ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Applications des Amplificateurs opérationnels

8.2 Applications non-linéaires

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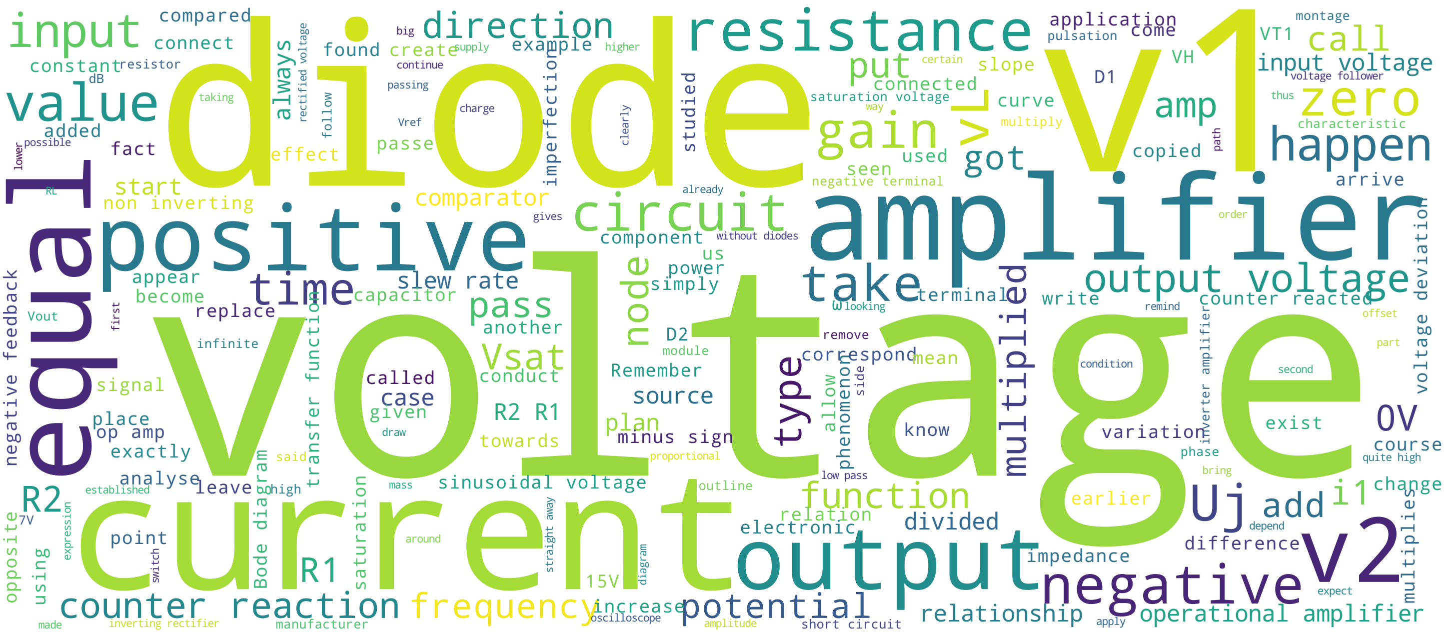
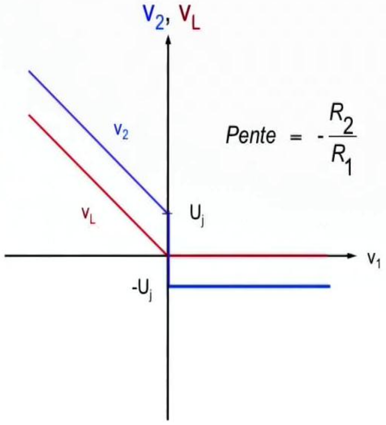
Electronics Laboratory-ELAB

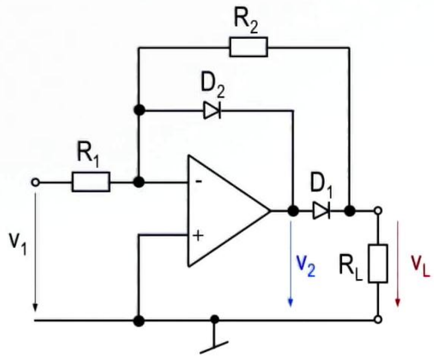


Video

EPFL

Redresseur inverseur simple-alternance





Electronique I

Now I would like to start with rectifying a signal, but do the opposite to what we did earlier. Earlier, we made a non-inverting rectifier, now, we are going to make an inverting rectifier. We would like to make a function if the input voltage *v1* is positive, I would like the output voltage *vL*, to be equal to zero. However, if my *v1* voltage is negative, I would like the output to be opposite, so it's positive. So I'll take the negative component of *v1* and rectify it, I'll make it positive. And if *v1* is positive, I'll put the *vL* voltage equal to zero. And we are going to analyse the montage based on an inverting montage. I am going to outline it without diodes. Compared to the montage that we've just analysed, I'm dealing with two diodes. Earlier, I used a single diode. You will see why I need two diodes. But I'm going to outline it without diodes. I'm going to outline an inverting montage without diodes. So I will try to modify this like that in real time, if I eliminate this diode *D2*, which is no longer there, and in place of this *D1* diode, that I will also remove, I'll replace that with a short-circuit which will join this node here to that node there.

