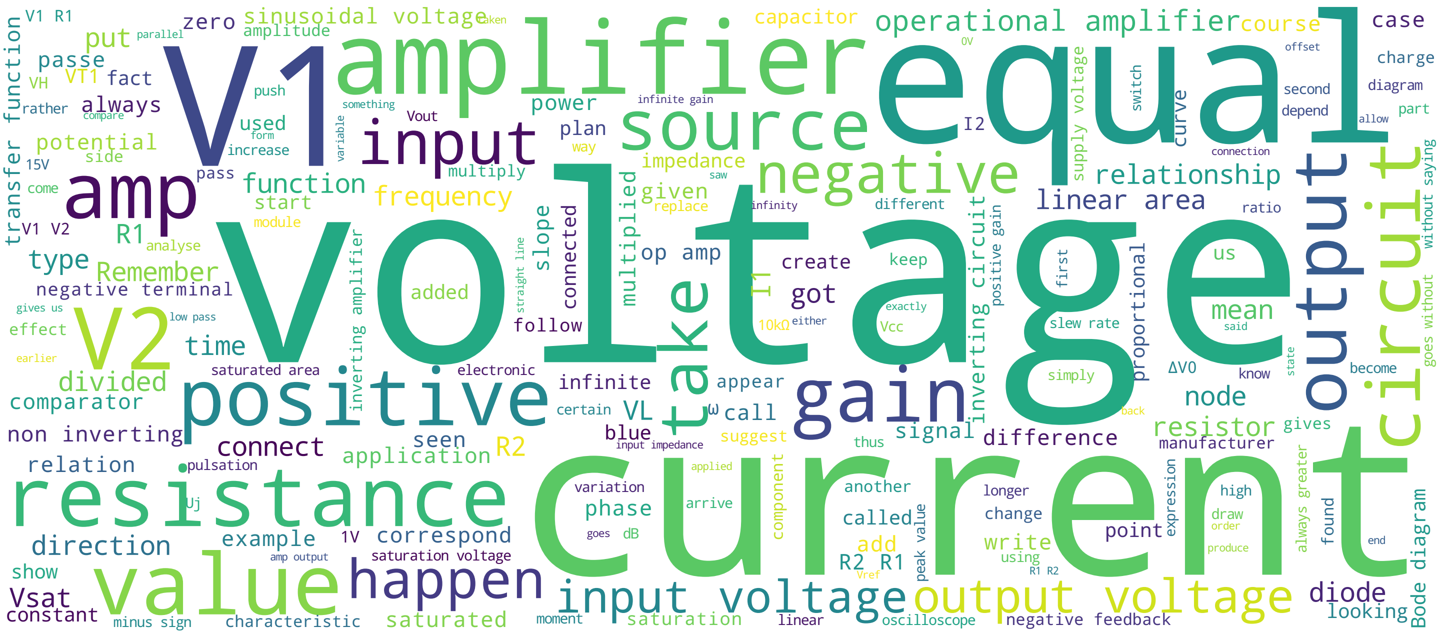
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Amplificateur opérationnel

