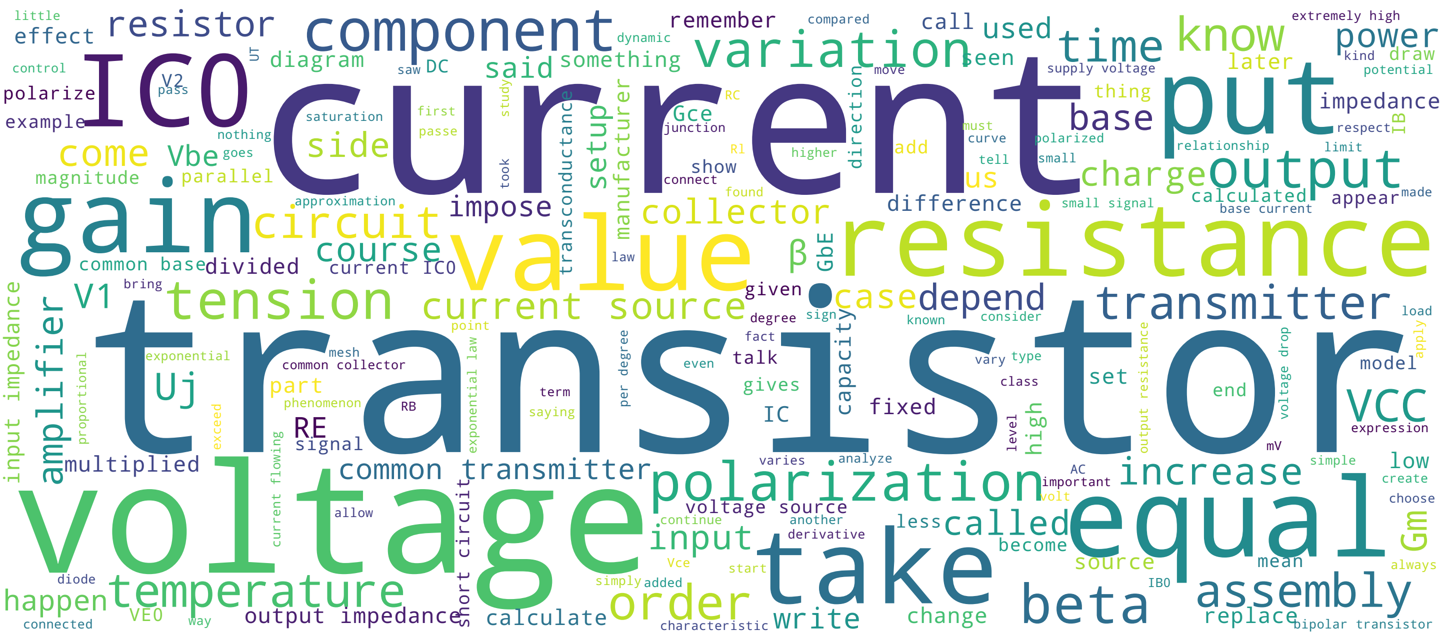
4.1-Polarisation et sources de courant

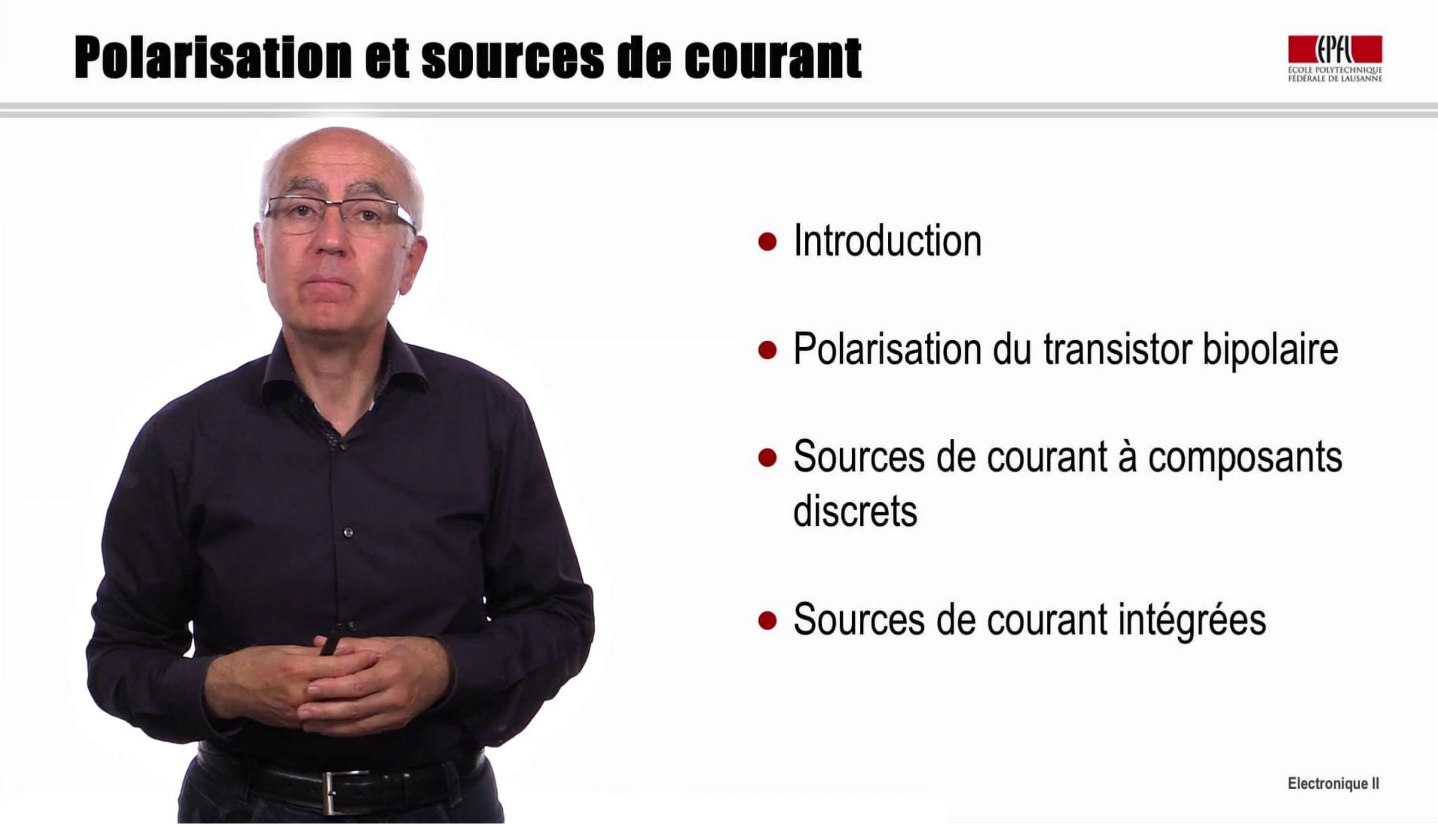
Introduction

Prof. Maher Kayal

Electronics Laboratory-ELAB



Video



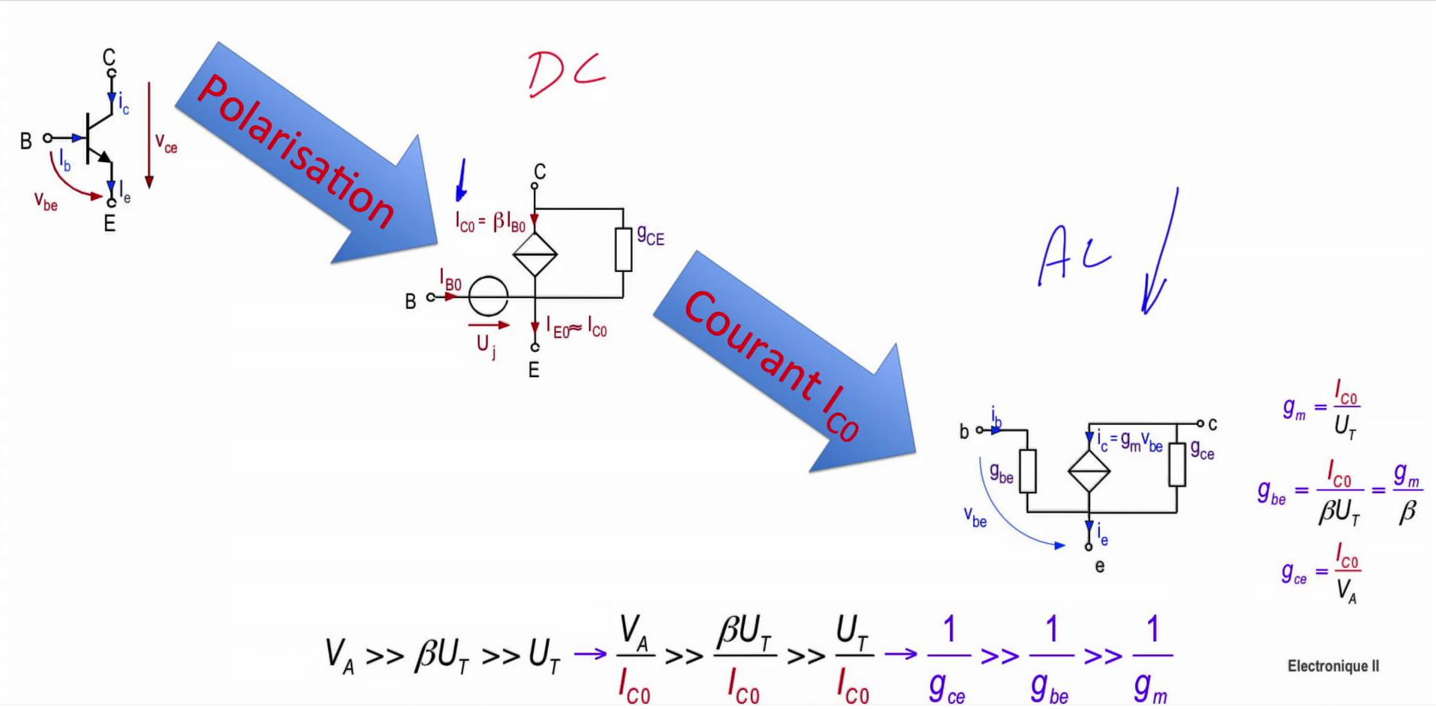
Good morning everyone. Today, we will study the polarization of transistors. So we have already passed through the small signals model of the transistor, but it was considered that the transistor has already been polarized, that is to say that the current flowing through our transistor has been set by a given technique. The objective of this chapter is actually to see how we polarize a transistor, first thing, so we'll see a small introduction, then we will look what are the polarization methods available and you will see that finally, there is only one method, the one that will be used practically all the time and afterwards, we will look at the assemblies based on discrete components, it means that you take a transistor from the market and you put around it some resistances and power supplies to realize your polarization and we will do this by current sources so learn to make current sources with discrete components to finish after with an assembly which is extremely known for making integrated circuits or in integrated circuits called "current mirror" and which enables us to make current sources based on transistors.

