ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Applications des Amplificateurs opérationnels

7.3 Applications linéaires

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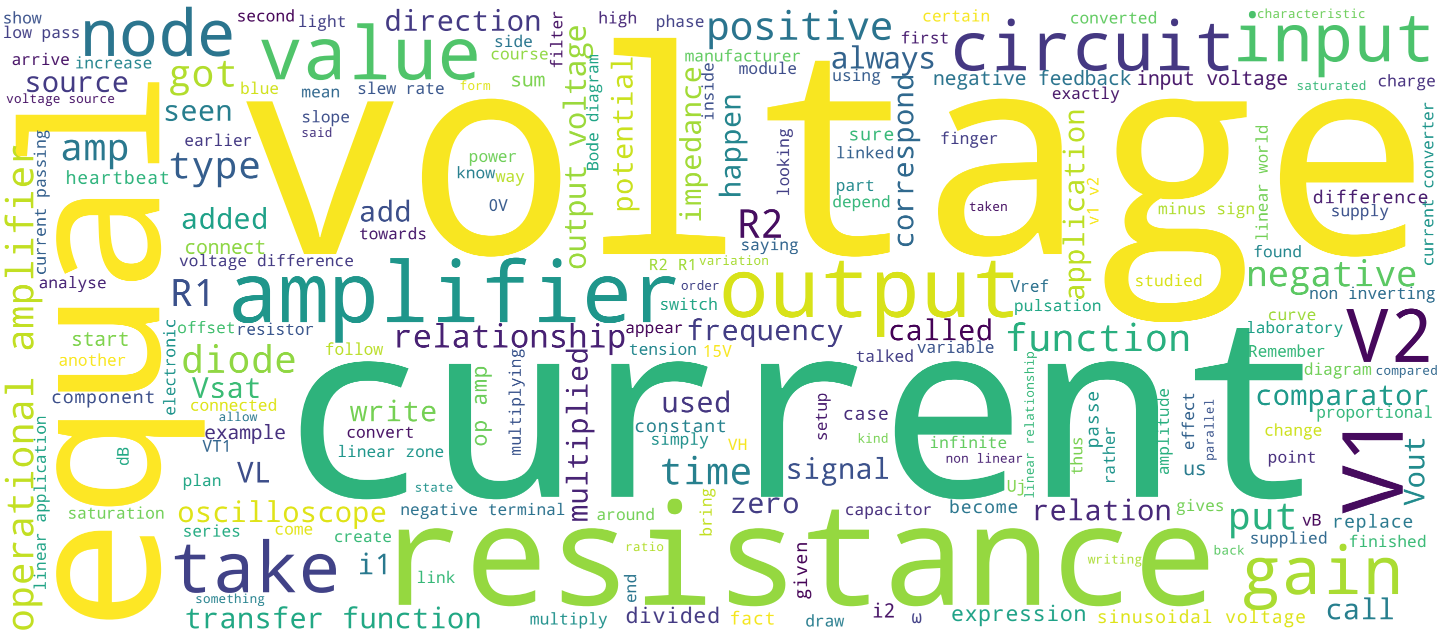
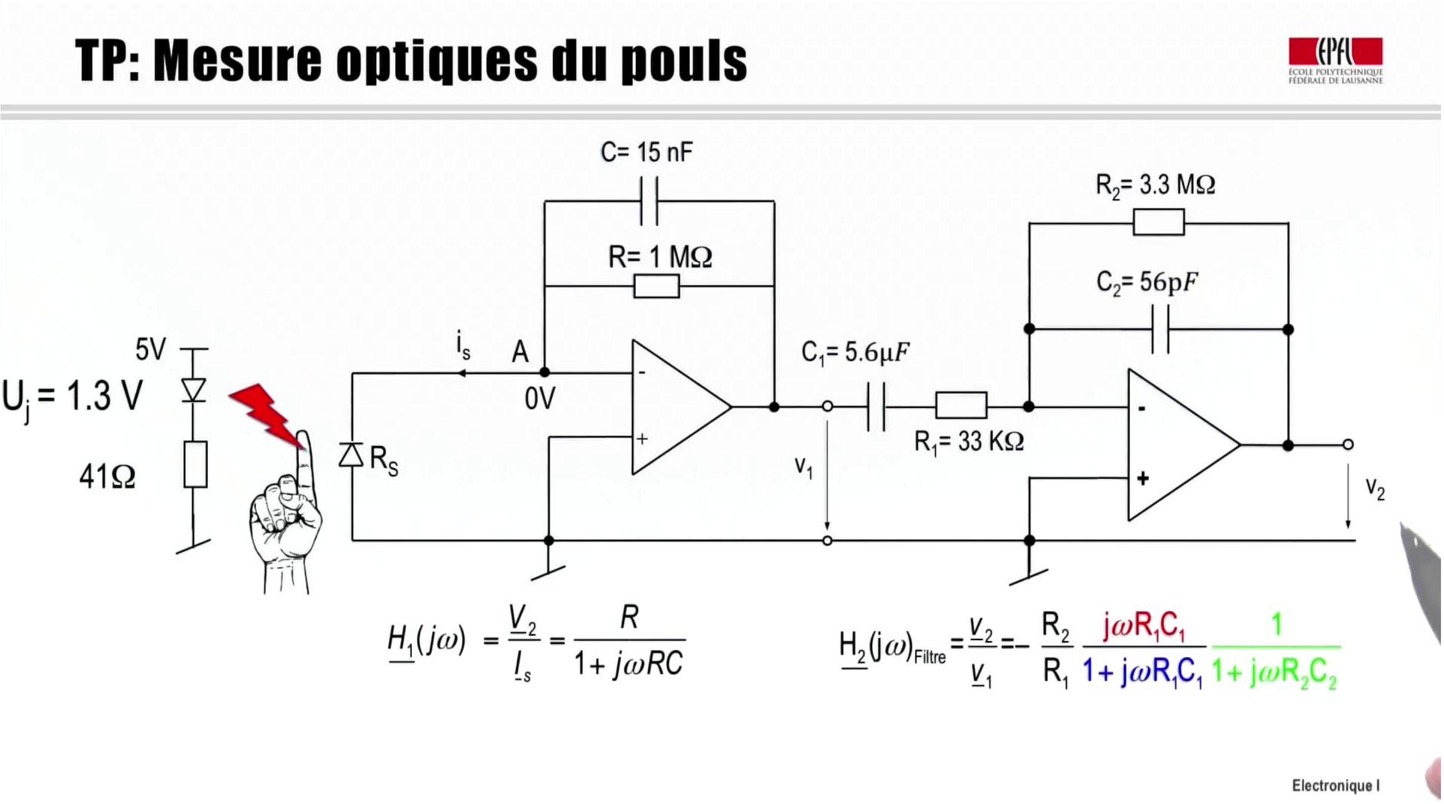


