ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Comparateur

5.3 Amplificateur opérationnel en réaction positive

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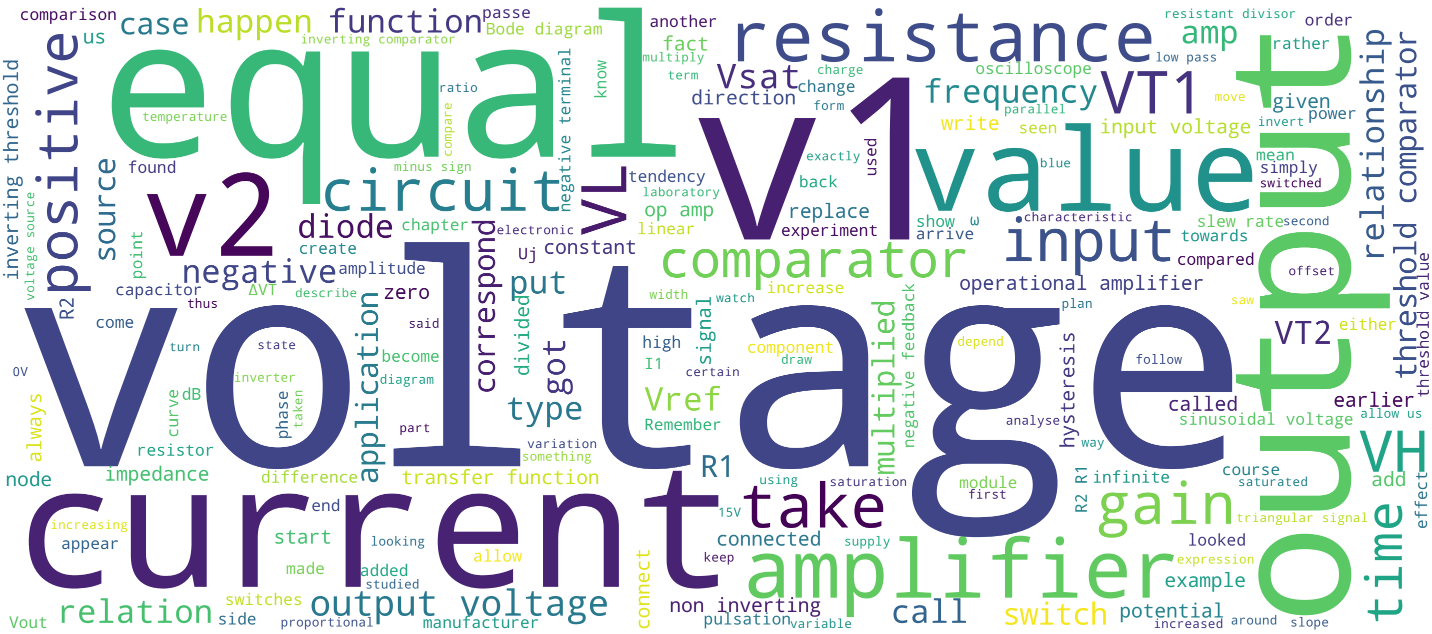
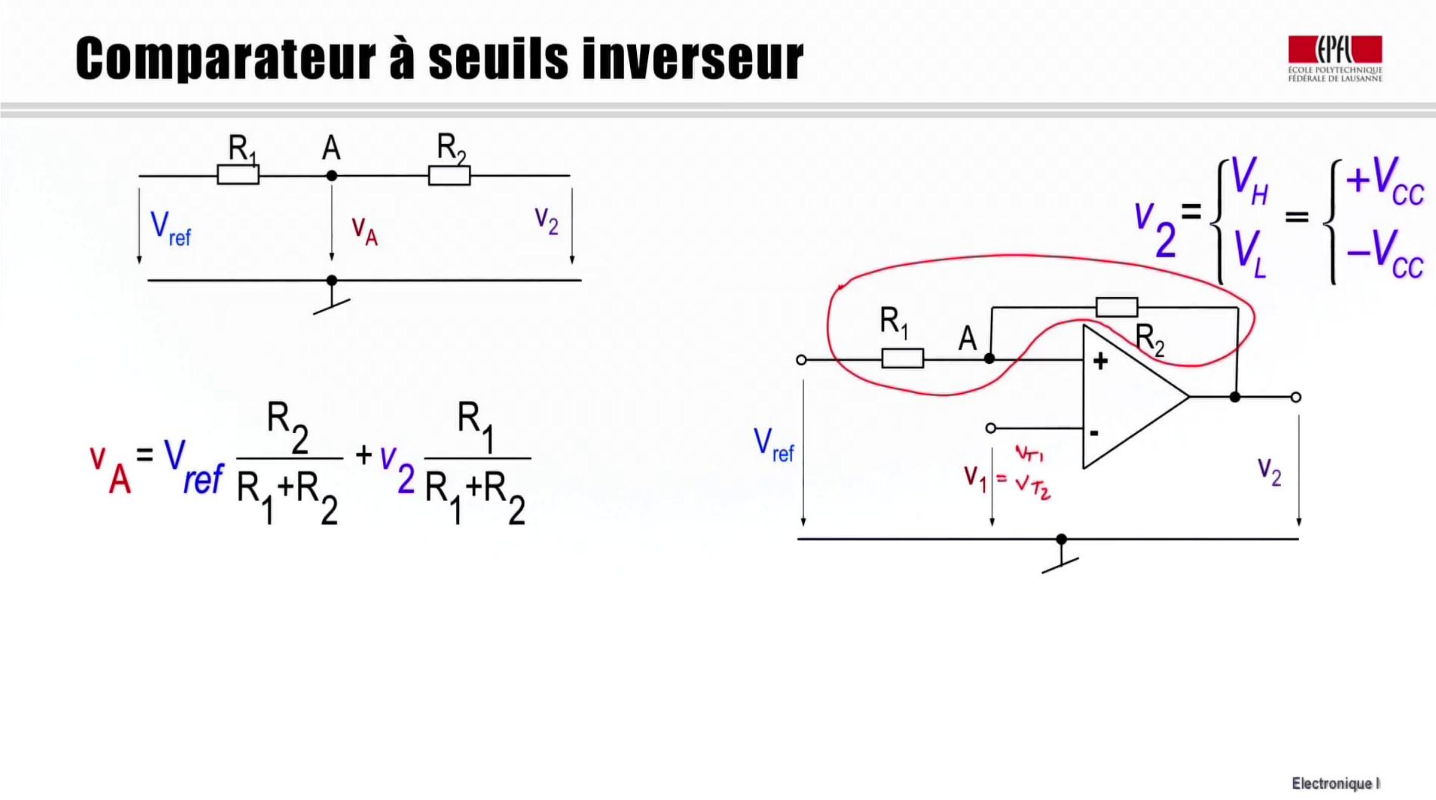


