Comparateur

5.2 Amplificateur opérationnel en réaction positive

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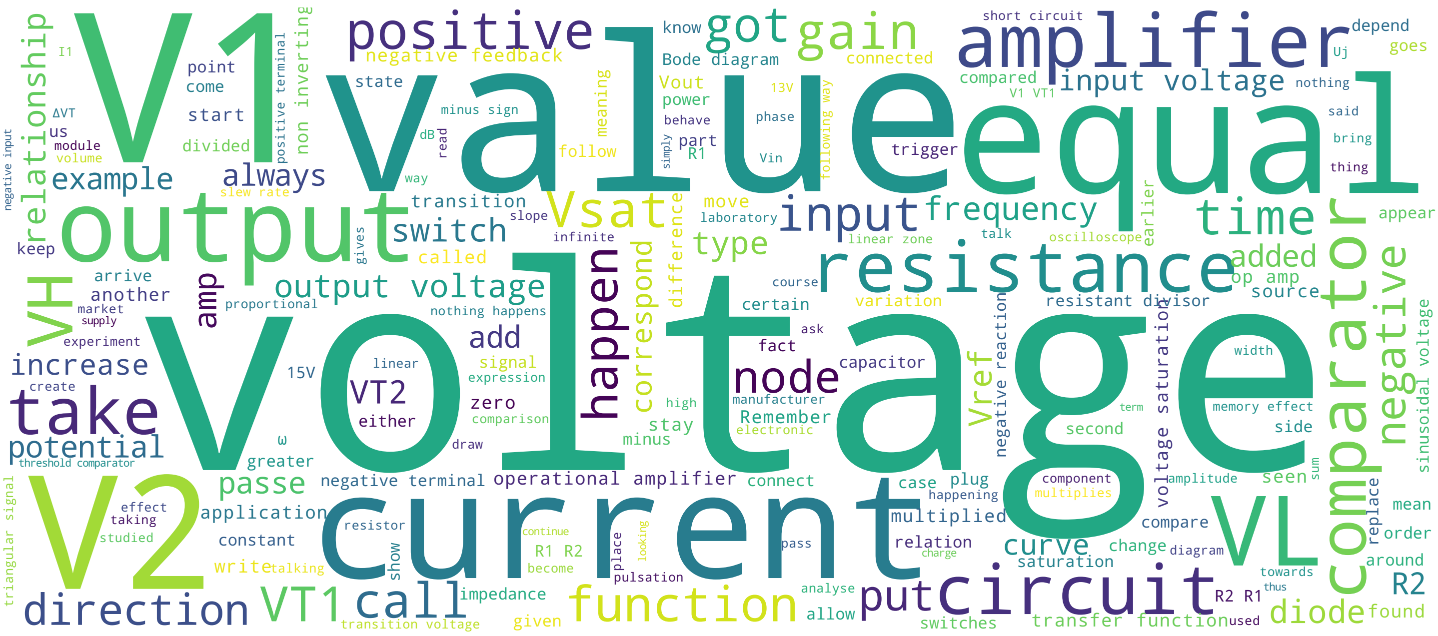
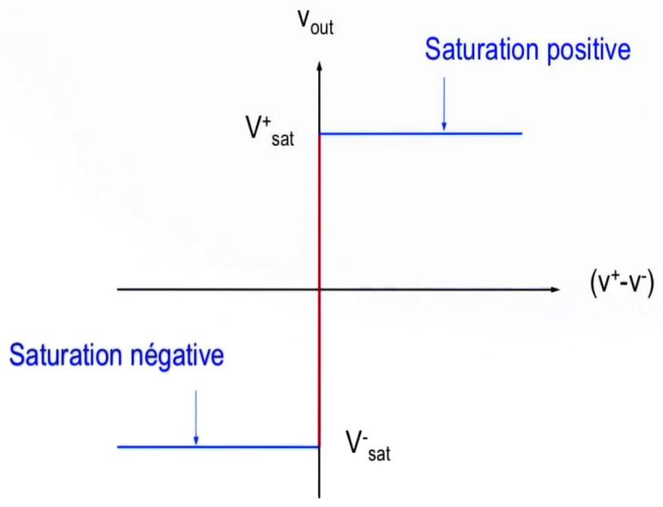
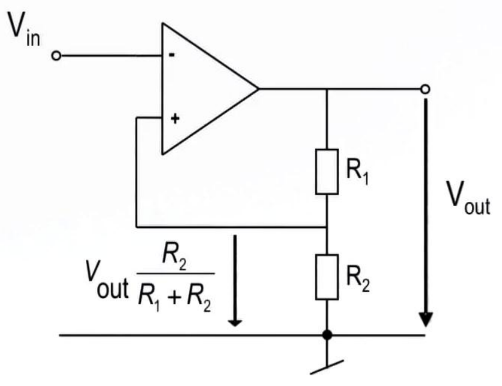


Video

Comparateur en réaction positive





Electronique I

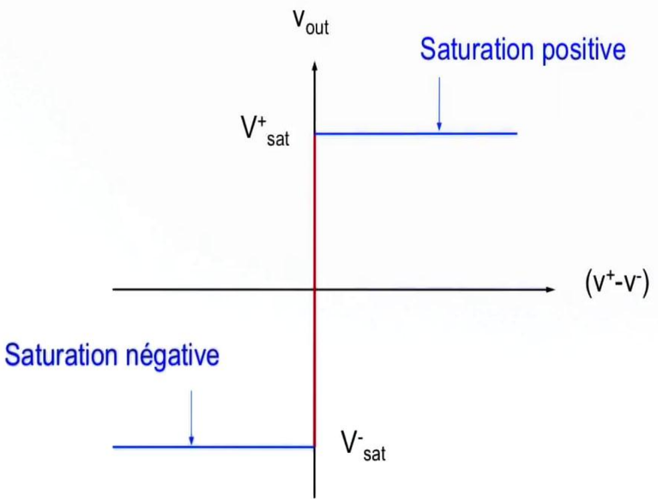
Now that we've seen the simple comparator, I would like to introduce what we call a positive reaction. We've talked about the negative reaction, the negative feedback, and here, we're going to talk about positive feedback. The comparator is here. We've added a resistant divisor at the output. And behaves like that. The resistant divisor will take the voltage Vout, and reduce it by multiplying it by R2/R1 + R2, and taking it to the positive terminal and add it to the input. We can come to a simple conclusion here to show how it would behave in this type of circuit as we did with the same circuit when it was in negative feedback. In negative feedback, remember what we did before. We called this a negative reaction when we had inverted the plus and the minus.