3.1 Montage non-inverseur indépendant de la fréquence

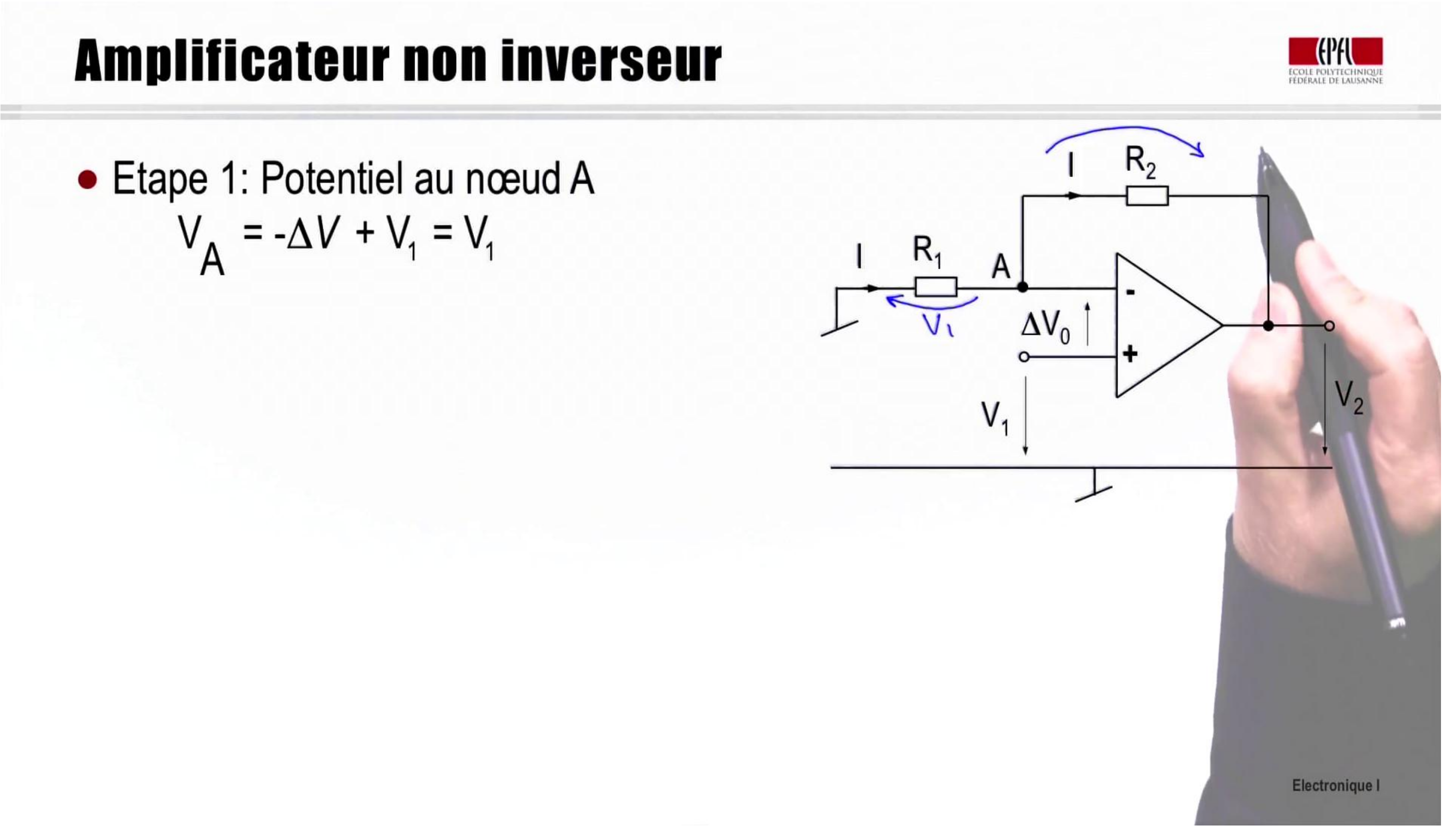
Prof. Maher Kayal

Electronics Laboratory-ELAB



Video

EPFL



Today we're looking at a circuit called a non-inverting circuit. It's a circuit which will produce a gain. So it's a circuit which will use the operational amplifier in the so-called linear area. There will be a positive gain and there will definitely be some advantages and disadvantages compared to the circuit we saw before, which was an inverting circuit. Here's the non-inverting circuit. So the plan that you see here shows an operational amplifier which is connected with two resistors, *R2* and *R1*, which create feedback. It goes without saying that the amplifier will be used in the linear area, so we'll immediately consider the voltage *ΔV0*, as the gain is infinite, as being equal to 0. This means that the voltage *V1* will be returned directly to node *A*. So when we look at the voltage *V1* from this node *A*, you'll get a positive in this direction. Because the voltage in *V1* will be here. And if you look at the voltage which appears from there to there, well this voltage will be proportional to the difference between *V1-V2*. So it's a voltage which is equal to *V1 - V2*.

Notes

Summary

0m 05s

Amplificateur non inverseur

- Etape 1: Potentiel au nœud A

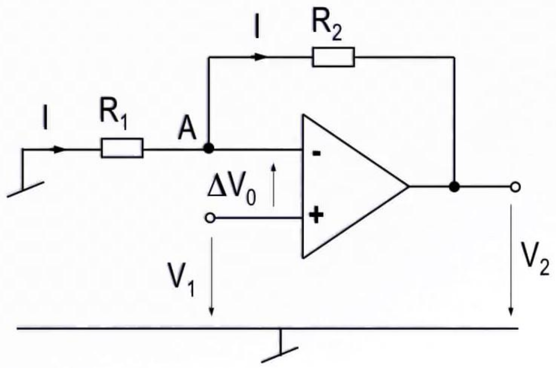
$$V_A = -\Delta v + v1 = v1$$

- Etape 2: Somme des courants nulle au nœud A

$$I = -\frac{V_A}{R_1} = -\frac{V_1}{R_1}$$

$$I = \frac{V_A - V_2}{R_2} = \frac{V_1 - V_2}{R_2}$$

$$\frac{V_2}{V_1} = \frac{R_1 + R_2}{R_1} > 1$$



Electronique I

Now if we want to write down what happens with the current *I*, we'll see that the current *I*, which is the same one that will pass through the two resistors *R1* and *R2* given that the current which passes through the amp is equal to 0. This current, remember, has always been equal to 0. The amp doesn't absorb current. So, you're going to see the current *I* on one side, produced by the relationship of -*V1/R1*. The negative sign comes from the fact that the current is positive in this direction and the voltage *V1* is positive in that direction. Remember that this potential and this potential are the same. So when you look at the same current *I* in the other connection, in the *R2* resistor, well you'll see that it's *V1-V2* divided by the *R2* resistor. We're going to take these two connections, balance the currents, since it's the same current on both sides, and we'll see what the relationship is between *V2* and *V1*. And here's the plan of our amp and the relationship that we'll get when we balance *I* to *I*. We'll find that the ratio of the output voltage *V2/V1* is *R1+R2* over *R1*, which is strictly always greater than 1.

