ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Comparateur

5.1 Amplificateur opérationnel en réaction positive

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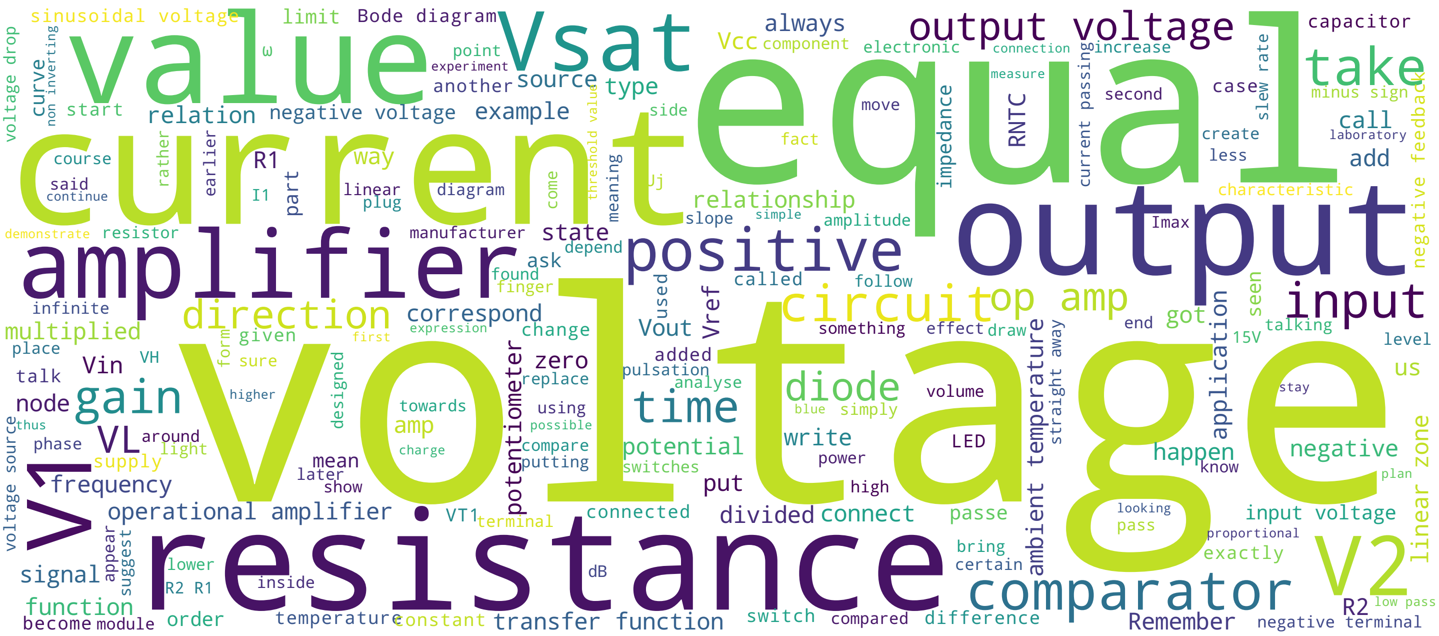
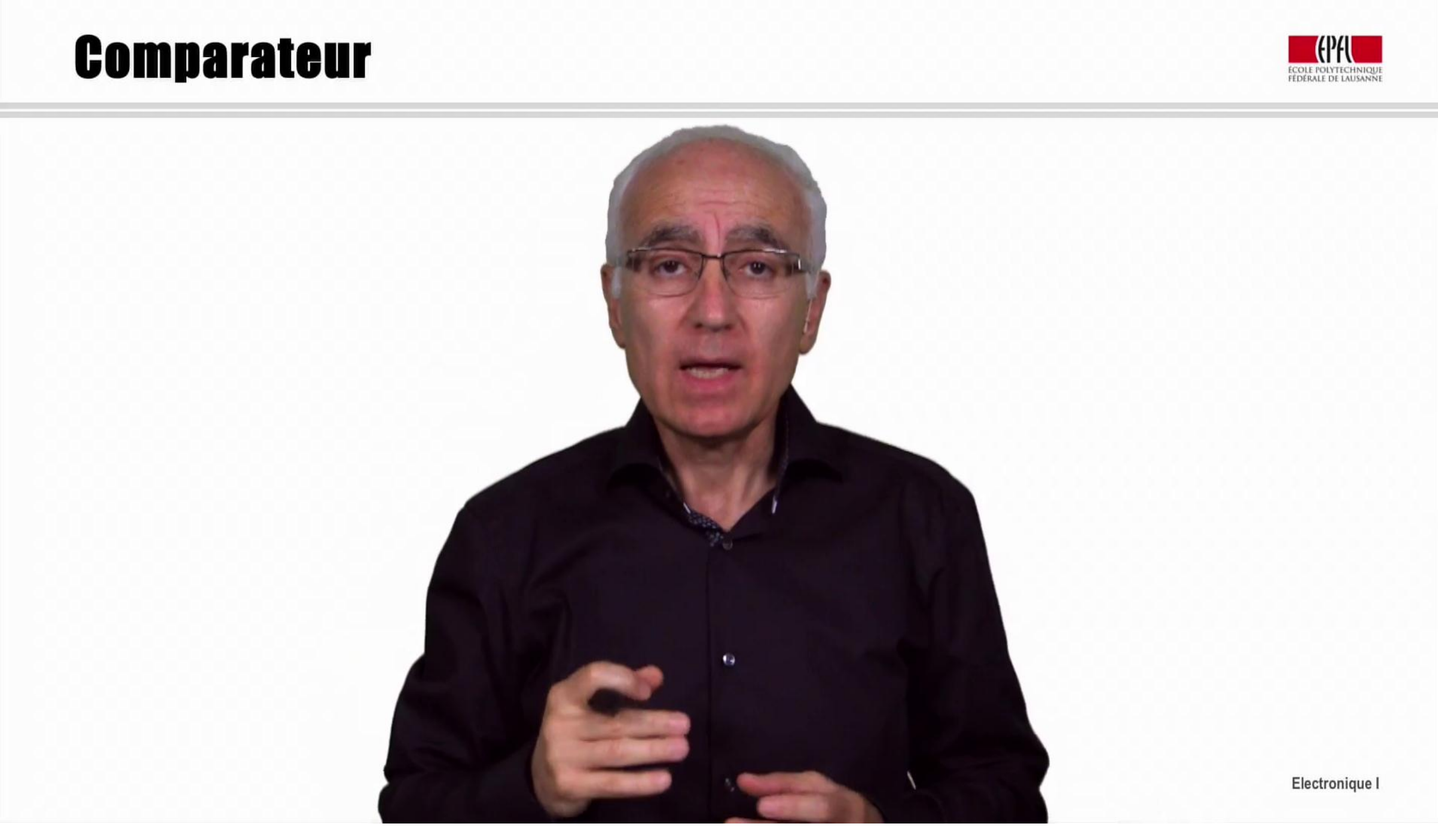


