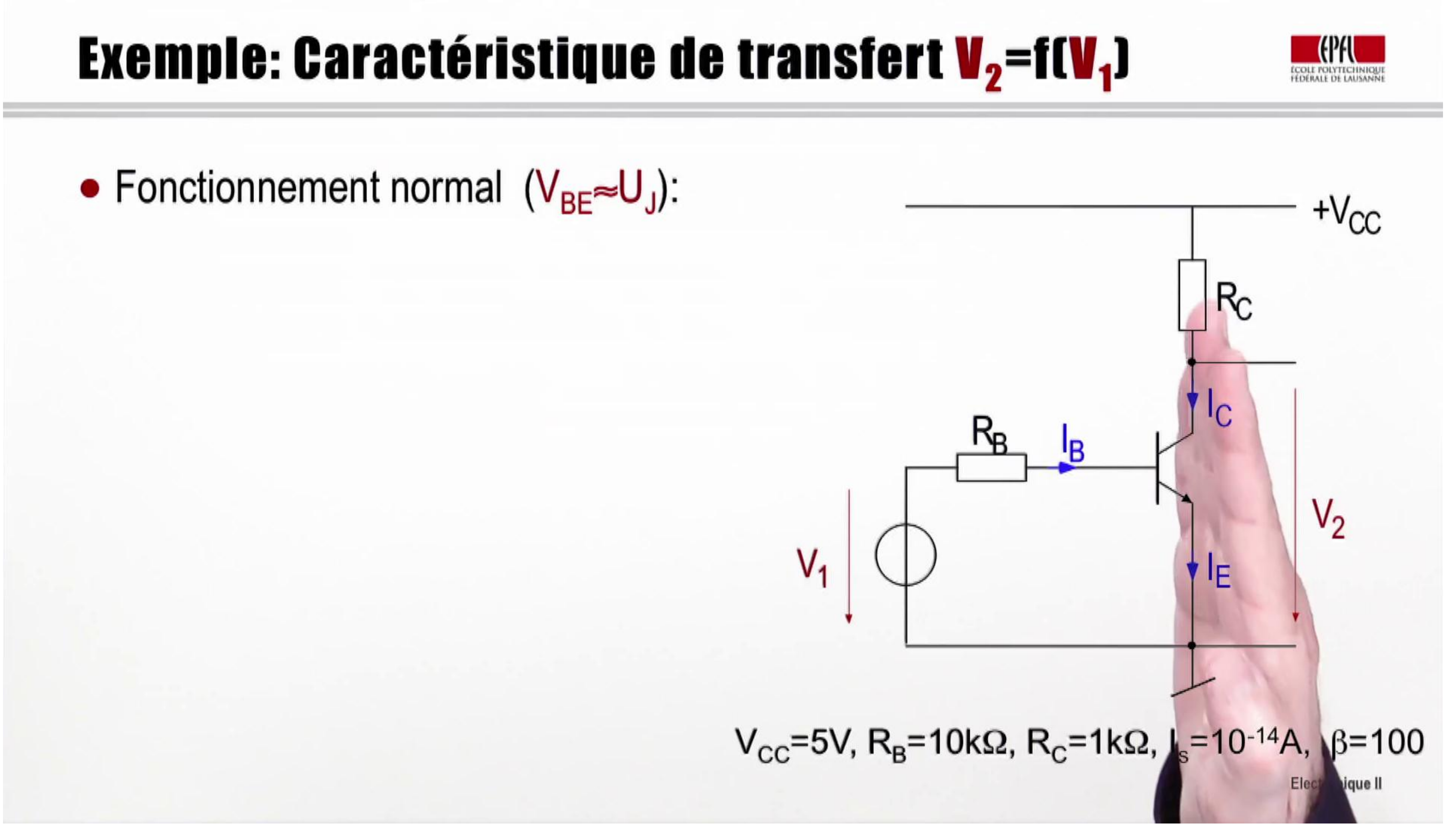



But what will happen with this mesh here? We have seen that if I am here, on this law, so I have a VBE voltage which is less than UJ, I'm here, it can not be an Ib, the transistor is blocked, no current flowing in either Ic or in Ie or in Ib. So voltage V1 here is the same that I would see here. If Ib is 0, if you put Ib = 0, then IbRb = 0 therefore this voltage drop is equal to 0, therefore the potential difference that you see here is the same potential difference here. And that condition is achieved when your transistor does not meet a junction voltage allowing it to conduct, and that's it. If Vbe is less than Uj, at that time, you can just remove what I noted and we will see what happens with this transistor. That is if your transistor is here, you can simply fall into the condition where the transistor is blocked and blocked mean, the model, the transistor disappear, I remove it, it's a blocked transistor. So the model of a blocked transistor is nothing at all it is... we are here, there is no Ib, there is no Ie, there is no Ic, it has justbeen erased. So if you put your fingers here to see the Voltage V2, well V2 is nothing other than Vcc. And if you look V1, well V1 on this side or that side is the same given the current here is 0. And like that, when we say, a transistor in a blocked state, it is simply an equivalent diagram, it is removed from the circuit.

Notes

Summary

12m 06s

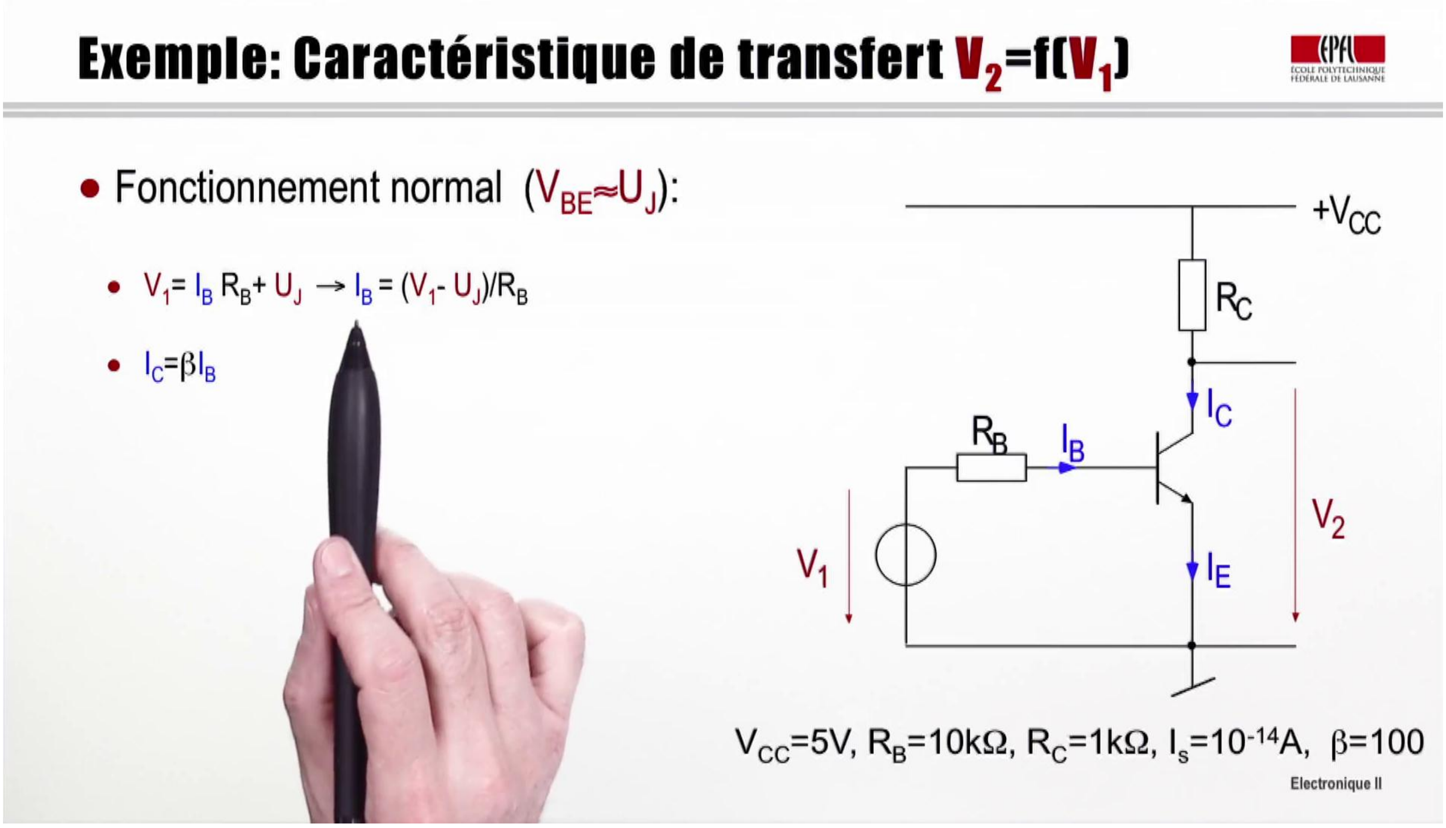



Therefore the blocking of the transistor when Vbe is less than Uj, that's what I just said, Ic = Ie = Ib = 0. And V1 is less than Uj, this voltage drop is zero. This voltage and this same voltage here are the same because Ib = 0 so this potential is equal to this potential and we said just now, and we have seen that V2 is equal to Vcc because there is no current flowing thus the current that passes Ic through the Rc resistor or this voltage drop here, that's VRc = 0. Therefore this voltage is equal to this voltage here. We will now start looking at when Vbe is of the order of Uj. So your transistor begins to conduct. If your transistor begins to conduct, the more you raise V1, the more the current Ib will increase. The more you will have a current Ic that increases with more Ie which is equal to Ic, so we're looking at this transistor as if there are two mesh and that's how it should be analyzed. So if someone shows you a diagram as this, you must look at what is on this side compared to what is on the other side. That is the entrance to your transistor, this is where you control it. This is the output of your transistor where you observe the voltage V2 which is proportional to the voltage VRC, of course, because the sum of the two is equal to VCC.

Notes

Summary

13m 48s

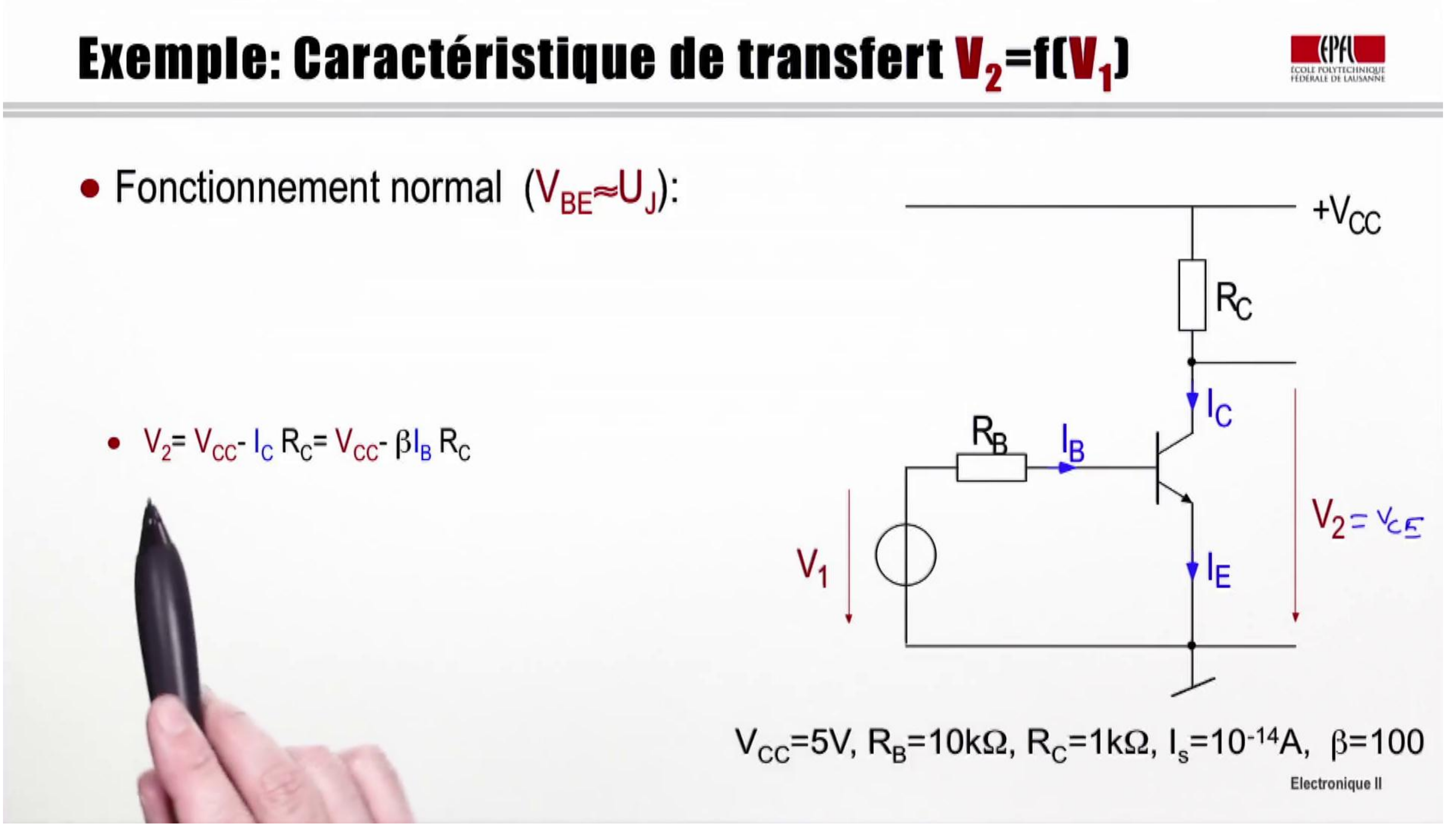



So if you look at this transistor, you always start by the control junction, or by the part where we're.. we said it is an electron tap, so that's where I'll control the tap. So this is where I'll change this voltage VBE for a current to begin flowing. Of course, the change in Vbe is extremely low, it is of the order of UJ, but we are talking about changes of millivolt. This is less than UT, and UT is 26 millivolts, so the thermodynamic voltage of the transistor. So when we vary VVE with very little variations, well we will observe the following. So when Vbe is equal to UJ, I'll take the mesh here and I'll write V1 equal, it is a vector, at Ib multiplied by RB, the more I'll make this approximation, the VBE order of magnitude will be of this approximation in large-signals equal to UJ. When you look at this, you will say, of course, when my transistor begins to conduct, it will have IB. Well IB will pass, it will generate a current IB. So there we analyzed what happens to this side. We will again look at it in more details. This is what I just calculate, V1 = IbRb + UJ. And there I can talk about a current IB, and this current IB depends on V1 and this approximation UJ divided by RB.