Video

EPFL



Now we're going to take a look at the inverting threshold comparator. So we've just looked at the non-inverting comparator, the Non-inverting Schmitt Trigger has been studied. So I'm going to quickly go over the inverting threshold comparator because the principles are the same. I take my comparator and invert *Vref* and *v1*. Remember that in the non-inverting application, *v1* was connected here, *Vref* was connected here. This time, I connect *v1* to the negative terminal and I put in a constant voltage *Vref* on this resistance *R1* and again, I isolate the resistant divisor part, here, and I watch what is happening to the potential *vA* because by comparing *vA* to *v1*, I will know when *v2* changes from *VL* to *VH* or from *VH* to *VL*. as usual, *v2* can only have one of two values. *vA* in relation to *v1*, we'll call *VT1* and *VT2*. There are two values for *v1* that allow *v2* to change from one to the other and these two values are either *VT1*, or *VT2*. So, we'll write down again the extracted expression in relation to the resistant divisor by superposition.

Notes

Summary

0m 04s

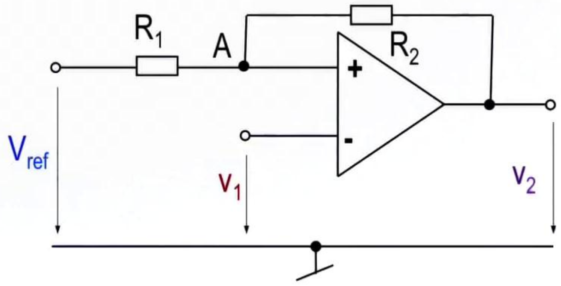
Comparateur à seuils inverseur

- Cas 1: Sortie initialement au niveau haut: $v_2 = V_H$
- Basculement vers le bas:

  $v_1 = V_{T1} = v_A$

$$v_A = v_{ref}\frac{R_2}{R_1+R_2} + v_2\frac{R_1}{R_1+R_2}$$

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



Electronique I

We'll take both cases. To start with, we put one times *v2* equals à *VH*. We're going to say that *v1* equals *VT1*, the first transition value for the output voltage. and we're going to replace *vA* therefore with *VT1* and *v2* by *VH* and we find a relationship that controls the behaviour of what passes through the comparator and that will give us when the value *v1* for *VT1*, that I'll call *VT1*, will switch the state from *VH* to *VL*.