Notes

Summary

0m 06s

Objectifs de la polarisation

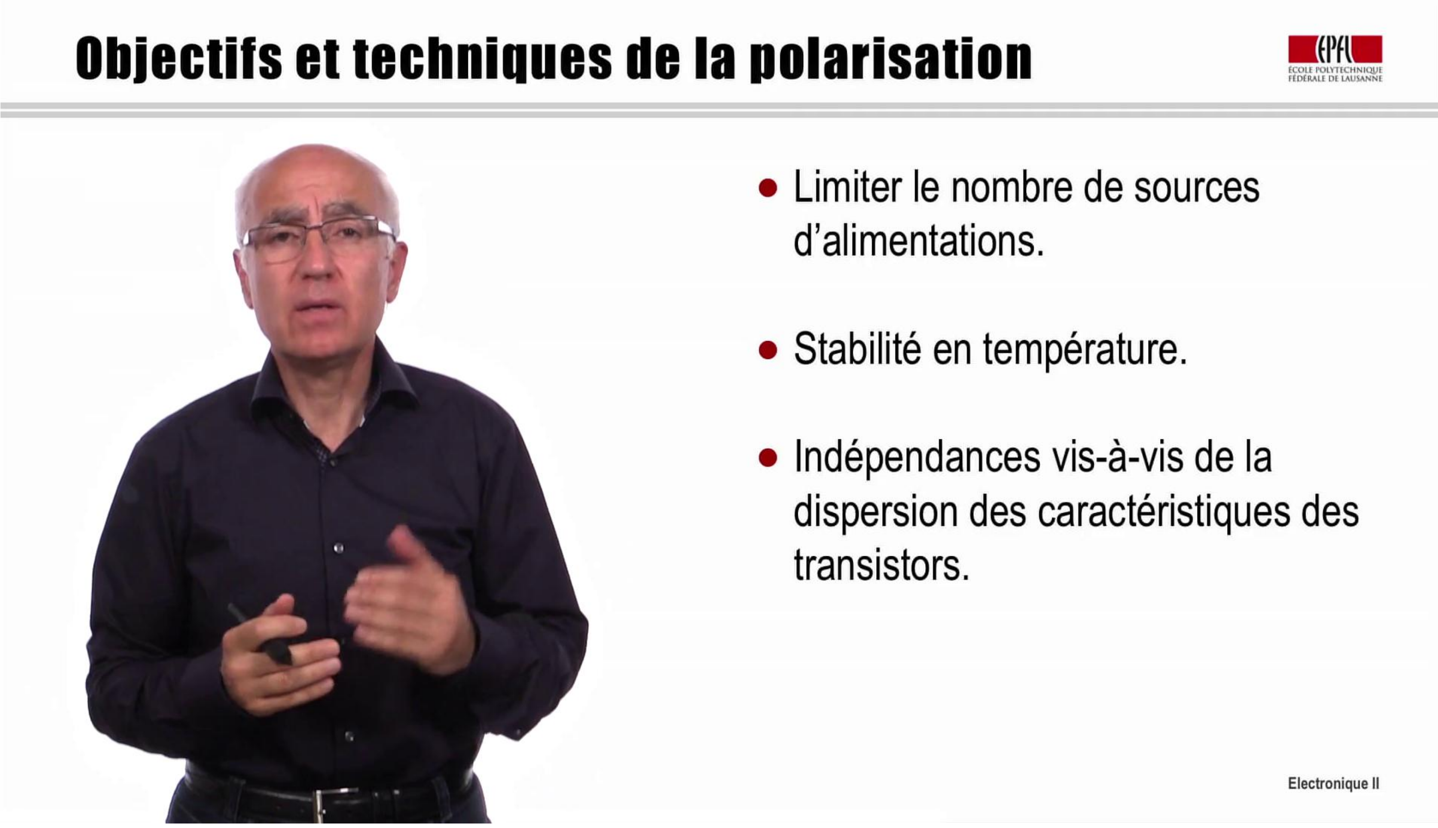


I would like to remind you again what was this objective of polarization. We started with the symbol and we examined it, and we did with it the small signals model, and we said that between two, we will have to polarize. Polarization means imposing the current of polarization IC0 because as soon as this is known, look, all parameters, we know them. Everything else depends on things determined by laws of physics or determined by the component that we used. The polarization means that we set all the potentials of a DC circuit and as soon as we set these DC potentials, we can forget that, and go directly to an AC analysis. So there you do your DC analysis by polarization, and then once it's done, we do the AC analysis. So, in the path of this course, I preferred to present you the purpose, that is to do linear functions with your circuit taking the diagram AC, and it was saying that later, we will study the polarization. But know that in practice, this, is much more important than this. That, is a goal, and that, is the way to do it.

Notes

Summary

1m 16s

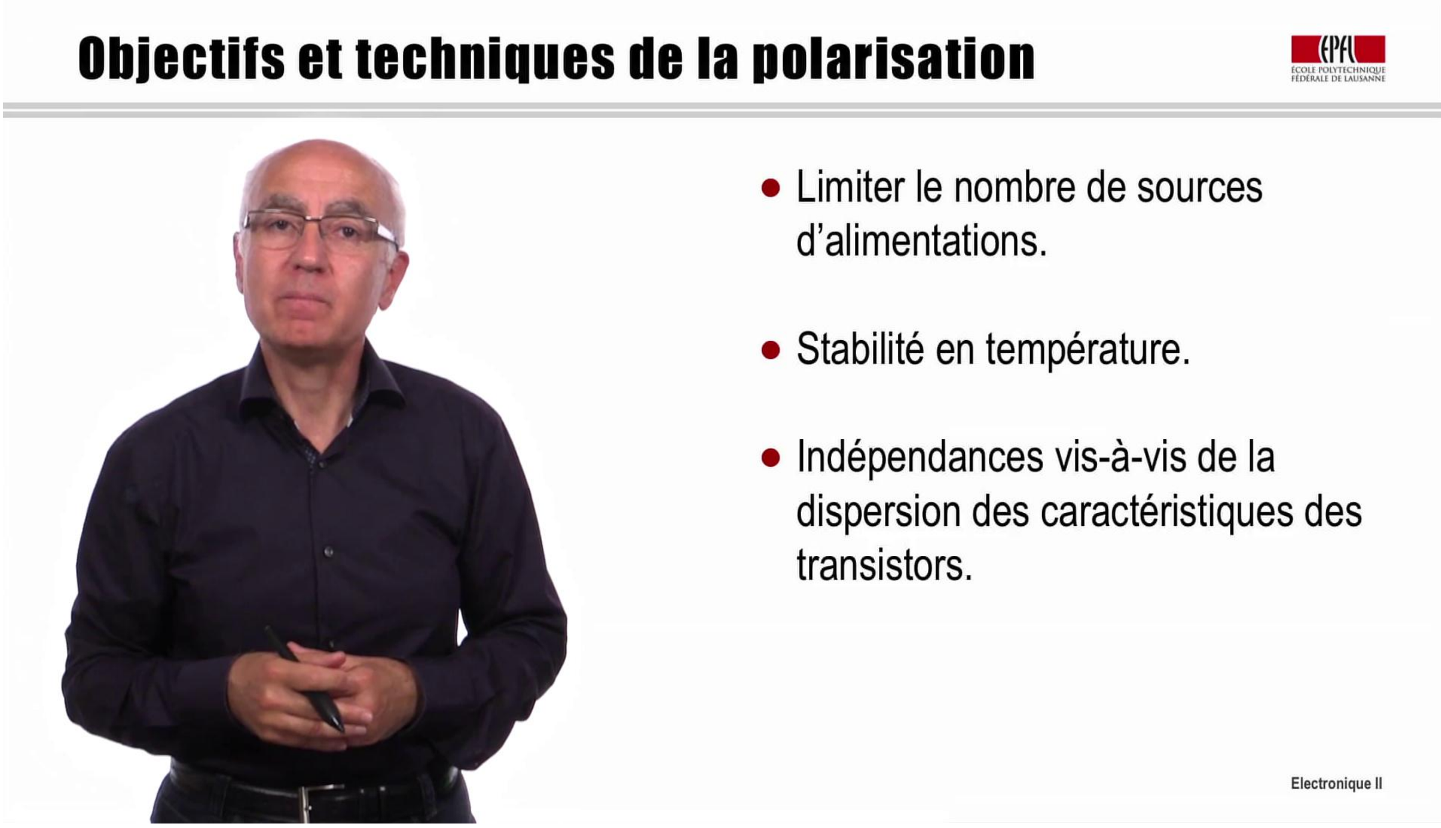


The objectives of polarization are first to set all the DC potentials of your diagram or electronic circuit. Know that it is very difficult to choose, to make the right choice of your DC potentials in all the nodes and all the polarizations in your circuit rather than calculate a gain, a gain is extremely simple calculate the input impedances, the output impedances, you have understood that it is a matter of correctly choosing your common transmitter- common base assembly or common collector. Now what you do not know, but you will learn it later, that your components first suffer from an inaccuracy, they change behavior with temperature and unfortunately they have values, such as beta, such as offline voltage that are not fixed values, this is not absolute values, it is things that vary and depend relatively on one component to another and that vary in extremely high errors. That's the first thing. Second thing, polarization is the spot that allows you later to say "I have a supply voltage that ranges between 0 and a certain amount." Today, the supply voltages are very low, we work around 1 volt.