Video

EPFL



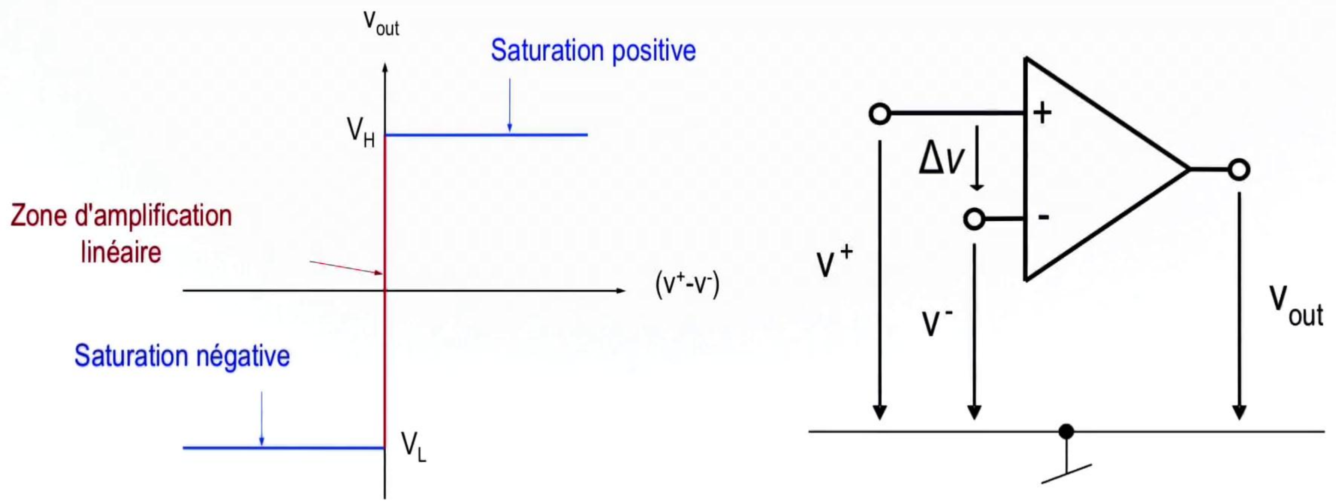
Hello, today, we're going to continue to look at operational amplifiers, but this time we are going to talk about comparison, meaning that we're going to take an op-amp and use it as a comparator. Why use the term comparator when talking about an electrical function that has been presented before as an operational amplifier? In reality, all op-amps are also comparators, but the internal structure of a comparator is not at all the same, it isn't designed in the same way as an operational amplifier for a simple reason. Operational amplifiers are designed to be stable in the linear zone. So, remember when we talked about the characteristics of the operational amplifier, we said that there is a linear central zone, and all values found here correspond to the value for which the voltage *V+* is equal to the voltage *V-*. Now we're going to use the same op-amp, but only in the so-called saturated zones. So, we're going to get out the amp which will be around *Vsat+* or *Vsat-*. The linear zone therefore won't be used it will be in the transition zone between *Vsat+* and *Vsat-*. And the amplifier has been designed in such a way that when it produces a negative feedback and stays in the linear zone, it stays stable.

Notes

Summary

0m 04s

Comparateur simple



Electronique I

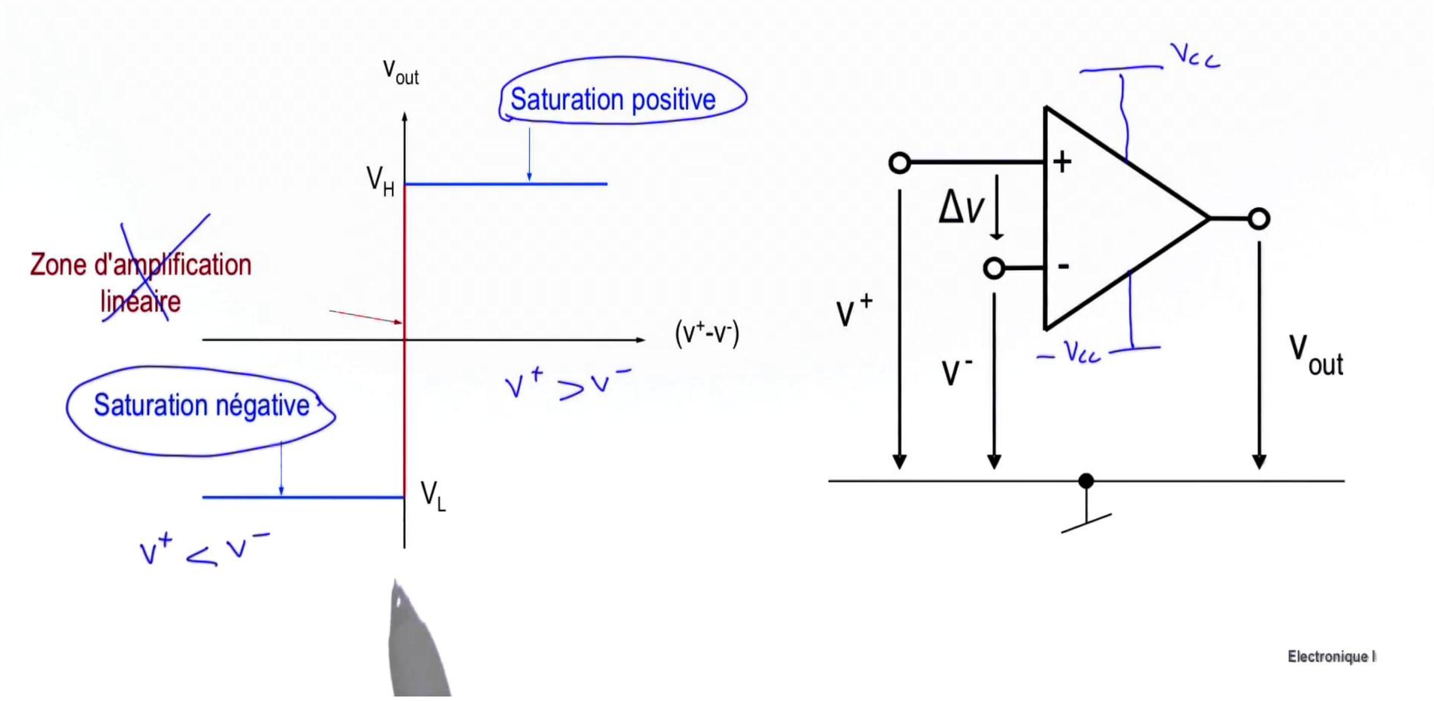
And here, it needs what we call an internal compensator, and that's the main difference of the comparator. We don't ask it to stay inside here, there isn't any linearity, there is a simple comparison between the positive and negative terminals. If *V+* is higher than *V-*, it will go to *Vsat+*, and if *V+* is lower than *V-*, it will go to *Vsat-*. And we will find ourselves with an output with two values. And here, it's the transition speed that is the most important. So we don't make any compensation for the stability because we're not asking it to be stable, instead we're asking it to be unstable, to rapidly switch from one state to another. In this chapter, we're going to look at two ways of using the comparator: simple use of a comparator, which means that we don't add any resistance which would react between the voltage output and the voltage input, and we're going to talk about a threshold or hysteresis comparator, it's two types of connection between the input and the output that will bring about a positive feedback from the output to the positive terminal. We're going to approach this study as we did with the op-amp.

