ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Amplificateur opérationnel

2.2 Montage inverseur indépendant de la fréquence

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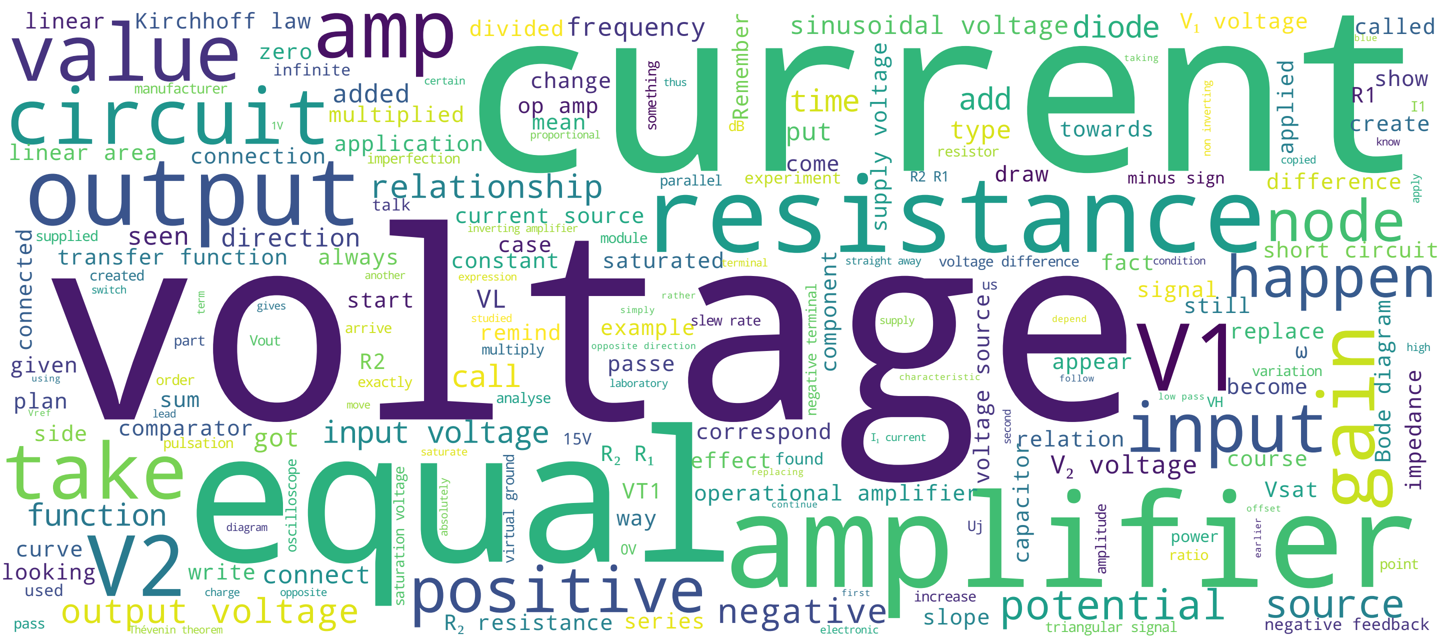
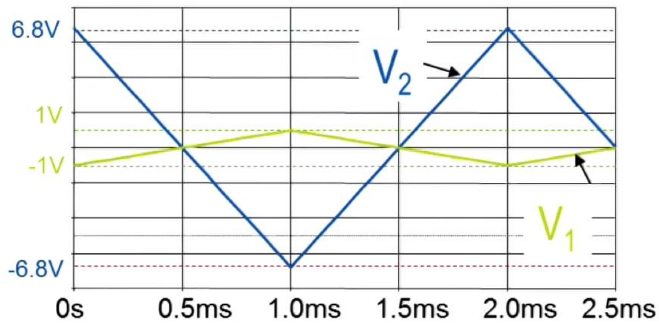
Electronics Laboratory-ELAB