Notes

Summary

1m 23s

Amplificateur non inverseur

- Etape 1: Potentiel au nœud A

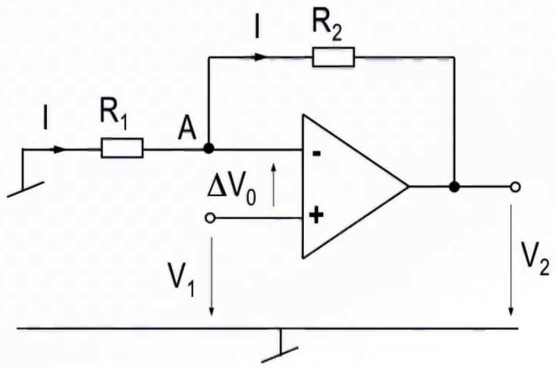
$$V_A = -\Delta v + v1 = v1$$

- Etape 2: Somme des courants nulle au nœud A

$$I = -\frac{V_A}{R_1} = -\frac{V_1}{R_1}$$

$$I = \frac{V_A - V_2}{R_2} = \frac{V_1 - V_2}{R_2}$$

$$\frac{V_2}{V_1} = \frac{R_1 + R_2}{R_1} > 1$$



$$R_{in} = \infty \qquad R_{out} = 0$$

Electronique I

A positive gain is always greater than 1. We can also write it like this: The gain *Av* which equals *V2* divided by *V1* which equals 1+*R2/R1*. So we always see that this gain *R2/R1*, that we add 1 to, so it's always greater than 1 and positive, and it's the gain of a non-inverting amplifier. Now, there's an extremely important feature that I would really like to highlight compared to an inverting circuit. The current that the source *V1* will have is current *I*, equal to 0. So if you connect a source here which produces a current *I1*, this current equals 0. No power will be taken from your source. And that is extremely important. I'd really like to emphasise that. When we use a non-inverting amplifier, the source that we connect at the input is positive. So it's a source that doesn't produce current, so no power is required from this source. And that leads us to use this type of amplifiers to create infinite input impedances. And we can summarise it here. So here, we see that the input impedance *R(in)* is infinite which gives this circuit one of the features that we'll hugely exploit later to create circuits which don't charge the source of voltage at all.

Notes

Summary

2m 39s

Amplificateur non inverseur

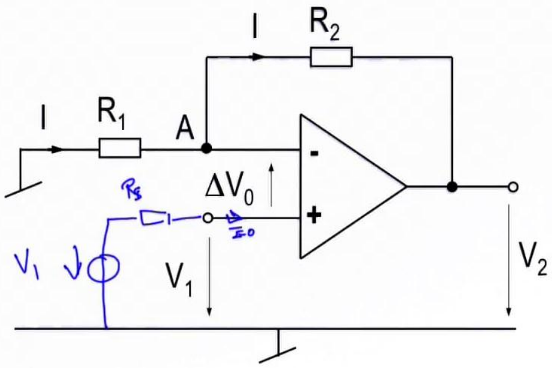
- Etape 1: Potentiel au nœud A

$$V_A = -\Delta v + v1 = v1$$

- Etape 2: Somme des courants nulle au nœud A

$$I = -\frac{V_A}{R_1} = -\frac{V_1}{R_1}$$

$$I = \frac{V_A - V_2}{R_2} = \frac{V_1 - V_2}{R_2} \qquad \frac{V_2}{V_1} = \frac{R_1 + R_2}{R_1} > 1$$