Notes

Summary

1m 41s

Comparateur simple



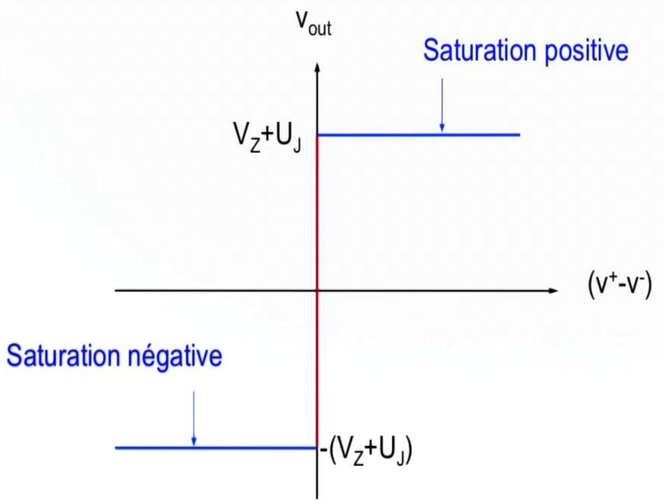
We took it, and said it's an op-amp, so, it's an op-amp. It's an amplifier that we're going to use exactly like a comparator, and it's going to be a simple comparator, meaning that it's got nothing to do with anything apart from the symbol that we've seen. For sure, it will have positive and negative power input as does the op-amp. It will have a *Vcc* and -*Vcc* as normal. The two voltage inputs will supply a current or reduce the current in relation to the common potential between the two input terminals and the output terminal. And here is the feature, that we looked at for the op-amp. So, I'll go over it again. Here, we're going to only use it here and here, and never in the linear zone. We will never keep it in the linear zone. It will simply pass from here to here. So for all values where *V+* is greater than *V-*, we will find a positive saturation. And for all values where *V+* is less than *V-*, we'll find negative saturations. And when *V+* is equal to *V-*, the amplifier will never stay in that zone it will switch, and therefore carry on, it will jump from here to here, and it's during that transition that we require it to be as quick as possible.

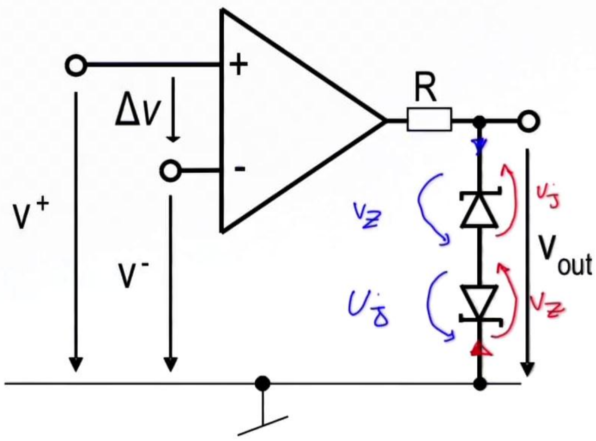
Notes

Summary

3m 08s

Comparateur simple





Electronique I

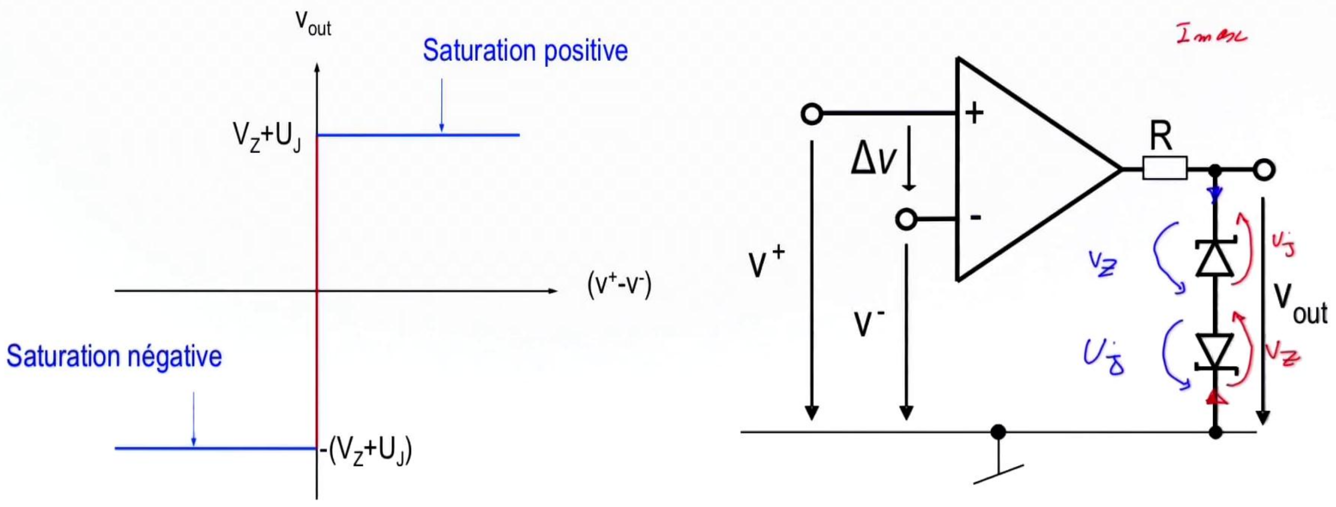
It's possible to take an op-amp or a comparator, and limit the output voltage to levels that the schema suggests here. We have used Zener diodes. We've got a voltage *VZ* when the current is positive in this direction. So when the current is in this direction, meaning that the voltage *Vout* is *Vsat+*. So we'll have a current that is going in this direction. It will conduct the Zener diode that is in the direction of a conducting diode, and therefore, I'll have a buffer voltage of around the junction voltage and a Zener voltage, that will bring an output voltage equal to *VZ* + *Uj*. Now, if we take a negative voltage, meaning *Vout* is equal to -*Vcc* or *Vsat-*, for sure, we'll find a current that will be positive in this direction and that will have a voltage *VZ*, that we see here, and we'll find a voltage *Uj* here, and we'll also find an output voltage limited to *VZ* + *Uj* in the other direction, with a minus sign. It's simple to demonstrate that we can easily impose voltage levels at the output that correspond to what we need outside of the power voltage.