EPFL

Video

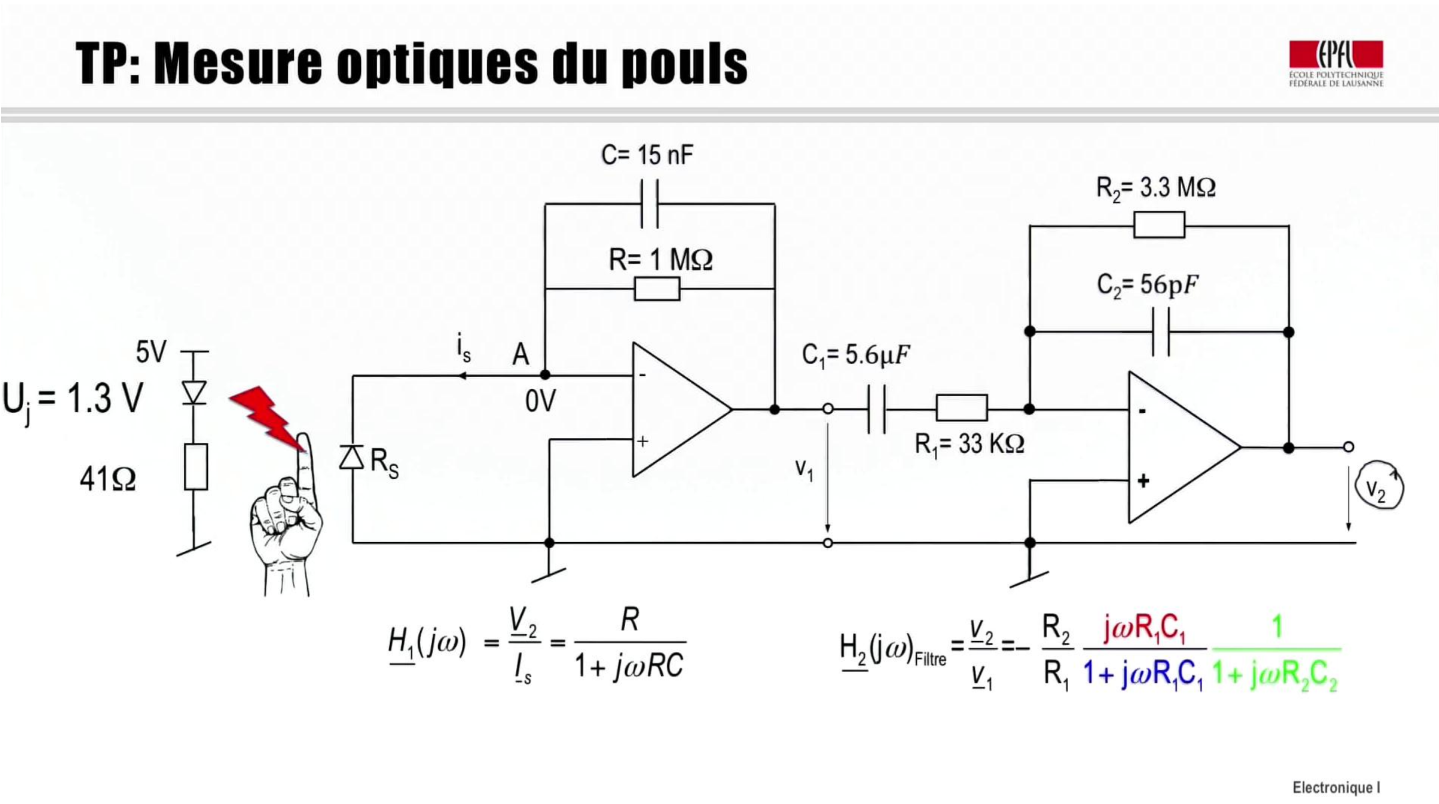


Earlier on, we studied this circuit. We called it a *distance sensor*, we called it a *voltage-current converter* ; we sent out an optical signal, we received it onto this diode, we converted it into current. Here, the photons are converted into current. The current is transformed into voltage by this impedance. The filter added by the resistance *R C* has cut off a frequency component. And here, please take this plan here, and go into a laboratory and wire it up. And you'll see, the same circuit as earlier on, has been used to detect an object that passes in front of an optical barrier, if you put your finger here, and your finger receives an optical signal through it, and the blood flowing through your body will modulate this light before reaching this diode here, the current that you see here corresponds to the modulation of the blood flow in your finger. And this current here becomes voltage, through this impendence and mainly through this resistance. And when this arrives at a filter, this frequency component will also be removed. So you'll get an output tension *v2*; this voltage *v2* is a component in which the input signal was a flux variation...