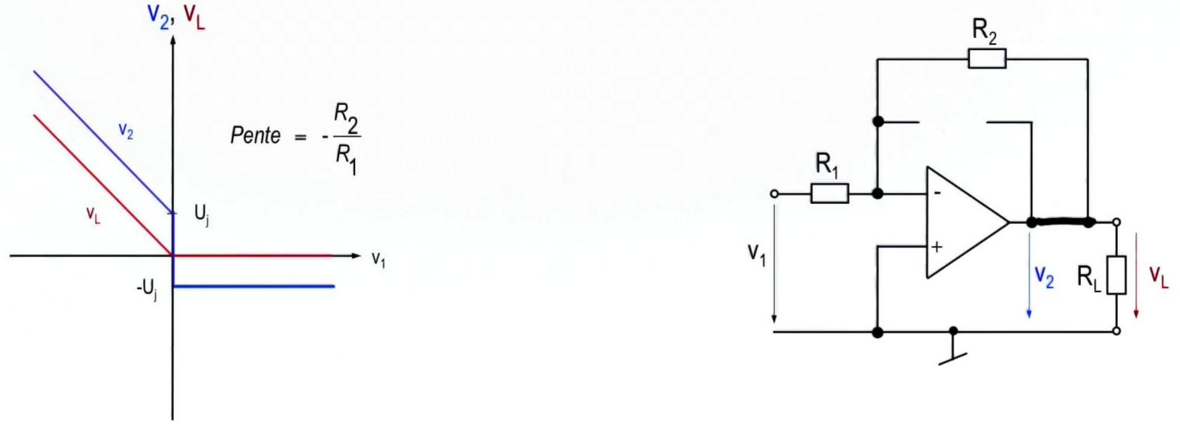
Notes

Summary

0m 04s

Redresseur inverseur simple-alternance

$$V_L = -\frac{R_2}{R_1} \cdot V_1$$



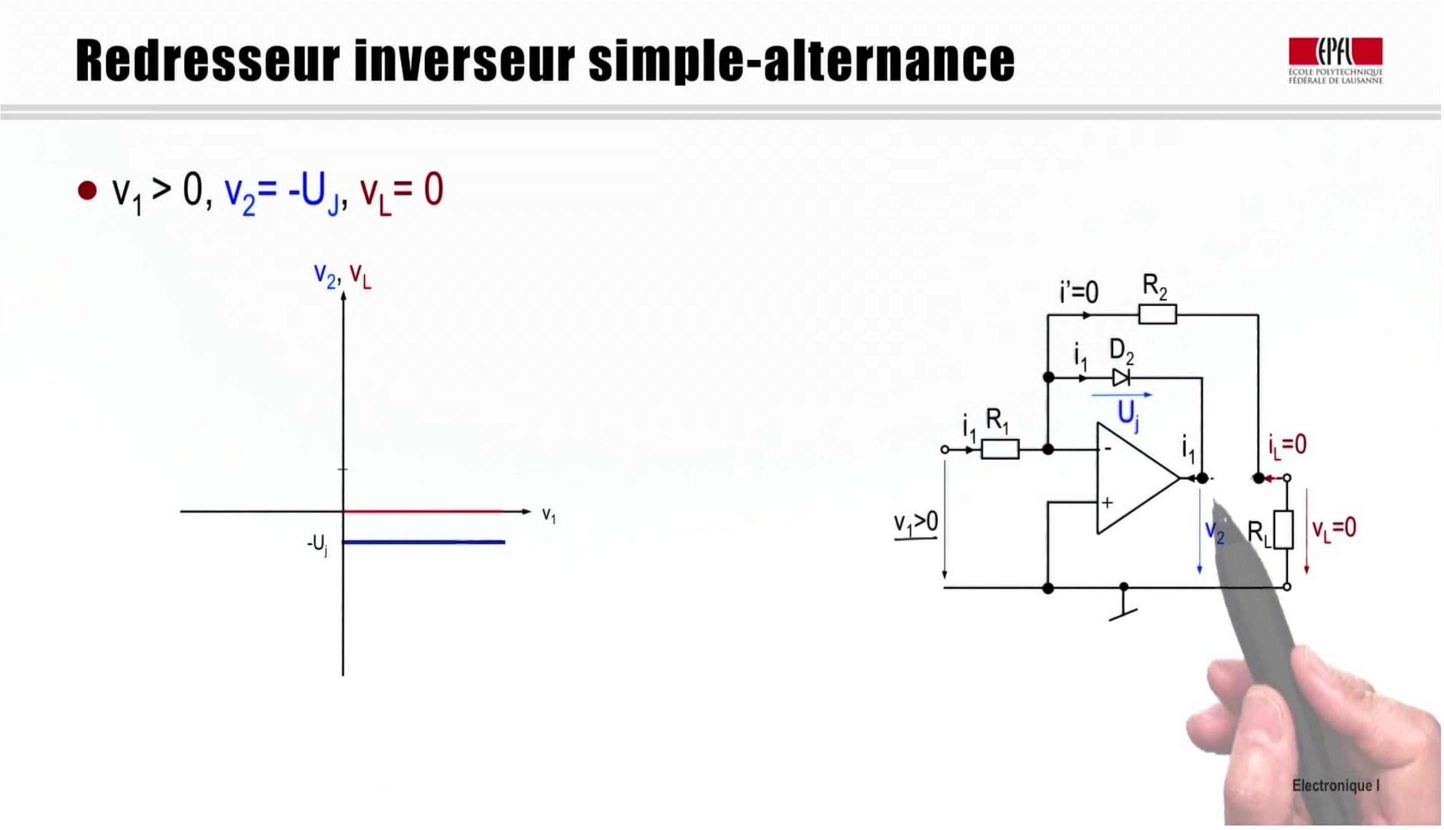
Electronique I

And I'll look at this circuit. This circuit, it's an inverter as we studied before whereby the *vL* voltage is equal to *-R2/R1* times *v1*. So I can write it here: *vL* = *-R2/R1* which multiplies the *v1* voltage. So if *v1* is positive, I will have a current which will leave the amplifier and descend in the charge. Sorry, I was wrong. If *v1* is positive, I will have *vL* which is negative. So I will have a current which will go in this direction there. If, however *v1* is negative, *vL* will be positive and the current will go in this direction there. And now, we are going to add these diodes and we will do exactly as we did earlier and by analysing the two conditions: once *v1* is positive, and once *v1* is negative.