$$R_{in} = \infty \qquad R_{out} = 0$$

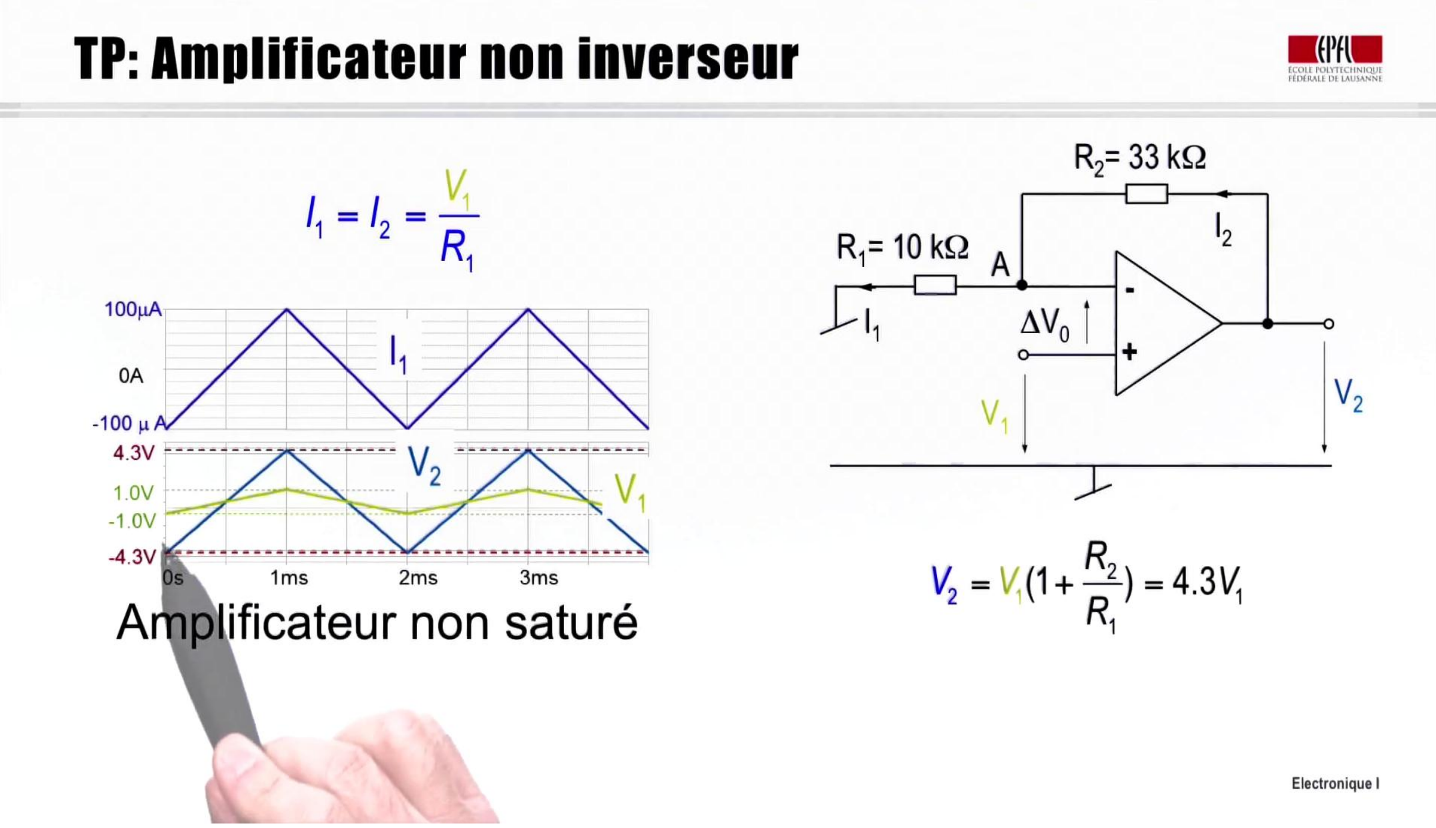
Electronique I

You can easily imagine connecting a source here, and this source will have a very, very high resistance. And that source could simply have a voltage *V1* which equals this voltage here, given that this current equals 0. So independently of the input resistance value of your source, the voltage drop at this resistor is always equal to 0 because there's no current taken by the amplifier. Remember that when the amplifier shows its output impedance *R(out)* is equal to 0, this simply means that the current that we get at the amp's output can be infinite. In reality, that doesn't happen because the current that we have in this node or at the amp's output is limited by the amp's manufacturer who will impose a maximum current that will always be indicated by the manufacturer.

Notes

Summary

4m 15s

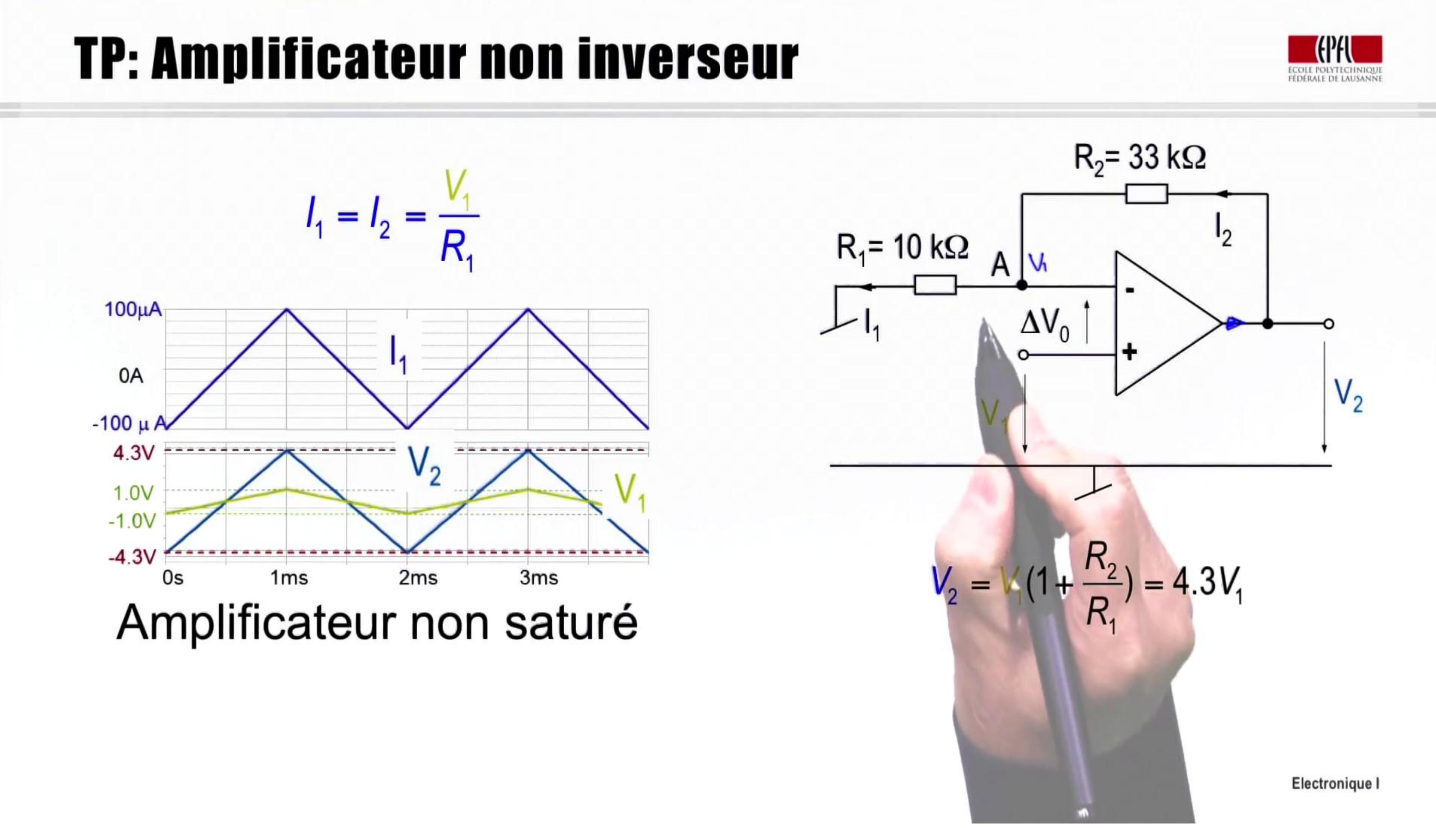


Now I invite you to connect a fairly classic operational amplifier. These amps which have extreme gains such as the 741 operational amplifier. When you connect an amplifier like this, and I suggest that you create a gain of, for example, 4.3, you have a choice to make about the resistance. If you take a resistance of 33kΩ, a resistance of 10kΩ, that gives you an *R2/R1* ratio equal to 3.3, which we'll add this 1 to. Remember that the gain is *1+R2/R1*, so you'll get a gain equal to 4.3. When you connect this amplifier in a lab, I suggest that you put this yellow signal at the input, which is a voltage *V1*. This voltage *V1* will... The example that I'm using here, I'm setting an amplitude of 1V. That means that it'll have a dynamic of plus or minus 1V, therefore a dynamic of 2V. And when you multiply that by 4.3, you can see that the voltage in blue, here, corresponds exactly to the glimmer of voltage in yellow, multiplied by 4.3. So the peak value in volts will be multiplied by 4.3 and gives us 4.3V. And that's what we see at the output. Why do we use a triangular voltage? Because linearity is almost visible to the naked eye. We have a positive slope, a negative slope.