Notes

Summary

0m 04s

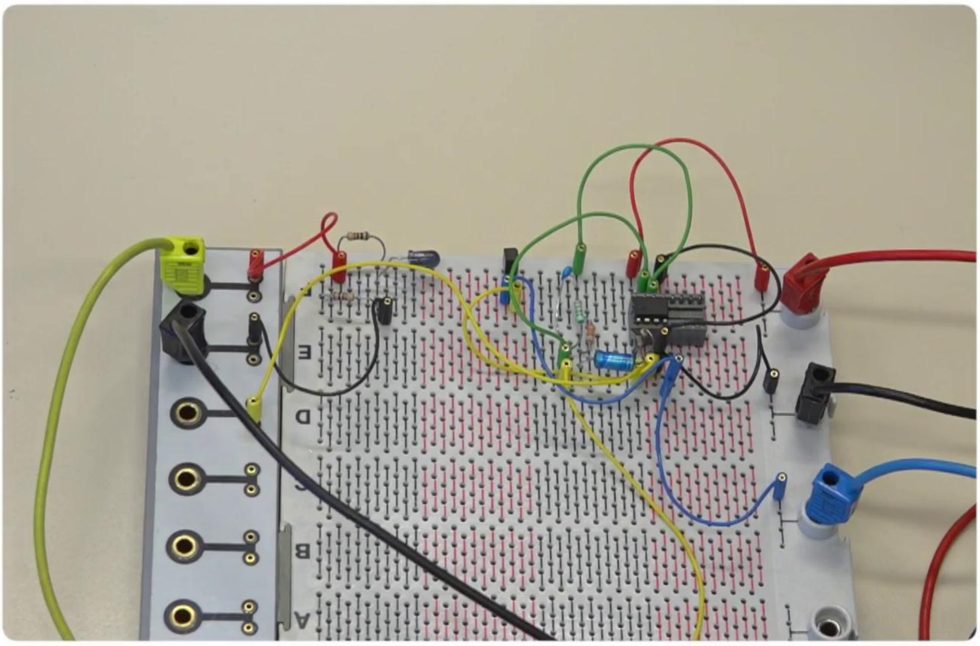


the blood in your veins converted into current modulations, converted into voltage brought to a tension that you can read on the oscilloscope and you'll see that the beating of your heart appears on the oscilloscope. The transfer functions and the transresistance that is here, is this here, we've taken a variable *i_s* that is a current and we've converted into tension by multiplying it by this transfer function. This voltage here, *v1* by multiplying it by this transfer function, we'll arrive at the voltage *v2* and it's this voltage that you see on the oscilloscope. If you plug this in, you'll be able to get a kind of signal reading on the oscilloscope of the heartbeat, as seen by the oscilloscope. You can put a comparator here which converts the signal that we're going to look at in a second. We've got a square wave signal and you put a counter, do a reset *reset* of the counter every minute, and there, you're capable of observing what your heart rate is per minute. So, this is a classic application that we find nowadays in certain wristwatches. Let's have a look now at the finished application and at what the oscilloscope is showing us.

Notes

Summary

1m 38s



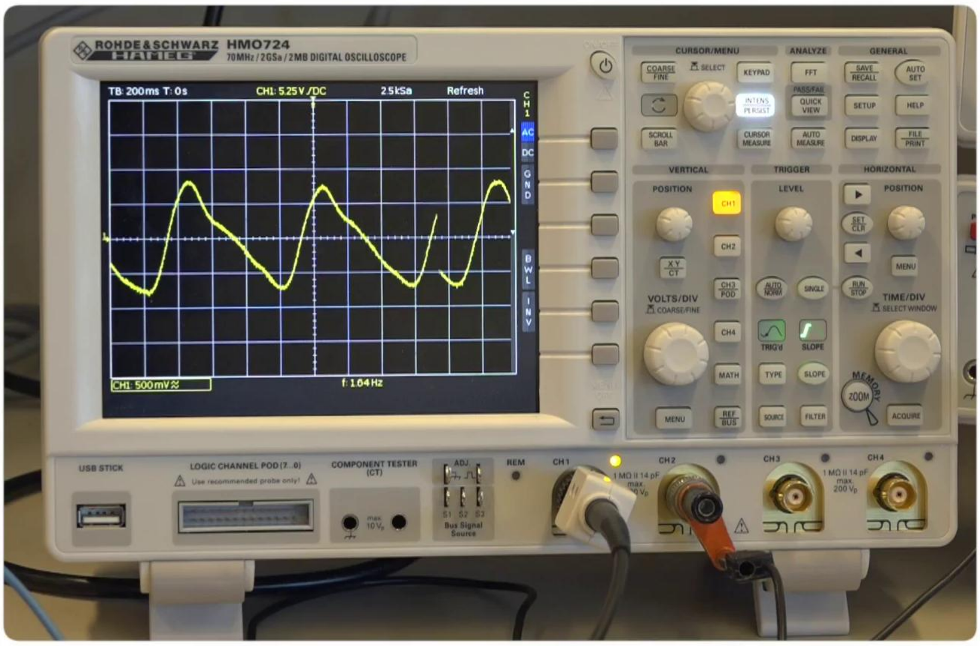
We take the same setup as earlier on, the one that we used as an object sensor, we'll put back the diode, this time opposite the other one. So, our emitting diode is here and here's the receiver, but we've put them opposite each other and this time, we'll try inserting a finger. The finger has blood vessels running through it, with blood flowing through them, and the heartbeat will modulate the light and that's what we saw earlier on, on the oscilloscope. We can see the heartbeat. I advise that you shield it while you take your measurements, to protect it from outside light and give you a steadier signal.