Notes

Summary

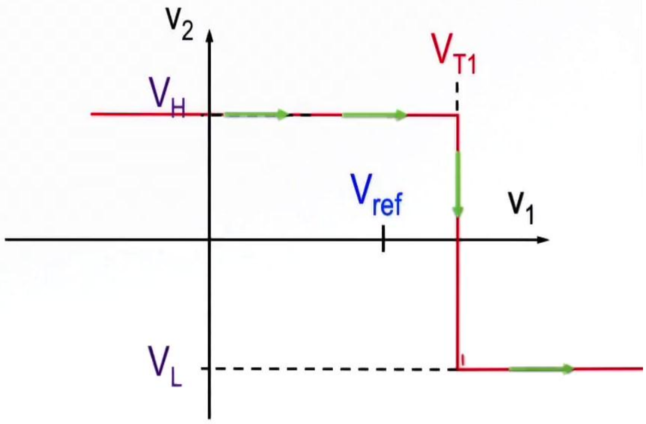
1m 32s

Comparateur à seuils 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 here's the expression written differently, exactly like we did before. So *VT1* is equal to *V'ref*, with *V'ref* being simply this term here, that I simplify just so I don't repeat myself, with *Vref* multiplied by the resistance relationship. And I see here that when *v1* increases, if the output is at *VH*, I will need to go up to *VT1* before the output switched to *VL*. So there is the voltage *VT1* that switched from *VH* to *VL* once I go over the value r*VT1* that I've given to *v1*.