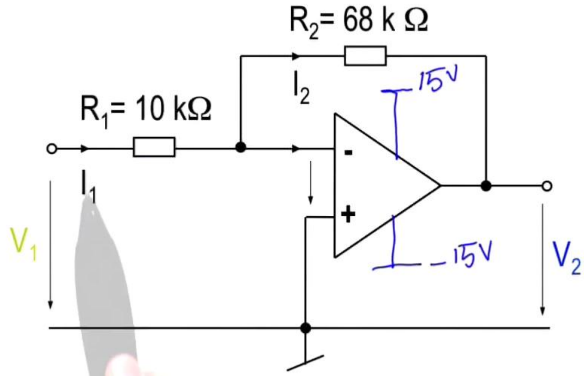


Video

EPFL

TP: Amplificateur inverseur





Amplificateur non saturé

$$I_1 = I_2 = \frac{V_1}{R_1} = -\frac{V_2}{R_2}$$

$$\frac{V_2}{V_1} = -\frac{R_2}{R_1} = -6.8$$

Electronique I

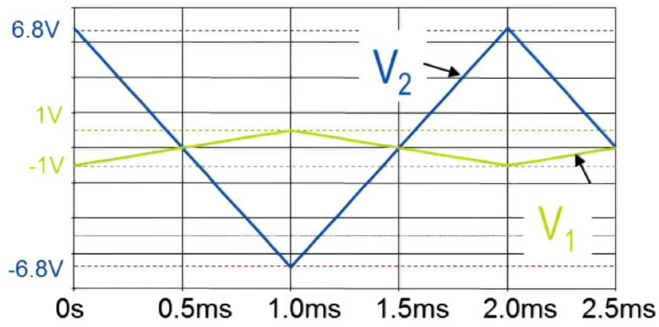
Now I'd like to invite you to do an experiment. We'll do this experiment together. You're going to take an operational amplifier, you'll supply it with two supply voltages. You'll take a supply voltage around 15V, for example, positive, and a supply voltage around -15V, negative. You'll choose an R_2 resistance, equal to 68 kΩ and an R_1 resistance of 10 kΩ. Set it up like this. We'll analyse what will happen between the blue ouput voltage and the yellow input voltage when the ratio between the two voltages is equal to -6.8 which is the same as 68 kΩ divided by 10 kΩ. Let's see what happens when you connect a triangular signal to the input. Here, I chose to connect a triangular voltage with a range equal to 1V. And I'm looking at the output. See how the output voltage is linear, compared to the input voltage, with a slope which is the opposite of the input. It's normal, because we have a negative sign and that negative voltage, for a triangular signal, means that when the slope is positive, the slope that we see at the output will be negative. Let's see what happens with the two currents. We have an R_1 and R_2 resistance. The I_1 current that we've just seen is the same as the V_1 voltage that we see here.