Notes

Summary

3m 00s

TP: Mesure optiques du pouls



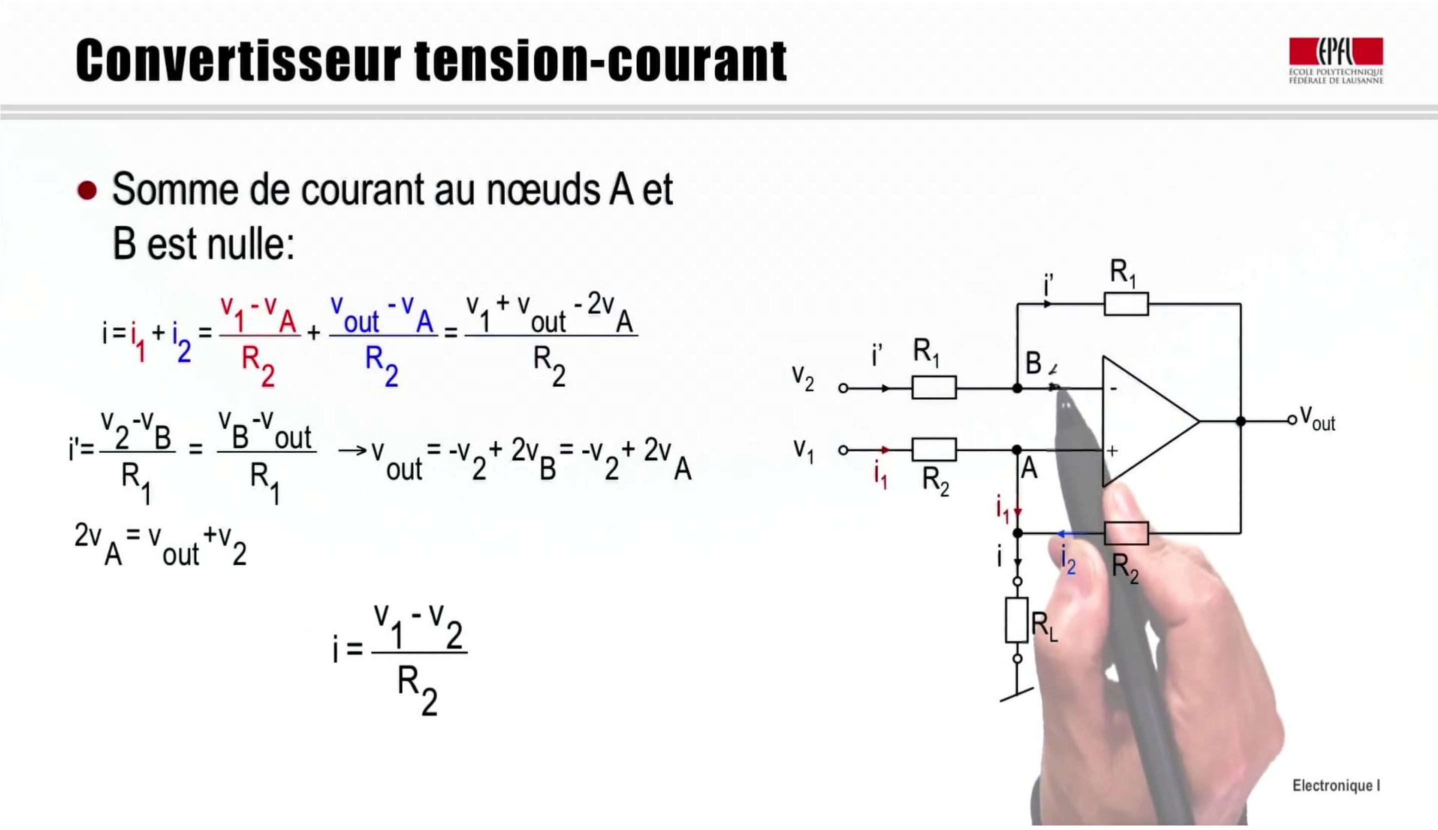
Electronique I

And here are the results that you can see at the output of this type of circuit, a heartbeat, which has exactly the flicker of a heartbeat that we expect on this type of equipment; you can see that the beat is quite regular, and you just have to add a counter. So we can put a simple comparator, and behind a digital counter and display the number of beats per minute to make use of this type of setup.