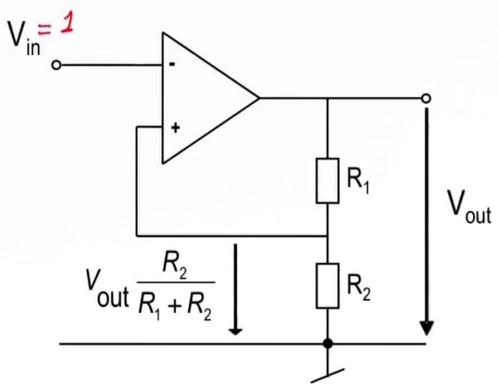
Notes

Summary

0m 03s

Comparateur en réaction positive





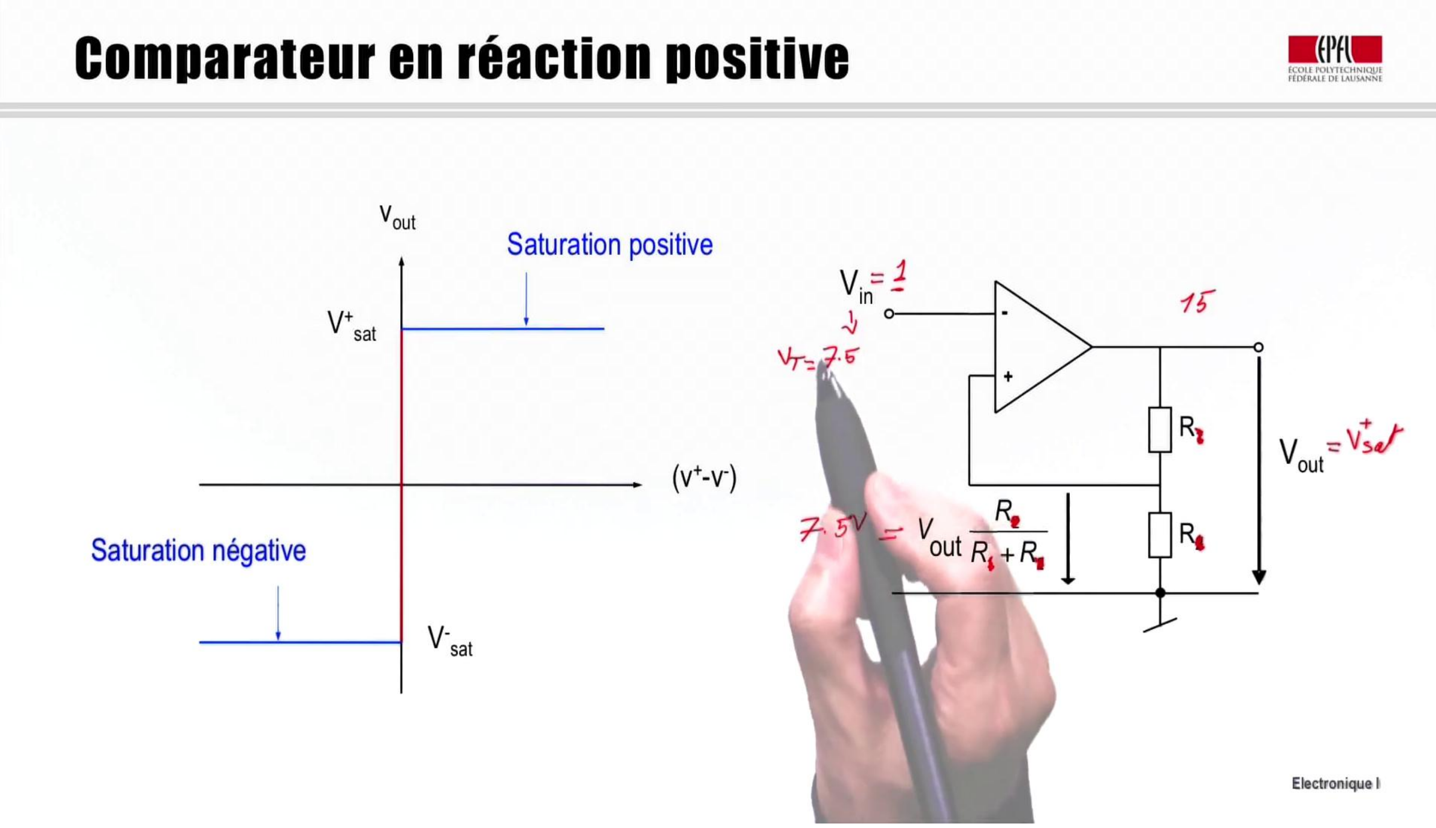
Electronique I

When the minus was here, we did the same operation, we have reduced the voltage output but we subtracted that to an op-amp and when we studied that, we said, that it was called a negative reaction because the relationship between Vin and Vout was linear and that our amplifier when in a negative reaction, meaning when the resistant divisor reduces the voltage, will take it to the negative terminal, it fixes our amplifier in the linear zone, it could also have one of the values that appear here and our amplifier won't move, it will stay here because there is a unique linear reaction between Vin and Vout that passes through the value of the resistance, or the resistances R1 et R2. So, whatever the values are here, the amp doesn't move, it stays here. Now, if you take the same circuit, and look at the circuit, but this time, we're going to put the reduced voltage output onto the positive terminal. Let's take an example. We've got a state at the input, Vin. We're going to use the example that Vin equals 1. Remember that Vout can only have one of two values, either saturation positive, or saturation negative. And at the moment when we plug in our comparator, we don't know if it's here, or here.