Notes

Summary

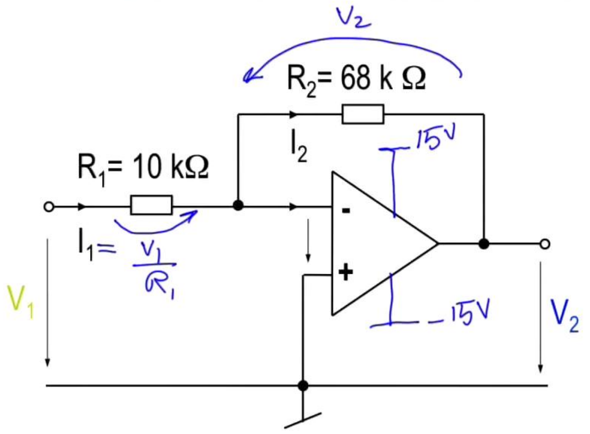
0m 04s

TP: Amplificateur inverseur



Amplificateur non saturé

$$I_1 = I_2 = \frac{V_1}{R_1} = -\frac{V_2}{R_2}$$



$$\frac{V_2}{V_1} = -\frac{R_2}{R_1} = -6.8$$

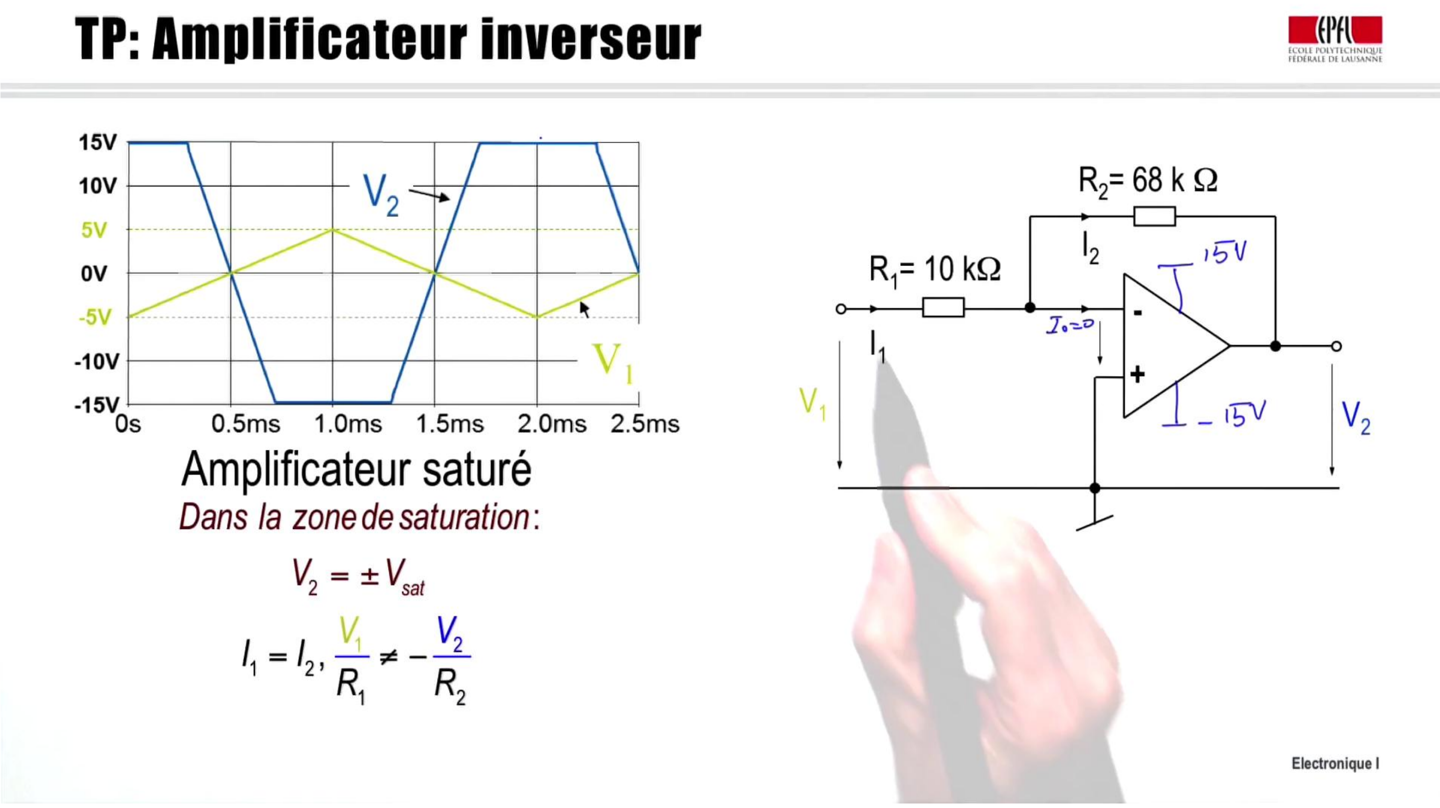
Electronique I

So this current is equal to V_1 divided by the R_1 resistance. It's the same for the R_2 resistance as the V_2 voltage is the voltage that we see here. Therefore the V_2 voltage, or the relationship with the I_2 current, is equal to $-V_2$ divided by the R_2 resistance. See the positive direction of the current and the opposite direction of the voltage, which leads us to talk about these minus signs. When we look at the two currents, and we balance them as we've seen, your oscilloscope will show you something like that. We're going to try to saturate our amplifier. Straight away, I'll change the level of input voltage and do it so that I push my amplifier to saturation point to a saturation voltage which is... which are the voltages that we've supplied the amp with.

Notes

Summary

1m 43s



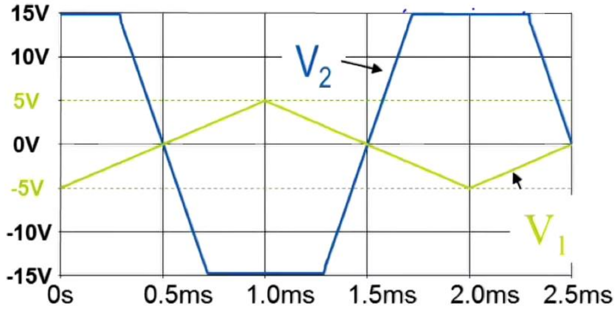
And watch what will happen: when your amplifier is saturated, so I've applied a voltage equal to 5V at peak value. Remember that we've supplied + or -15V so there was 15V on that side and -15V on this side. So, our amplifier can't go beyond the conductor rails. Its saturation voltages are Vsat+ = 15V and Vsat- = 15V so it will come up against these supply voltages and our amp will be saturated all the way through. The amp is therefore no longer linear. We applied a linear voltage, we expect the output to be linear, but seeing as the amplifier can't exceed these supply voltages, it saturates. Can I still say that the I_1 connection is equal to I_2? Absolutely not. When the amplifier goes outside of its linear area it becomes saturated. It's impossible for me to talk about an amplifier which behaves in accordance with a linear law. I can still say that $I_1 = I_2$, that goes without saying because the current here is still equal to 0. However, this current will continue on its way, but that current, or that voltage, is no longer copied from here to there, because the amp no longer finds itself in the linear area where V+ = V- so I can't say that $V_1 / R_1 = -V_2 / R_2$ given that this potential is no longer equal to 0.