Notes

Summary

1m 36s

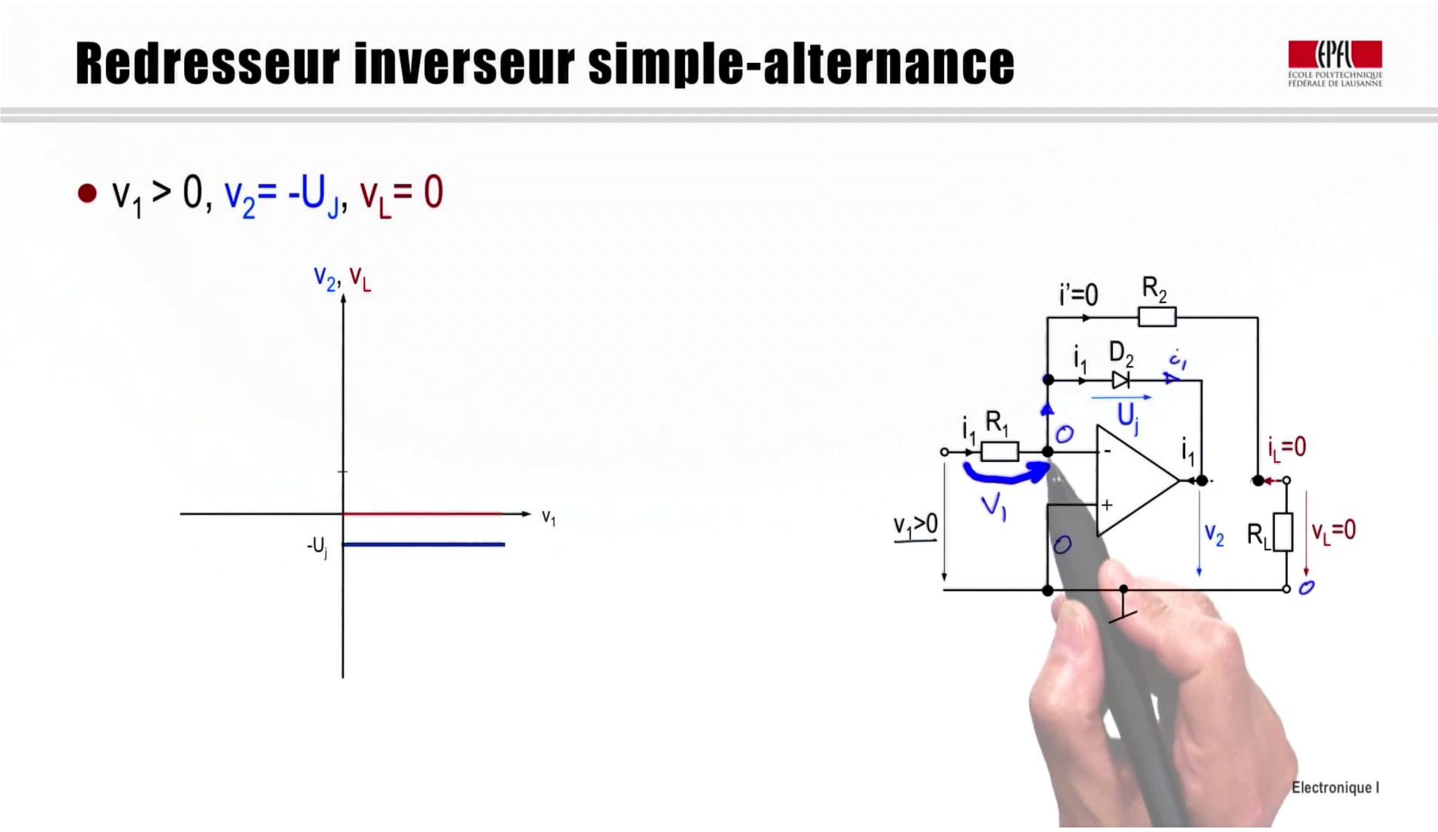


I'll start with the case of *v1* is positive. I'll take my plan, how do we analyse this circuit? To analyse this circuit, you will always reason as if the diodes didn't exist and you will tell yourself that *v1* is positive, *vL* should be negative. So there's going to be a current which will go in this direction. And now, we will add the diodes. So we place the condition as if the diodes didn't exist, I'm dealing with an inverter. I place *v1* and I look at *vL* and after I add my diodes and I will see how these diodes will behave. So I took *v1* as positive, I expect *vL* to be negative because it will be opposite, there is a minus sign. The current will want to pass like that. It comes into this node, this current. There is this diode there. This diode will block its path, it won't let it pass. So it's as if this diode will be removed, and so what I'm going to do straight away, as if *D1* wasn't there. So this *D1* here will disappear and I have this montage. Look at what I have now. This diode is useless. A blocked diode, we can't see it in the plan. So my current which would like to go in there, it can't go. And so, what is happening to this diode?