Notes

Summary

2m 41s



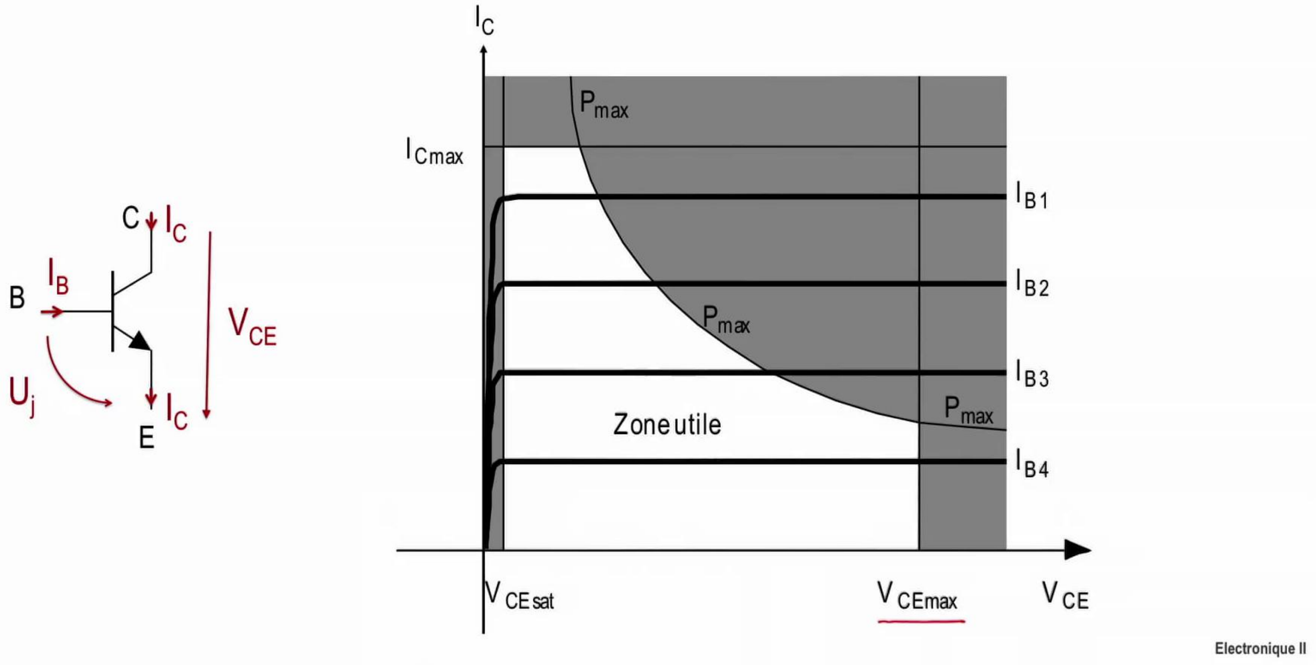
So when you work with low supply voltages, and you want to have a dynamic of your signal that is a range in which your signal will change, the choice of polarization will be among the most difficult things to do. So I'm not going to start moving quickly in the course because we're going to analyze all of these things, showing first how we polarize, and later we'll see how we choose the value of the polarization which would become the most important parameter of a circuit design and it is with that, once it has been determined, everything else becomes easy to find.

Notes

Summary

4m 03s

Choix du point de fonctionnement

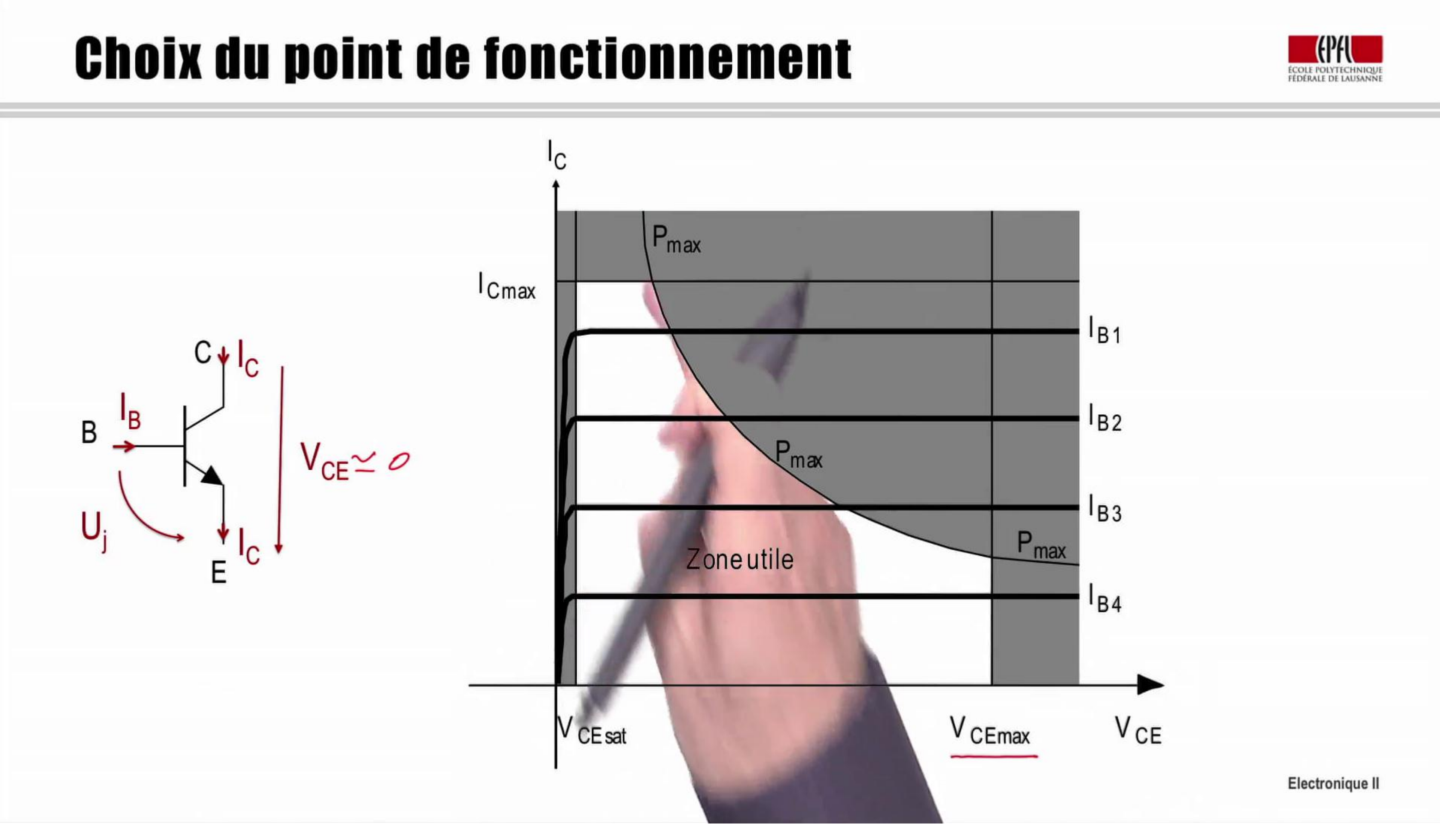


Here is the output characteristic of any transistor, in this case bipolar, as an example here. The manufacturer will give you a lot of limits. He'll tell you "Caution, my component would not like to have a higher voltage than the so called VCEmax." This tension, it can not exceed a certain value that the manufacturer of this component will give you. When he gives you this value, it does not mean that if you exceed it, you will damage your component, you can spoil it if you are not careful, there is a phenomenon called drilling phenomenon, this is when the base of a bipolar transistor it has disappeared, the PN junctions on either side are found without an active zone of bipolar, that is to say there is the depletion zone of this junction and this junction there that touch completely and this creates a phenomenon where your transistor appears as a low resistance and the current flows directly from the emitter to the collector. And that is because of a voltage VCEmax that you have exceeded So the manufacturer gives it to you, if you are able to put a resistance either to the collector or to the transmitter, and limit the current that passes, your component, it is not dead, you can retrieve it nevertheless your transistor is no longer a transistor, it becomes a resistance.

Notes

Summary

4m 42s



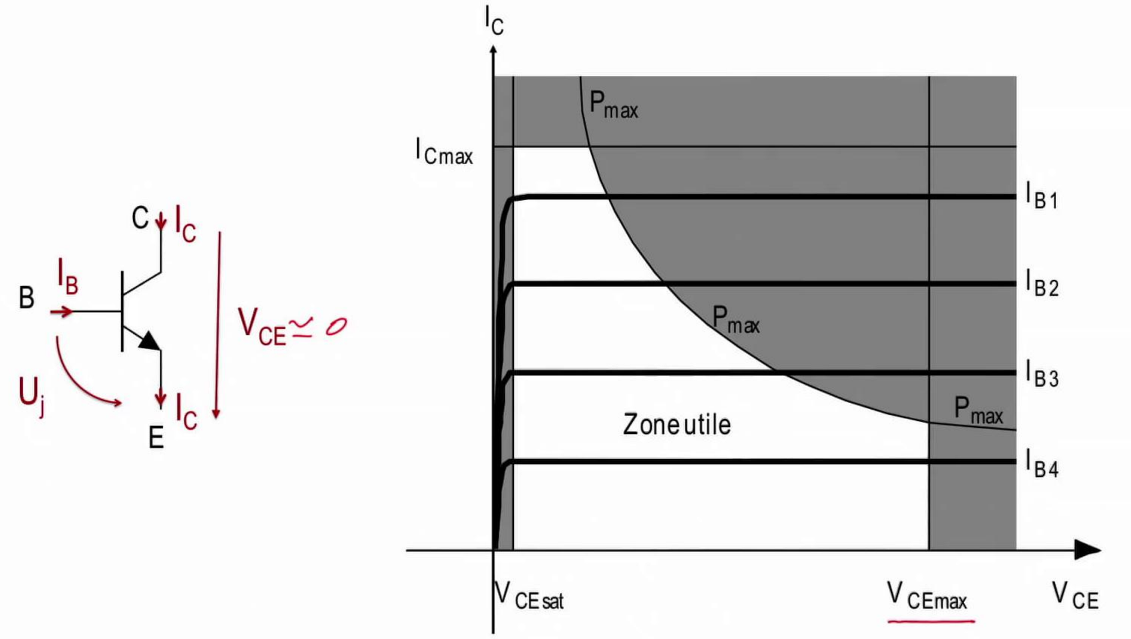
Likewise, the manufacturer will tell you, "Do not exceed a maximum current, if you put into the component a current that exceeds the ICmax, there may be a destruction." It can simply be the wires that connect the silicon to your case which limit this or simply the capacity or the density of the current which passes through the silicon that the component can not support beyond a certain density of the current which is given by the manufacturer So we have a limitation there and we have a limitation here. The VCEsat is a voltage that is specific to the transistor and specific to your assembly. That's when your voltage goes on to the order of magnitude of 0 or a few hundred millivolts, from 100 to 200 mV there, you've lost the so-called linear part of using the one that's here. This part the maximum power that your component could support, is mainly determined of course, by the size of your transistor, active part of your transistor, and in large part also by the housing capacity to evacuate the accumulated heat.