Notes

Summary

5m 14s

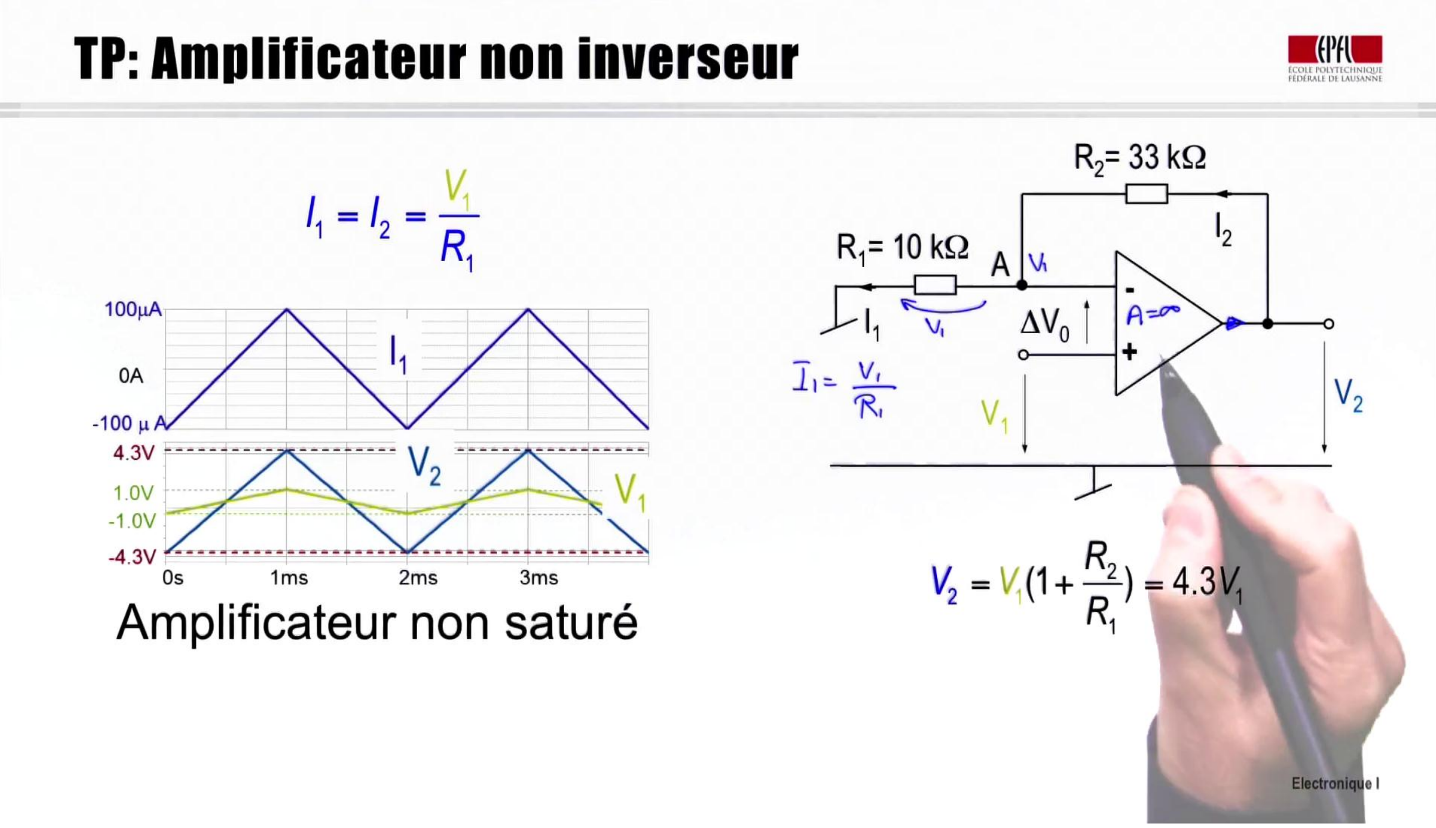


We only have to compare the slope and we'll see that thanks to the amplifier gain this slope is completely linear between -4.3 and 4.3 and vice versa, whether it's positive or negative. I'd like to reflect a little on the current that will be given out by the amp. Remember, when we look at an amp connected like this, you're watching the voltage *V2*. The current *I2* will of course come from the amplifier. It's a current which will be positive and negative. When the slope is positive and the voltage *V2* is positive or negative, well you'll see that the current will follow it. There will be a slope which follows the voltage. There'll be a current value which will be positive and negative. So the current which will pass here... Remember one of the characteristics of the amplifier. When the amp is in a linear area, that means the amp is not at all saturated. As we can see here. For it to be saturated, its voltage must reach 15V, which is the supply voltage if you've supplied 15V. The voltage *V1* is the voltage that we'll see in this node. So the voltage *V1* is this one.