Notes

Summary

4m 36s

Comparateur simple



Electronique I

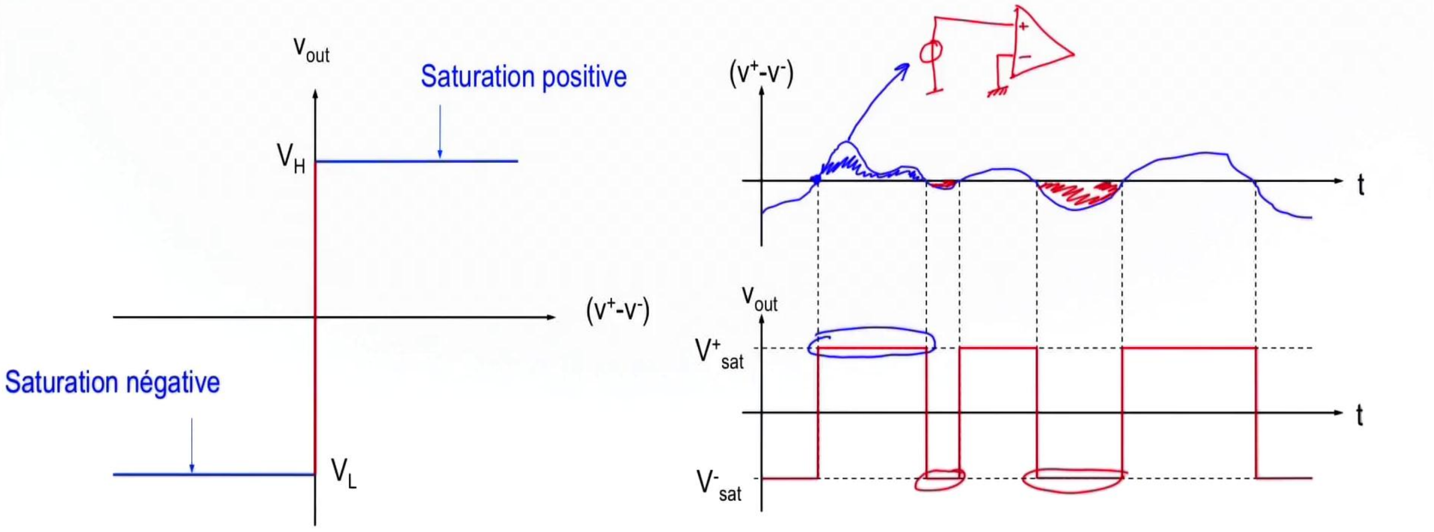
Remember that the resistance R is there to limit the current $I+$ and $I-$, that will enter or exit the comparator because there is a maximum current that can be tolerated by the comparator. If we exceed this, the output cuts out. Here, this resistance should be calculated in order to impose a traversing current equal to *Imax*. So, we're going to look at exactly what is the current *Imax* that we need to obtain. And the current *Imax* depends on the voltage here and also on the resistance R that we will have chosen.