Notes

Summary

1m 10s



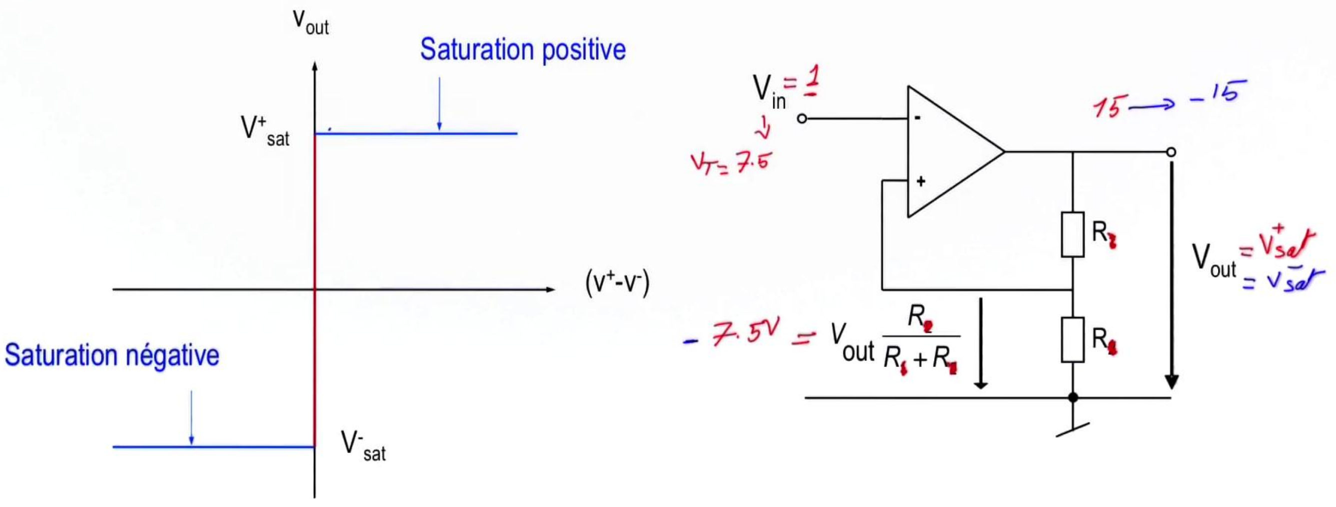
It could be either. Suppose that we find that Vout is equal to Vsat+. Here, if the power supply is 15V, so we have 15V, 15V, we'll take the same example as before, meaning that I've got R and R, the same value, therefore, if I've the same value, I'll find myself here with Vout times 1/2 so, I'll get 7.5V. 7.5 is much greater than 1V, so the plus is greater than the minus, so, nothing will happen, it will stay here. So, there's nothing that will trigger the comparator in this situation. The only thing that could trigger it is this. It's that if we find ourselves in this situation, and that Vin equalises with a transition voltage, that I'm going to call VT, that is equal to 7.5. So, we're going to change this voltage from 1 to 7.5 meaning that the voltage that you see on the V- compared to 7.5 that was on the V+. If the transition voltage equals, this one here equals this one here, it's as if we were saying that we've got to here. We've changed the voltage, and we've got a voltage transition, and here, my comparator, if by chance 7.5 is an epsilon greater than 7.5, that's it, the negative terminal is greater than the positive and it will trigger the comparator from 15v that will seek out the -15v, because here, the voltage at the negative terminal has gone over the positive value.

Notes

Summary

2m 37s

Comparateur en réaction positive



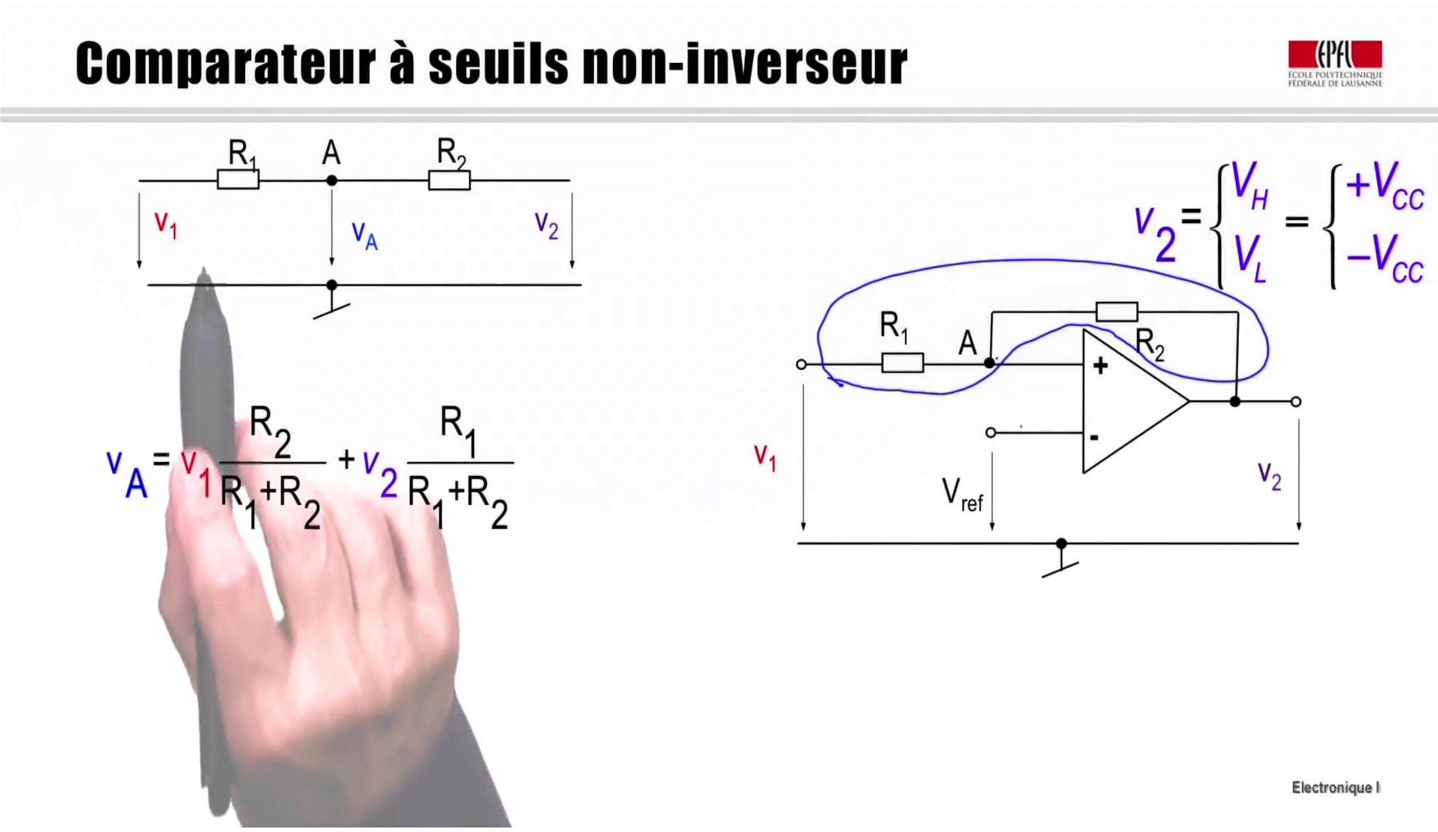
Electronique I

So, we're talking about the transition voltage that will trigger our comparator. And here, once it has switched over here, we can add a minus sign here, and we'll keep the same condition until, once more, the transition voltage goes over 7.5 because if the voltage here wasn't 7.5, nothing would happen, we'd be either here, or here. So, you'd still find yourselves with either Vsat+, or Vsat-. There isn't any other option for the voltage Vout.