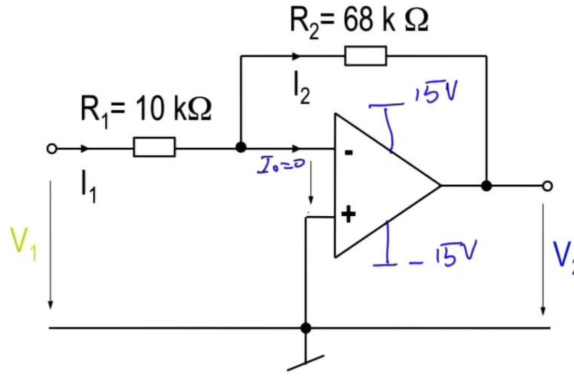
Notes

Summary

2m 35s

TP: Amplificateur inverseur





Amplificateur saturé

Dans la zone de saturation:

$$V_2 = \pm V_{sat}$$

$$I_1 = I_2, \frac{V_1}{R_1} \neq -\frac{V_2}{R_2}$$

Electronique I

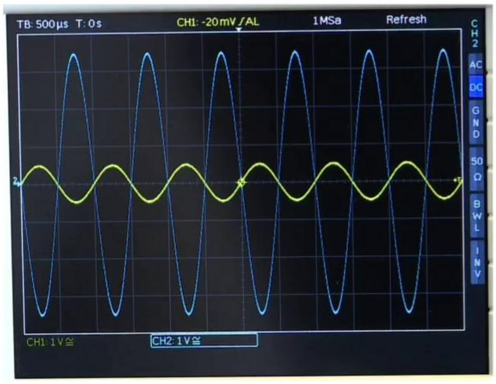
So the amplifier is in the saturation area here. There, when the amp is in the linear area, again it leads to being in a loop of negative reactions, it stayed in its linear area therefore the connection V(out) or V_2 in terms of V_1 = $-R_2 / R_1$ is applied there, according to that. But when I reach saturation point, I find myself from there to here with a saturated amplifier. Do this experiment in the lab and see what happens. You can, of course, connect other types of signals, and I advise you to connect a sinusoidal voltage. We'll see what will happen if, in your laboratory, you replace the triangular signal with a sinusoidal one which we'll see at the output.

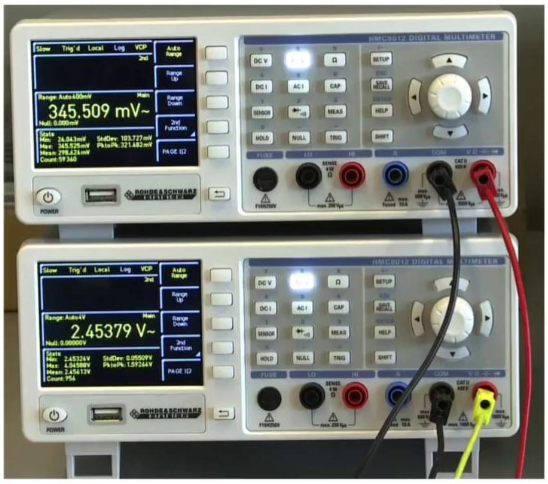
Notes

Summary

4m 13s

TP: Amplificateur inverseur





Electronique I

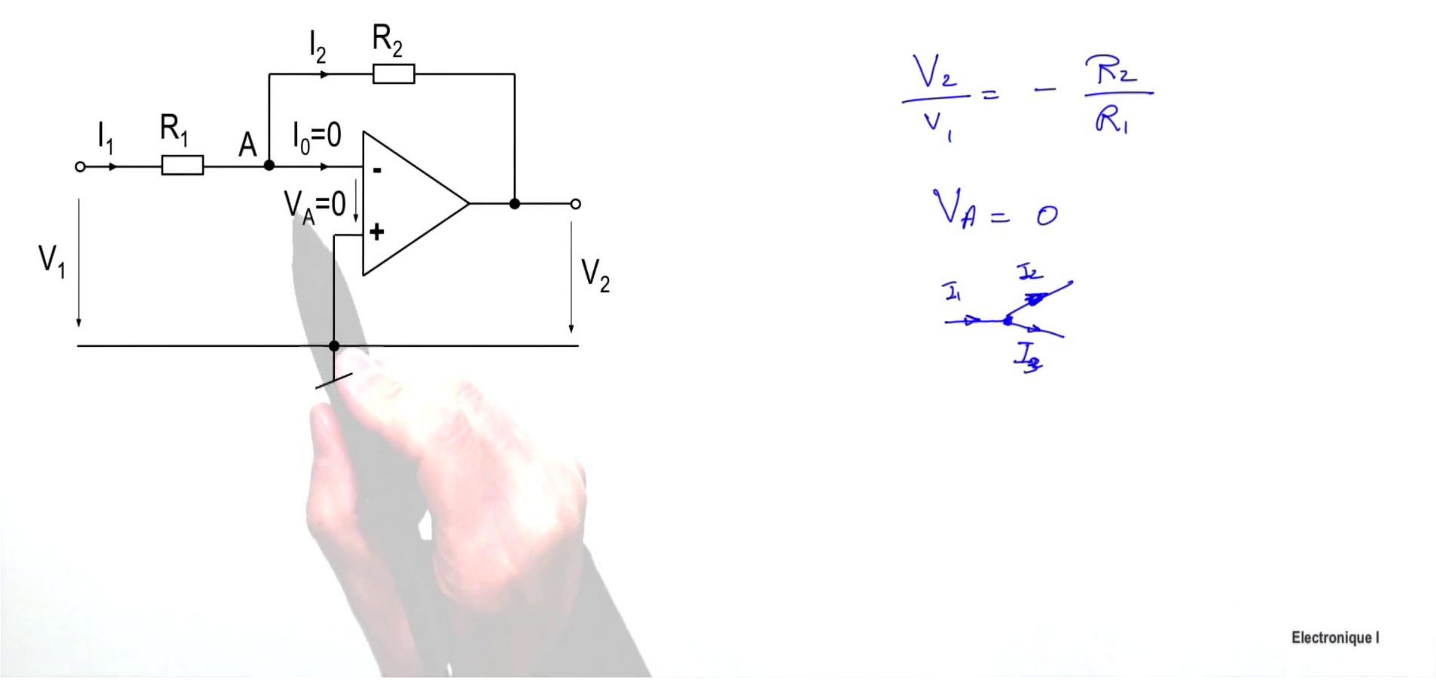
Here is what we'll observe at the output of an amp that a sinusoidal voltage has been connected to at the input, which you can see in yellow, and the sinusoidal voltage which appears at the output, with a complete 180° phase difference. The notion of the - sign with a sinusoidal voltage means a phase inversion. Therefore the output voltage has undergone a phase inversion. There's a phase difference of 180° between the sinusoidal voltage which was inputted and that which would be amplified, of course, we can see that the amp multiplied it by 6.8 which was the amp gain. You only have to look at the two displays of these two voltages, they are RMS values of the input voltage, the input voltage which is here, and the output voltage there. If you make the connection between these two voltages, you're led to find the amplification gain which is around 6.8 kΩ. Of course, you must consider that this experiment was done with resistances which have a certain tolerance. Therefore the difference is explained by the tolerance of our components.