Notes

Summary

6m 06s

Comparateur en boucle ouverte



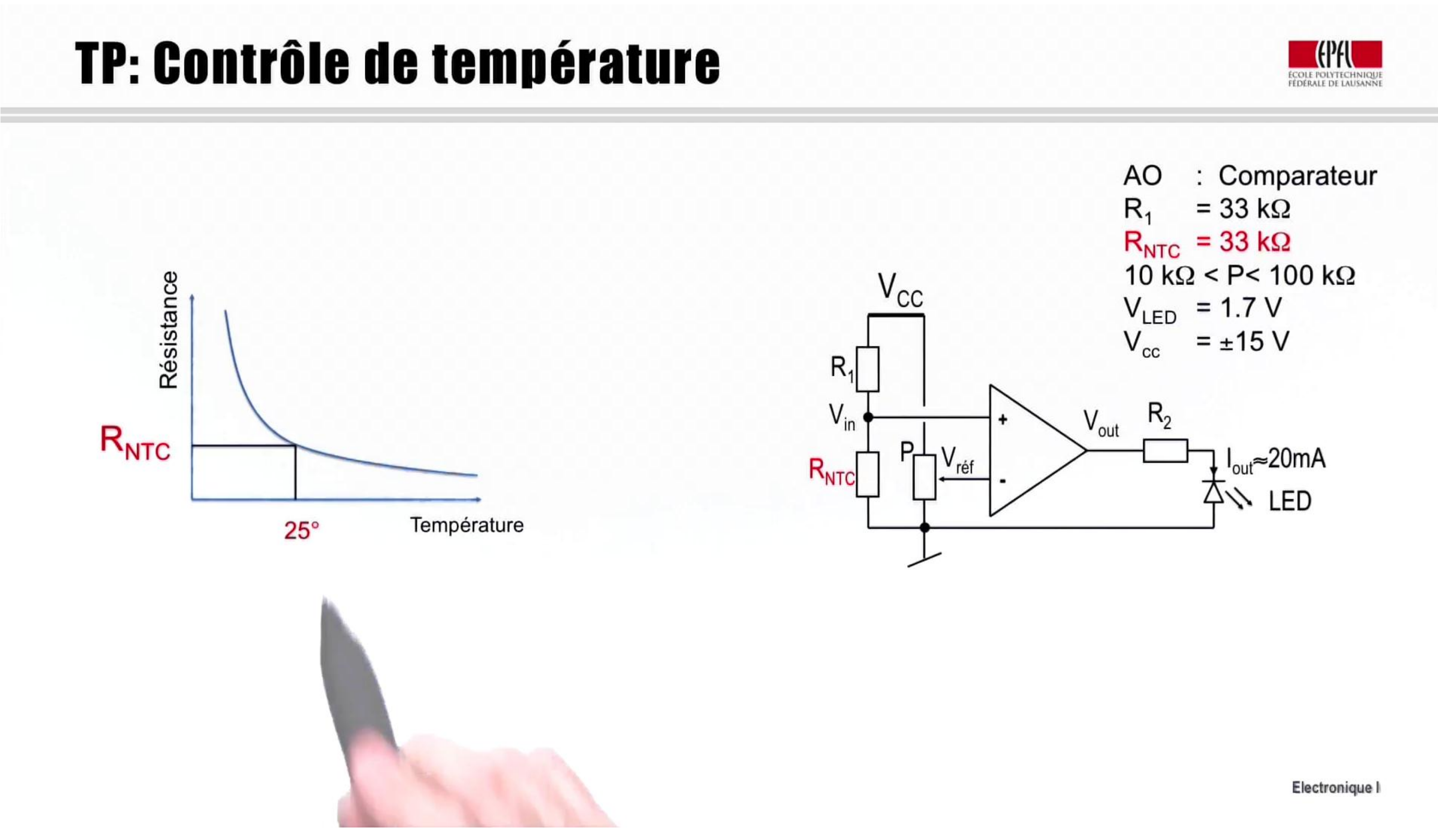
Electronique I

This schema here, we have already seen, or rather the graphs that we see here, we have already seen with the operational amplifiers. If you take a comparator, and the negative input of your comparator, you put it to the volume, and the positive input of your comparator, and that the voltage source is the signal that is here, that has compared it to the volume, forcibly while passing through zero, so each time your comparator passes through zero, it will compare in relation to the potential here. So if the voltage is positive, as we can see here, this voltage here is positive so we see that this part of the curve corresponds to the state *Vsat+* and we discover that this part of the curve, this part here for example, and this one here for sure, that switches the comparator to *Vsat-* et *Vsat-* here. The same for *Vsat+*, etc., etc. We call that a Zero-point detector. We have been able to compare any form of signals that passes through zero each time the signal passes through, switched the negative voltage to a positive voltage, we've got a strange signal showing up at the output that will give us a state 1 and a state 0, if we're talking about a logical circuit.

Notes

Summary

6m 37s

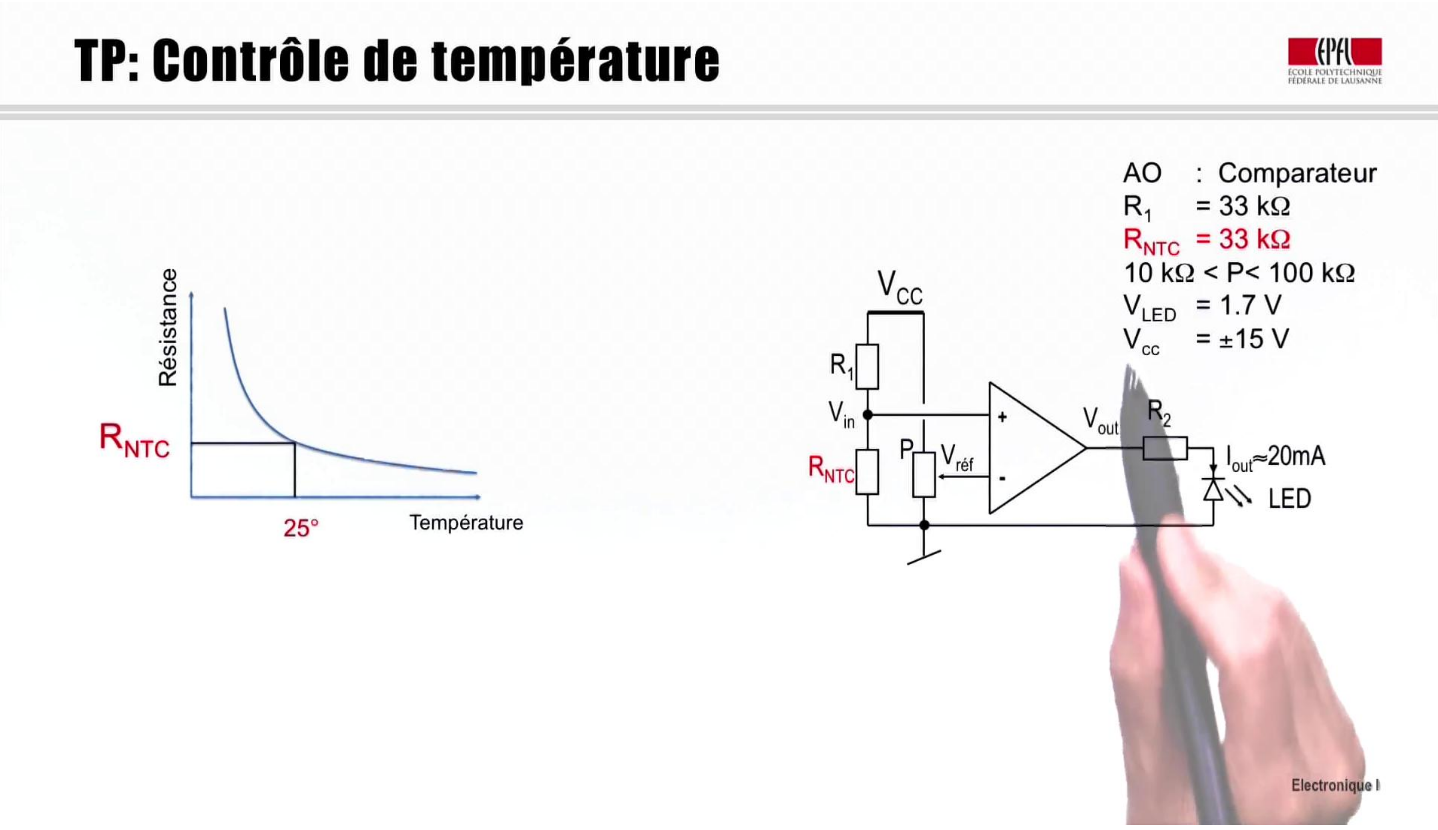


I'd like to now give you an example, and guide you towards some practical work, and let you know that you can already do tri circuits such as a temperature controller. What's a temperature controller? It's a type of regulation that we call all or nothing. Meaning that I'd like to have an output voltage or something that gives me a signal, and that signal tells me that the temperature has risen up to a threshold value or falls below the threshold value. So, in this example, I've decided to ask you to make a circuit where we use a resistance called *RNTC*, or a resistance coefficient to negative temperature. It's a resistance that has a non-linier curve. Its resistance depends on the temperature. We talk about a resistance *RNTC* to an ambient temperature that the manufacturer gives us. Here, the manufacturer says that this resistance is 33kΩ when the temperature is 25°. If you take this value and you put a resistance *R1* that is equal to the value *RNTC* it signifies that at ambient temperature, you will have a voltage equal to *Vcc/2*, *R1* equals *RNTC*, and here, I suggest you take a potentiometer and connect the potentiometer as if it's a resistant divisor, this time that you're controlling manually, and you also divide *Vcc* by two.