Notes

Summary

4m 35s

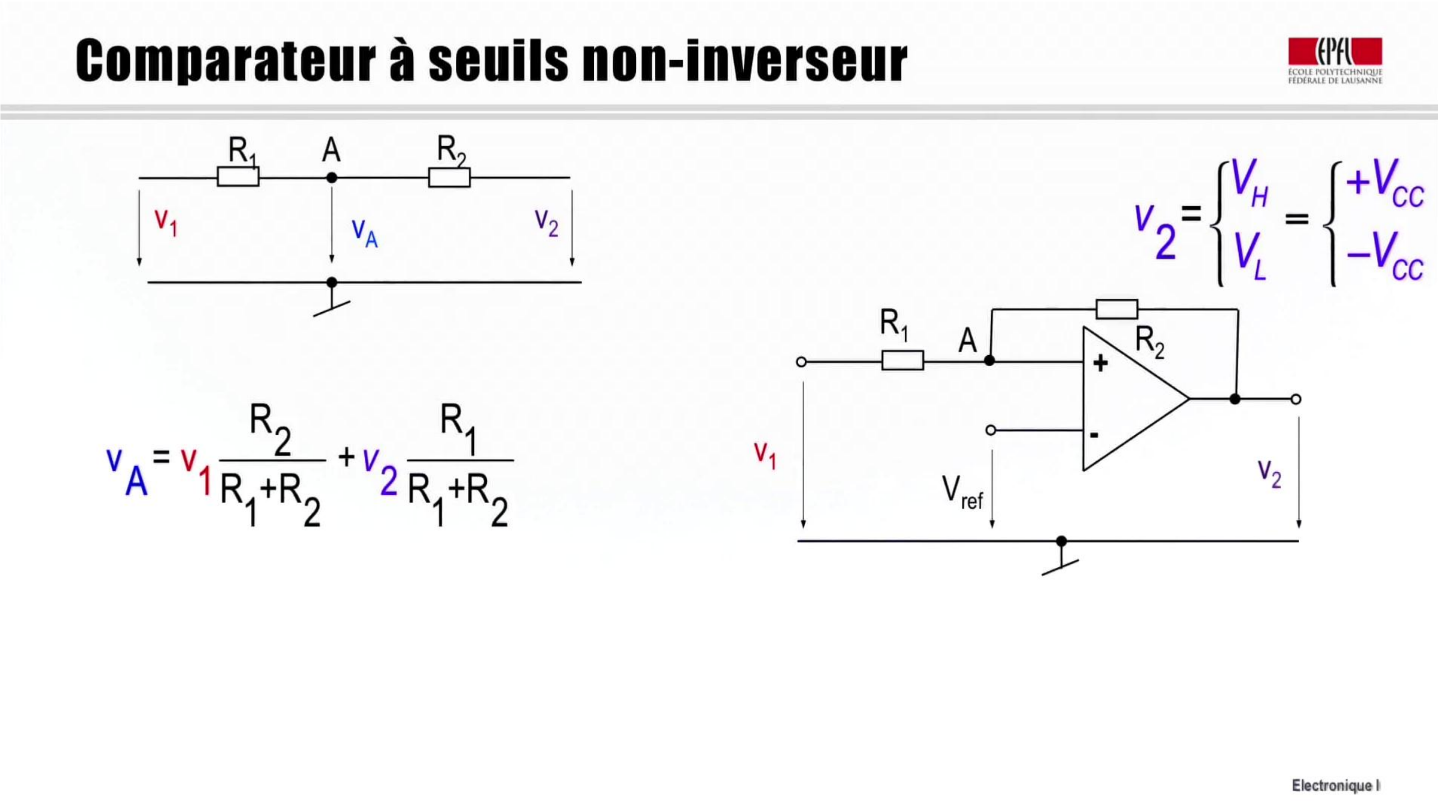


We're going to take our comparators again and we're going to add the circuit that you see around it. Meaning that, this time, we're going to do two things. We've added a resistant divisor R2 and R1, that has got an output voltage V2 and an input voltage V1 but we've also added a voltage reference, a DC value that we're going to put at the negative input. We're going to analyse what happens and you'll see, this is called non-inverting threshold comparator, or a Schmitt trigger, and we'll look at it in the following way. If you take the voltage V2, so V2, as always, can only be VH or VL. VH is Vsat+, VL for Vsat-, which are generally around about +Vcc, -Vcc, but these, these are values linked to comparators that we purchase and that we use, there are different values of VH and of VL found on the market and it depends on the power voltage. We've understood that the comparator will react by comparing V+ with V-. So now, I should look at what's happening in the node A, and I should compare it to what's happening in the node Vref. In order to understand what's going on in the node A, take this part of the circuit, and draw it on the side. So we know R1 and R2, the node A.

Notes

Summary

5m 11s



I would like to know what happens with the voltage vA compared to Vref to see if vA is greater than Vref. We've just seen that the comparator is going to go towards Vsat+, and the opposite, it's going towards Vsat-. So, I'd like to write this voltage VA. By analysing this part, the superposition principle allows us to read it in the following way. I'm going to start by... I'm going to start by cancelling V2. So, I short circuit V2 to the volume. and I express VA in function to V1. And it gives me this. So VA = V1 R2/R1 + R2, as long as V2 = 0. I'll do the same over this side here. I put V1 = 0 and I look at VA in function to V2 and I find this second part here, so I find that VA = V2 R1/R1 + R2. Coming from this postulate, I get the voltage VA that depends on V1 an on V2. I know V2. V2 can only be VH and VL. Now, what's happening to V1? V1, is the input voltage that the user plugs in, it's a voltage that varies over time, and the voltage VA will subject the variation of V1 depending on if V2 is VH or VL. So, we're going to decide to proceed in the following way.