Notes

Summary

5m 01s

Exercice: Amplificateur inverseur



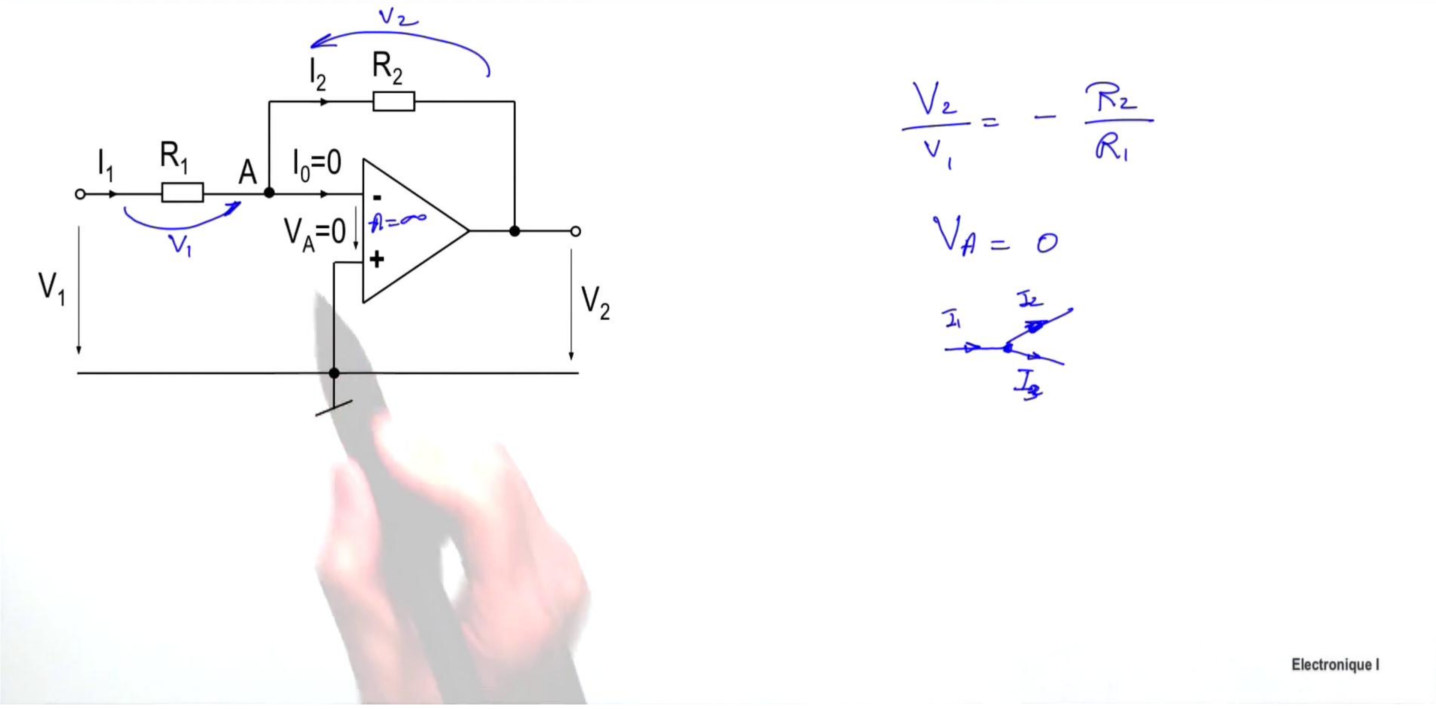
Here's the last plan we studied. It's an amplifier which includes a feedback resistance, an input resistance, with an output voltage which is always the opposite of the input voltage. I'd like to quickly remind you that the relationship between the voltage V_2/V_1 is equal to -R_2 over R_1. And I'd now like to show the possibility offered by the amplifier when the potential of this node A is equal to the potential which is connected to the positive terminal. In other words, the voltage V_A = 0. This is a highly interesting feature. Because upon analysing what we see here, I'm just going to remind you that Kirchhoff's law says that when you take a node and you direct a current towards that node if that current, we'll call it I_1, well the currents that exit this node are exactly the sum of this I_1 current. You have a current $I_1 = I_2 + I_3$. This law is always true. The current which arrives here, it'll pass again through there, because no current passes the Io node so that current is equal to this + this. Very simple, easy. But in that plan, if we look at what happens in the potential of the A node, we see that the difference in potential, thanks to the amp feedback, that is the fact that an amp, when it starts to feedback, it will try to find a linear connection between this voltage and that, the one that you see there.