Notes

Summary

8m 15s

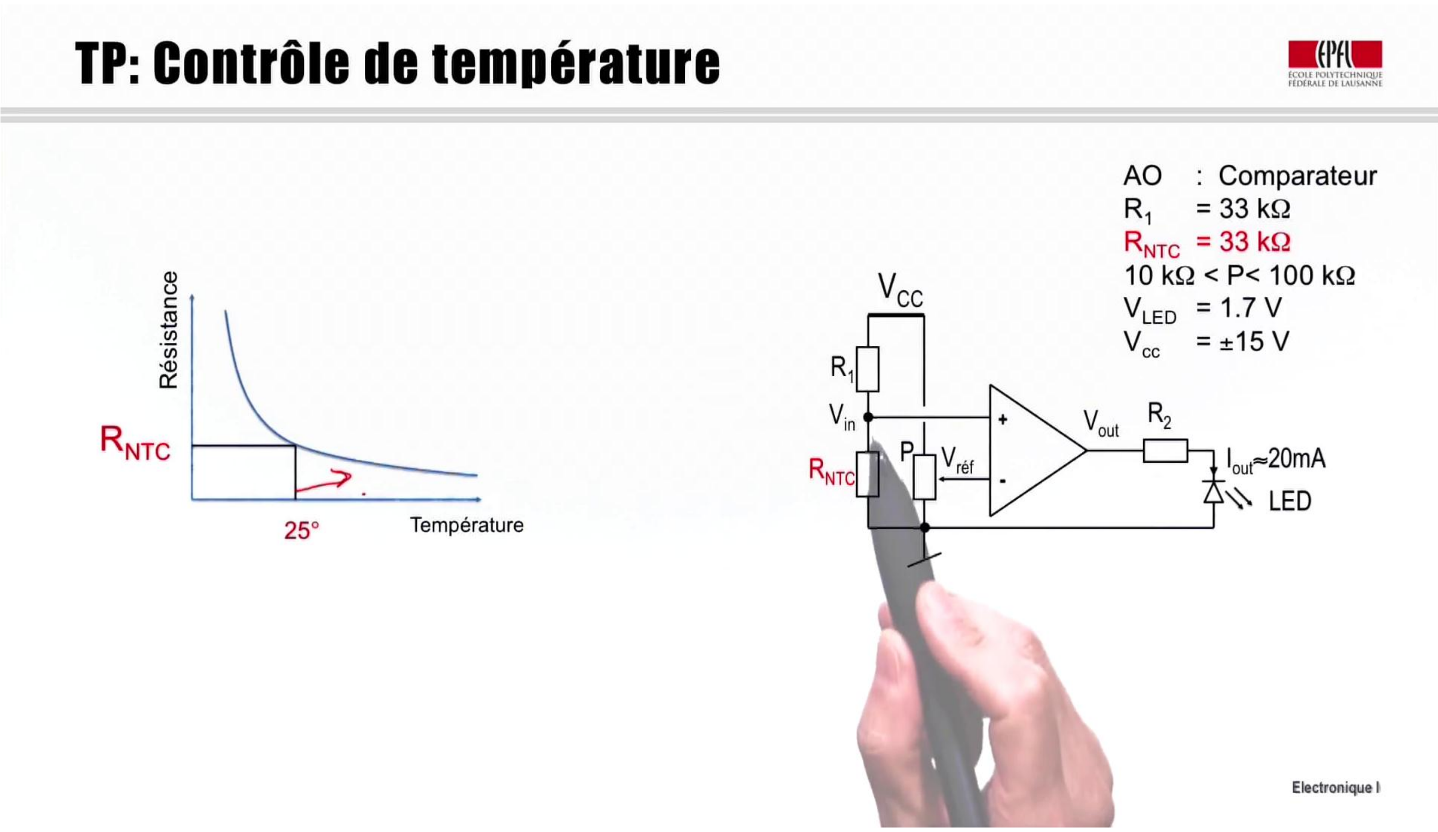


This means that you place the cursor in the middle of the range of the potentiometer. So you can put any time of potentiometer between this value and this value. It's simply its limit. The current that passes, the comparison effect, it's when the cursor is in the middle, independent from the potentiometer’s value, you will find here *Vref* is equal to *Vcc/2*. And if you have an ambient temperature on this side, you will find *Vin* equals *Vcc/2*. Plug in the comparator. The comparator will have *Vin* equals *Vref*. Meaning that the voltage *Vout* is in the transition zone, in practice. If you really want to maintain this state that is extremely difficult, because you only need a very small variation in temperature here, or a small mechanical variation in order that straight away *Vout* switches to *Vsat+* and *Vsat-*. But suppose that *Vin* equals *Vref*. In practice, this voltage, here, is starting to move all over the place. It's jumping up to *Vsat+* and falling down to *Vsat-*.