Notes

Summary

2m 32s

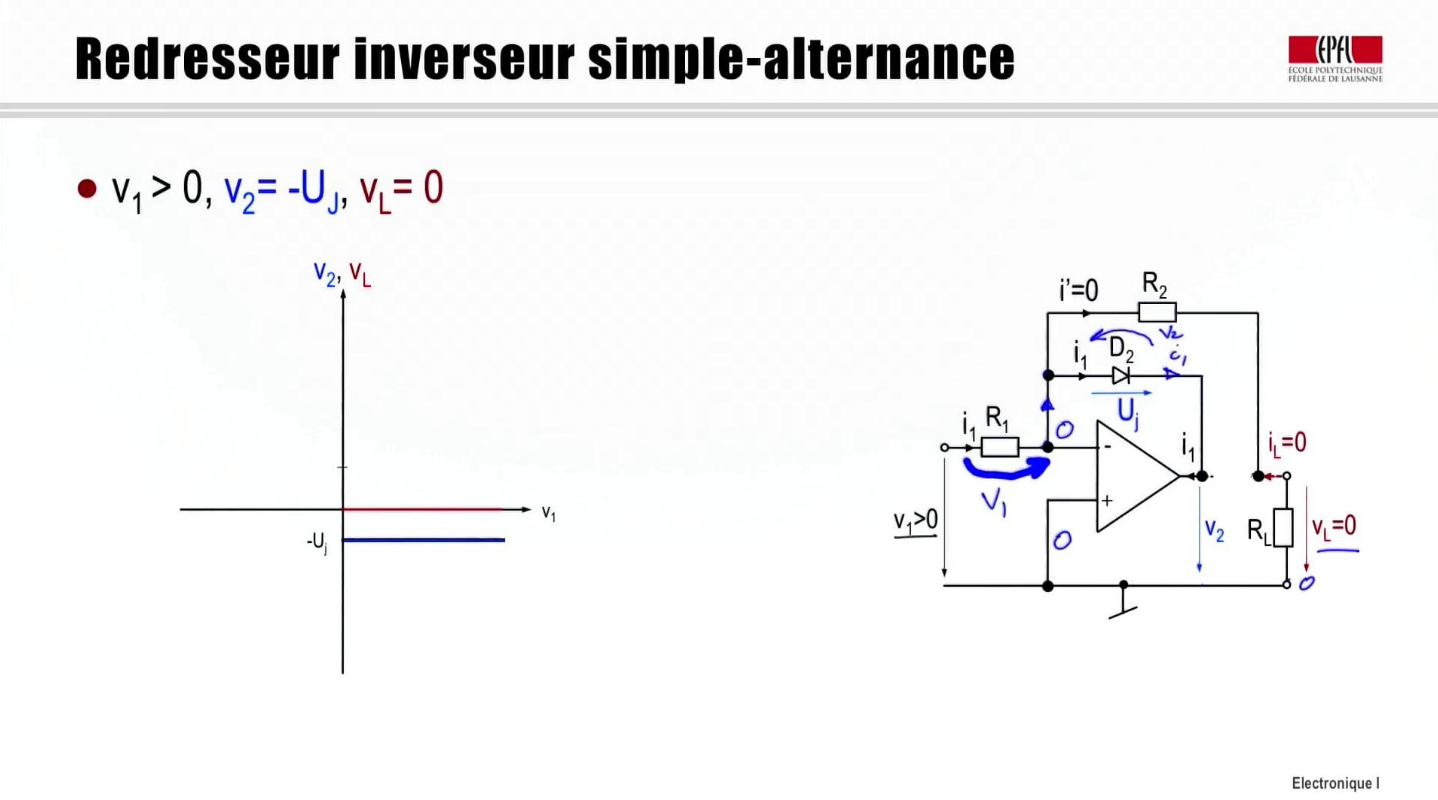


If *v1* is positive and when *v1* is positive, I will have *v1* which, theoretically, will appear there. And there, I will have a *v1* voltage. I have 0V there and the 0V, it's copied by the counter reaction here. And there, you must listen to what happens because we will see that this 0V, which is what I can see here, is copied there. So if this 0V here, and this 0V here, that is the real 0V and that is the virtual 0V, I have no current at all which can't cross this resistance, when this diode is a conductor. Having added this diode there, this diode will have *v1* and *i1* which would like to pass like that. So if *i1* arises here, it comes into this node here. Can *i1* pass through this diode? Yes, the diode is in the right direction. It would be able to let *i1* pass. So the *i1* current will pass through the diode. And if the *i1* current passes via the diode, passes in the amplifier, that's it, we have a counter reaction established. When this counter reaction is established, the potential here is copied here. And there, I have 0V. So having 0V, thanks to this diode there, if this diode hadn't been here, I would have no chance at all of having a copy of this potential towards this potential.