Notes

Summary

6m 14s

Choix du point de fonctionnement

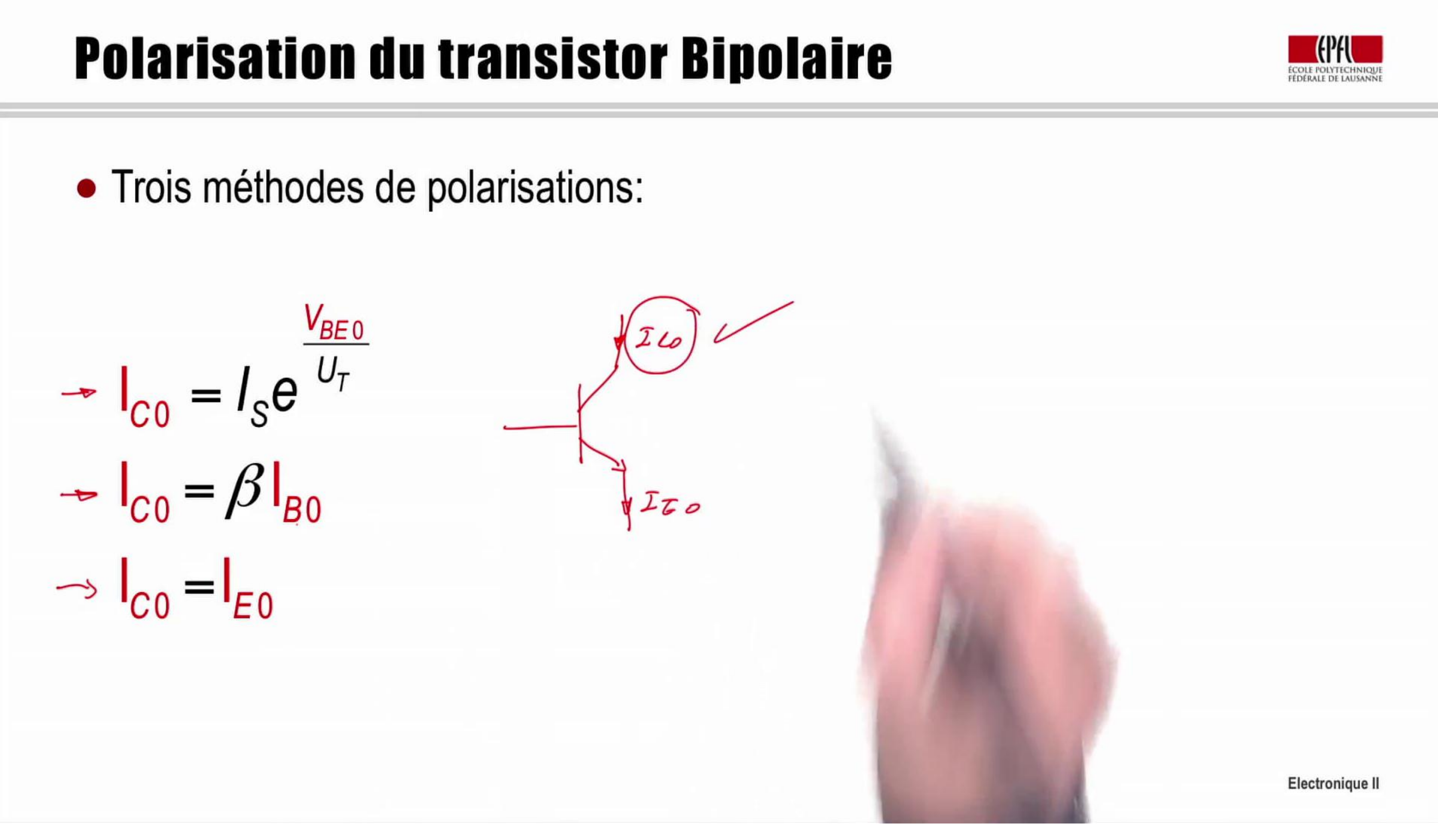


So the person who makes you the component, will put it in a given box, and that box, if you get to cool it, or you get to put it in a condition where you stay below this curve for the product VCE x IC, well, you're going to have the transistor behaving as a power source as you see it and we should not overflow here, there or here, to ensure that we are well polarized and we do not exceed the limits of use of the component sold by a manufacturer.

Notes

Summary

7m 26s



Let us now start with the polarization techniques of bipolar transistor. The goal is to find the IC0. We will give a numerical value to IC0. So, it is simple, in the bipolar, it is understood that the IC0 is exponentially proportional to the transmitter base voltage, so if you put a base transmitter voltage of a given VC value, IC0 will automatically have a certain value. It is proportional to a parameter specific to the component, which is given by the manufacturer, or you can measure it, and the thermodynamic voltage and otherwise, there is an exponential relationship. Similarly, your current IC0 depends on the base current IB0, multiplied by beta. So of course, you can also get an IC0 value simply by imposing a base current IB0. And finally, it was said that in the bipolar transistor, I want to redraw again next, if you neglect the base current, so you consider that there is beta which is very high, the current flowing in the collector, the IC0, will be equal to your transmitter current, IE0. That's it. Thus there are 3 ways to determine the polarization current which is the goal. That's what we would like to have and give it a value in a circuit.

Notes

Summary

8m 01s

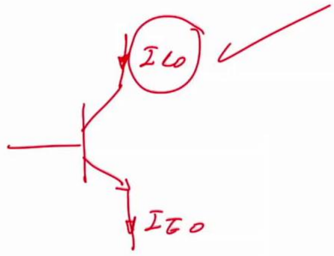
Polarisation du transistor Bipolaire

- Trois méthodes de polarisations:

$$I_{C0} = I_S e^{\frac{V_{BE0}}{U_T}}$$

$$I_{C0} = \beta I_{B0}$$

$$I_{C0} = I_{E0}$$



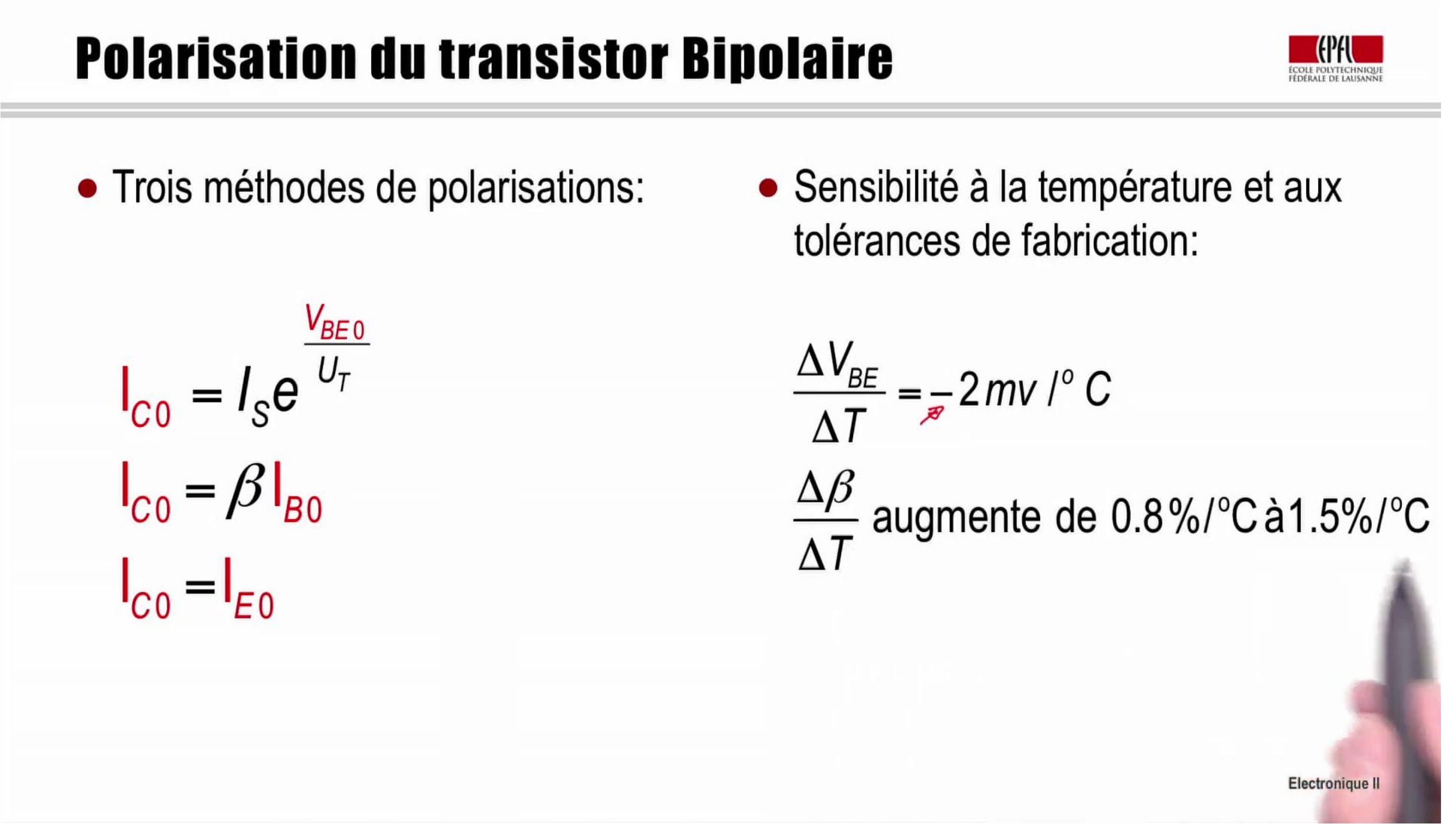
Electronique II

Looking at these 3 techniques, I can immediately tell you, we will see right away, that this technique is never used, because an exponential relationship between a voltage and a current would pose a problem because it is necessary to control this value well and there is another parameter related to the temperature, we already saw, I will repeat immediately after, but know that this, we never use it. When you look at IC0 according to beta, well, there is the beta value that is between two, so this value of beta depends on the accuracy of beta. And know that the manufacturer of your bipolar components has great difficulty to ensure you betas that have some fairly accurate value. Thus, from one transistor to another, the beta will vary and there is an extremely high error and there is a dependency of beta with respect to the similar temperature between the two cases. It is less dependent on temperature here, but the dispersion of betas is extremely high. This will stay. And that's what we're going to use. So that's valid, but in a laboratory. And that, will really be the solution that we will use all the time.