Notes

Summary

15m 21s

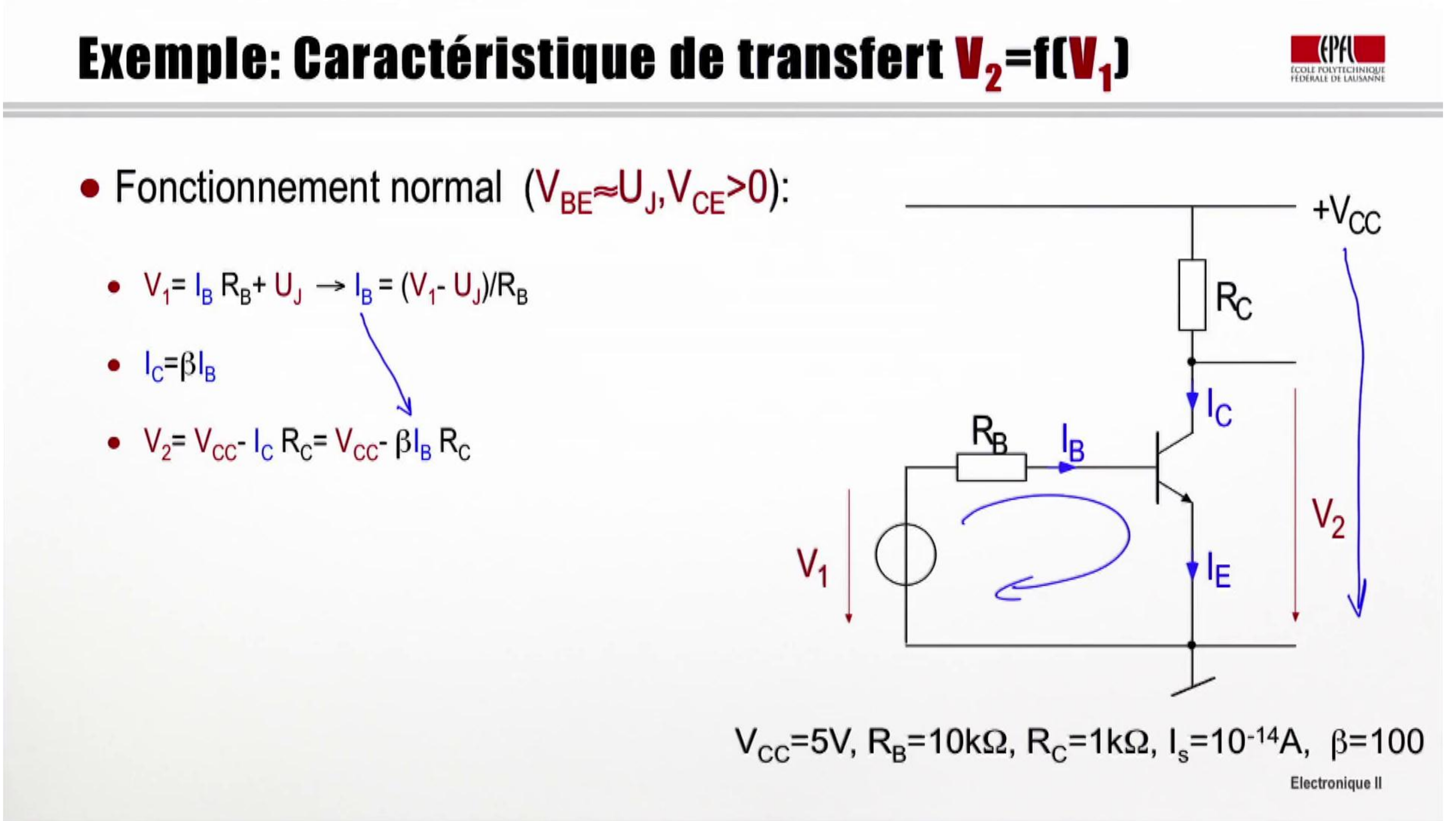



Of course, the resistance RB is extremely important. If we would not have put RB here, we would have ended up controlling the voltage V1 that comes directly in base-transmitter, it is impossible to do because you have an exponential variation of the current with respect to this voltage. But when we look at it here we're saying Ib is equal to the voltage V1 minus some constant UJ. And it remains the law of ohm RBIB that we see, so it's Ib this voltage divided by the resistor Rb. And here I can talk of this law provided that I verify that V2 is necessarily greater than 0. If I do not check it, well I can not write this law, that means that my transistor is saturated. If I made such a calculation and I check, I can even put the numerical values I have here and see what the current going through my transistor is with respect to a given voltage. We said we analyze what is on this side and now we will analyze what is on the other side. So we looked at the control part, we will look at how the transistor output, V2, which is nothing other than Vce. In this case, it's V2, it is between collector and transmitter. So this voltage here, V2, I only have to take the vector Vcc from here to here, which is equal to IcRc, so here I have IcRc + V2.

Notes

Summary

17m 08s

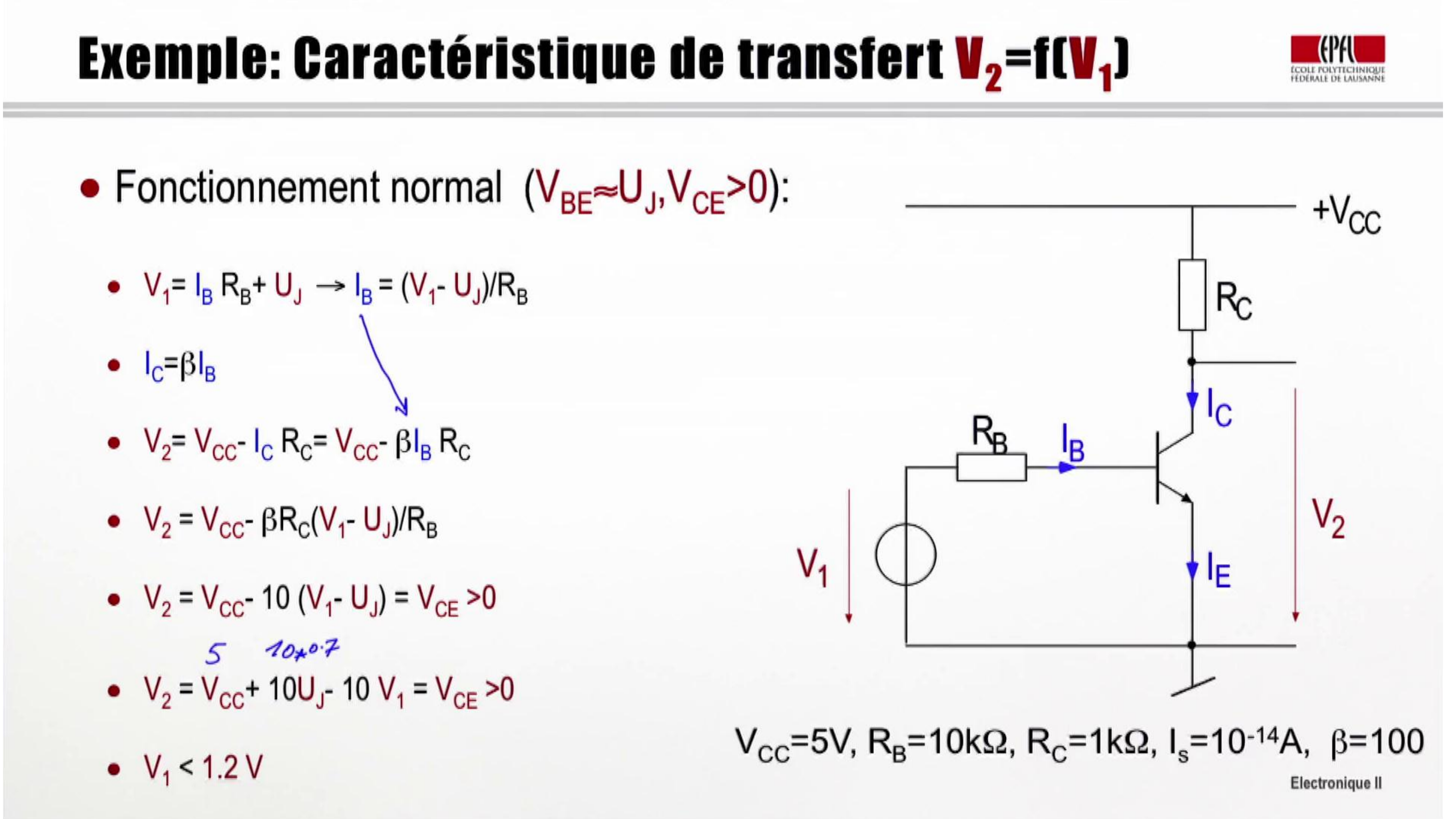



And that's what I wrote here, So Vcc = IcRc + V2. In other words, V2 = Vcc-IcRc. And I know that this current Ic, if my transistor is in normal mode, is proportional to β x Ib, that's what I'm doing here, I replace it. Sure I can write, if V2 is greater than 0, so it is in the condition that C2 is strictly positive. And once I have that, I can replace Ib that I have just calculated, Ib was calculated in this mesh, we are bringing it back towards the exit through Ic and there, I really wrote all I can draw as Kirchoff law that allows me to write all voltages and current in an operation mode with the output voltages in respect to the input voltage. Remember that in Ib hides V1 and that's what I'll do now. This is what I wrote at the beginning for this mesh and for this second mesh here, I just wrote this. And we saw that the current Ib is the link between the two. This is what connects the output to the input because it will be at the output multiplied by β to give Ic and I will replace it here and I get a relationship in which I see that V2, F2V1, which is my goal. I would like to do a transfer function in which I put a voltage V1 and I want to see the voltage V2 with the transistor which may be in all these modes. So I replaced this by this and I get this.