Notes

Summary

9m 54s

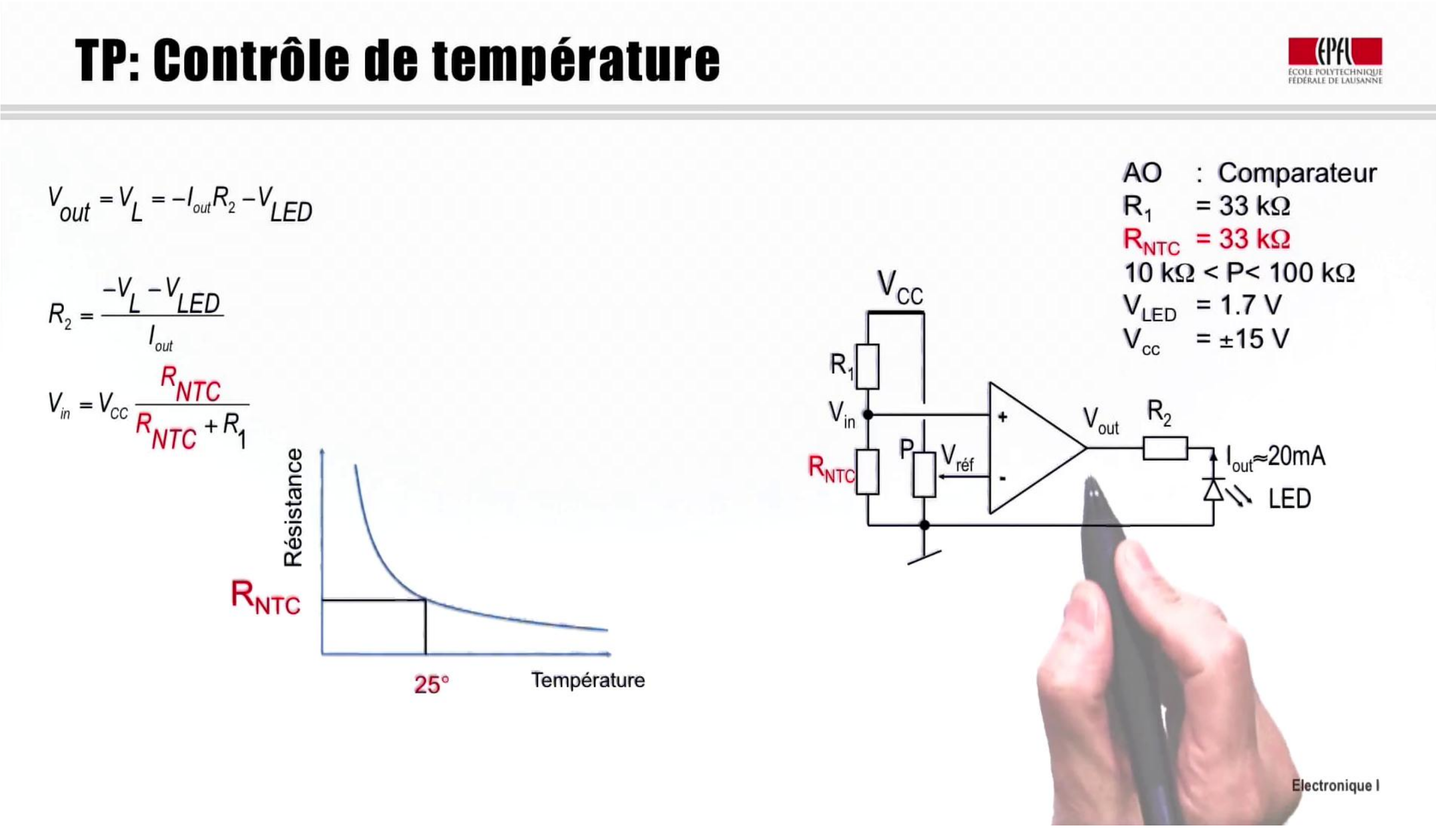


In the case of the example that I'm going to give you, I ask you to plug in a luminescent diode, an LED, and I'm going to ask you to regulate this voltage to the same level as this voltage, approximately, in order to be at the regulation buffer at an ambient temperature. Then, we're going to try to warm up the resistance *RNTC* by blowing on it, and putting on a finger at body temperature, and you will see the temperature rise, and we will get... When the temperature rises, we will have a lower resistance. And if the resistance goes down, we'll get *Vin* that follows the value of *RNTC*. If *RNTC* gets smaller, *Vin* will get smaller with it. So, if *Vin* drops with it, having given *Vref* we will have regulated to an ambient temperature equal to *Vin*, you'll get the *V+* that will drop less than the *V-*, and straight away the *Vout* will switch to saturated negative voltage.

Notes

Summary

10m 57s



And if it's the saturated negative voltage via a comparator supplied with more or less 15V, probably the output value will be about the same size as the power supply, so you'll get *Vout* equals -15V and there will be a current passing in that direction from the zero, because here, we've connected it to the volume, to the output of our comparator, it will go inside there, and pick up the negative voltage in order to pass into the circuit here to -*Vcc*. And your diode will light up. As usual, I'm going to ask you to calculate the resistance *R2* As soon as we connect a diode at the output and that diode becomes a conductor, we'll need to limit the current. Here, I suggest that you limit the current to around 20mA. And I'll tell you some classic effects that light-emitting diodes have on voltage drop that is around 1.7V for a red diode, that I chose because, later on I'm going to demonstrate that experiment. Here's the relationship that we can write at the output. Remember that here, *Vout*, when the voltage *Vin* is lower than *Vref*, so when *Vin* drops below *Vref*, we get *Vout* equal to the voltage *VL* or -*Vcc*, so *L* is *low*.

Notes

Summary

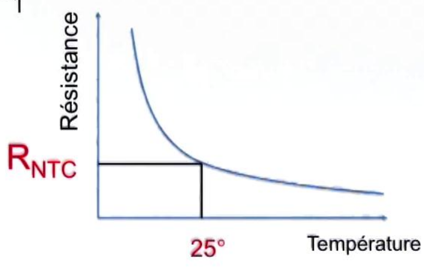
12m 06s

TP: Contrôle de température

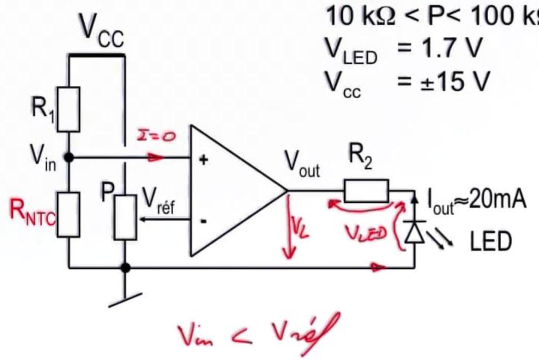
$$V_{out} = V_L = -I_{out} R_2 - V_{LED}$$

$$R_2 = \frac{-V_L - V_{LED}}{I_{out}}$$ $I_{out} = 20\ mA$

$$V_{in} = V_{CC} \frac{R_{NTC}}{R_{NTC} + R_1}$$



AO : Comparateur
R_1 = 33 kΩ
R_{NTC} = 33 kΩ
10 kΩ < P< 100 kΩ
V_{LED} = 1.7 V
V_{cc} = ±15 V