Notes

Summary

6m 47s

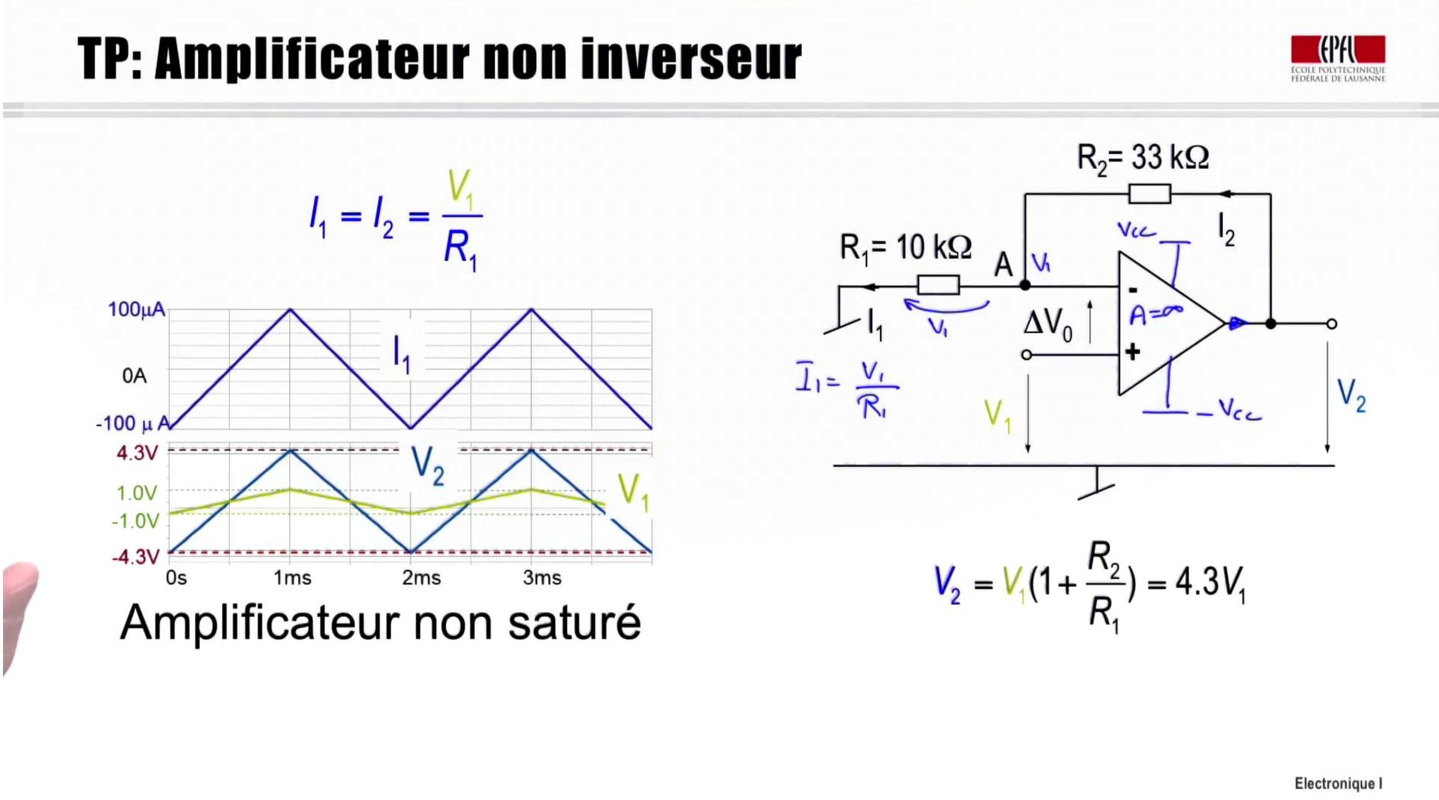


When you look at the current, this current *I1*, which is due to the voltage *V1*, which is the input voltage, you can simply write that the current *I1* equals *V1/R1*. And that's it, you have the exact value of *I1* and the current *I1* which will absolutely follow the voltage *V1* and which means you'll have 10kΩ and you're looking for a current which will go up to 100µA, knowing that we have 4.3. So you'll find that the current will go up to 100µA with positive value, and up to -100µA negative value. And this is what you'll see the whole time. With the output voltage being 4.3, the input voltage is 1V, so we can simply divide the 1V, divided by the 10kΩ and at any point, with the peak value being 1V, we find then that 100µA and -1V makes -100µA. So what happens with this circuit when the amplifier becomes saturated? Will it keep the same characteristics? Definitely not. I'll emphasise and repeat. The amplifier, due to its infinite gain, when it is in the linear area, it takes any value of the *V2* voltage. It divides it by the infinite gain and the difference between the positive and negative terminal should be *V2* divided by infinity, therefore equal to 0.