Notes

Summary

18m 50s

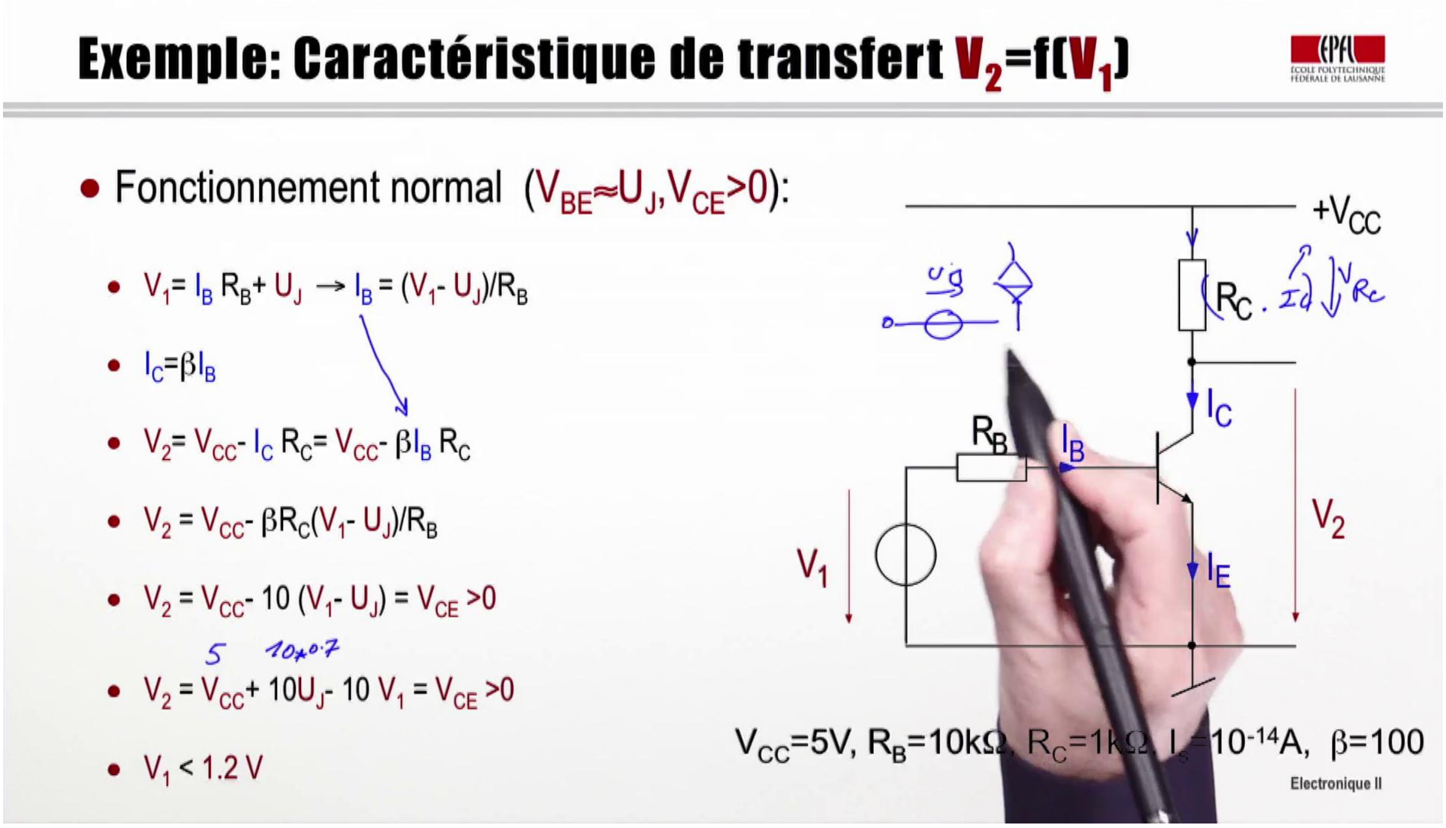



So once replaced Ib in there, it gives me the relationship. I'll let you check, you're going to end up with a relationship in which you have β values, remember that it is a given transistor, So we gave a β = 100, we were given a resistance value of 10 kilohms and a collector resistor of 1 kilohm and we supply with a voltage source of 5 volts. And we get a voltage V2 = Vcc - 10 V1 -J = V2 AVce. It is this voltage here, collector transmitter, and we would like to check what value of V1, or what is the limit value of V1 for which V2 is not equal to 0. What I'm saying is extremely important because now in reality we see, what will happen with your layout, if you write that law and you replace with the values we have here βRcRb by their value, you find V2 is equal to Vcc, remember that this is 5 volts, 10 x UJ, so it's 10 x 07 volts and - 10 x V1, it will depend on the value of V1. And all this will give you the Vce voltage. Obviously, if you have some V1 that you put in here that gives you this equal to 0, it's the limit value, so VCE becomes equal to 0 if V1 = 1.2. So less than 1.2, you are sure that your transistor has a strictly positive V2 voltage.

Notes

Summary

20m 36s

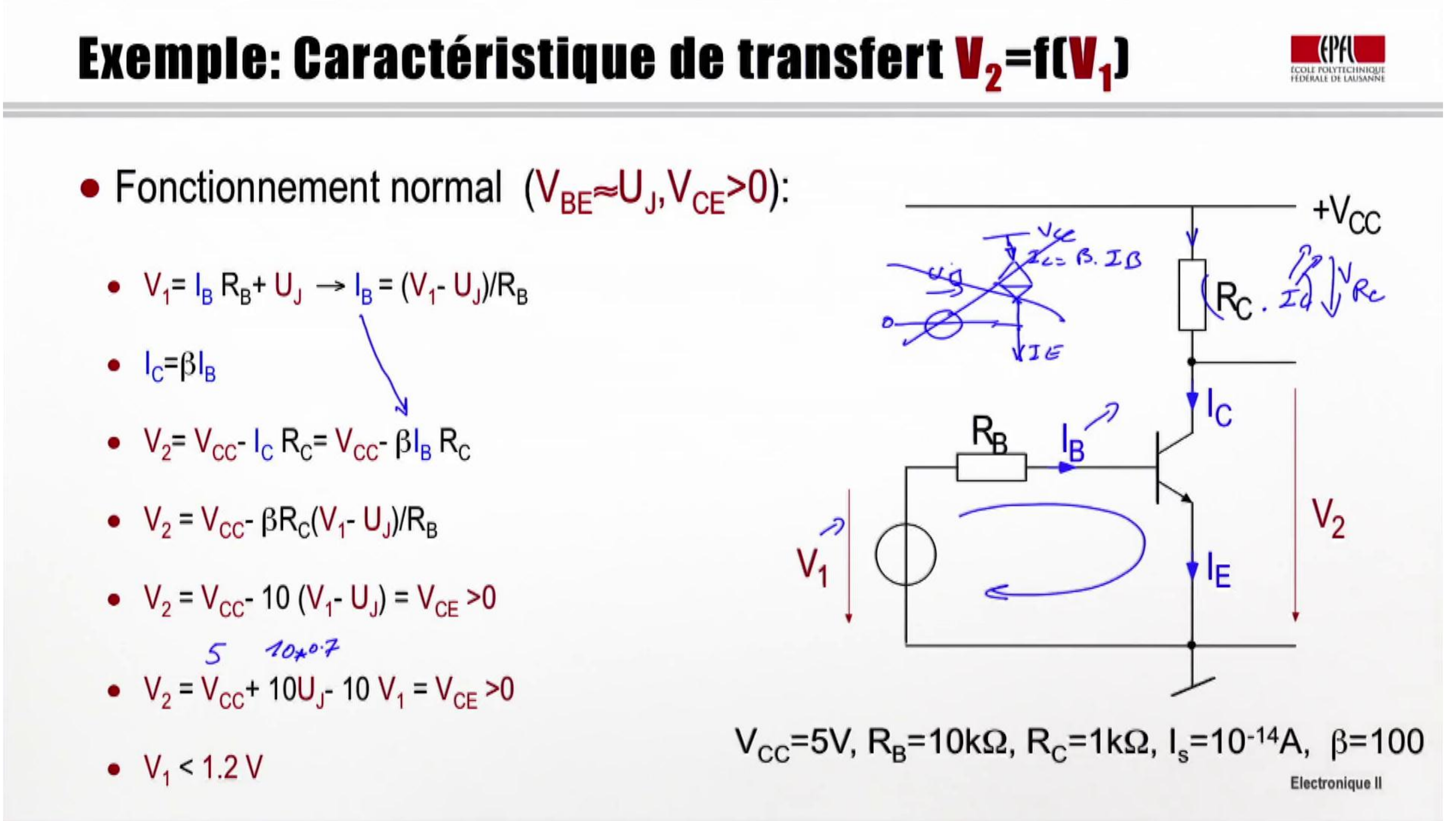



If you have V1 = 1.2 volts, you will get a relationship in which the voltage V2 will be equal to 0. And who did it? It's you. Because you chose a resistor RC which is 1 kilo ohm. You applied voltage here. If you put a vector here, you say this vector is Rc x Ic that gives you the VRc voltage, know that this parameter RcIc, which is equal to VRc,plus Ic increases, look at what happens with this vector. You are about to increase this current, voltage and the current in a resistor follows. Look, this voltage increases, increases, increases. During that time, the voltage V2 drops, drops, drops, drops, until you apply on V2 = 0, and you push your transistors in saturation. As long as you are with a voltage IcRc which allows this tension not to crush the voltage V2 so that it becomes 0, you are sure your transistor is in normal mode. So your transistor gives you a current source, here. Ic remains a source of current. It was said that if I want to replace this diagram by its earlier model, I only have to take a source voltage I call UJ. I refer you to the table that had been drawn before. We place a controlled current source, here. And this controlled current source is the source of your current.

Notes

Summary

22m 28s

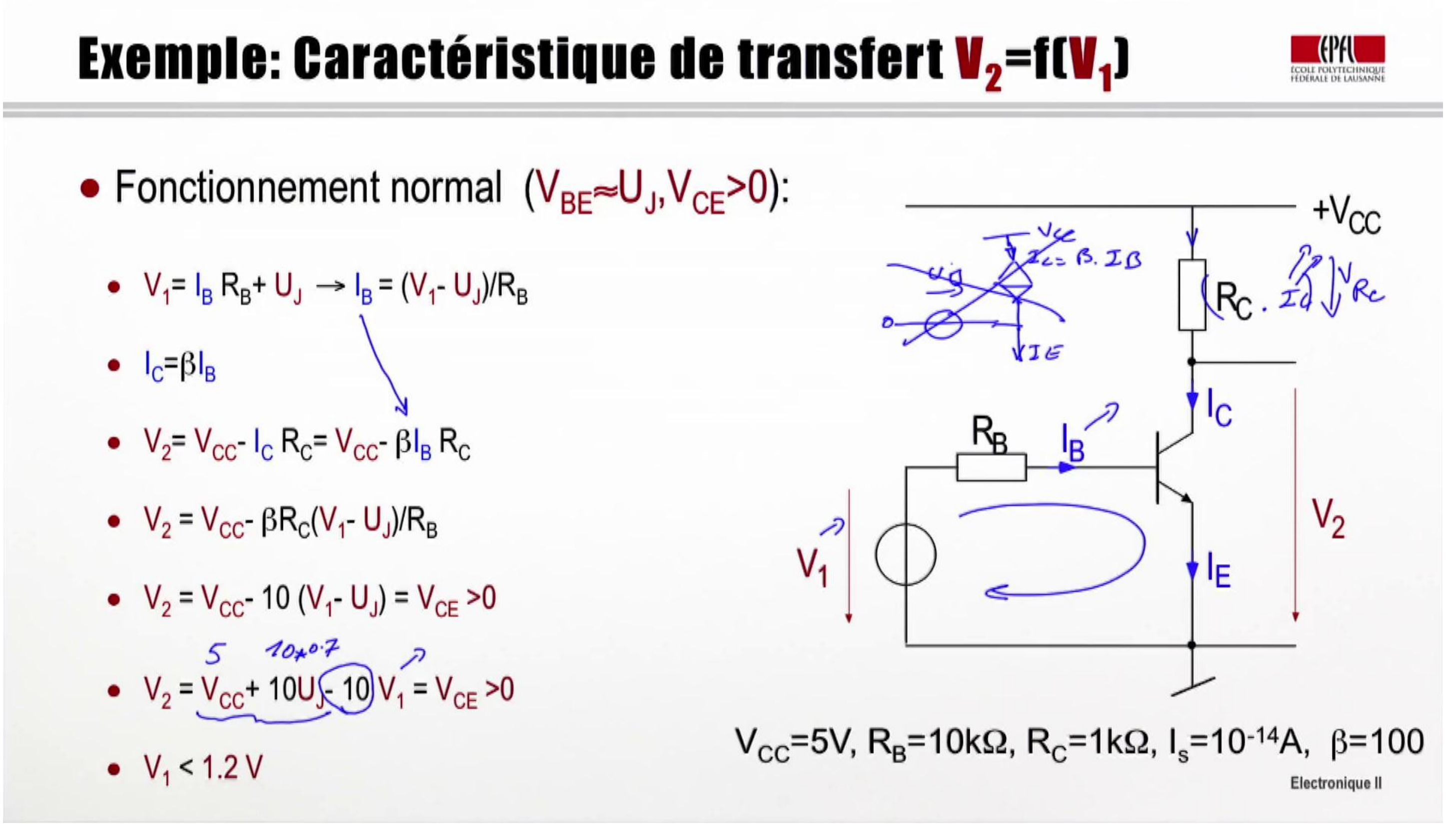



Here you have Ie. And here you have a current Ic = β x Ib. Look, if you remove this transistor and you put this in its place, you will see what happens with your circuit in normal mode. But the more you increase Ib, the more you will increase Ic, the greater the voltage drop across Rc increases. And it will push V2 to stretch to 0. But when you have crushed, V2 is equal to 0, know that your transistor, is no more this. You can remove it and replace it with the famous diagram that we showed too, that I will show right after. There is a short-circuit between collector-transmitter. And then if you look at what is happening in this mesh here, whenever you increase V1, you will increase Ib. Ic no longer follows, there is no more this relationship. So Ie will increase, of course. And as you continue to increase, Ib increases, and you are just in this mesh that will push Ib to increase, and you no longer have a transistor effect, it is replaced by a short-circuit. Therefore the saturation of a transistor is not a fact related to the transistor,it is the circuit in which you have set it, and the values of elements that impose this saturation.