Notes

Summary

3m 36s



I'd like to finish off the linear applications with a voltage-current converter. We talked about a voltage-current converter, this time, we've got a voltage difference at the input and we'd like to see a current at the output proportional to this voltage difference. For sure, we're going to use our operational amplifier, with a resistance *R1*, that is used as negative feedback, we've added another resistance *R2* and *R2* twice. Our charge is added to this node here, so we won't connect to the amp's *Vout*, we're going to use the current coming from here instead, that is supplied by the amplifier through the current *i2* with a contribution of *i1*. So each time we've got a plan with an operational amplifier, and if the amplifier is in the linear zone, we can be sure in saying: the voltage *vB* = the voltage *vA*. It's always the case. We can be sure in saying that this current here, on node B, the sum of the current on node B = 0 it's linked to Kirchhoff's law, but in having this current... $i^- = 0$ and this current $i+ = 0$ an yes, we can always say: the sum of the current here is equal to 0 but without taking into account this current and the same here.

Notes

Summary

4m 03s

Convertisseur tension-courant

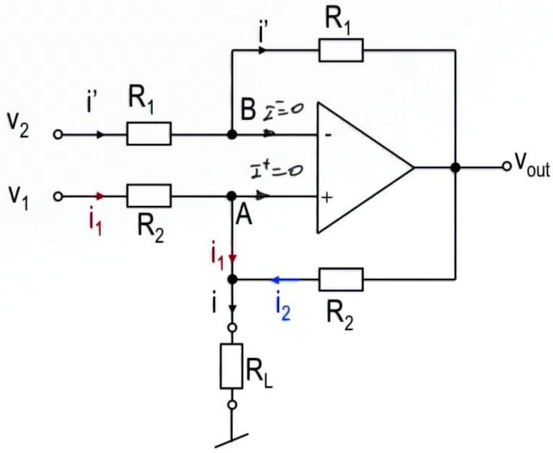
- Somme de courant au nœuds A et B est nulle:

$$i = i_1 + i_2 = \frac{v_1 - v_A}{R_2} + \frac{v_{out} - v_A}{R_2} = \frac{v_1 + v_{out} - 2v_A}{R_2}$$

$$i' = \frac{v_2 - v_B}{R_1} = \frac{v_B - v_{out}}{R_1} \rightarrow v_{out} = -v_2 + 2v_B = -v_2 + 2v_A$$

$$2v_A = v_{out} + v_2$$

$$i = \frac{v_1 - v_2}{R_2}$$



Electronique I

So, I'm going to write down two expressions: A first one that says: the sum of the current where Node A = 0 the sum of the current where Node B = 0 and I'm going to use the fact that the voltage i>vB = the voltage *vA*. So, it's a linear application and that the amplifier guarantees that the voltage *V+* = voltage *V-*. Let's start with Node A in writing down that *i*, this current here, = *i1* + *i2*. *i1*, it's this current, the input current, *i2*, it's the current that is supplied by the *Vout* at the output. So I'm going to add *i1* and *i2* and bring that to a current *i*. I'm writing it down here. The current *i1*, it's *v1* - *vA*; the current *i2*, it's *Vout* - *vA* and there we have it. *(v1 - vA) / R2* for *i1 (Vout - vA) / R2* gives me the current *i2*. I write down these two expressions and I develop them. If the expression of the current *i* in function to *v1*, *Vout* and the potential, or the potential variation, that I see on Node A. Divide all of it by R_2. The same, I take the Node B and all I have to say here is that this current is equal to this current, given that there isn't any current passing through here.