Notes

Summary

9m 30s



I repeat the 3 methods and I now add what will prevent me not to use this one to start, less use this one and especially use this one. The first method, that one based on the use of BVE0, so put a voltage between base and emitter which is DC, except that to control exponentially a current is very difficult on one side, know that any variation of this tension with respect to temperature, will create a variation, any change of delta T, will make me a drift of the temperature of 2 mV per degree. But there is this sign (-), and that is what is the most critical. If you now take the beta of the transistor, it also depends on the temperature and it varies in the order of 0.8% per degree centigrade or degree, and it varies up to 1.5 In reality, here, there is no minus sign. So that's fine. We can handle it.

Notes

Summary

10m 45s

Polarisation du transistor Bipolaire

- Trois méthodes de polarisations:

$$I_{C0} = I_S e^{\frac{V_{BE0}}{U_T}}$$

$$I_{C0} = \beta I_{B0}$$

$$I_{C0} = I_{E0}$$

- Sensibilité à la température et aux tolérances de fabrication:

$$\frac{\Delta V_{BE}}{\Delta T} = -2 mv / ^{o} C$$

$$\frac{\Delta \beta}{\Delta T} \text{ augmente de } 0.8\%/^{o}C \text{ à } 1.5\%/^{o}C$$

Electronique II

There it can be destructive for the transistor if you impose a fixed voltage and if the temperature changes, you made a bipolar transistor circuit that you use in a car and in your car, you have a temperature, may be in winter, negative, and in summer positive, know that the polarization that is calculated will give you a variation, there is a huge variation between a temperature of maybe 0 degrees to something that goes up to 20 to 30 degrees, it will strongly influence, depending on temperature, the value of the polarization because this one, if it varies according to that, it will impose a runaway of your transistor because of this IC0.

Notes

Summary

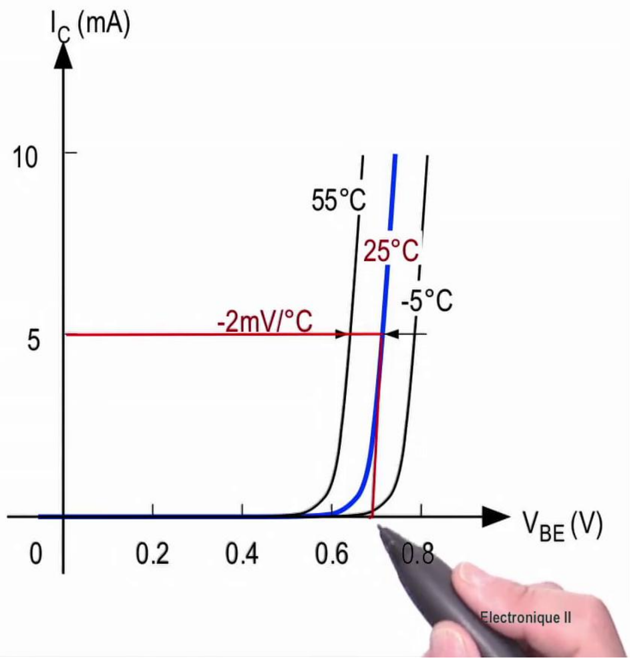
11m 54s

Polarisation par contrôle de V_{BE}

☹ Jamais utilisée!

☹ Forte sensibilité à la température

☹ Emballement thermique



So I would like to show you how and why this VBE0, I took the IC-VBE curve of the transistor and I drew the behavior of this at room temperature, in the order of 25 degrees, j I took a case where it was very cold, -5 degrees, and a case where it was heated because there is a certain efficiency in your assembly and your assembly heated, it reached 55 degrees. and I drew the behavior of this at room temperature, in the order of 25 degrees, I took a case where it is very cold, -5 degrees, and a case where it was heated because there is a certain efficiency in your assembly and your assembly heated, it reached 55 degrees. Suppose you have polarized your transistor somewhere here. You came with a temperature, you want to have a current that is there, this current from here to there, on that curve here, and that's it, you have calculated what is the voltage you need. And you found this voltage here. The VBE0, it's there. Well, if you are here at 25 degrees, and all of a sudden, for a given reason, it was cold, look at the value of your current that will pass.

Notes

Summary

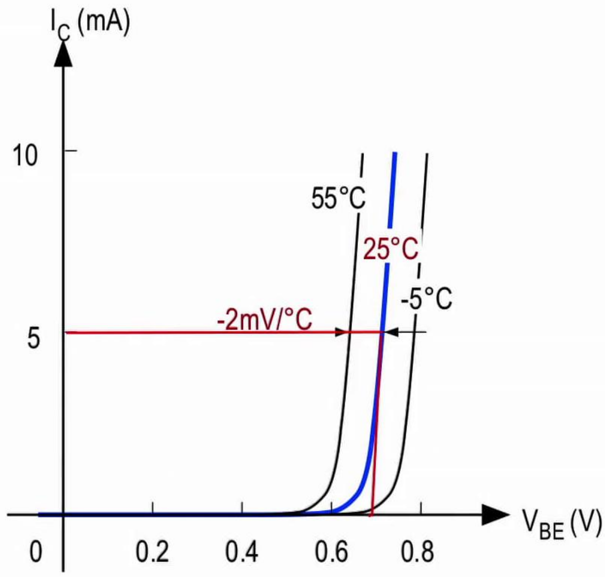
12m 37s

Polarisation par contrôle de V_{BE}

☹ Jamais utilisée!

☹ Forte sensibilité à la température

☹ Emballement thermique



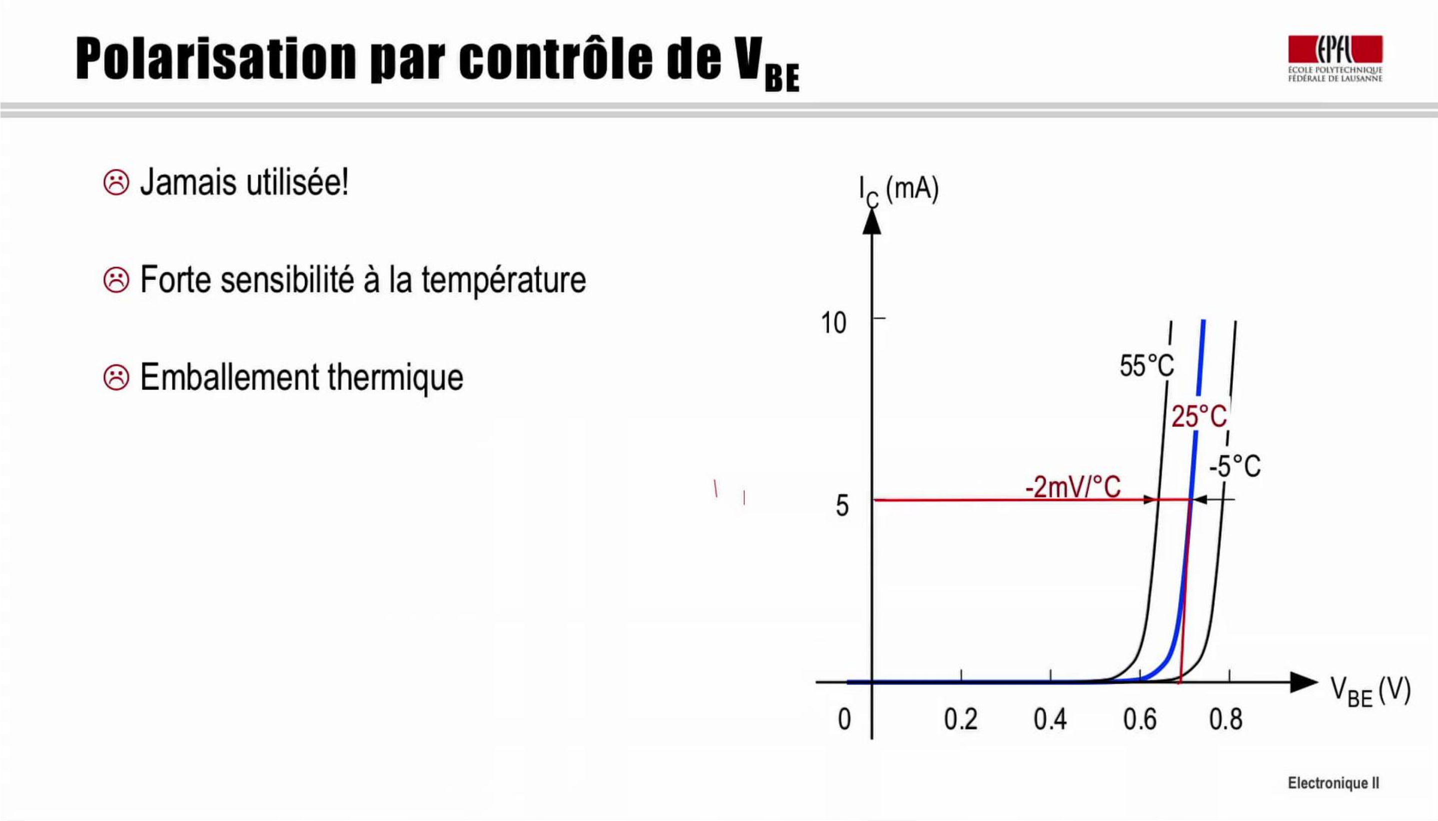
Electronique II

If you are at -5 degrees, and in your laboratory, when you have calculated your circuit, you find 5 mA of IC0 in it, so your IC0 you searched for and assume that your IC0 here is equal to 5mA, and this 5 mA here, you calculated it and it gave you a value of 0.7 V, well, if by chance you hold this 0.7 V but it is less cold, look at the current that flowing in. Your current becomes extremely low, it is barely somewhere, some micro-ampers and the opposite is true. If by chance you find yourself with a situation in which your temperature has risen it is 55 degrees, there you have to go very far and you will see a current IC that is going to be much higher than this knowing that the curve is exponential. So, that thing, we never use it. So it's never used because it is really not possible to first control such a stable tension.