Notes

Summary

3m 55s

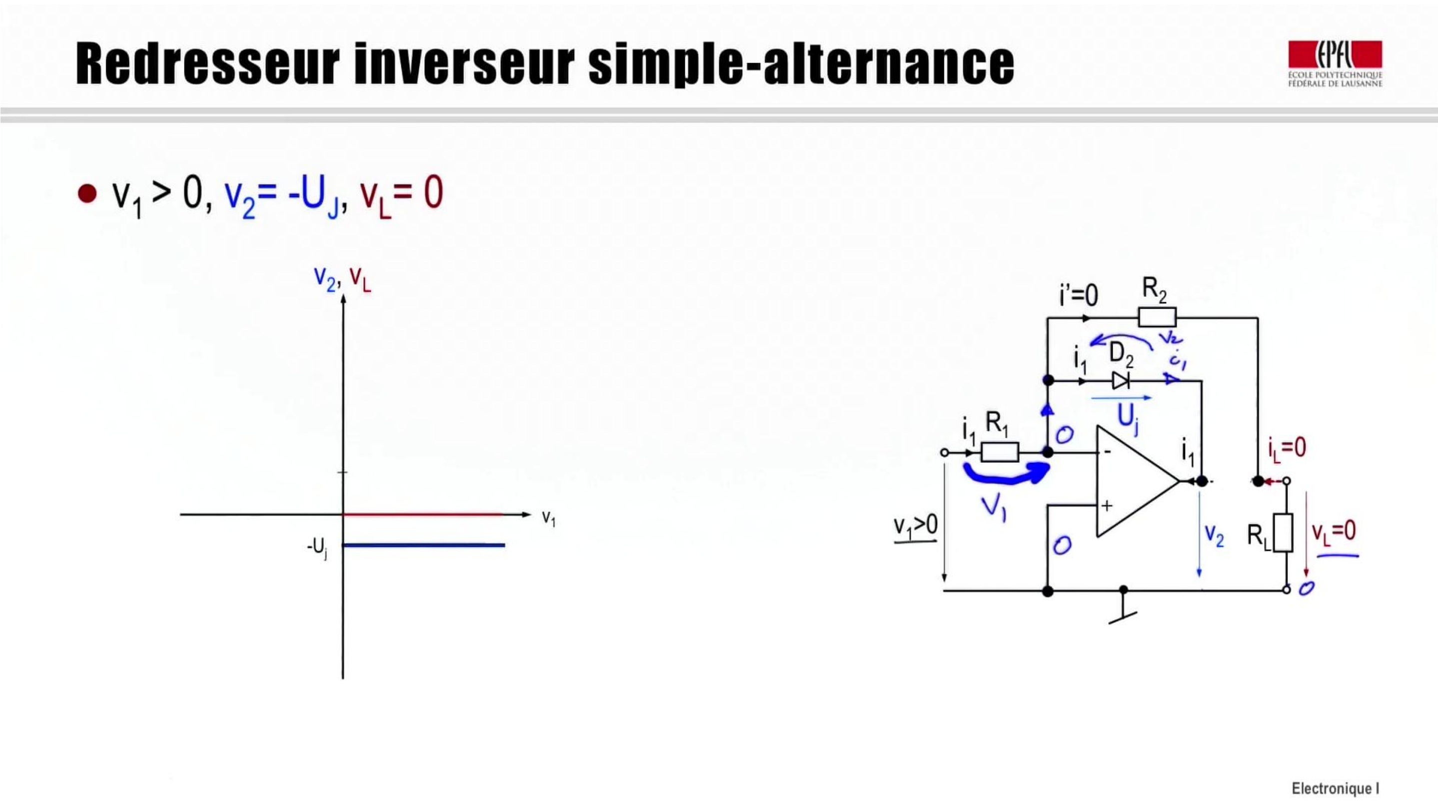


This potential will rely on *R1*, *R2* and *RL* and I will have *v1* which will be on the terminals of these three resistances and that will have a given potential thanks to that. But the diode, when it conducted, created a counter reaction so the amplifier created the virtual mass. So I have 0V there and I have 0V here because 0V from there to there doesn't allow a current to pass through *RL* and *R2* which gives me *i' = 0* and therefore I have zero current. And I have the voltage *vL = 0*. So we've just found straight away that if *v1* is positive, a diode creates the counter reaction, the other, we can't see it on a plan. And this enables us to have *vL = 0* and this gives us that. What happens with *v2*? *v2*, is from this node towards the mass. And this potential is the same as this one so *v2*, I have it here. So that is exactly the *v2* voltage. So *v2*is equal to a *-Uj* voltage. When the diode will conduct, it will create a connection voltage that I call *Uj*. So *v2*, it's from this node here to this node there, on the terminals of the same diode so *v2* is located at *-Uj*.