Notes

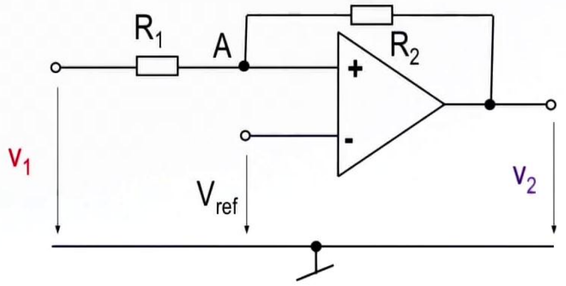
Summary

6m 49s

Comparateur à seuils non-inverseur

- Cas 1: Sortie initialement au niveau haut: $v_2 = V_H$
- Basculement vers le bas: $v_A = V_{ref}$ et $v_1 = V_{T1}$

$$v_A = v_1 \frac{R_2}{R_1+R_2} + v_2 \frac{R_1}{R_1+R_2}$$



Electronique I

We're going to take example 1 and consider that we're starting with V2 = VH. So, the output tension is equal to a voltage of Vsat+, VH. And we ask ourselves this: what is the value of V1 that will allow V2 to transit the value VH to the value VL? So we ask ourselves this question. When varying, it will cause A to vary, knowing that V2 is fixed. Watch, VA depends on V1 and V2 but V2 is fixed, there is only on value V1 for which this node here is equal to this node here, and straight away V2 will witch states, it will pass from one value to another, and in doing so, we want to see what the value is. We were at VH and we want to go towards a voltage VL. So, we're going to call the voltage V1 = VT1, the value for which, when V1 = VT1, V2 will switch from VH to VL. So, I'm going to replace V1 with VT1 because I'm asking myself what is the value of this V1, that I'm going to call VT1, for which the voltage V2, which is nothing more than equal to VH, will switch when VA = Vref. So I will get the switch.

Notes

Summary

8m 40s

Comparateur à seuils non-inverseur

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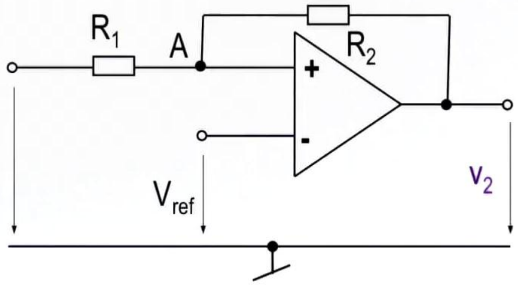
- Cas 1: Sortie initialement au niveau haut: $v_2 = V_H$
- Basculement vers le bas: $v_A = V_{ref}$ et $v_1 = V_{T1}$

$$v_A = v_1 \frac{R_2}{R_1+R_2} + v_2 \frac{R_1}{R_1+R_2}$$

$$V_{ref} = V_{T1} \frac{R_2}{R_1+R_2} + V_H \frac{R_1}{R_1+R_2}$$

V_{T1} ? $V_H \downarrow V_L$



Electronique I

And here's the reasoning that I've just done. I replaced V1 with VT1. I replaced V2 with VH. And I watch VA and I'm going to say that when VA = Vref, it's when this equals this, that I've the right to put this and this because it's at this point, that the switch will occur and that the famous VH will switch and become equal to VL. So I should say what is the value of VT1 for which VH will switch to VL.

Notes

Summary

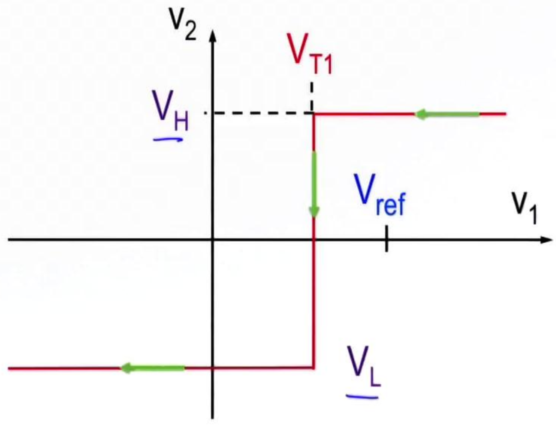
10m 26s

Comparateur à seuils non-inverseur

$$V_{T1} = V_{ref}\frac{R_1+R_2}{R_2} - V_H\frac{R_1}{R_2}$$

$$V'_{ref} = V_{ref}\frac{R_1+R_2}{R_2}$$

$$V_{T1} = V'_{ref} - V_H\frac{R_1}{R_2}$$



Electronique I

And the calculation comes from this analysis. I expressed i>VT1 and that gave me this relationship that I replaced by a simple reading, Vref R1 + R2/R2 by a value that I call V'ref. So that can give me this simple relationship that has the transition value VT1. And this transition value VT1 for which I've the transition that I see here. Meaning that we have the state V2 = VH here. We get to a value of VT1. Watch, V1 goes down, V2 remains equal to VH. Nothing happens. We get to a value of VT1. VT1 corresponds to the potential value VA = Vref. So immediately my comparator switches, and the output goes back to being equal to VL. So it's certain than V2 is either this, or this, nothing else. And we have lots of possible values for V1. And it's only one value that will push my resistant divisor to bring the potential to the node A so that it is equal to the potential at Vref and it's here that the comparator changes the output and switches from here to here.

Notes

Summary

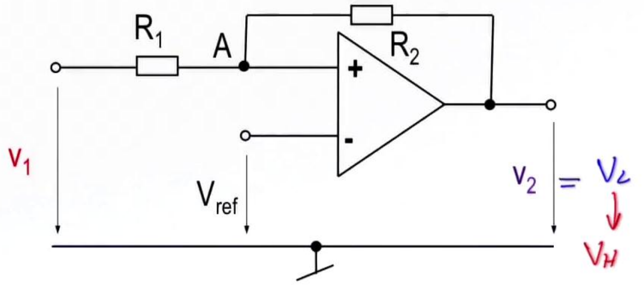
11m 07s

Comparateur à seuils non-inverseur

- Cas 2: Sortie initialement au niveau bas: $v_2 = V_L$
- Basculement vers le haut: $v_A = V_{ref}$ et $v_1 = V_{T2}$

$$v_A = v_1 \frac{R_2}{R_1+R_2} + v_2 \frac{R_1}{R_1+R_2}$$

$$V_A = V_{ref} = V_{T2} \frac{R_2}{R_1+R_2} + V_L \frac{R_1}{R_1+R_2}$$



Electronique I

We're going to look at the same circuit and this time we're going to look at when V2 = VL. We're at VL. We've got V2 = VL and we're going to see what happens when now there is a change from VL to VH. So I'd like to go backwards using the same relationships, but this time replacing V2 with VL, and I'm going to call V1 VT2, because it's a transition to another value. And I'm going to replace V2 with VL and I write here and say that when VA = Vref, this transition will take place and I can calculate the expression as I did earlier on.