Notes

Summary

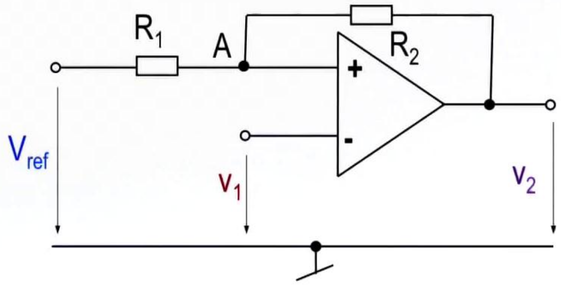
2m 11s

Comparateur à seuils inverseur

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

$$v_A = v_{ref}\frac{R_2}{R_1+R_2} + v_2\frac{R_1}{R_1+R_2}$$

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



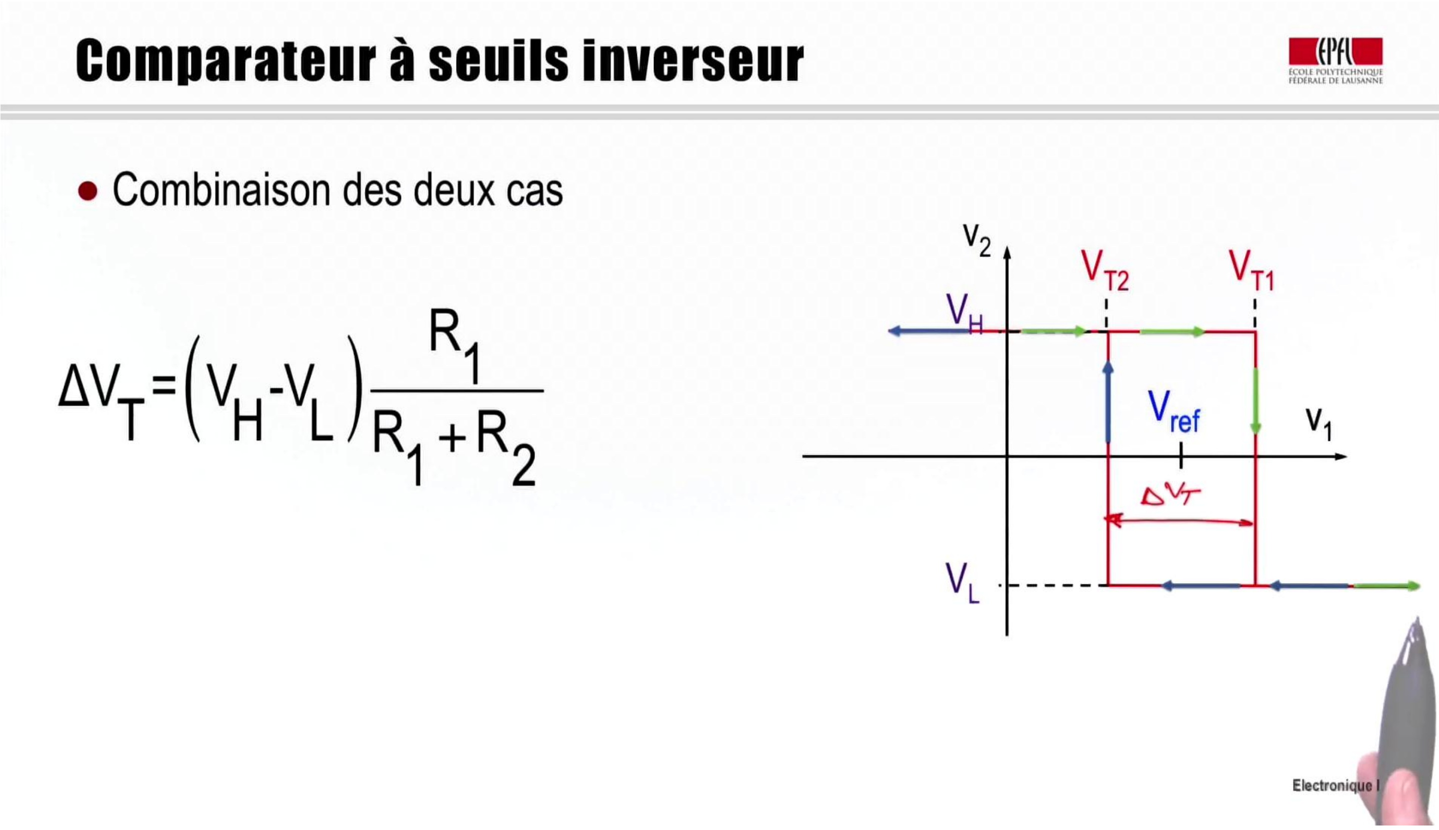
Electronique I

I'm going to look at when the output is at *VL*. So, we've just looked at the case where *v2* is equal to *VH*, now we're going to look at the case where *v2* is equal to *VL*. I replace *v2* with *VL*. I replace *vA* by the voltage value *VT2* that I should have in order for it to switch. And I write down the relationship in a simple way.

Notes

Summary

2m 56s



It comes out like that I have simplified like this and that I describe like this. And here, we've got the same story. I need to reduce the value of *v1*, the voltage output is *VL*, so negative saturation. I'm now reducing the value of *v1*. I'm lowering the value. I arrive at a certain threshold, a threshold value and voila, the output voltage switches to *VH* and I go from *VL* up until *VH* for the voltage switch *VT2* in relation to the input voltage *v1*. And here is the accumulation of both cases and I find myself with this story of hysteresis that we talked about earlier on that has the width *ΔVT*. So this width from here to here is always equal to *ΔVT*. But we call it an inverting threshold comparator. The word "inverting" comes from the fact that in increasing the value of *v1*, I find myself with *VH*. The output *v2* is at *VH*. I was increasing it up to *VT1* and there, the output switched to a lower value. So, the tendency on *v1* being to increase, the tendency on *v2* is to switch from high to low.