Notes

Summary

13m 49s

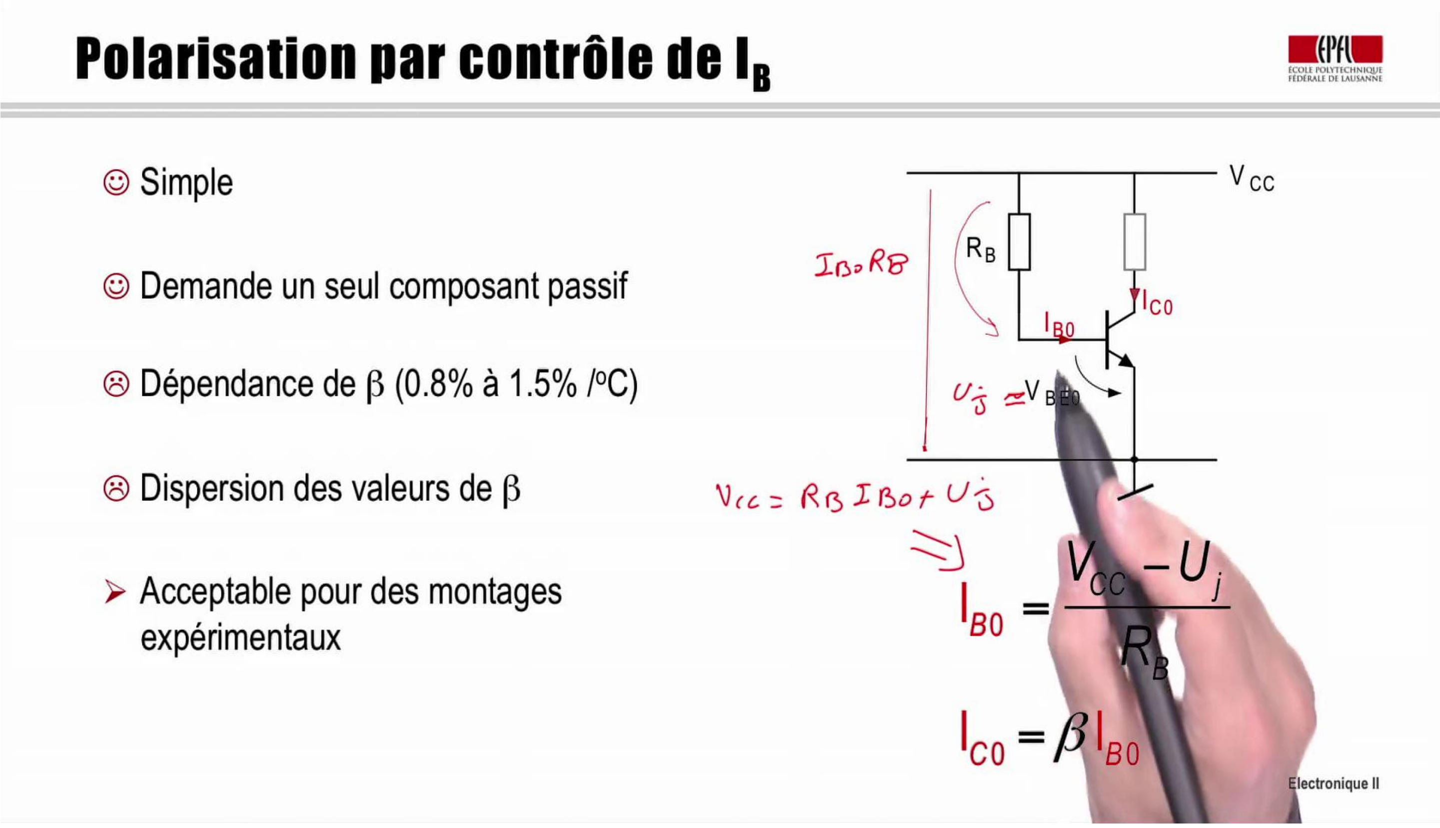


Two, the component itself when it passes from one characteristic to another, it may create a low current or a high current and the fact that it moves in that direction, whenever it heats, it moves in that direction, the meaning of this -2 mV it makes the problem very tricky because the more the current increases, the more your component will consume even more, or will dissipate more power, then the power is IC x VCE so it will heat up even more and the more it heats, the more this characteristic moves in that direction, and the more the current increases and it will eventually destroy your component and it is called the thermal runaway. It is the phenomenon that is very destructive in a bipolar type transistor because of this phenomenon that we have just seen.

Notes

Summary

15m 02s

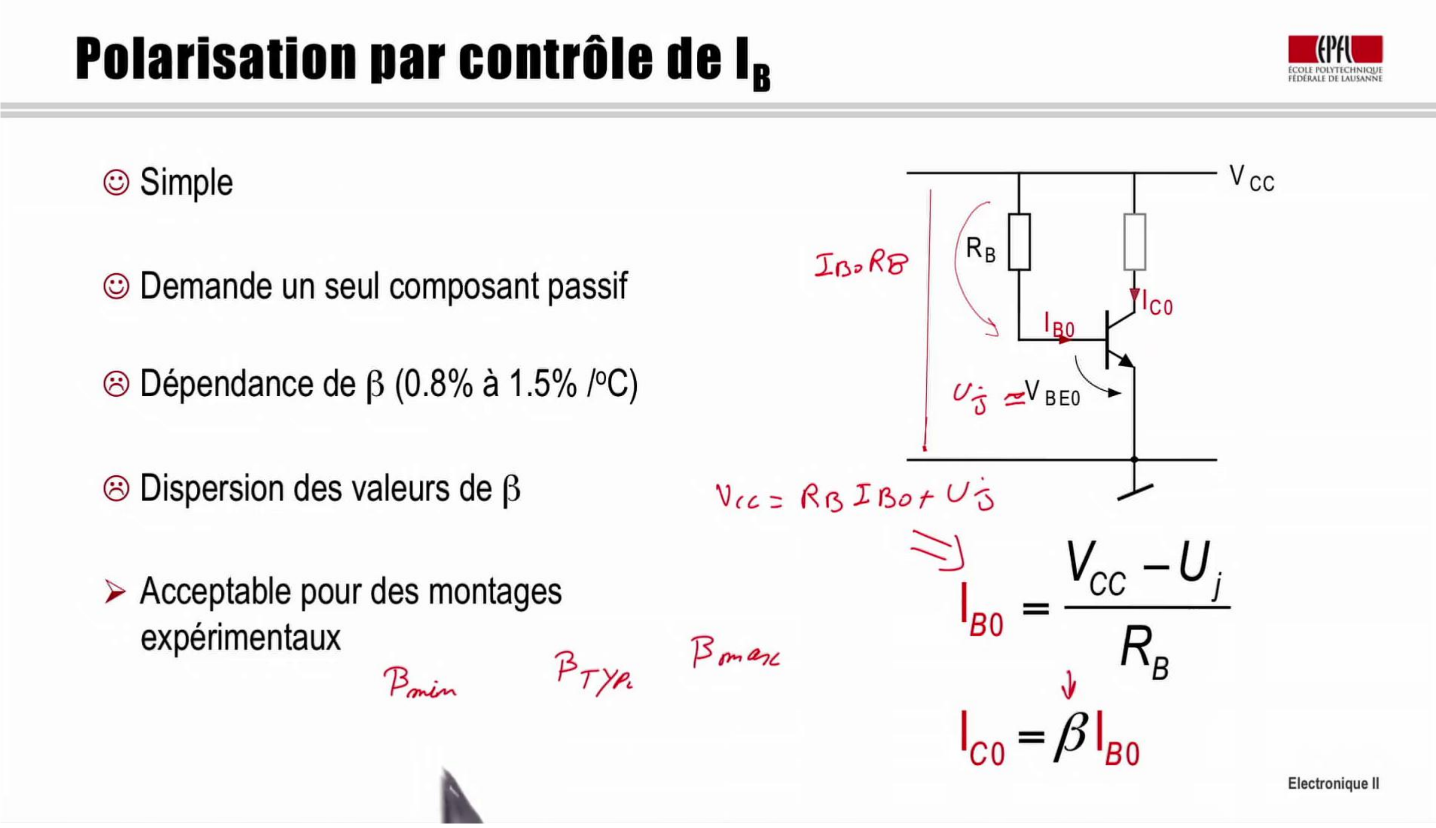


Take the second case of polarization by controlling the base current. I want to impose a constant IB0 current and say "This current and this current are linked by a beta relationship." Can I calculate this current? Very easy! I just have to look at the current that I see from there to there, if I look at that current, if I look at this current in that direction, well, I will be able to say that this voltage from there to there it's VCC, is equal to that voltage from there to there which is IB0 x RB, so that is IB0 x RB, and there I have the voltage VBE0 and if you remember that this approximates to Uj when it comes to the polarization because the error is very small, it is simply in polarization that we have the right to say that. So, in this loop VCC is equal RB x IB + Uj this is what I wrote here, VCC is equal RB x IB + Uj I only have to take the value of IB0 I'll write it here anyway, VCC is equal to RB x IB0 + Uj which will give me the relation IB0. So, I have to choose RB, knowing VCC, knowing that it is of the order of 0.7, it's good, I have my basic current. The basic current, I just have to choose a transistor, and then, my transistor, it has its beta that comes with, and it will give me directly IC0.

Notes

Summary

15m 54s



First thing is that your beta varies with the temperature, it is true that there, it is not as serious that the case of VB0, first, there is no exponential, it is a linear relation, one. Two, the variation with respect to the temperature is there but it is relatively low. But the beta dispersion, you only have to take a component of the market and watch the beta. The manufacturer, he gives you that famous beta with a beta min, a beta type, and a beta max. It gives you these different values in 3 columns, it tells you, the beta min, I take an example of transistors such as the BC107 or the BC77, the beta min, it can go down to the order of magnitude of 50, The beta type is about 200, or even 300, it depends on the manufacturer, and the beta max, it can go up to 300 and some. So when you look between this and that, you'll see that there is an extreme difference and this extreme difference, it means that you can easily fall, when you buy a lot of transistors, you can find betas that are of the order of 100, and betas of the order of 300 for the same component.