Notes

Summary

5m 30s

Convertisseur tension-courant

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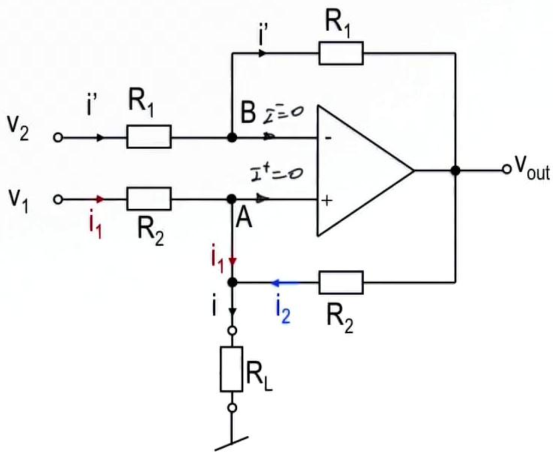

Electronique I

So, the current *i' = (v2 - vB) / R1*, what I've written down here. For sure, I can say *(vB - Vout) / R1* giving me again i>i' because it's the same current that I'm seeing on both sides. I write down this relationship and I can draw from here a relationship of *Vout* in function to *vB* because when I look at this node *vB* but it's the same as this node *vA*. I can replace *vB* with *vA* and I find the same expression that links *Vout* to *-v2 + 2vA* and I take the *2vA* here and I express it in this relationship here that is equal to *Vout + v2* because inside here I've got *2vA* that I just have to replace with *Vout + v2* and this relationship *i* straight away gives me a voltage difference *(v1 - v2) / R2*. So, if you've got a potential difference, and you'd like to see a current *i* proportional to this potential difference, in relation to a given resistance, you'll get *v1 - v2* over the resistance *R2* that you can inject into an external resistance that we call *RL*, so the current being drawn from this node here, you put into a linear relationship, will be converted by a current added to or injected into a resistance, but in reality, the current is proportional to a difference in voltage.

Notes

Summary

7m 08s

This type of setup can be unstable. Remember that the negative feedback is established by *R1* that is here, we had detected a component at the output, on the positive terminal, that could possibly create instability, yes, it could be that the choice of resistances here could pose a problem. This type of setup also suffers from equipment problems that we've talked about. They seem to be symmetric, we'd like to have *R1* absolutely equal to *R1* and *R2* absolutely equal to *R2* knowing that when we take a discrete resistor, we often get a value tolerance, so this could be severely affected by the resistance values. In an integrated circuit, we can do better, because we can equip *R1* with *R1* and *R2* with *R2* and find values that are, in relative value, quite correct. So we've just finished a whole series of linear applications, with operational amplifiers; with this, I've finished a whole series that demonstrates that operational amplifiers with specific circuits added on can take a voltage, multiply it by a constant, and convert it into output voltage all while keeping within the linear zone of the amp and all in keeping a linear relationship between the input and the output.

Notes

Summary

8m 40s

Convertisseur tension-courant

- Somme de courant au nœuds A et B est nulle:

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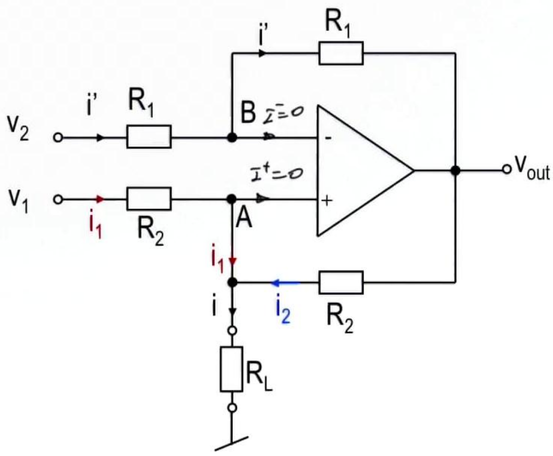

Electronique I

We've also seen that we an do the same with a current by converting it into a voltage, and we've seen that we can do the same with a voltage, or a voltage difference, by converting it to a current at the output. There are lots of applications in the linear world of the amplifier but I now think that, a student that has followed this course along with the previous lessons will always be able to analyse the circuits inside an operational amplifier when the amplifier hasn't been saturated, meaning when the amplifier stays within the linear zone. We've understood that superposition works very well indeed, and that we can cancel out the voltage between the + and the - of the amp when the gain is very high, and when there isn't any current entering the positive and negative terminals and that at the output, we can supply large amounts of current. With that, we've come to the end of the operational amplifier with a series of examples coming from the linear world. Now we're going to look at the non-linear world.

Notes

Summary

9m 59s