Notes

Summary

24m 06s

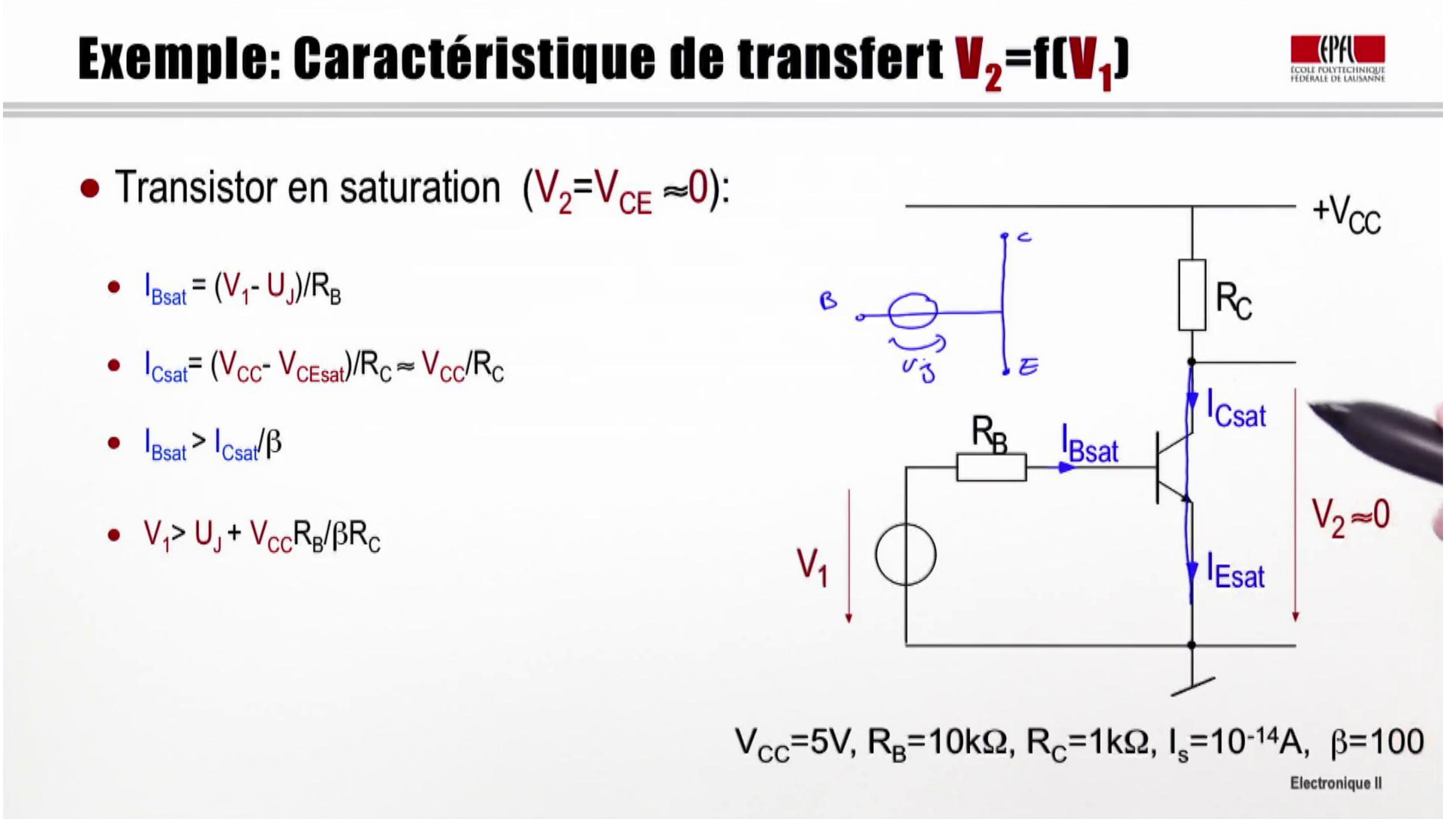



I would like to draw your attention to this factor of 10, that I see here, with a minus sign in front. So if you look V2F2V1, what we want to get, is a DC component. This, is 5+7. So we have here a completely DC component, it will not change, it's always like that. - 10 x V1. So every time you increase V1, you subtract from that amount an amount 10 x V1. But remember this 10 x V1. Thus, V2 is associated with 10, in absolute value, compared to V1, and that's what we will call later the gain of your transistor. And this is where your transistor will work as an amplifier. We will see it afterwards.

Notes

Summary

25m 29s

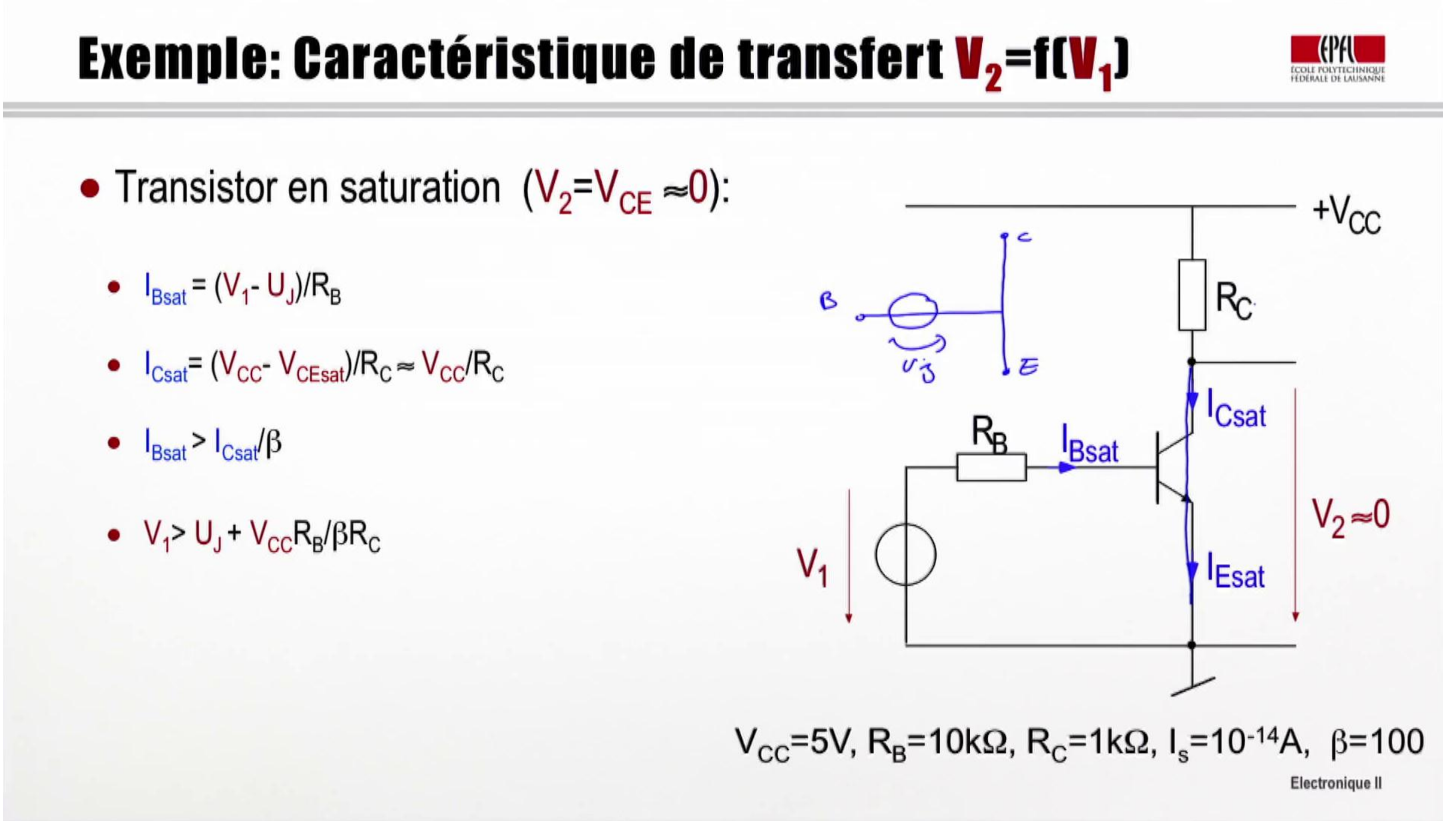



Here is your transistor. If you did what I said just now, you have increased the current such that V2 is short-circuited by the fact that Rc has become very large. So V2 = 0 = Vce, your transistor is indeed saturated. And if your transistor is in saturation, what will happen in this mesh is it's no longer an Ic control mesh. You are obliged to add the concept of saturation, saturation, saturation, and you find yourself in this. You are with your saturated transistor, and there, I SATRb + UJ, this, you must always remember that the UJ approximation always works, because it is the exponential that is always in the order of UJ. So you write IbSAT = V1 - UJ / Rb. And then, instead of your transistor, you take the model that was right before, and replace your transistor by a short-circuit between the collector and transmitter, and between the base and transmitter, you have a voltage UJ. So you take this, you put in the place of your transistor, and you will end up with UJ between the base-transmitter, and you write this law here. Whereas, on the other side, when you have a short-circuit between collector and transmitter, look at this transistor, it's a short-circuit here. So that V2 = 0.

Notes

Summary

26m 23s

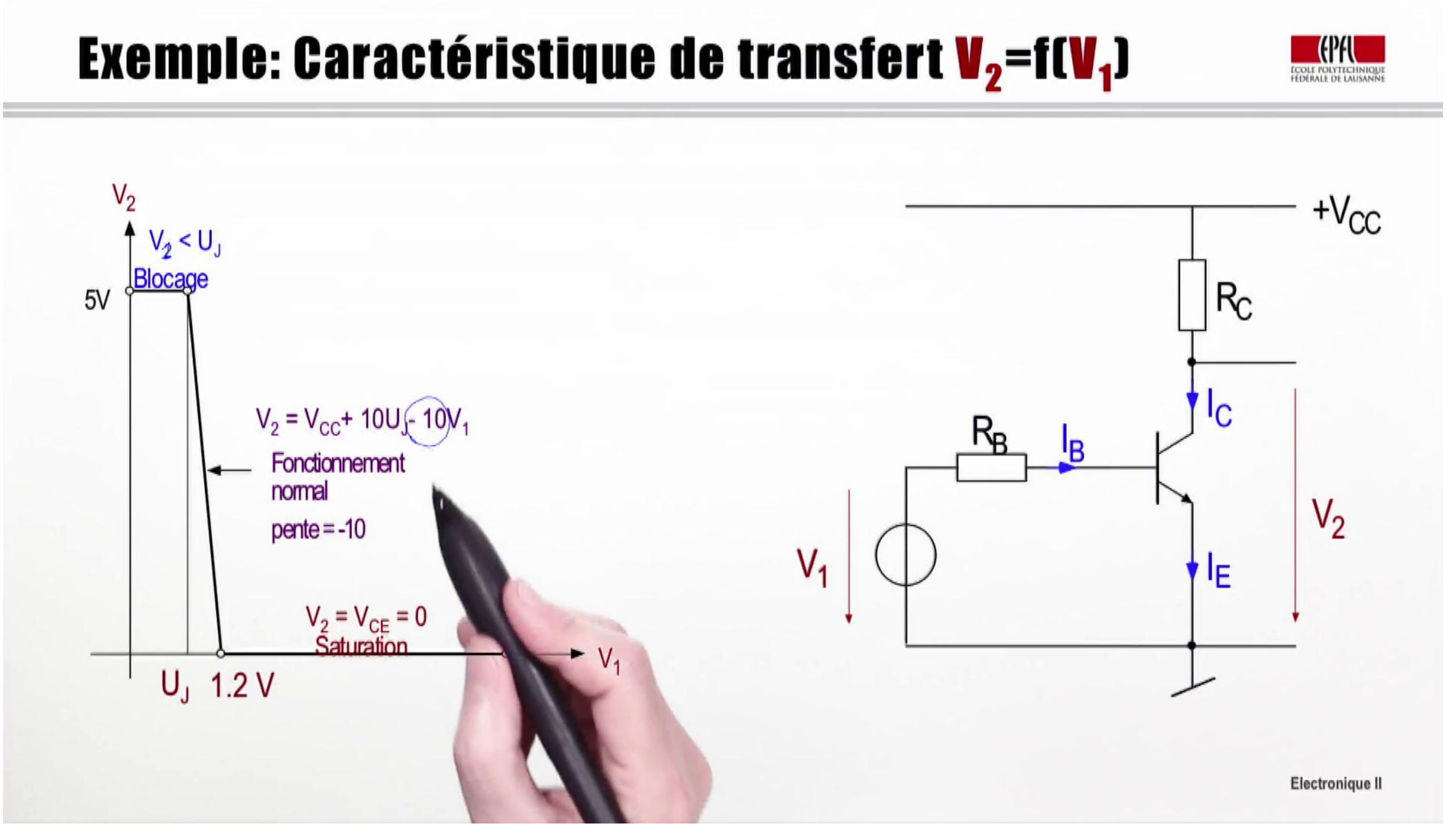



So there is, between Vcc and the ground, just the resistor Rc, which is traversed by this current IcSAT. So it comes here, and we have IcSAT x Rc = Vcc. And that's what I write here. So the current IcSAT, it will become constant, it can not increase. It is no longer controlled by the base current, it is equal to a constant which depends simply on the value of Rc and power supply, finally inversely proportional to Rc and the supply voltage Vcc. In this law, there is no more equality. And here you can make the same calculation as earlier and find that when V1 is higher than 1.2 volts we calculated with respect to the voltage V2, you find V2 = 0 when V1 is greater than a voltage which is proportional to the values that we put here. And your transistor can no longer be used in an analog circuit, it is rather in a digital circuit, because it gives zero voltage beyond a certain value.