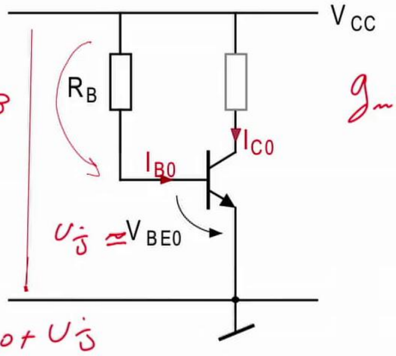
Notes

Summary

17m 41s

Polarisation par contrôle de I_B

- ☺ Simple
- ☺ Demande un seul composant passif
- ☹ Dépendance de β (0.8% à 1.5% /°C)
- ☹ Dispersion des valeurs de β
- ➢ Acceptable pour des montages expérimentaux



$$I_{B0} = \frac{V_{CC} - U_j}{R_B}$$

$$I_{C0} = \beta I_{B0}$$

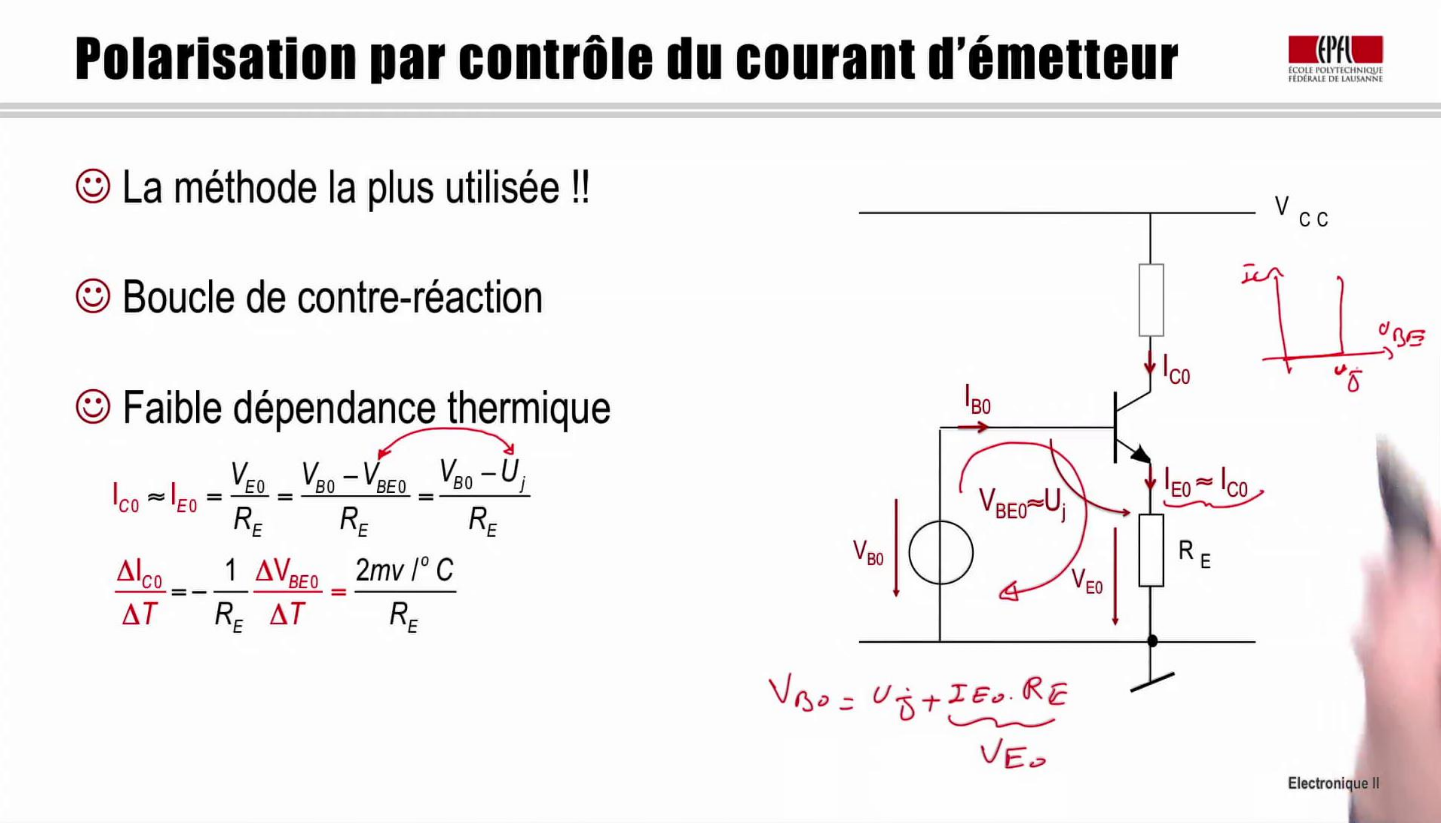
Electronique II

If you want to mass-produce an electronic circuit, and you base your calculation on that beta, know that your current of polarization it will fluctuate with the difference between that beta and that beta and you remember that the gain of that assembly it is gm times the resistance that is here and the gm of this transistor is directly your IC0 in question divided by UT. So the variation of that IC0 that you see there, It varies in the order of magnitude of the change in beta. So, this is not a good choice. It can go into a lab because when you polarize by a basic current, look how simple it is! You will see, the solution I am going to propose, it would pose a little more problems because we will have to insert a resistance here that will create other conflicts. To say here a common transmitter the transmitter is directly grounded a resistor that comes to the base and right away you have your gm compared to that IC0 and you are gone to use it as an amplifier directly.

Notes

Summary

18m 58s

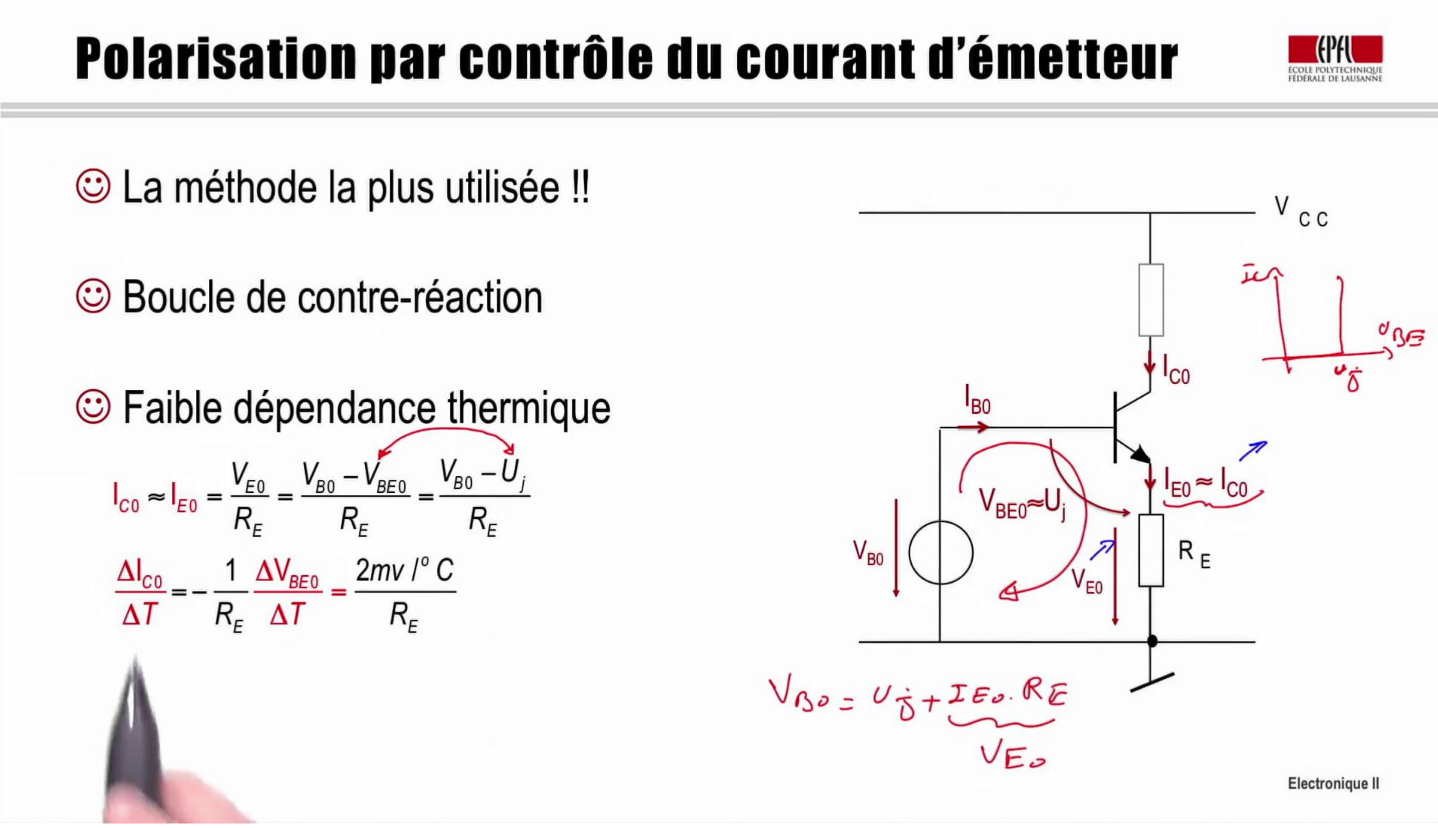


I will now show you the second solution, or the third solution. It is the polarization by control of the emitter current. So we're going to try to apply this legislation. It's that this current and that current are the same. Imposing a current in the transmitter depends on that mesh you see there. It is the mesh that is there. One has a mesh in tension, one says this tension from there to there equal to this one plus this one. If you write that like that, and you choose your VB0 wisely and you say your VBE0 is of the order of Uj, that's it, VE0, it is automatically known. That is what is noted there. If this current, or rather writing VB0 equal to Uj + IE0 x RE, which is nothing but VE0, it is good! You only have to write it there, and you make the approximation that this base current is negligible, and at that moment you have IC0 equal to I0, equal to VE0 / RE equal to VB0 - VBE0 / RE, and you make this linear model by segment to say that it is not exponential finally, we can simplify it by simply putting a curve IC, UBE that comes to do something like this instead of the exponential and this is called Uj. That allows us to make this approximation which is quite valid in a mesh if this voltage is not very, very low.

Notes

Summary

20m 01s



Here's the relationship: your IE0 is set, it's called a feedback loop. Let's analyze the definition of feedback loop here. It is written there actually, what happens in this mesh so your IE0, it is proportional to VB0 - VBE0. So if by chance, for a given reason, your current IC0 increases, if this current increases, the voltage VE0 is nothing but IC0 x RE. Therefore VE0 = IC0 x RE. So that tension will increase. If this tension is fixed, if that is fixed, then that tension increases what happens with it? It will decrease. If the base-emitter voltage decreases, you will lower IC0. Thus, we are acting in feedback on the variation of IC0. IC0 wanted to climb it has pushed the voltage VE0 with, it is fixed, their difference between the two has dropped, this loop will again regulate IC0, to decrease it again and we speak of a feedback loop because this relation puts us the relation IC0 and U0 with respect to VBE0 with a sign (-) which is in front. Let us take this relation which is here, which we have just derived from there. Let's look at the parameters that depend on the temperature, so derive delta IC0 on dT, I would like to see how IC0 varies with temperature, I want to derive this in relation to dT.