Notes

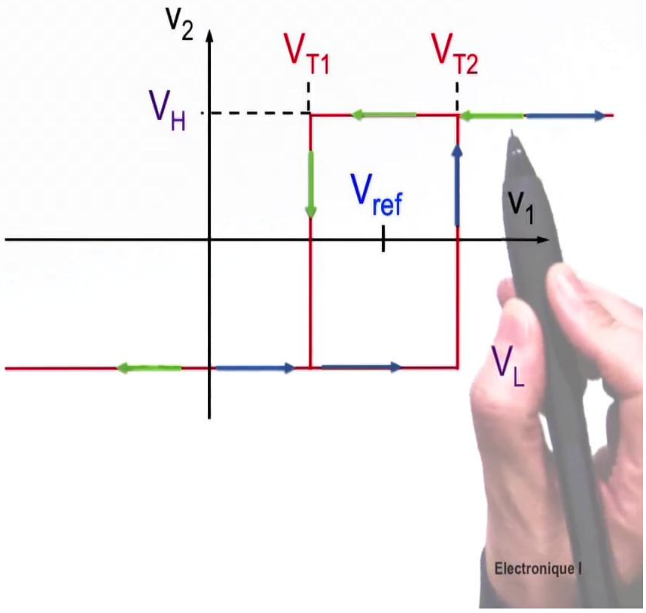
Summary

12m 43s

Comparateur à seuils non-inverseur

- Combinaison des deux cas

$$\Delta V_T = V_{T2} - V_{T1} = \left(V_H - V_L\right)\frac{R_1}{R_2}$$

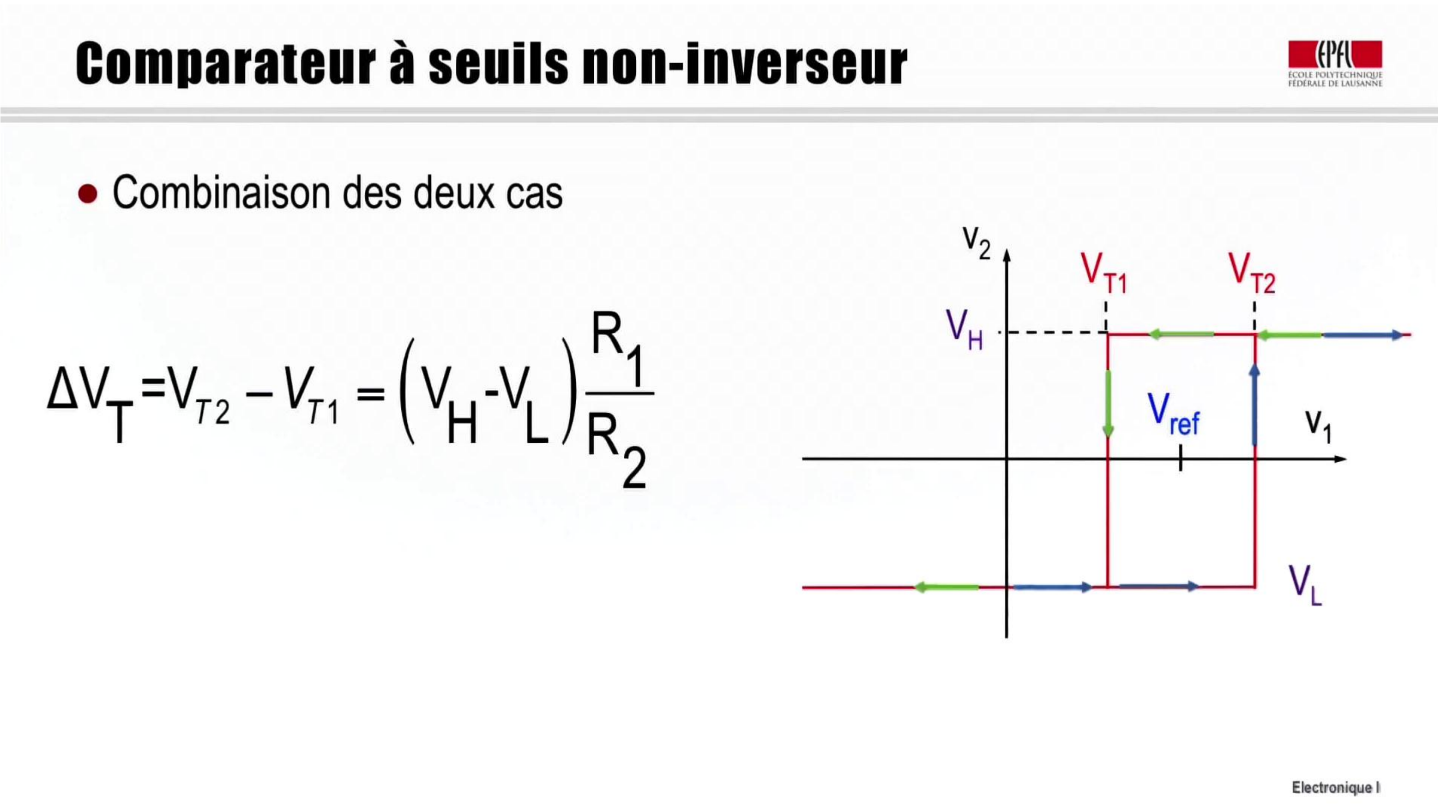


And here are the results once VT2 is expressed in function to our Vref and the negative voltage saturation of the comparator. In the same way, I replace the term that I've got here, to make it easier to read the formula, by a value that I call Vref, and I find a second voltage switch VT2 in order that my output voltage passed from VL à VH and that, this time, the transition goes up. So we increase V1, there are all the values, nothing happens to the output of the comparator, it's going to stay in negative saturation, it will arrive at a calculated value that corresponds to VT2, and here, the comparator will sense that the V+, the positive input, becomes greater than the negative input, and it can only compare the two, therefore it switches and will find itself with a positive voltage saturation that is VH. I'd like to accumulate the two curves from earlier on, and we get this type of curve. In both cases, when the output was VH, and we have a transition to VL, and we call the voltage V1 = VT1 for which there was this transition, and we ended up with VL, and this time we increased V1 and look what happens. We found ourselves at VH and we started to reduce V1. V1 is going down.