Notes

Summary

6m 11s

Exercice: Amplificateur inverseur



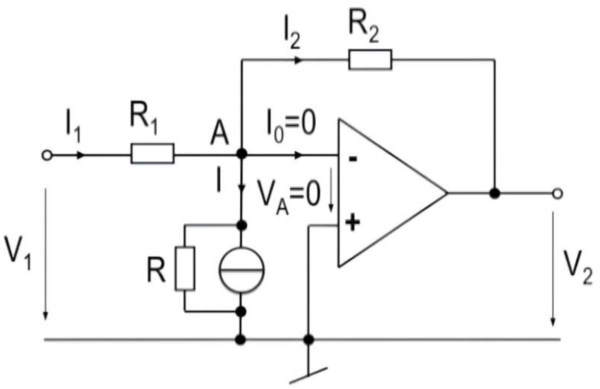
The voltage difference is always equal to 0. I remind you that the gain of this A amp is infinite. Therefore, for a finite output voltage, the amp isn't saturated, this V_2 voltage divided by A always brings about a voltage difference equal to 0. So the voltage in the A node is equal to the voltage we have here. As it happens, in this example, we show that we have grounded the connection. So if this potential equals 0V, then this potential also equals 0V. It's an extraordinary feature. Watch what happens. You'll have a current which moves. This current goes via this path here. The potential in that node is equal to here, therefore equal to 0V. So there's no variation of this voltage, independently of what happens with the V_1 voltage which will appear here, that's the V_1 voltage, and the V_2 voltage will appear here, that's the V_2 voltage. We're going to use this. If you can connect something to that node, any kind of external source which will add current, it won't affect the voltage. We call that the virtual ground. We created a grounded short circuit with a voltage difference of 0 without applying that on the current. The current won't pass through the ground. So it won't run in this 0 potential.