Notes

Summary

5m 27s

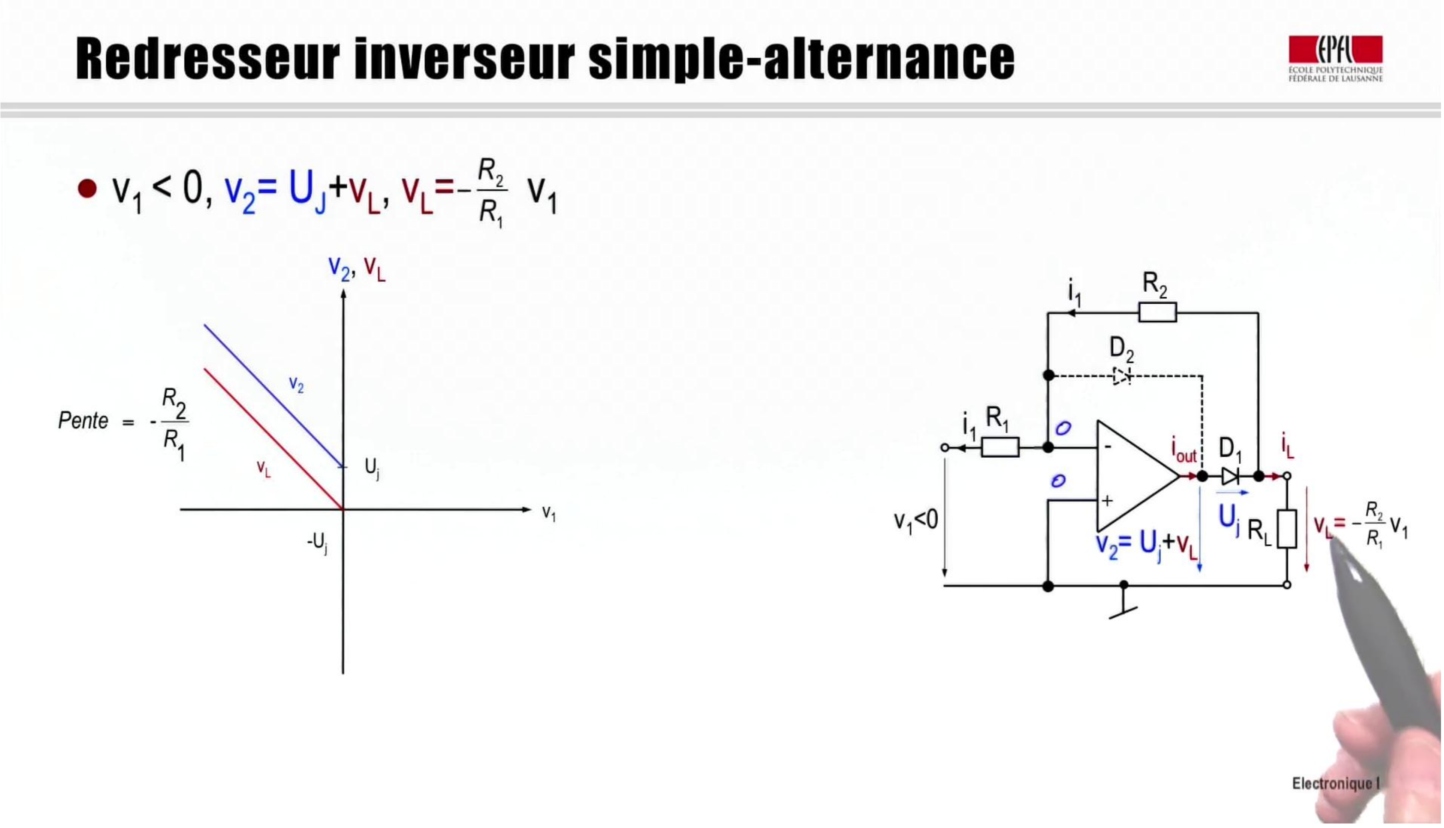


I would just like to insist on that. In the case of a non-inverter rectifying amplifier, that we studied earlier, we found that when the output voltage was zero, we found that *v2* was equal to -*Vsat*. There, it's already better. Instead of going towards the saturation voltage which is quite high, to a relatively weak voltage compared to *Vsat*, which is on an order of -0.6 to -0.7V which is a connection voltage.