Notes

Summary

13m 39s



We went via here VT2, nothing happened. We got VT1. When we reached VT1, the comparator switched over. It had VL. Now, we can continue to decrease V1, nothing happens, it stays at VL. If we go in the opposite direction, and in the opposite direction, we are now increasing V1, we are going in the direction here, and we arrive here V1 is VT1, nothing happens. We need to keep going until we reach here, around the value VT2 and, voila, the comparator switches to VT2. So, we find ourselves with a schema that has two possible outcomes, one that switcher to VH, and one that switches to VL, but they aren't found in the same place. The simple comparator has a unique threshold value at which it switches each time. This type of comparator has two threshold values, and between the two, it depends on which direction it goes, if it passes the first value, it will switch to the second, if it passes in this direction, it passes to the first value and switches to the second. We call this shape a hysteresis loop, and we call it a non-inverting hysteresis threshold comparator And why do we call in "non-inverting"? The term "non-inverting" comes from the fact that when V1 increases, at a given moment, the output will also increase from VL à VH following it for a value.

Notes

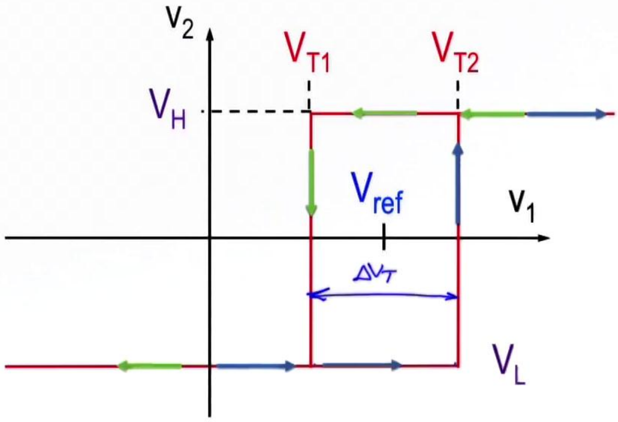
Summary

15m 21s

Comparateur à seuils non-inverseur

- Combinaison des deux cas

$$\Delta V_T = V_{T2} - V_{T1} = \left(V_H - V_L\right)\frac{R_1}{R_2}$$



Electronique I

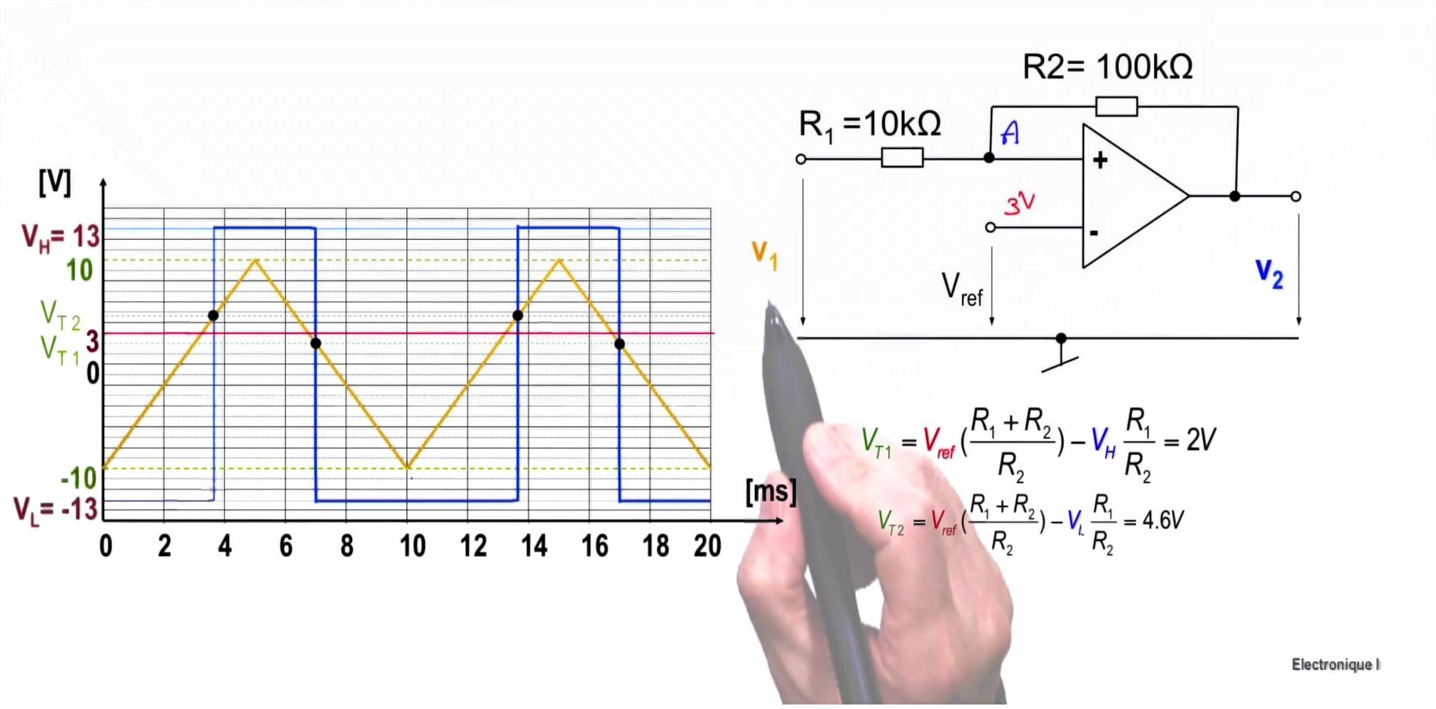
The same when V1 decreases, we arrive at a value where the output voltage follows in a binary action, where it was at, it will come to VL. So, if you make the width of this hysteresis, this famous ΔVT, that is the difference between VT1 and VT2, you'll find that ΔVT is proportional to the resistance relationship that you will have added, R1/R2, that multiplies the difference of the voltage saturation of your comparator. And you'll see now what happens with your voltage reference, if you move this point here, you'll see that the whole window will follow in function to the value of Vref. The width of your hysteresis depends therefore on the resistance relationship and voltage saturation, however, the reference value that you added, will be centred and will move your window from one place to another, so you can compare that in function to this Vref. We're talking here about a memory effect. We say that your hysteresis comparator retains the information here. So here, it passed, it didn't switch, it continued to have a memory effect, and it switched again further on, the same in this direction, so there is a memory effect. It remembers the state in which it was before. It keeps it for longer before switching to another state, it's the same in both directions.