Notes

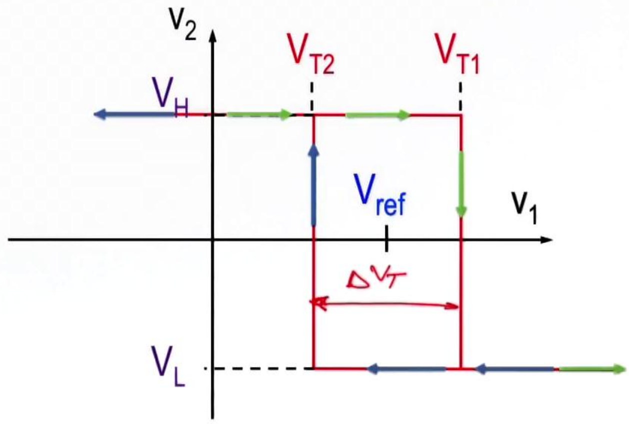
Summary

3m 27s

Comparateur à seuils inverseur

- Combinaison des deux cas

$$\Delta V_T = (V_H - V_L)\frac{R_1}{R_1 + R_2}$$



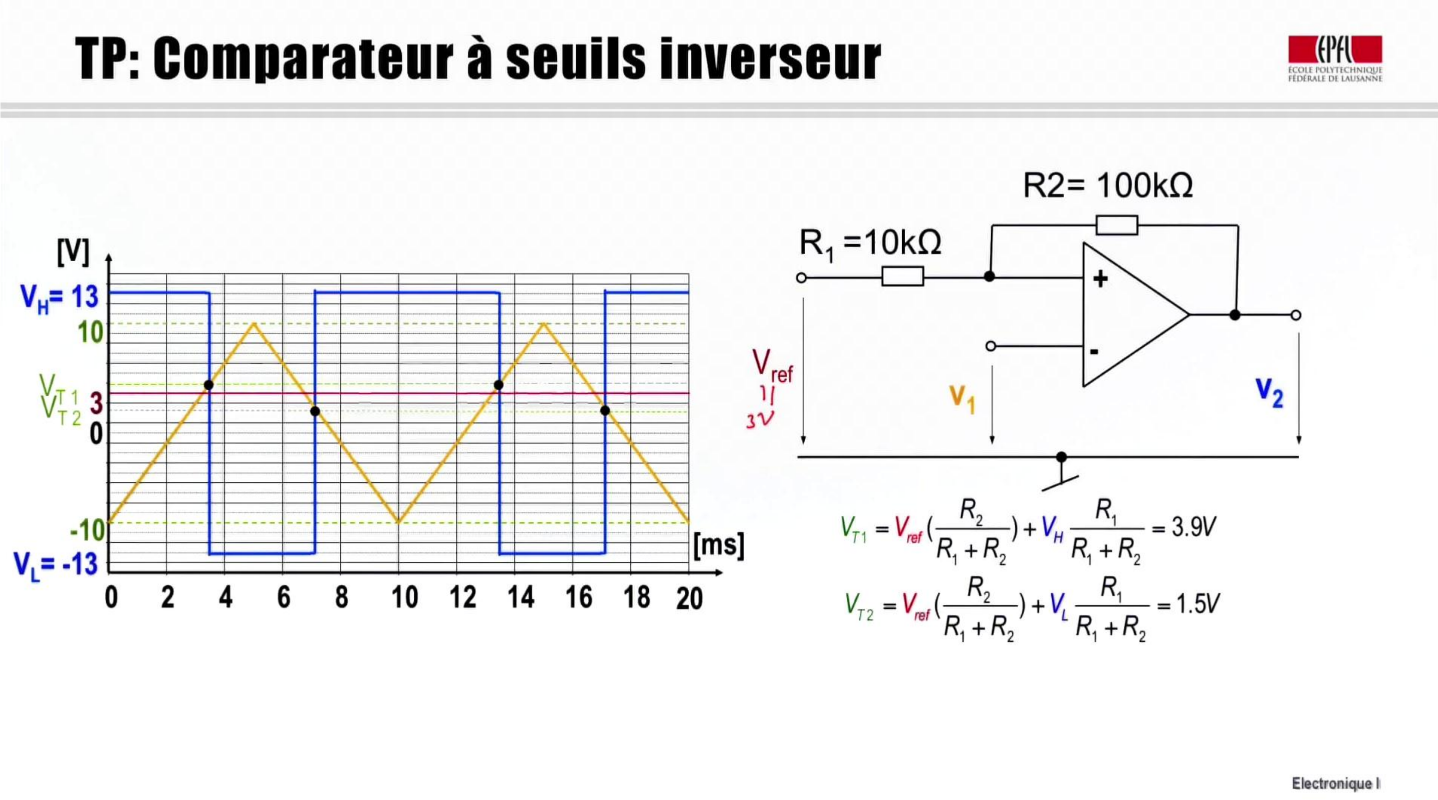
Electronique I

And the same when *v1* decreases, the tendency on *v1* is to decrease and the tendency on *v2* is to afterwards switch to the opposite direction, meaning that *VL* switches to *VH*. That's why it's called an inverting threshold comparator. And again, the width of our hysteresis depends on the resistance relationship and that the reference voltage allows me to move this on the dial or rather move it to remain centred in relation to the value *Vref*.

Notes

Summary

5m 04s



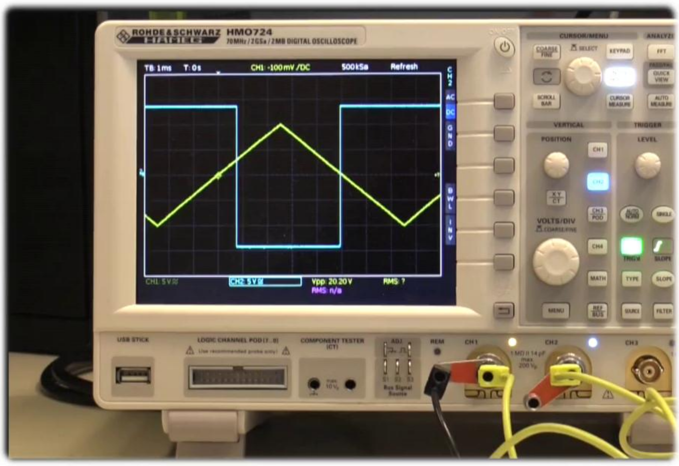
To see this type of phenomenon in the laboratory, the experiment is always the same. As we did earlier on, we take our TP with the comparator, putting a resistance of 100kΩ and another of 1kΩ. If you keep to the same experiment as earlier on, you just need to invert *Vref* and *v1* and calculate the two voltage thresholds and you'll get 3.9 for *VT1* and *VT2* is equal to 1.5V. And you'll find, the same, we put here a voltage *Vref* equal to 3V. And we put a triangular signal with a peak value of +/-10V. And we saw the comparison in relation to *VT1* and *VT2*. Here, we need that the voltage *v1* becomes greater than *VT1* in order for the output voltage to switch from *VH* to *VL*. And again, it's the opposite so we see the effect inverted. Here, the voltage has increased and the output has decreased. Here, the voltage has decreased and the output has increased, has passed to *VH*. And this same TP, we're going to connect and look at on an oscilloscope.