Notes

Summary

6m 45s

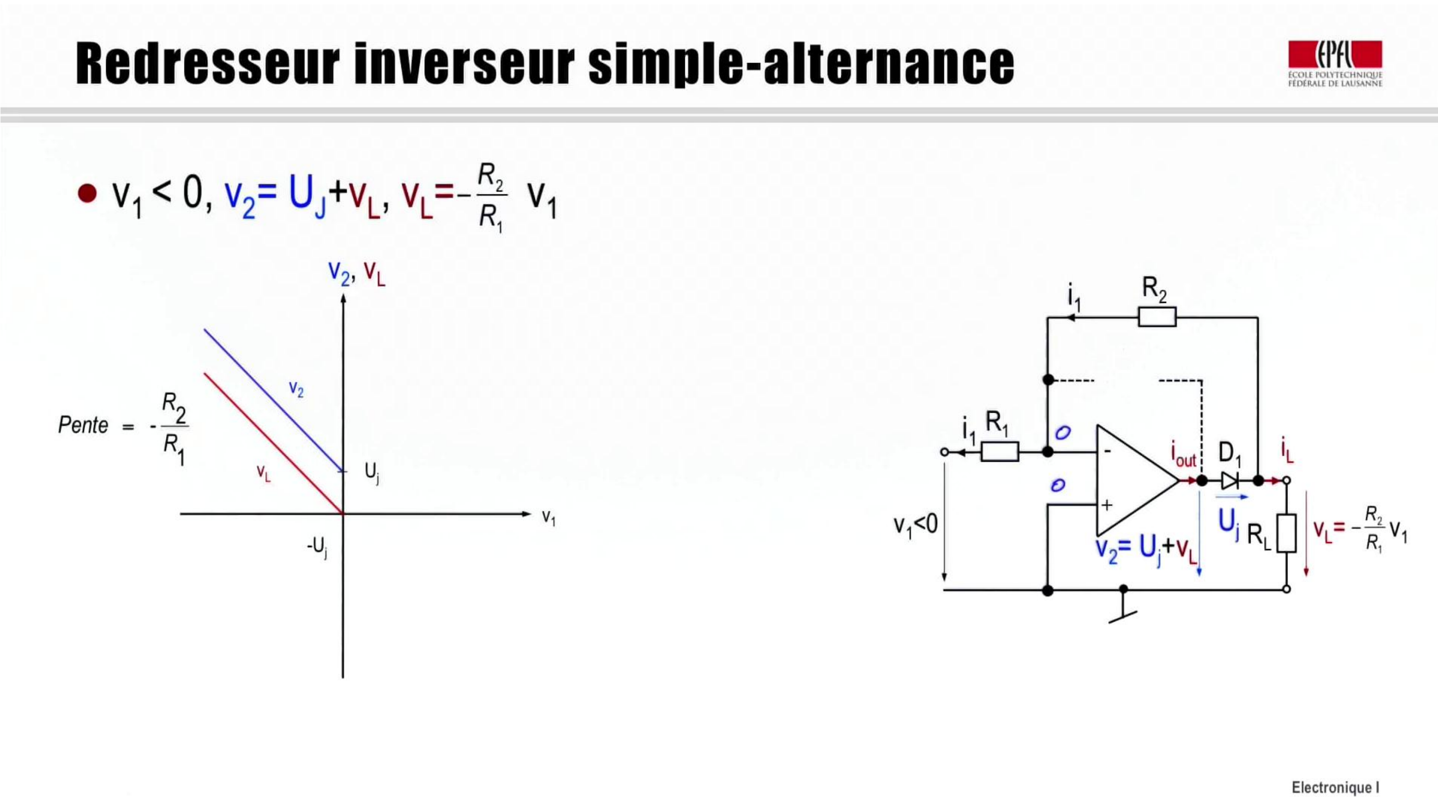


We will now analyse what will happen with the same plan, but taking an alternation for which *v1* is negative. So I'll put *v1* negative. Same logic. If I apply a negative voltage, I reason as if my diodes didn't exist and I would say in an inverter amplifier when *v1* is negative, I will find myself with a *vL* postive voltage. So the current will want to come in this direction there. There is a diode. This diode this time is in the right direction of the current flow. So the amplifier which provides the current passes through the diode and continues its path. So the counter reaction is established through the *R2* and *R1* resistances and allows the counter reaction to happen. But what happens with the *D2* diode? The *D2* diode has 0V here, so the counter-reacting amplifier will impose 0V there. And there, the voltage will be positive. So we said *v1* negative, *vL* will be positive, so this voltage is quite high. So if this voltage is quite high, this voltage there will also be high compared to zero. So *v2* is positive and higher than zero, so this diode is blocked, so we can remove it. We can imagine that this diode doesn't exist.

Notes

Summary

7m 14s



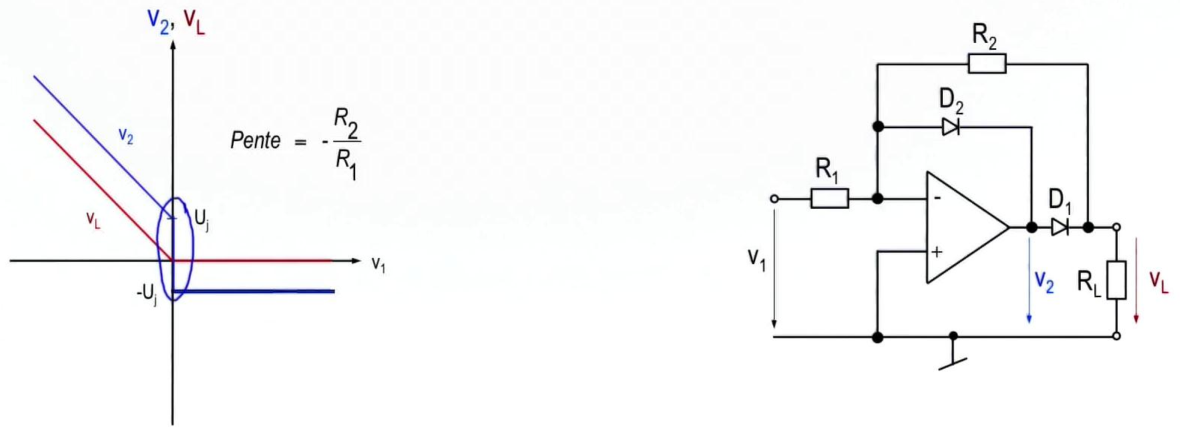
I'll remove it from my circuit and I have a circuit in which there is simply a *D1* diode which created the counter reaction and the inverter plan, we can also demonstrate like earlier, that adding a serial *Uj* threshold voltage, if you bring this voltage to the input, you