Notes

Summary

17m 09s

TP: Comparateur à seuils non-inverseur



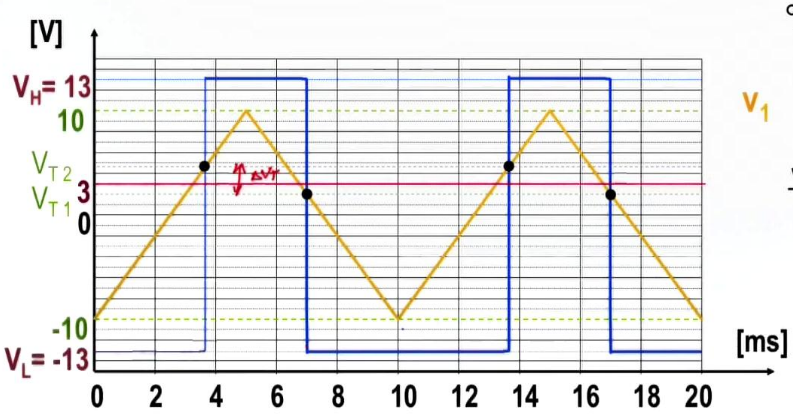
I suggest that you test it for yourselves in a laboratory. So, take a comparator, and plug in a resistance R2 = 100kΩ, a resistance R1 = 10kΩ, take note of the relationships that we calculated earlier on, to make a numerical calculation in function to the resistance values that I gave you, taking into account the VH and VL of a comparator on the market. There are different types of these comparators. Generally, the voltage saturations are symmetrical. Not always, we sometimes find asymmetry in some of these values, but here, I've chosen a comparator that has a voltage saturation of 13V for VH, so Vsat+ = 13 and Vsat- = -13. And at the same time, I ask you to take a voltage V1 and plug in a triangular signal that has a peak value equal to +10V and -10V, and plug it in here and put a continuous voltage Vref = 3V. So to compare this node A, that we talked about earlier on, to the value that we find here that equals 3V, so we put 3V here. We're going to arrive for sure at a given state. V1 will vary depending on this curve. While V1 varies, this is fixed, VA will follow the variation of V1.

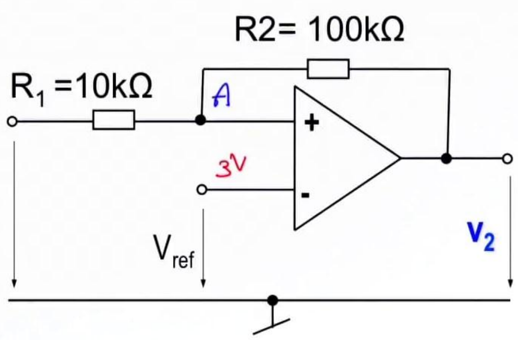
Notes

Summary

18m 48s

TP: Comparateur à seuils non-inverseur





$$V_{T1} = V_{ref}\left(\frac{R_1+R_2}{R_2}\right) - V_H\frac{R_1}{R_2} = 2V$$

$$V_{T2} = V_{ref}\left(\frac{R_1+R_2}{R_2}\right) - V_L\frac{R_1}{R_2} = 4.6V$$

Electronique I

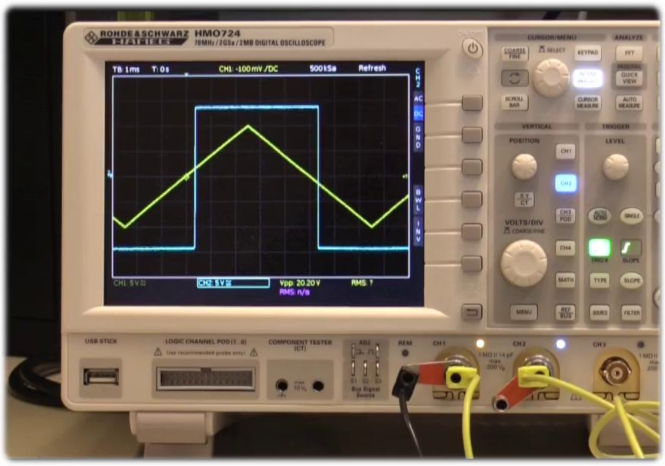
At a given moment, VA will equal 3V and your voltage will switch in one direction, and then, switch back to the other direction depending on VT1 and VT2 that come from the analytic relationships that we've already calculated. And here's what happens. You will have a voltage VT1, that's here, that equals 2V. You will have a voltage VT2 that equals 4.6V and you will have the comparison between your triangular signal and these two voltage levels that appear with the output of your V2. Therefore V2, is either at 13V when we are over VT2, and we are at -13V when we are below VT1. And so we have the ΔVT that appears here. This is our ΔVT that is found between VT2 - VT1, so the sum of 2.6V between the two and that will be centred in relationship to the 3v, that we can, by changing the 3V, move up or down, which is what we'll see during the experiment once we have plugged in this type of circuit to a oscilloscope.

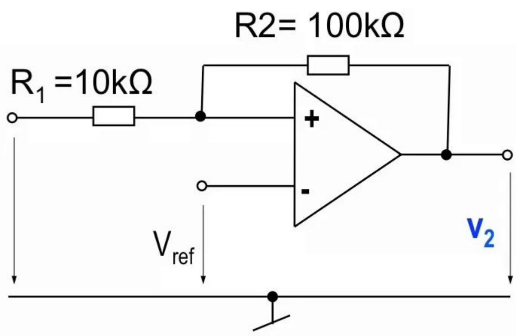
Notes

Summary

20m 21s

TP: Comparateur à seuils non-inverseur





$$V_{T1} = V_{ref}\left(\frac{R_1+R_2}{R_2}\right) - V_H \frac{R_1}{R_2} = 2V$$

$$V_{T2} = V_{ref}\left(\frac{R_1+R_2}{R_2}\right) - V_L \frac{R_1}{R_2} = 4.6V$$

$$\Delta V_T = V_{T2} - V_{T1} = \left(V_H - V_L\right)\frac{R_1}{R_2}$$

Electronique I

So here's our experiment, now to the laboratory, so our comparator, that has to voltage switches: VT1, that allows the output to pass to Vsat+, VT2, that allows the output to descend to Vsat-. And now, this output state that you see here, whether it be at Vsat+ or Vsat-, is managed by a comparison with the triangular signal. We are changing the reference voltage and you are learning how we move the hysteresis window on the input of this comparator. Here, the width of the window stays the same, however, moving it means we can increase or increase the states Vsat+ and Vsat-.

Notes

Summary

21m 48s