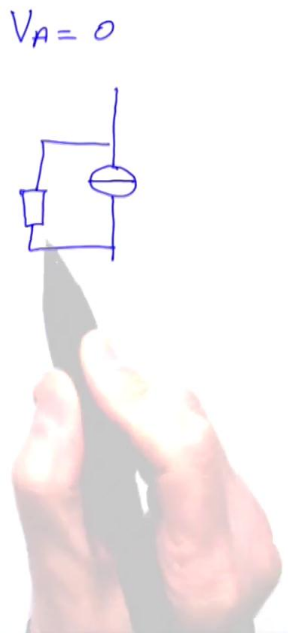
Notes

Summary

8m 00s

Exercice: Amplificateur inverseur





Electronique I

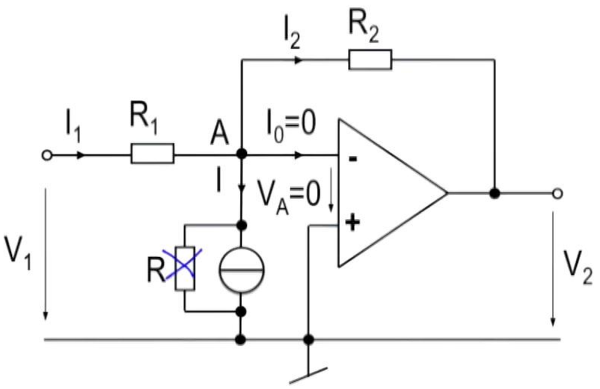
It continues via another way, through the R_2 resistance, all whilst imposing the potential of the ground still at node A. So there's absolutely no effect of current that passes through this potential because the amp will manage the potential and the current continues to apply the Kirchhoff laws that we've seen here. And this, this virtual ground, created by an amplifier will be used minutely in circuits. And we'll see a first example of this. Here's the plan of my inverting amplifier where I've just added a source of current to this node A which corresponds to the virtual ground. So, you remember that the potential at node A V_A is really equal to 0. When you're looking at a source of current connected to a potential $V_A = 0$, it's that any resistance is connected in parallel, I'm going to draw my source of current, this current source finds itself with a parallel resistance and this parallel resistance is one of the flaws of a current source. We don't like this resistance, but it exists, and you've just imposed a voltage equal to 0, so this resistance can't in any case let a current pass in.

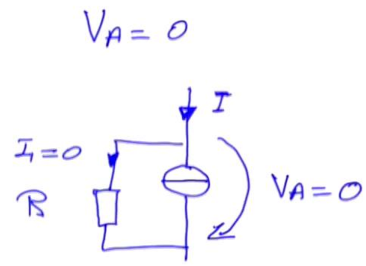
Notes

Summary

9m 31s

Exercice: Amplificateur inverseur





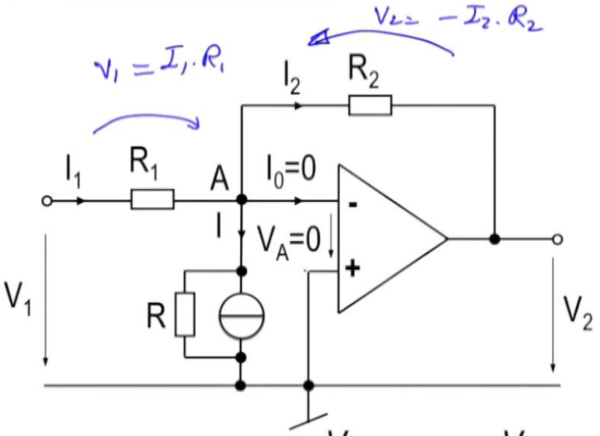
You have a voltage equal to 0 at the terminals of this resistance therefore the current crossing it is going to be I = 0 So all the current put out by our source of current, which in this example is this current I, is what we see here, it will definitely pass through this node, it's as if we created a short circuit on a current source. And the short circuit current helps us greatly to eliminate this imperfection and the existence of a resistance which won't take the current from the main source at all.

Notes

Summary

10m 57s

Exercice: Amplificateur inverseur



$I_1 = I_2 + I$

$$I_1 = I + I_2 \ \ avec \ \ I_1 = \frac{V_1}{R_1} \ \ et \ \ I_2 = -\frac{V_2}{R_2}$$

$$V_2 = -V_1\frac{R_2}{R_1} + I.R_2$$

Electronique I

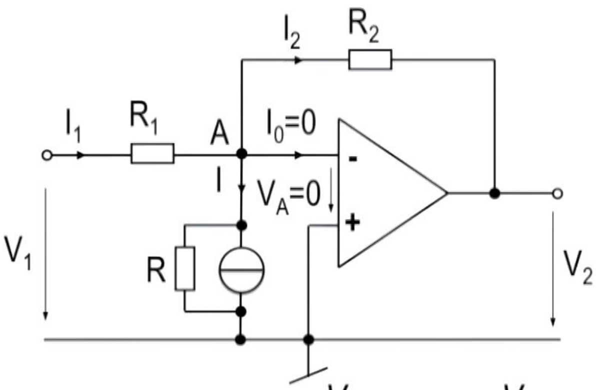
If we apply Kirchhoff's law on what we've just seen, I can say that the sum of the current that passes here, the I_1 current, will be equal to the I_2 current + the current I. I invite you to think about this exercise. This exercise shows you that whatever source you add here, you create an effect by analysing the relationships we've seen, that the V_1 voltage, here, this V_1 voltage is equal to I_1 multiplied by R_1, and the V_2 voltage, in the other direction, V_2 is equal to $-I_2$ times the R_2 resistance. I'd like to remind you that the direction of the V_2 voltage is positive in this direction given that the potential is copied here and the current is in the opposite direction, which leads me to add this negative sign before the connection. And the current I which was imposed by this source that we decided to connect to a source of current which gives out a current in this direction. You'll see clearly that the current which enters is equal to the sum of the two currents that exit. And you'll write it copying the relationship $I_1 = V_1 / R_1$ here the same for I_2. And you'll find this connection which is there.