Notes

Summary

27m 59s

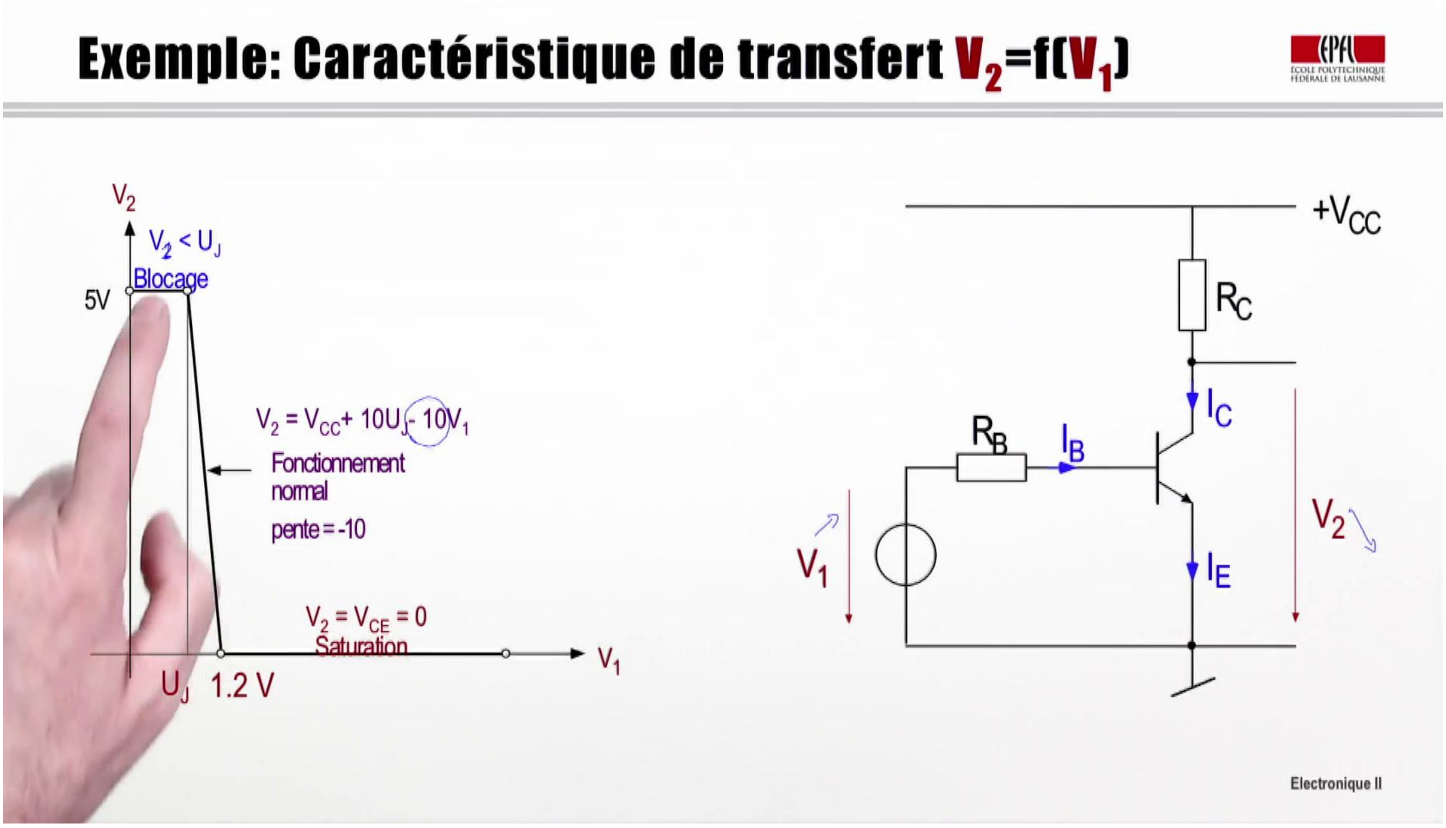



Finally, I take the same circuit, and I begin to analyze in the three cases. If the Vbe voltage, is there, that is proportional to V1, so if the voltage Vbe, there... sorry, if V1 is less than UJ, there is no IB current, your transistor is blocked. And we said at that time, the equivalent diagram of your transistor is really this. You remove it, that's in the case you are here. Here there is an error. It is the voltage V1, not the voltage V2. So if the voltage V1 is lower than UJ, you end up with a model of a transistor, we remove. Then after, we will look at what will happen when one begins to make the transistor conduct. So it is here, in this part, between the blocking and saturation, there is a part here. There is a linear relationship between V2 and V1, and we calculated it. The linear voltage between V1 and V2, I will continue to correct the typo, that's V1. So when V1 exceeds the voltage UJ, your transistor, starts to conduct, and it is in normal mode. So this is a current source. And just now, we released this expression, if you recall. And I emphasized the concept of 10 x V1, with a minus sign, and it can be seen here. So you will end up with a voltage V2 proportional to -10 x V1 plus some constant.

Notes

Summary

29m 04s

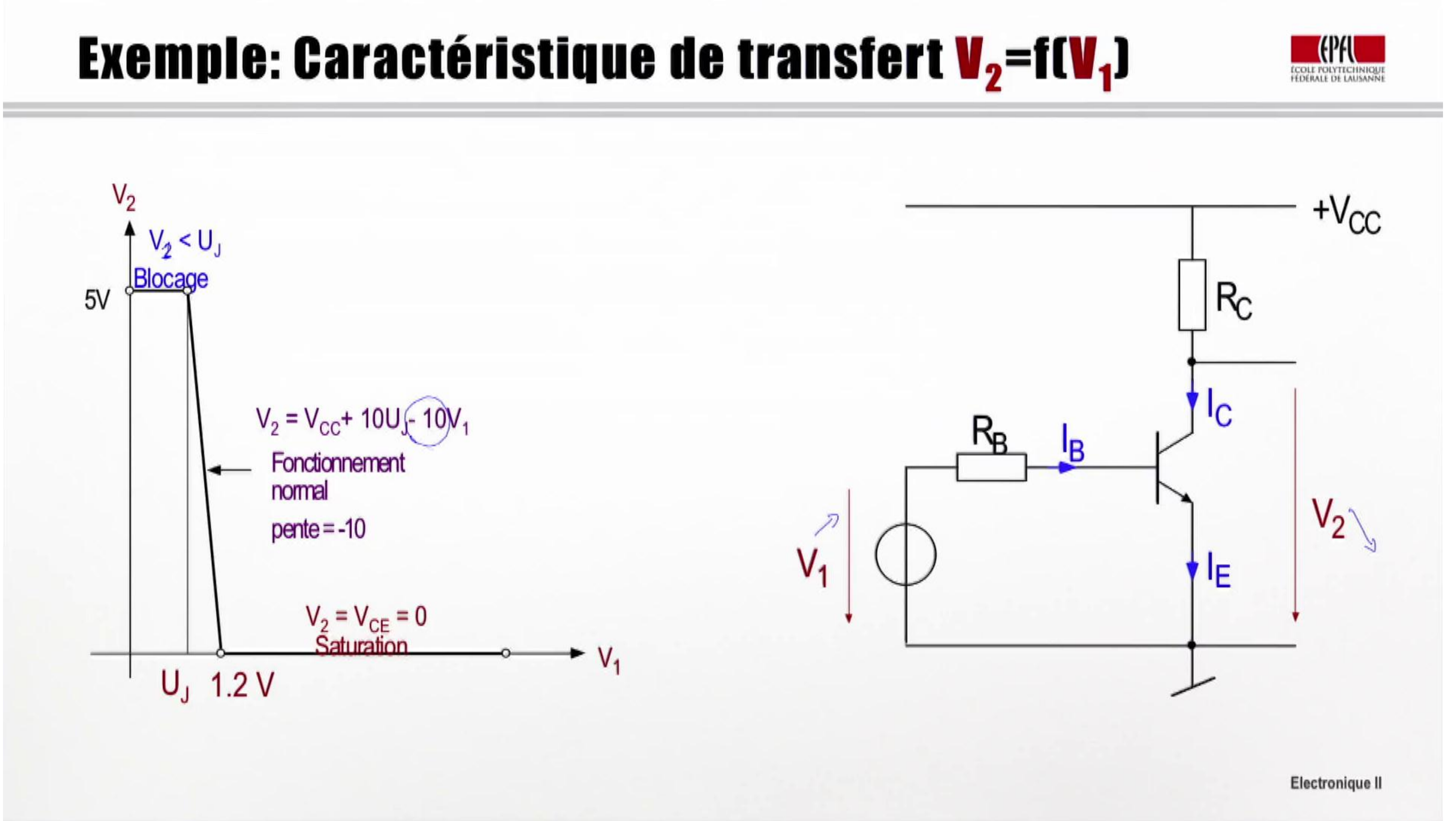



This is what makes the line you see here don't pass through the origin, because there is a DC component. Still, it has a slope that is equal to -10. Therefore the voltage V2 with respect to V1, is, there is a minus sign, when one increases, the other decreases. And it multiplies the voltage V2 = 10 x V1. It's awesome. We made an amp. So what you put here, you find it 10 times, multiplied by what is in this diagram, at the output V2. And you find it reversed. So if there is a sinusoidal voltage, there will be a 180 ° phase shift which is due to the minus sign. Now, when you arrive, you continue to increase V1. Then, the voltage V2 decreases, there is the minus sign. The voltage across Rc increases until you get a voltage in which V2 = 0. So your transistor is short-circuited. If it is shorted-circuited, V2 = 0, we are here, and your transistor is saturated. And when your transistor is saturated, here we can no longer bind Ic to Ib because Ic is proportional to a value Ic x Rc = Vcc. This is what we just saw. I would like to take the time and insist on the three modes seen here. Blocking, the so-called analog part of operation, wherein we had an amplifier, wherein the output voltage is multiplied by a constant which depends on the Rc and Rb values, which multiplies voltage V1.

Notes

Summary

30m 49s

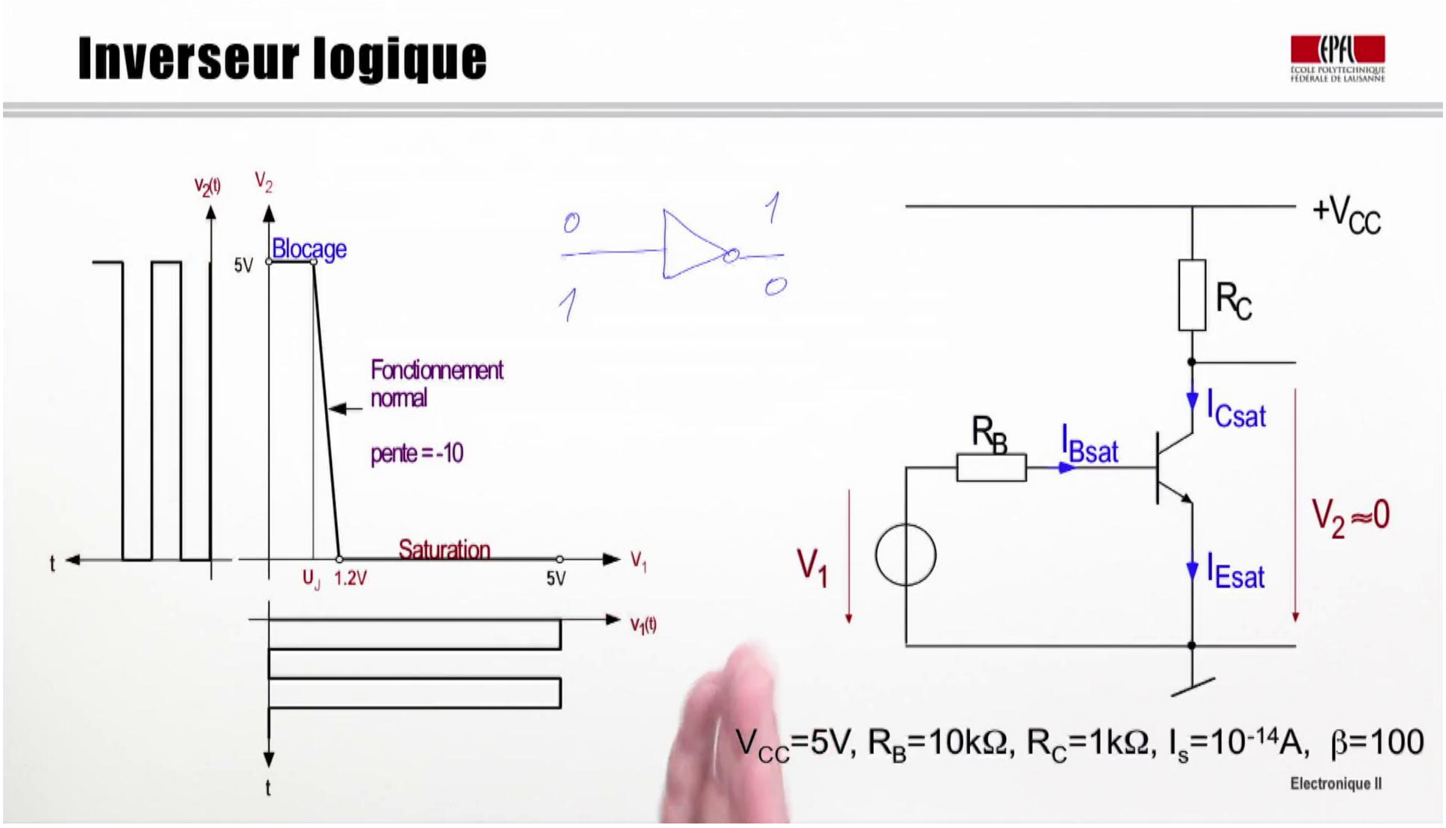



This is where we will use the transistor as an amplifier, and later we have the transistor that is saturated. So when I see this diagram here, and I want to talk about a transistor that is used as an amplifier, that we will see all along the course, later, always check that your transistor is not blocked or saturated. If you remember these two words, you say: "If my transistor is neither blocked nor saturated, my transistor is in normal operation ", and it corresponds to its use as an amplifier, with the amplifier diagrams we will study later.