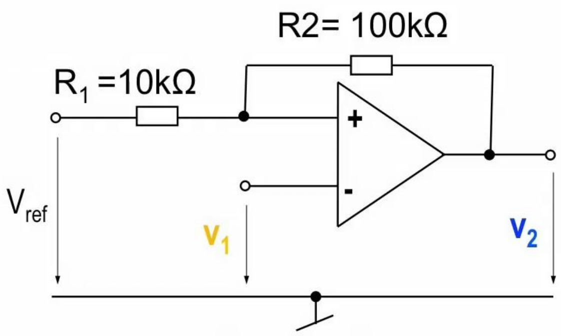
Notes

Summary

5m 41s

TP: Comparateur à seuils inverseur





$$V_{T1} = V_{ref}\left(\frac{R_2}{R_1+R_2}\right) + V_H \frac{R_1}{R_1+R_2} = 3.9V$$

$$V_{T2} = V_{ref}\left(\frac{R_2}{R_1+R_2}\right) + V_L \frac{R_1}{R_1+R_2} = 1.5V$$

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

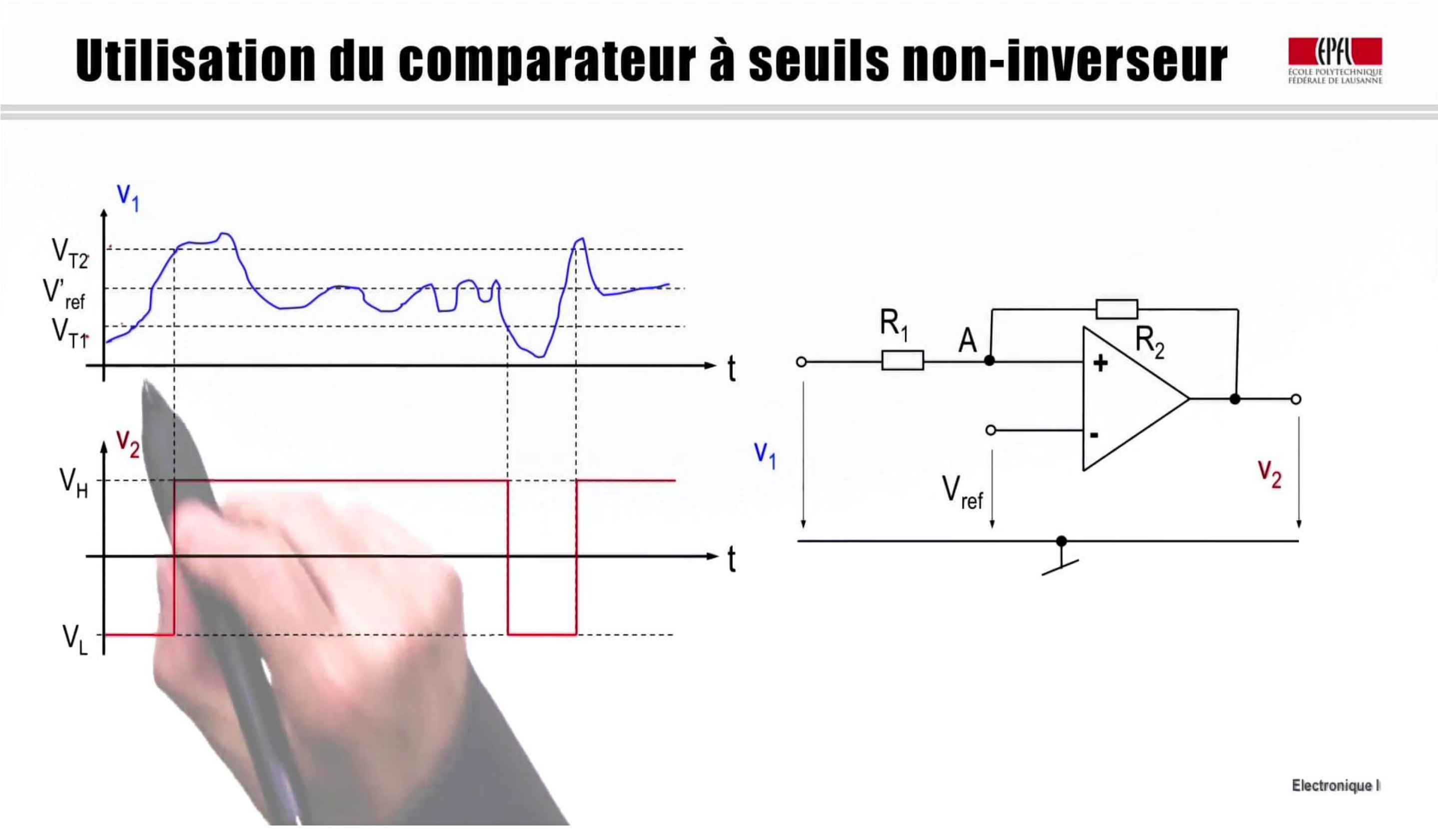
Electronique I

And here is our inverting comparator that is now connected. We've got the triangular signal and we can see the switching threshold that will switch the output voltage to *Vsat-*. And on the other side, when the output switches to *Vsat+* we can see very clearly that it's an inverter because when the voltage goes over a certain value, the output reduces. And now, we're modifying the reference value. So we see that *ΔVT* is constant, but we are changing the impulsion width at the output of our threshold comparator.