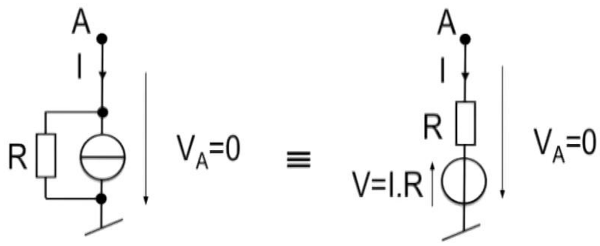
Notes

Summary

11m 36s

Exercice: Amplificateur inverseur





$$I_1 = I + I_2 \quad avec \quad I_1 = \frac{V_1}{R_1} \quad et \quad I_2 = -\frac{V_2}{R_2}$$

$$V_2 = -V_1 \frac{R_2}{R_1} + I.R_2$$

Electronique I

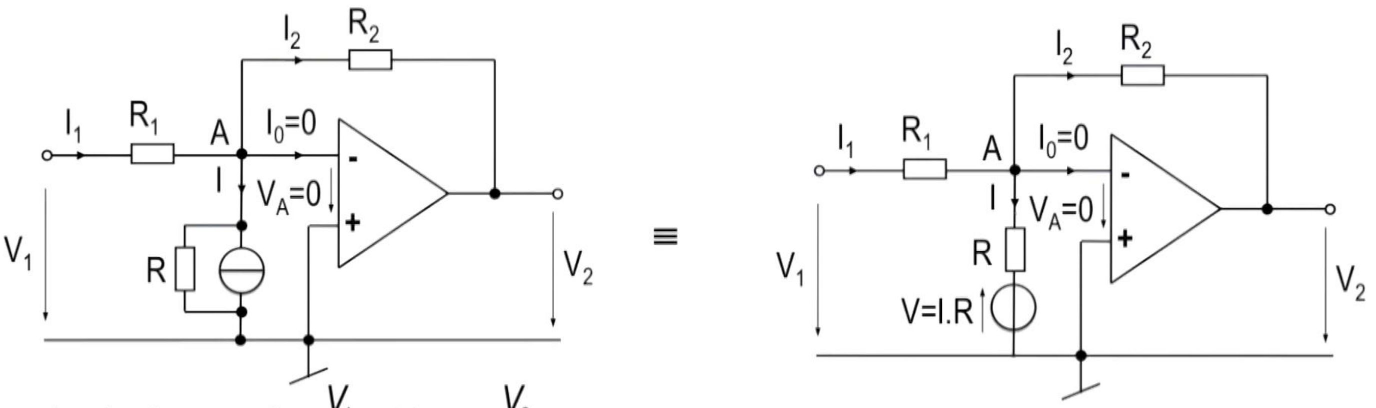
That allows me to show that the current given out by my source only adds a certain current in I_2 which doesn't influence what comes from I_1 because it adds to I_1 all whilst knowing that the voltage remains zero. Here's the same plan, the same conclusion, which takes us back to the V_2 voltage in relation to the V_1 voltage multiplied by a resistance relationship of R_2 / R_1, and what we discovered with our amplifier, the fact of having added this current, I have added an extra current which will multiply the R_2 resistance and change into a voltage which is added to the one which appeared when we saw the voltage V_1 multiplied by R_1 / R_2. It's shown here. I'd like to remind you that when a source of current like this, when you want to convert it into a source of voltage it becomes a source of voltage in series with the resistance, whilst obeying the Kirchhoff law. So we've made Thévenin's theorem, and Thévenin's theorem says that these two representations are the same. The condition is replacing the current source by an equivalent voltage source equal to I x R with a resistance R in series. And remember that the voltage V_A, from there to there, is still the same. I simply made a replacement according to Thévenin's theorem of a current source with a resistance in parallel with a voltage source with a resistance in series.

Notes

Summary

12m 58s

Exercice: Amplificateur inverseur



$$I_1 = I + I_2 \quad avec \quad I_1 = \frac{V_1}{R_1} \quad et \quad I_2 = -\frac{V_2}{R_2}$$

$$V_2 = -V_1 \frac{R_2}{R_1} + I.R_2$$

$$V_2 = -V_1 \frac{R_2}{R_1} + V.\frac{R_2}{R}$$

Electronique I

And here's the equivalent plan that we got and I'm going to be able to write that and draw it taking the current source and its resistance and replacing it with a voltage source and its resistance. This exercise shows you, if you calculate it and do it, that this plan allows us to transform an effect of the current when we replace it with a voltage into an effect of addition. I'm going to look at the V_2 voltage now in order of an added source of voltage and you'll see that $V_2 = -V_1 \times R_2 / R_1$ + the equivalent of this source $V \times R_2 / R_1$. With this we discover a very important circuit that we'll analyse straight away and that we call a summing circuit. We see that there is a summing effect between the V_1 and V voltages with an absolute value according to the conditions of vectors, currents and voltages. And we see that these two voltages are balanced by a relationship of R_2/R_1 and R_2/R.

Notes

Summary

14m 31s