Notes

Summary

32m 28s

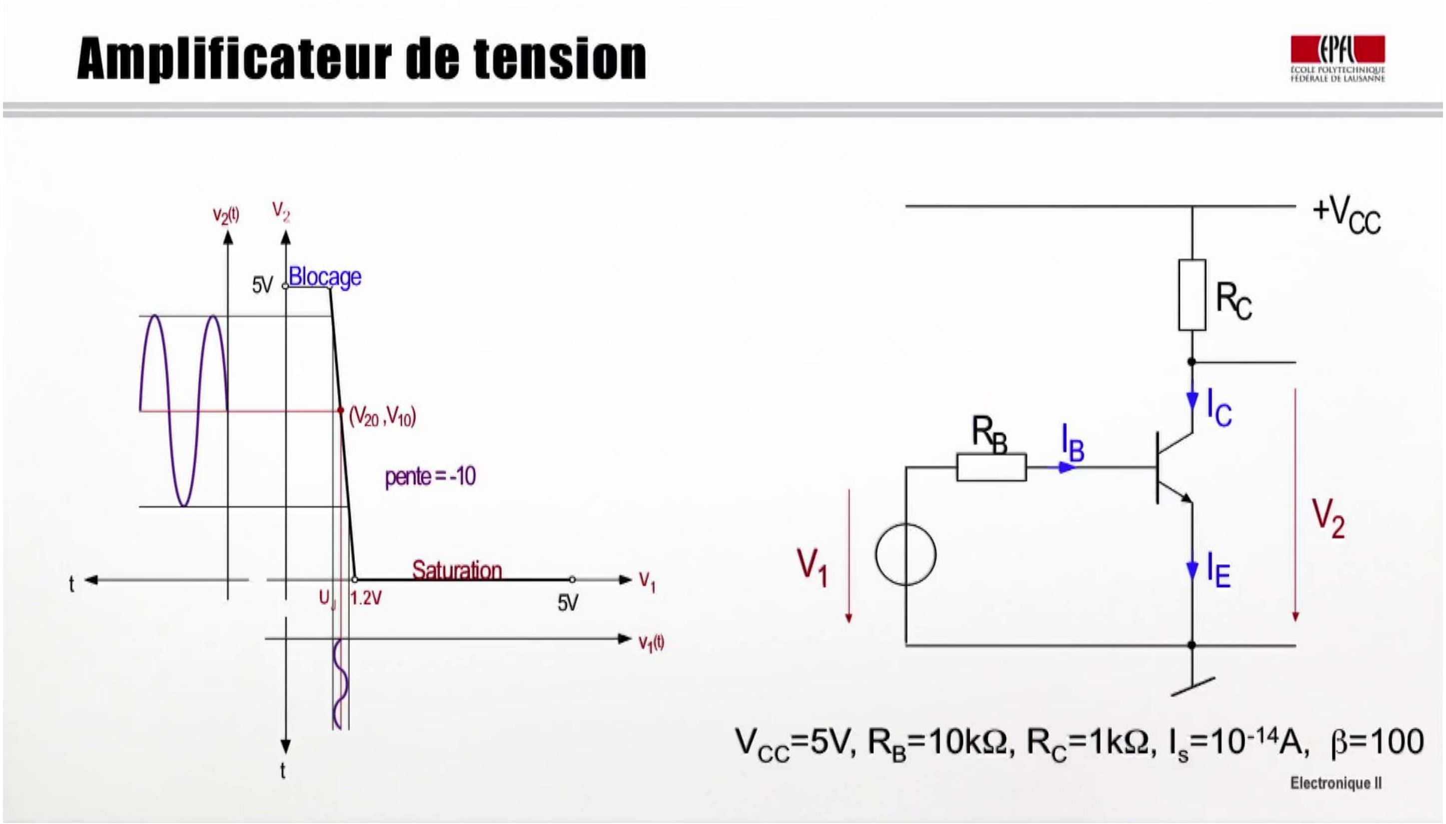



However if your transistor is blocked or saturated, your transistor is used, simply as a digital circuit, and it acts as an inverter. If you inject a voltage V1, a binary signal, which oscillates between 1 and 0, you will see a voltage V2 which is also binary. It is as if you had done a logic inverter set-up, which is like this. And what you put in binary state, you find the opposite state, so a 0 gives us a 1 and 1 gives us a 0. And that's it, it's the behavior of your transistor, when you are in the blocked or saturated state.

Notes

Summary

33m 03s

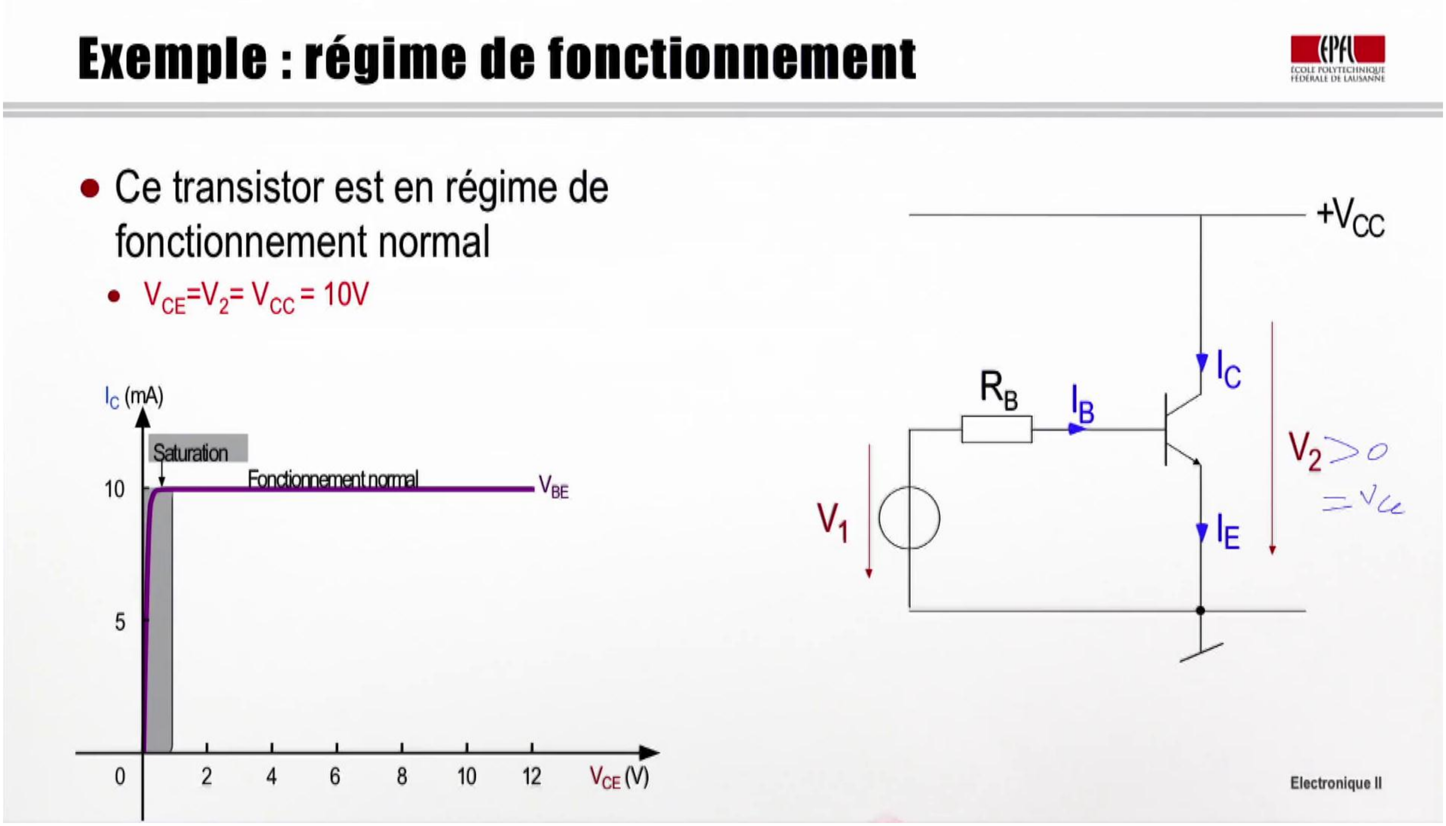



If you want to use your transistor, if your transistor is in normal mode, there you go to put very low voltage variations on V1, it is less than the thermodynamic voltage 26 millivolts, and since there is a slope, you will find the linear output voltage, which is the voltage V2, which transforms the variation V1 into a variation V2, which is 10 times higher, because we have a multiplication factor equal to 10. But then that's where we see the need to polarize the transistor. One of the things that will be discussed in great lengths, is that if we want to have a signal whose dynamic or whose variation is within a certain range, it is necessary to impose to this transistor a direct current and voltage. So there will be a current through the IC0 for an IB0 current, and then there will be a voltage V10, which will allow it to be in a range that all small variations imposed here turns into a variation found in the output. And we now talk of a voltage amplifier. And this is an amp that has a gain.

Notes

Summary

33m 42s

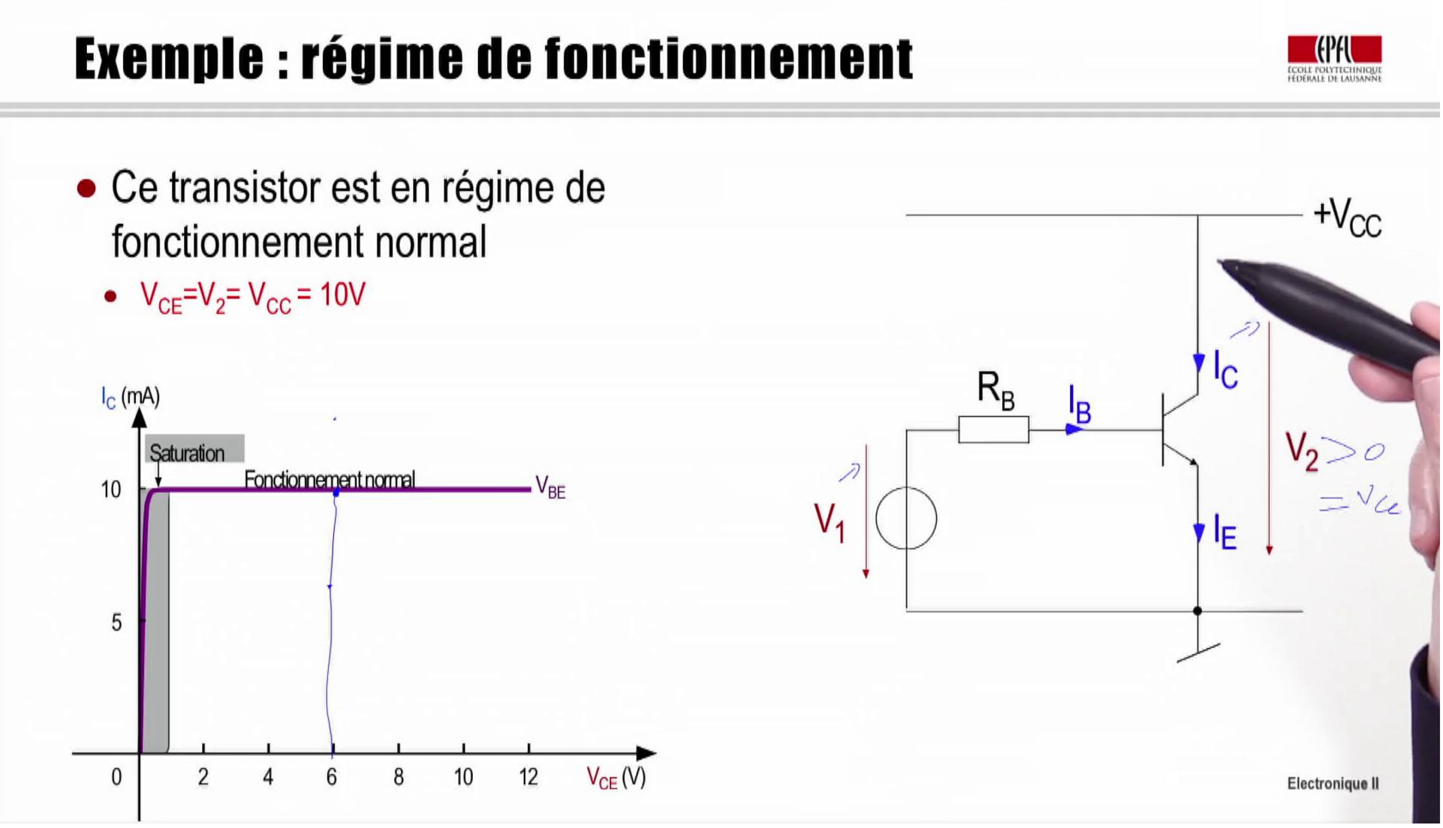



To conclude and summarize what we just saw, and really set the idea on what is an operating system of a transistor, I want to take again the diagram. In this diagram, I don't have, but the resistor RC, I took the transistor and I put it between the supply voltage and ground. It's of no use. Do you understand that if I pull the current from VCC and send it back into the current in the ground, generally, reading current is very difficult? It is read through a voltage, by Ohm's law. So I have to put it in the resistance to be able to see it. But if you take this diagram and you say: "I applied a voltage V1". Let me give you an example: I put V1 is equal to perhaps 650 millivolts, something of this magnitude, and I see that there is an IB current that will pass, therefore, this junction is of the order of 0.6 to 0.7 volts. Then I will have a current flowing. Does V2 = 0? No way. V2, in this case, is always equal to VCC. So this is a transistor that is at all times in normal state. It can, in no case, be saturated. Why ? Because the voltage V2 is constant and strictly positive, and equal to VCC. So this is just to show that if you have a transistor, and you plug it like this, so you have a transistor that is useless, because we can not read the variation of the current.