Notes

Summary

7m 07s

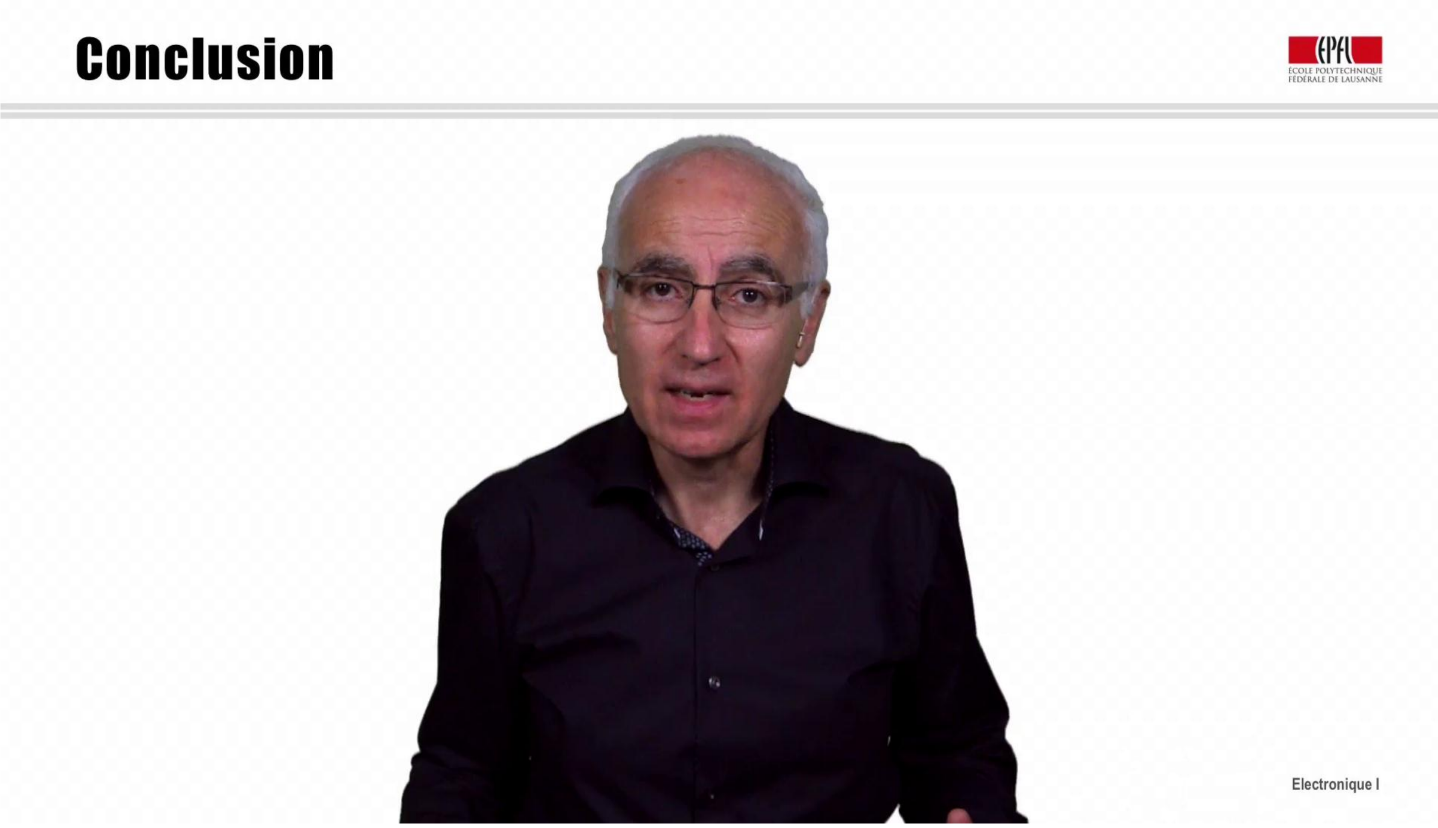


I'd like to conclude this lesson with by comparing two applications of a non-inverting threshold comparator and the application of an inverting threshold comparator. I think we can use the example of the temperature experiment and say that earlier on, when we made a comparison with the resistance *RCTN*, we simply demonstrated that there was only one threshold value. When we create two threshold values, any comparison, or any interior fluctuation of this window *VT1* to *VT2* is absorbed by the hysteresis. So, if we had compared to one reference threshold value, each time that we went over the reference value, the output would have switched. Now we've got this hysteresis which shows that all variation needs to be over *VT2* or below *VT1* in order to correspond to an output state. So, if you use a thermostat that contains a hysteresis and you compare the thresholds that you have set up, let’s say from 19° to 21°, your thermostat won't turn on the heating controls until the temperature goes over 21° to stop the heating and it needs to drop below 19° before the heating will turn back on. Any fluctuation between the two, is in fact the memory effect of the hysteresis.

Notes

Summary

7m 49s



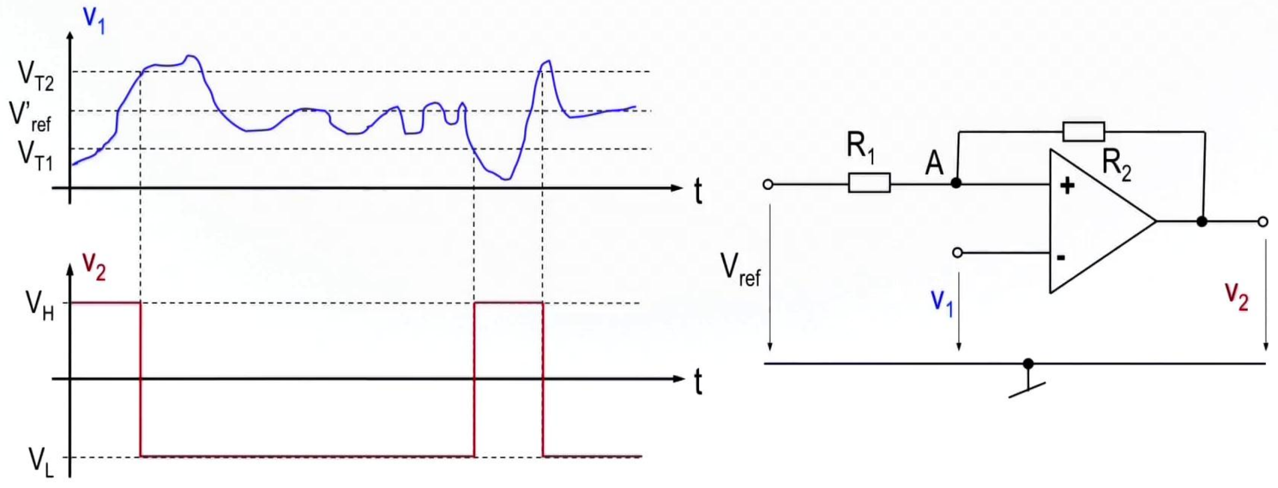
So a decision has to be made here. And a decision is to be made here, or maybe here. And that's it. It's the same for the other one where we find a reversed logic. So, I'll take the same curves as earlier on and we find that there's a reverse logic. And this logic, put simply, it’s the tri-logic circuits that come afterwards and allow us to say how to treat a signal, to turn something off, to turn it back on if we speak about temperature. The state needs to be read -*VL*, or rather the value *Vsat*-, and *Vsat*+ with the decision circuits necessary for this type of control box. And so, we've come to the end of the chapter on comparators. We looked at the simple comparator, the inverting threshold comparator, the non-inverting comparator. It's a chapter that is relatively easy to understand because all that is needed, is a conversation between analog data at the input that becomes digital at the output. And with that, I'd like to add one more thing: using the comparator, using the comparator circuit, it's the interface between the analog world and the digital world. And in practice, the comparator has at its input, as does an op-amp, a positive and a negative terminal.

Notes

Summary

9m 30s

Utilisation du comparateur à seuils inverseur



Electronique I

And at the output, there is an output that could be binary. So it's a logical circuit. And quite often, it's preceded by a simple inverter. If there is no simple inverter, I'm talking about a logical inverter that's found inside and that plays the role of the output stage of a comparator. So, the input of a comparator is analog. The output of a comparator is fundamentally logic because once we've taken the output that is binary, well, we just have to treat it as a binary signal and that leads us on to tri-digital circuits.

Notes

Summary

11m 04s