Notes

Summary

8m 01s

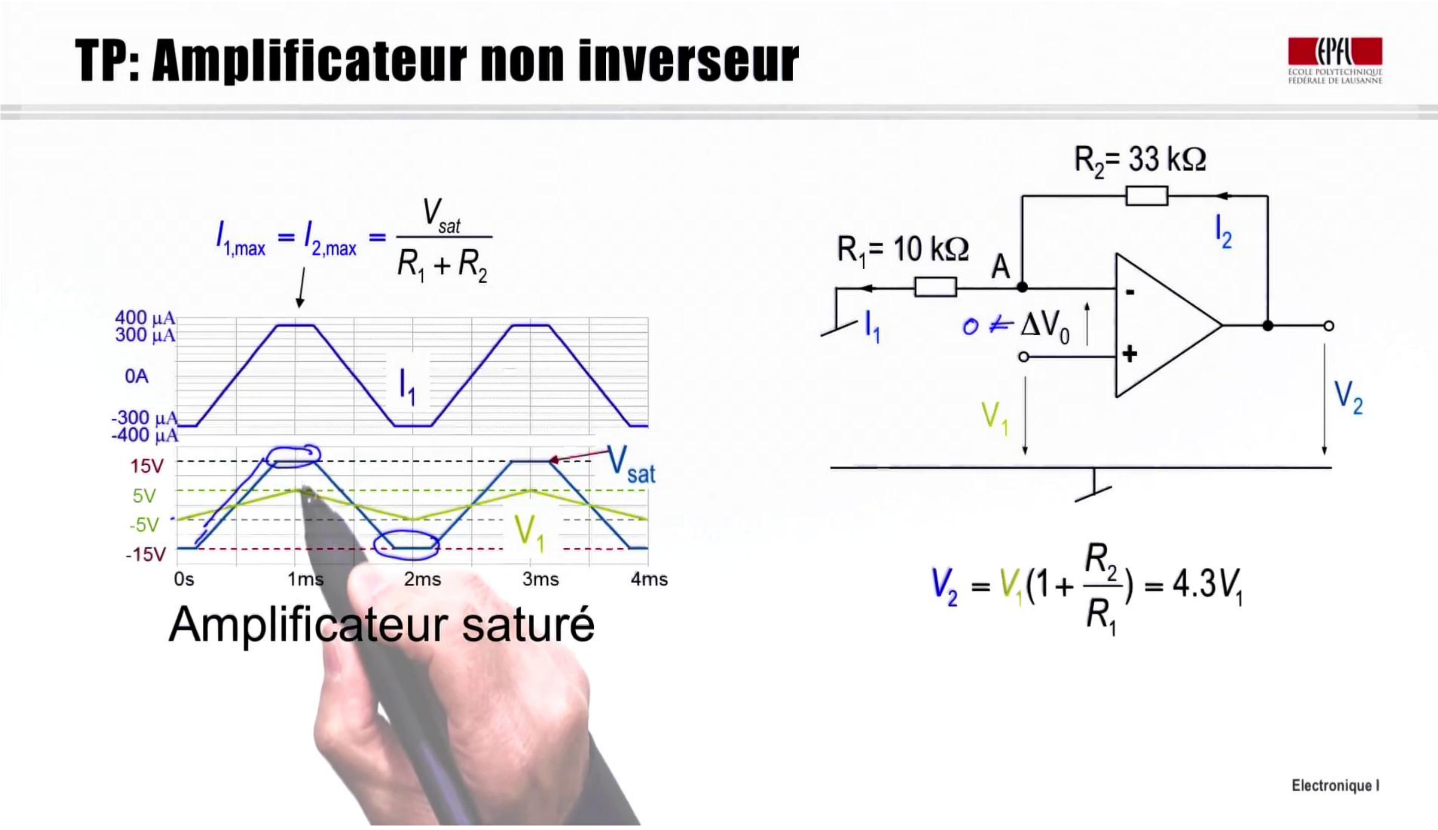


So when the amp is not saturated, this characteristic is true. And at that moment, this voltage is equal to this one. And the current is the current provided by the amplifier when the current is positive. And it's a current which is absorbed by the amplifier and which will go towards the voltage -*Vcc* when the current is negative, because remember that it's a supply voltage which provides this energy to our amplifier. Let's see if we push this amplifier towards saturation. I suggest you put a voltage *V1* at the input which pushes the amplifier to reach this saturation voltage, and we'll see the following thing: here's what happens with our amplifier when you push your amplifier towards saturation.