Notes

Summary

34m 59s

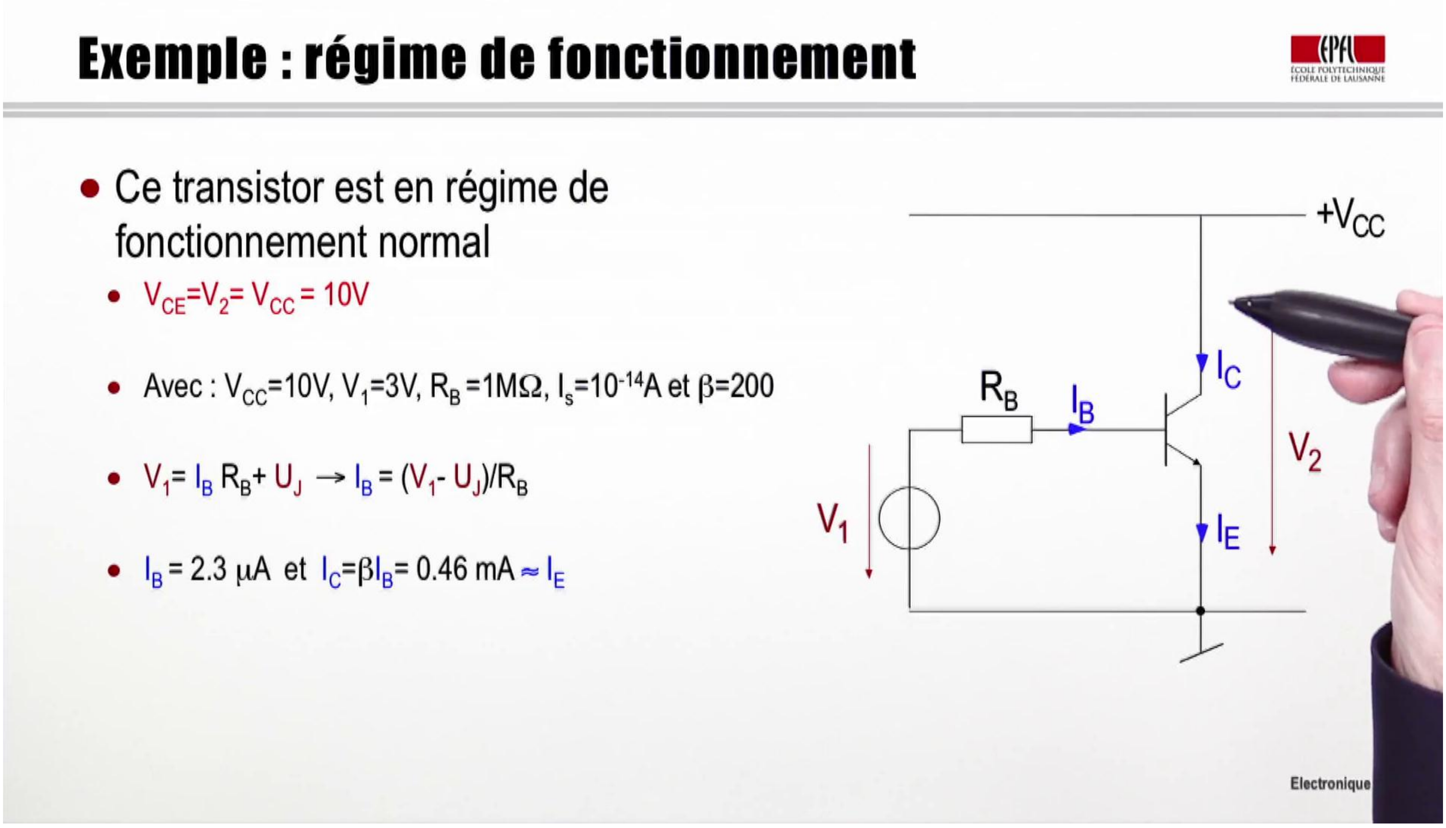



I can increase V1 so I increases IC, but I have not converted IC into Ohm's law to read it in the form of voltage. So I have a current that increases, but I can not observe it. Now I'll take the same diagram. But before moving on something, so I am all the time here, I took V2 = VCC, and if we say VCC equal to 6 volts, so I'm here somewhere. So this is a current increases. Now if you increase V1, you increase VBE, then you're going to have this decreasing curve. And you are all the time with a single point, so you will change the current IC. So if I increase V1, I'll raise the current IC. And if I drop V1, I'll lower the current IC. So I only observe current variation, provided that I check it with an ammeter. I repeat the same thing, and I'll just add a resistance here.

Notes

Summary

36m 20s

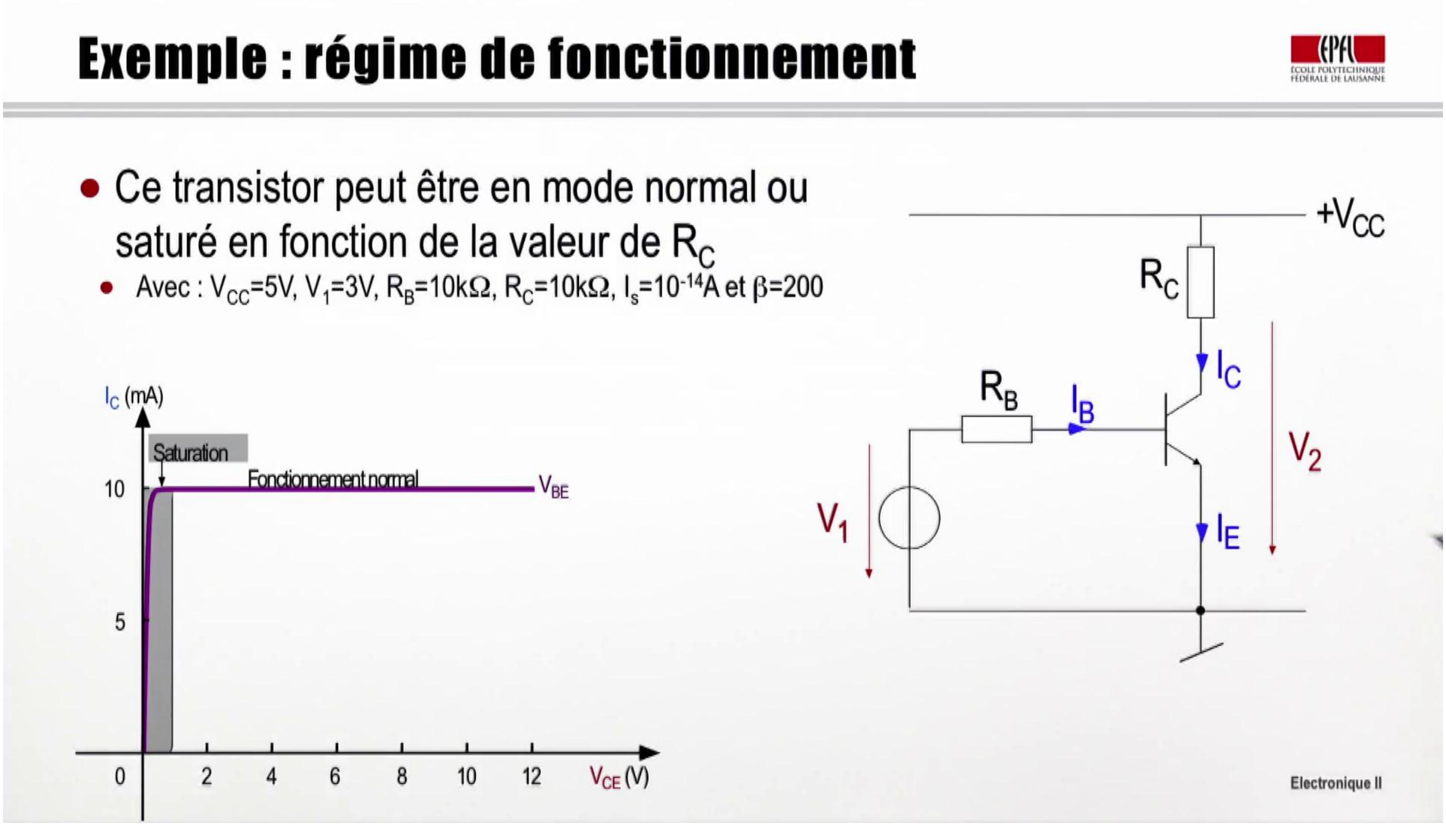



So I take this transistor, and I will, if I calculate it like this without adding to it a resistance, by taking the numerical values that are here, I will end up with a current IB which will give me a current IC = IE. Regarding the digital application I have put with the values given here, I think the base current for a transistor which has a β = 200 is of the order of 2.3 microamps, to give me a current 200 times greater, thus equal to 0.46 milliampere. But it's of no use to me, because I could not read the current. I will add a resistor here.

Notes

Summary

37m 18s

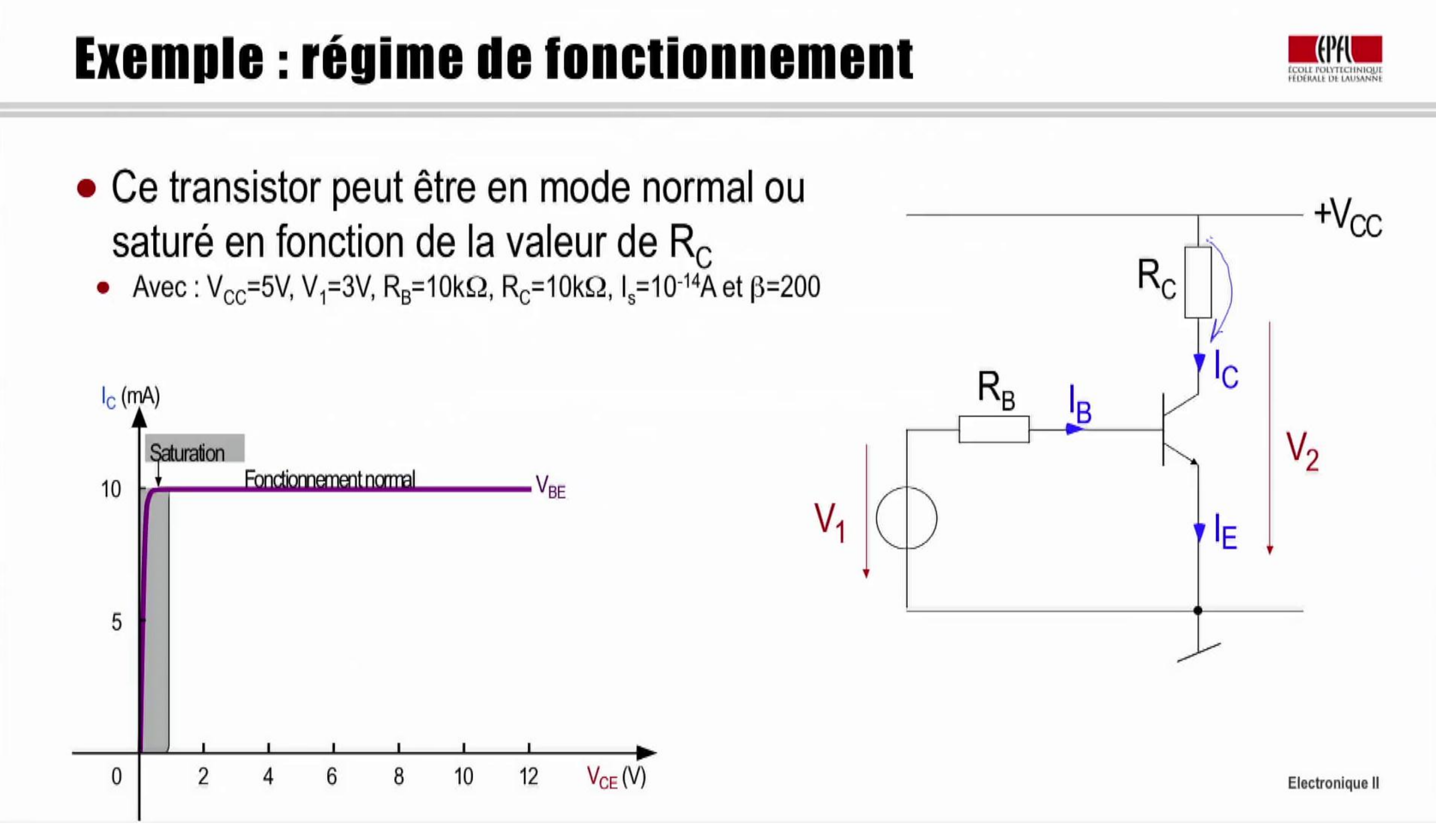



When I add a resistor here, it changes the data. Now, current IC has not changed.