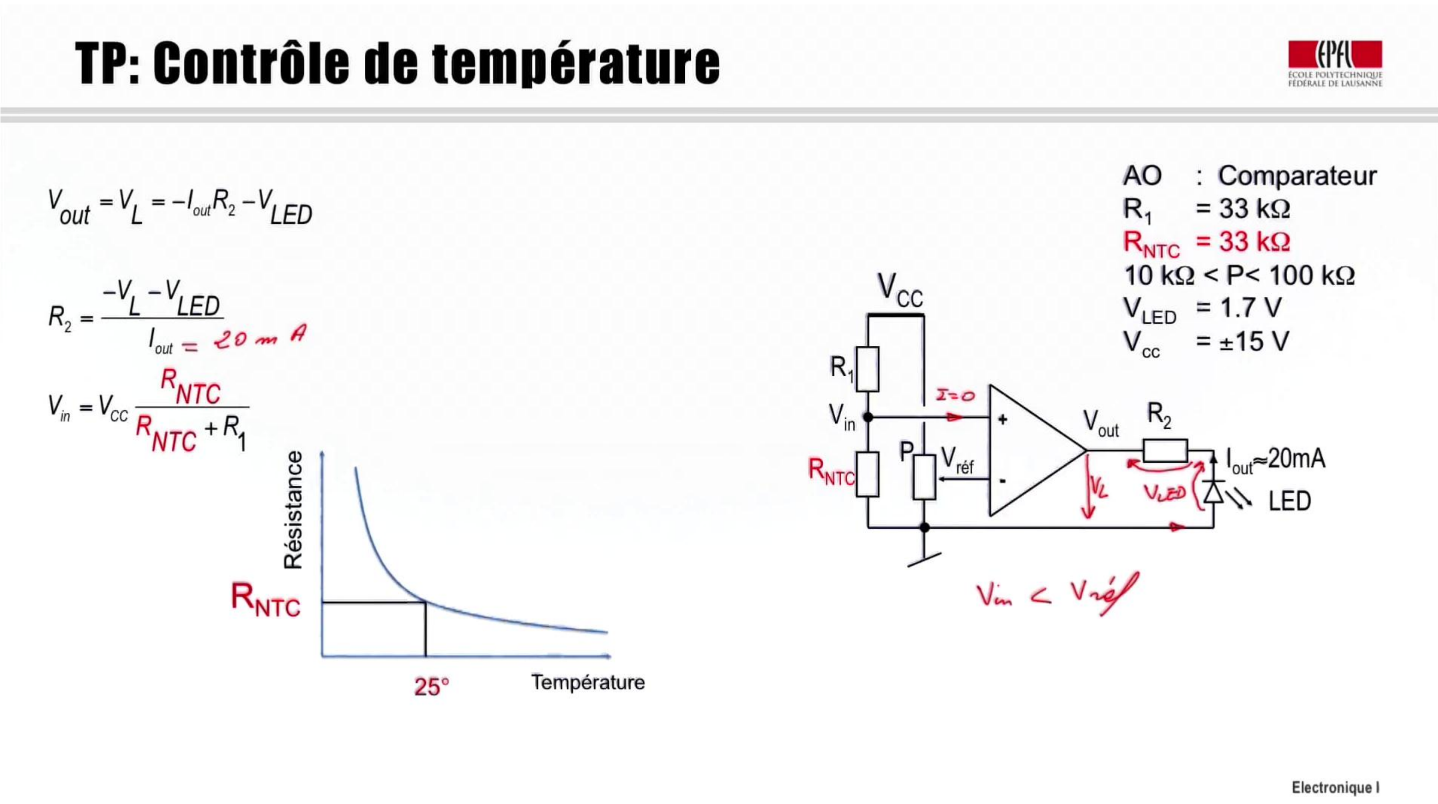
Electronique I

And at this point, we have a current that is flowing in this direction. So it's this *VL* that is equal to -15V, it should be equal to the voltage drop on this resistance. So it's *Iout* times *R2* plus the voltage drop here, which is the voltage of *VLED*. That's what I've written here. So, *VL* equals - *Iout R2* - *VLED*. You can measure the resistance *R2* to guarantee that your current *Iout* stays around 20mA to avoid having a large current passing through the diode, that could either damage it if the comparator manages to supply a large current, either cut the output voltage tolerated by the comparators. The voltage *Vin* is a resistance divisor, clear, because the current here is equal to zero. So maybe we could write *RNTC* divided by *RNTC* + *R1* to find out the voltage *Vin*. And we'll see what happens in the laboratory if we connect this and equalise ourselves to an ambient temperature.

Notes

Summary

13m 44s



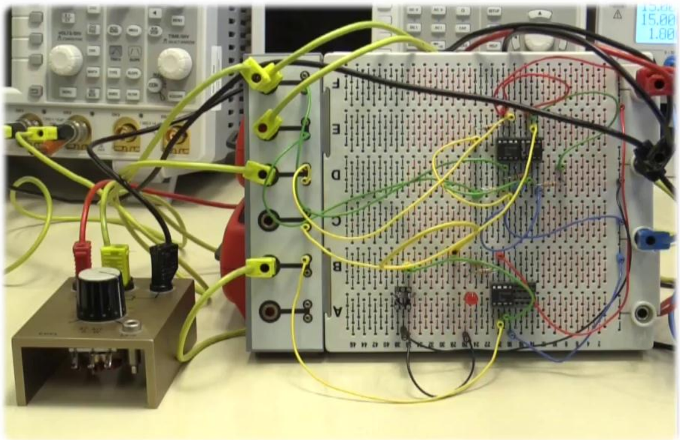
Afterwards, we'll see what happens when we heat the diode *RNTC* when we put our finger over it and change the temperature, by increasing the temperature in this way, we're lowering the resistance value, thereby we're reducing the voltage *Vin* and so the voltage *V+* becomes less than *V-* and the output voltage switches to *-VL*, and ends up at *VL* that is -15V, and will induct a current that will pass in this direction.

Notes

Summary

15m 00s

TP: Contrôle de température



AO : Comparateur
R_1 = 33 kΩ
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10 kΩ < P< 100 kΩ
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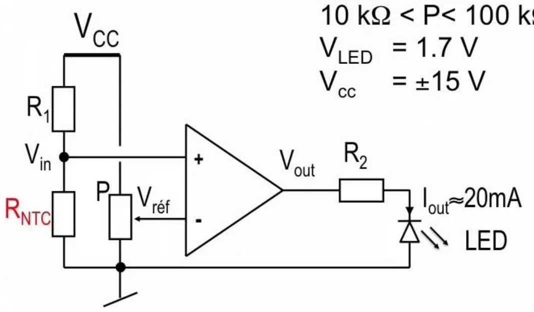

Electronique I

Here is our CTN resistance and here's the LED which will light up later on. So what we're going to do now, is adjust the potentiometer to the voltage *Vcc/2*, so compare the tension to the reference value, that corresponds to the ambient temperature. We see that the LED is flashing on and off, corresponding to the settings and the ambient temperature. So, from now on, we are more or less on the switching threshold. We'll warm up the CTN. We'll try to get it to measure the body temperature by putting our finger over it. So 37° is surely warmer than the outside temperature, and we'll see the LED light up. Here, the LED is now showing that there has been a switch in our comparator. We'll let the resistor take the external temperature again and we'll see the LED go out until the CTN temperature equalises, like earlier on, at the room temperature where we're carrying out the experiment.

Notes

Summary

15m 26s