Notes

Summary

21m 53s

Polarisation par contrôle du courant d'émetteur

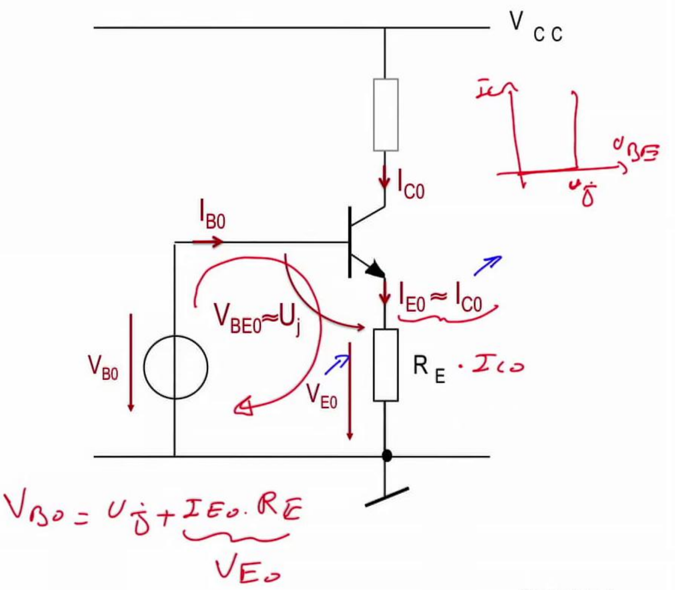
☺ La méthode la plus utilisée !!

☺ Boucle de contre-réaction

☺ Faible dépendance thermique

$$I_{C0} \approx I_{E0} = \frac{V_{E0}}{R_E} = \frac{V_{B0} - V_{BE0}}{R_E} = \frac{V_{B0} - U_j}{R_E}$$

$$\frac{\Delta I_{C0}}{I_{C0}\,\Delta T} = -\frac{1}{I_{C0} R_E}\,\frac{\Delta V_{BE0}}{\Delta T} = \frac{2mv/^{\circ}C}{\underbrace{I_{C0} R_E}_{V_{E0}}}$$



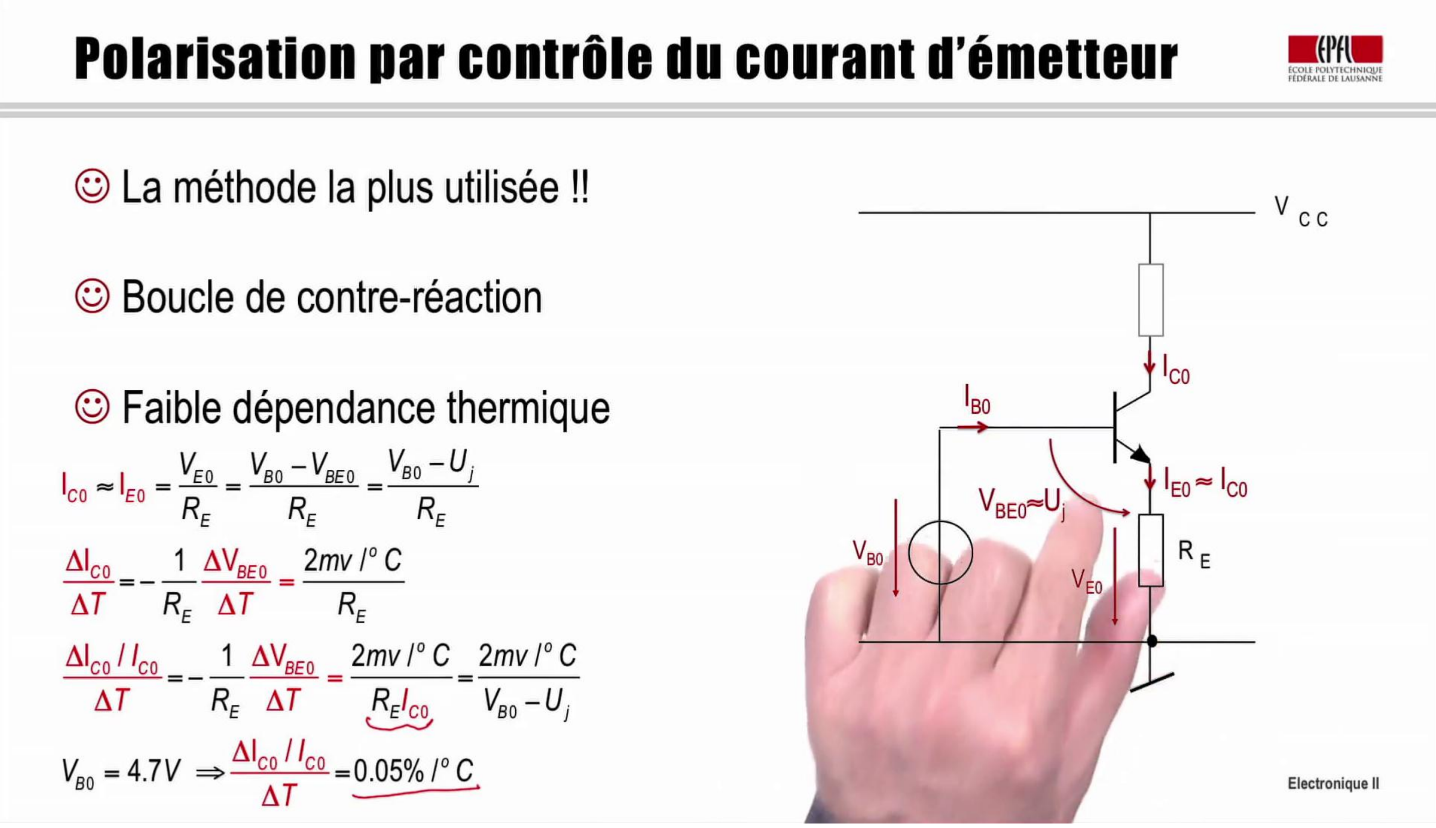
Electronique II

VB0 being independent of temperature, it is a voltage source that is considered not to be temperature dependent. So the derivative of VB0 on dT is equal to 0. The derivative of the base-emitter junction VBE0 depending on the temperature, that's what I note here, it is known, it is equal to -2 mV per degree. So I replace the dVB0 on dT by -2 mV. But since there is a sign (-) in front, the derivative, it will give (+). The resistance RE will stay here. And it will give you something that your component or current it will vary by 2 mV for each degree but divided by the value of RE. It means that this value of RE that you will select yourself to put in the transmitter will divide this variation and this is very important because if you wished to take a polarization current IC0, so you are looking for, you normalize this variation from a given current IC0, so you need to write IC0 here, and you need to write IC0 there. So I divided, divided, divided by IC0, look what I find there. IC0 x RE IC0 x RE is VE0. So that's VE0. It is as if I am saying: In an assembly like this, when I add a resistance here in the transmitter, for a polarization current sought, set by you, the more you put a high resistance, the more you increase VE0 with, the less there is a variation effect of your transistor itself.

Notes

Summary

23m 43s



So the higher this voltage is, the effect of variation of 2 mV per degree will become divided by the voltage VE0 you impose or, in other words, by the RE resistance you chose yourself. I repeat the same thing I just explained but I will put numerical values. So I rewrote a little more cleanly what I just noted, and I showed that these 2 mV are all the time divided by the voltage VE0. So it is this tension, it is this one less this one. I noted it here. And I put numerical values. I simply took VB0 equal to 4.7 V and I wanted to see what is the effect of this dIC0 on IC0 on the temperature dT, the temperature variation, and I found something that varies from 0.05% per degree. So you see? And that is a manageable value through RE x IC0 so your design parameter is going to be this resistance less, or rather more, the designer is trying to make dIC0 on dT low, he only has to increase the voltage drop of this VE0 and like that, your effect of temperature variation on IC0 will be more and more limited. In fact, one can easily see here. You have an exponential junction and you have a linear law and both see the same current.

Notes

Summary

25m 33s

Polarisation du transistor: résumé

The exponential junction sees the current IC0 and the linear law sees the current IC0 once in a resistance and once in the exponential law and you are saying: Make the linear law wage on the exponential law and like that, you gain in terms of temperature regulation. I would like to finish this first part of this week with a summary on polarization. So we have analyzed the 3 techniques of polarization and we have just discarded one that is never used, it's to fix a voltage VBE in the transistor in DC voltage and say: we would get with it a continuous current fixed. It was eliminated because of the phenomenon of thermal runaway and especially in the control of an exponential law also by a tension, very, very difficult to fix. We used the second one, which involves the beta of the transistor, also to say, in the laboratory, go do it, but you will have great difficulty in using this for manufacture in large quantities of electronic circuits based on a polarization basing everything on the beta of the transistor.

Notes

Summary

27m 18s

Polarisation par contrôle du courant d'émetteur

☺ La méthode la plus utilisée !!

☺ Boucle de contre-réaction

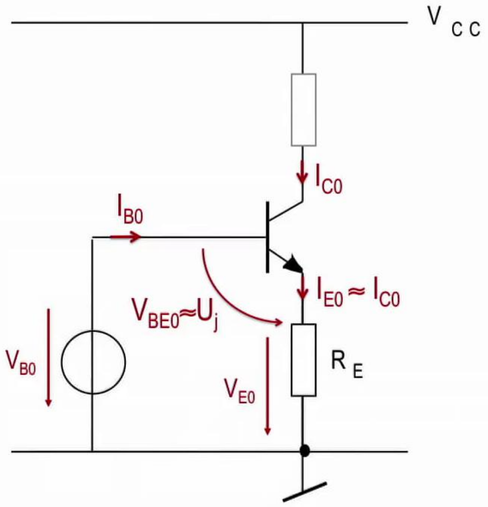
☺ Faible dépendance thermique

$$I_{C0} \approx I_{E0} = \frac{V_{E0}}{R_E} = \frac{V_{B0}-V_{BE0}}{R_E} = \frac{V_{B0}-U_j}{R_E}$$

$$\frac{\Delta I_{C0}}{\Delta T} = -\frac{1}{R_E}\frac{\Delta V_{BE0}}{\Delta T} = \frac{2mv/^{\circ}C}{R_E}$$

$$\frac{\Delta I_{C0}/I_{C0}}{\Delta T} = -\frac{1}{R_E}\frac{\Delta V_{BE0}}{\Delta T} = \frac{2mv/^{\circ}C}{R_E I_{C0}} = \frac{2mv/^{\circ}C}{V_{B0}-U_j}$$

$$V_{B0} = 4.7V \Rightarrow \frac{\Delta I_{C0}/I_{C0}}{\Delta T} = 0.05\%/^{\circ}C$$



Electronique II

And we ended by adding an additional component in the transmitter and say: thanks to a resistance, inserted in the emitter in the bipolar transistor, we can find a fixed current IE0 and if the transistor is of low power, it is as if we are saying: we fixed IC0 and it is going to be this assembly that will be used for the following and we'll see how to now generate all the components around this transistor and polarize it with passive components that we will add around.

Notes

Summary

28m 29s