Notes

Summary

38m 00s




I go back, I have a current IC = 0.46 and now I converted this current in a resistor which I inserted here. And this resistor, will convert this current into voltage at its terminals which is equal IC x RC. This I can read. This I can well take and even inject into another transistor stage here. But it changes the data. Is this tension very big to be of the order of magnitude of VCC, which cancels V2? And it saturates my transistor. Or it is small and it puts the transistor in the linear region? And that is something extremely important, so it's me who decided the resistor RC value, which I inserted, and it is my decision that RC x IC will have some value. And there, in that case, we can take that same set-up and make the same calculation as earlier.

Notes

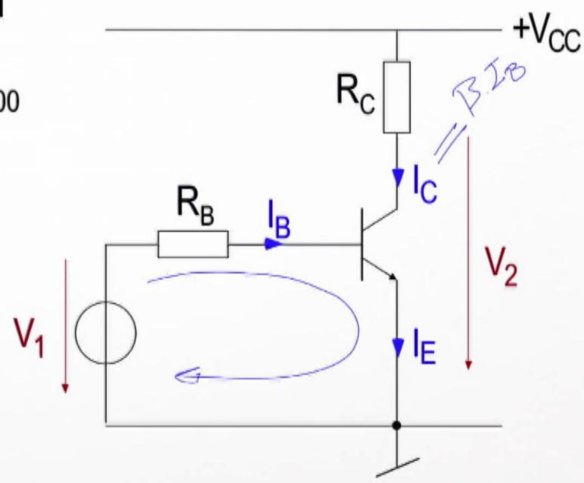
Summary

38m 06s

# Exemple : régime de fonctionnement

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

- Ce transistor peut être en mode normal ou saturé en fonction de la valeur de $R_C$
  - Avec : $V_{CC}$=5V, $V_1$=3V, $R_B$=10kΩ, $R_C$=10kΩ, $I_s=10^{-14}$A et β=200
  - $V_1 = I_B R_B + U_J \rightarrow I_B = (V_1 - U_J)/R_B$ = 230 μA
  - On suppose que $I_C = \beta I_B$=23mA
  - $V_2 = V_{CC} - I_C R_C$ = 5V – 230V= -225 V!!! Donc $V_2 = V_{CE}$=0
  - $I_{Csat} = (V_{CC} - V_{CEsat})/R_C \approx V_{CC}/R_C$=0.5mA
  - $I_{Esat} = I_{Csat} + I_{Bsat}$= 0.5 + 0.23 = 0.23 mA




Electronique II

I took a resistor RC and I put 10 kilo ohms. There, this side, I have not changed anything. You remember, we said, we reason always on this side and that side. I take that side and I write the famous law of the mesh that is here: IBRB + UJ = V1, which is written here. And I extract the value IB. And I chose a value of RB: 10 kilo ohms. What will give me, in this case, 230 microamps. So I have 230 microamps that will circulate here. If this set-up was in normal mode, IC should have been equal to β x 230 microamps here. So times IB. So that will give me a current IC, that I just have to calculate with the β which is equal to 200 in the example, it will give me 23 milliamps. I imposed myself 23 milliamps here. 23 milliamps which will circulate in a resistor, I gave a value of 10 kilo. If I take 23 milliamps, I put in a a resistance of 10 kilohms, the Ohm's law says 23 x 10 kilohms they will lead you to a voltage drop, or rather you write this mesh from here to here, you say VCC = RCIC+ V2. Or you put V2 = VCC - RCIC, and you write that 23 milliamps, which multiplies the resistance of 10 kilohms here, and you're going to get a voltage drop on V2 = - 225 volts. So it's impossible.

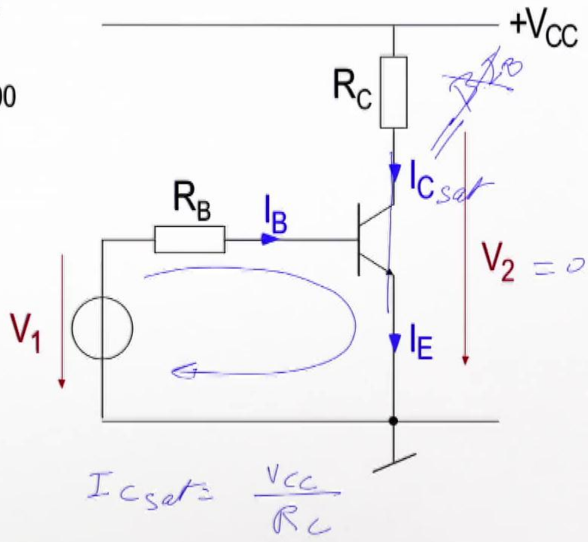
Notes

Summary

39m 06s

# Exemple : régime de fonctionnement

- Ce transistor peut être en mode normal ou saturé en fonction de la valeur de $R_C$
  - Avec : $V_{CC}$=5V, $V_1$=3V, $R_B$=10kΩ, $R_C$=10kΩ, $I_s=10^{-14}$A et $\beta$=200
  - $V_1 = I_B R_B + U_J \rightarrow I_B = (V_1 - U_J)/R_B = 230\ \mu A$
  - On suppose que $I_C = \beta I_B = 23mA$
  - $V_2 = V_{CC} - I_C R_C$ = 5V – 230V= -225 V!!! Donc $V_2 = V_{CE}=0$
  - $I_{Csat} = (V_{CC} - V_{CEsat})/R_C \approx V_{CC}/R_C = 0.5mA$
  - $I_{Esat} = I_{Csat} + I_{Bsat}$ = 0.5 + 0.23 = 0.23 mA




Electronique II

When you feed a transistor with 5 volts, there is a supposition we just made, which is not correct, that is to say β IB is valid. Why ? Because I have found that by feeding 5 volts V2 = - 225 volts, so it's not possible. So there is an assumption that I just did which is not correct: this is IC = β x IB. Why ? Because when I added that RC and this RC, by a current going through, imposed V2 = 0, you remember that this voltage drop is very large, and it saturated the transistor. So in reality, V2 = VCE = 0. So that law is not at all correct, in this example here. So you will end up with something else instead, you'll say ICSAT is limited. The current here can never reach the value I calculated here, it is certainly lower. Why ? Because the maximum value of this current is when the transistor saturates. So here, I have a short-circuit, and I can write at this point, V2 = 0 and ICSAT x RC can not be equal to VCC. And that's the maximum I can get. So it will give me a ICSAT current that will be a constant equal to VCC/RC. And this is the maximum current that I can have. And when I get to this current here, it stabilizes here.

Notes

Summary

40m 56s

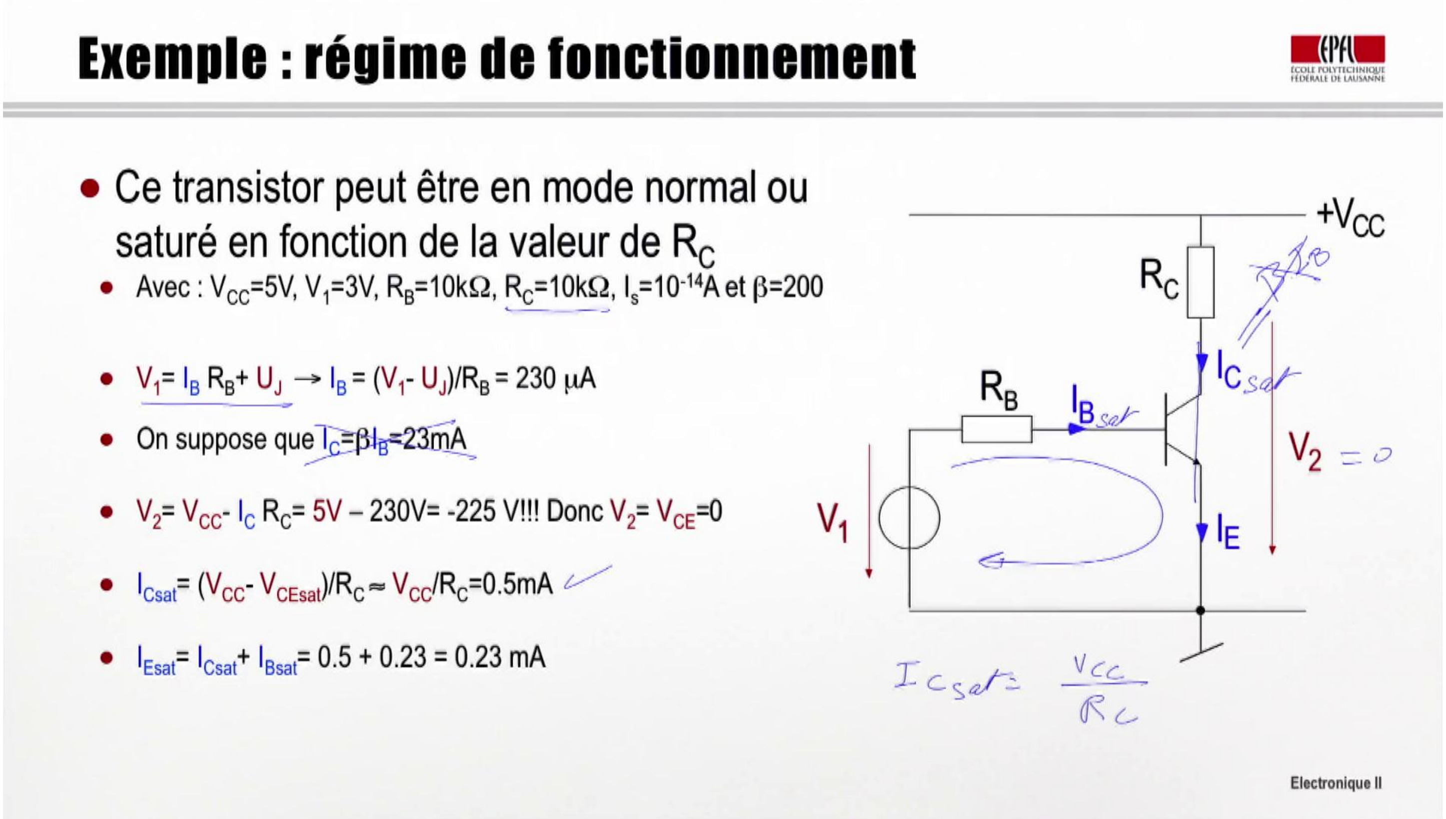
# Résumé des modes de fonctionnement


The transistor is no longer a current source, and the transistor will act in saturated mode, and I can continue to increase IB, but it has no impact on the output. So I find a current of 0.5 milliamps, so I am far from these 23 milliamps I assumed to be, if the transistor had not been saturated. Then that is right. And now, if I want to calculate IB, I have no right divide ICSAT by β. I have to take the mesh that is here, and say what is the value of IB. Beside, it was calculated, it is there. And it is sure that IE is equal to the sum of this and this, that will give IE. It is not at all equal to ICSAT. I hope that with that example, you managed to understand that it is the values you give yourself that can saturate a transistor or bring your transistor to operate in normal mode, or block it. It's you who decide it, based on these different values of resistance you have chosen. This week, we saw all modes of transistor operation, we studied in details the different electrical characteristics of the transistor, and we drew useful conclusions as introduction, to show that a transistor, of course, has modes of operation which are mainly dependent on the circuits in which we will put them.

Notes

Summary

42m 24s




And this is especially the calculations of elements and components that we will put around that will allow us to make electrical diagrams that hold. Either you want to use it in analog mode and we made an amp, and must polarize, and it will have a gain, and it is a linear gain. Either we use it in the blocked or saturated mode and there, it would be useful to make an open or closed switch, so useful for logic circuits.

Notes

Summary

43m 52s