Notes

Summary

9m 33s

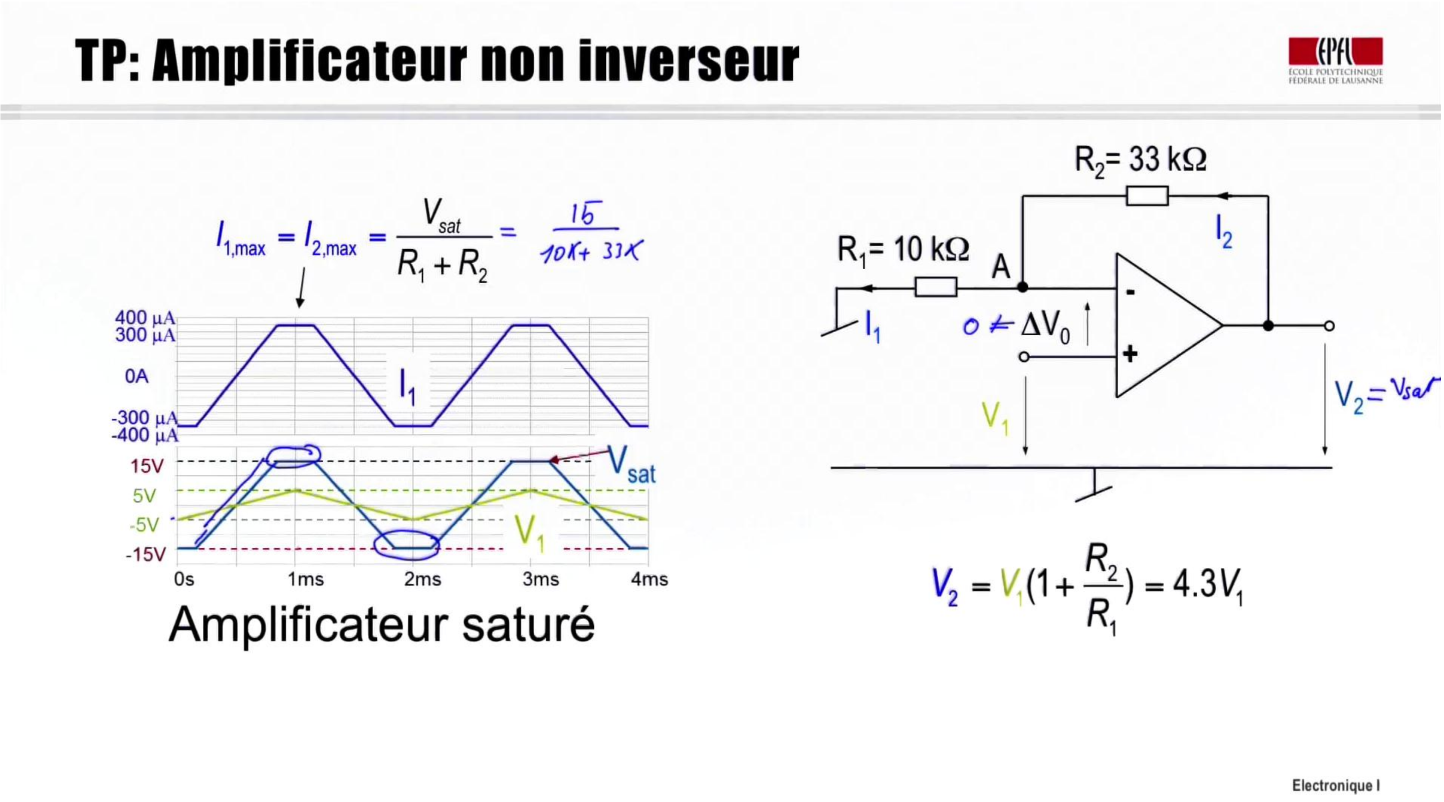


So we had a peak voltage value of 5V. You multiply that by 4.3. So you'll have a voltage which exceeds 15V. Your amplifier can't go beyond the supply voltage. It will saturate at +15 and -15. What happens with this circuit? The amplifier can't in any case, at that moment, remain in the linear area. The voltage difference *ΔV0* can no longer be equal to 0 because your amplifier can't remain linear. We applied a linear voltage at the input and we see a voltage which is no longer linear. When the voltage is a straight line the amp remains in the linear area from here to here. It arrives here and there, the amp is becoming saturated, here also the amp is becoming saturated. So at that moment, when the amp is saturated, *ΔV0* will of course be different to 0. So the current *I2* which crosses the two resistors can no longer be proportional to *V1* at all. So there, the current *I1* here was *V1/R1* when the amp wasn't saturated, so when it's here in this area, the linear area, there it's in the saturated area. And when we're in the saturated areas, this current, or rather this voltage *V2*, in the saturated area, will be equal to *Vsat*.

Notes

Summary

10m 19s



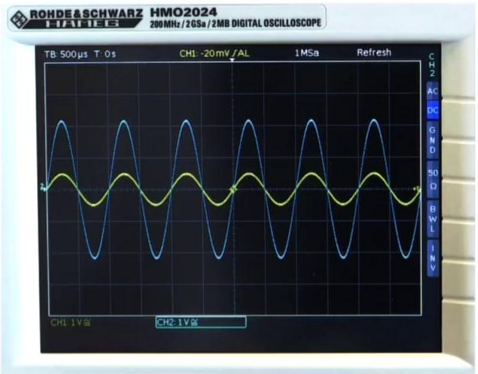
So it depends on the saturation voltage. Here, as it happens, it's 15V. So it's the 15V divided by the resistances of 10kΩ + 33kΩ which will give you 350µA as a saturation current. So it's very important to realise that the value of these resistances when the amp is saturated will lead us to have the maximum current produced by the amp, and it's the max current and the same current of course which passes through resistors *I2* and *I1*. And remember, when the amp was in the linear area, the current is especially proportional to *V1/R1* and still supplied by the operational amplifier.

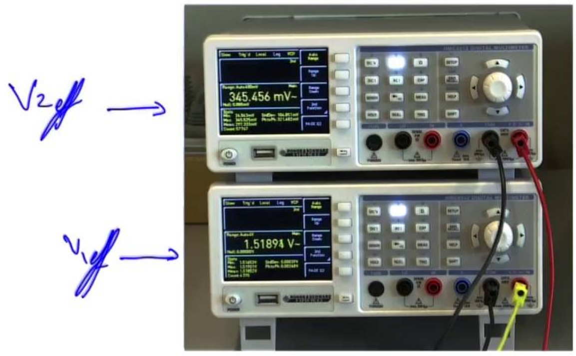
Notes

Summary

11m 49s

TP: Amplificateur non inverseur





Electronique I

Which you will have seen on the oscilloscope if the input voltage was a sinusoidal voltage in yellow, and an output voltage in blue which is also a sinusoidal voltage, you'll still observe a gain of 4.3. There, I measured the effective values of the input voltage. Here is the input voltage *V1* and here, the input voltage *V2*. And you'll see that the effective value from one to the other if you do the equation, you'll get an amplification gain around 4.3. Remember that these measurements were done in the lab, which means that error is introduced, it goes without saying, by the tolerance of resistors and the precision of measuring equipment but in this case, the equipment is very, very precise. Look at this phase: it's a positive phase. It's equal to 0. When we look at it, the two voltages are completely in phase, which explains the behaviour of this amp which is a non-inverting amp, so it doesn't invert, it doesn't dephase the signals and it keeps the output voltage in phase with the input voltage, on the contrary to an inverting circuit in which we have observed a 180° dephasing with a sinusoidal voltage.

Notes

Summary

12m 39s