will take *Uj* divided by the gain of the amplifier which is very, very big, so *Uj* divided by infinity, there's no real effect of *Uj* if the gain is very, very big. In this case, in this type of plan, we can clearly see that the amplifier becomes an inverter amplifier, as we know, as usual, which will take a *vL* voltage and which will multiply by a constant *-R2/R1* multiplied by *v1*, which is what we expect from an inverter amplifier and which will give us a slope which, for a negative voltage, makes it positive. It multiplies it by a *R2/R1* value. And that's it, we have this famous relation that the negative voltage *v1* would be multiplied by a minus sign so it becomes positive again, multiplied by a constant *R2/R1*. And the *v2* voltage is always behind compared to the *v1* voltage of a quantity which is equal to this *Uj* voltage.

Notes

Summary

8m 40s

Redresseur inverseur simple-alternance



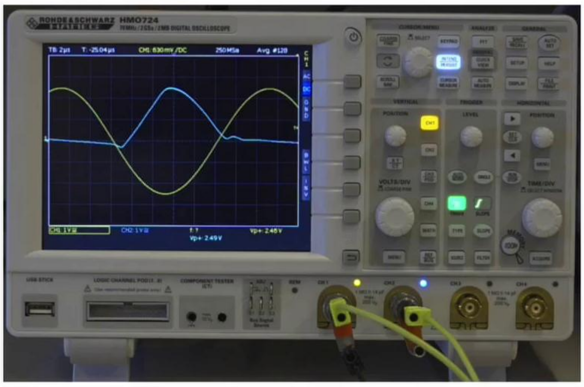
So this *Uj* voltage is always the voltage that we will see between these two curves. So we have two curves following each other, with a *Uj* voltage between *vL* and *v2*, and we can clearly see that here. And to finish, here is our complete plan with the two diodes, with the characteristics that we analysed earlier. It's a non-linear function. When the voltage is positive, the output is zero and when the voltage is negative, the output becomes positive. And we have this type of plan. There is a big advantage, it's that the *v2* voltage will never look for a saturation voltage, so a high voltage. So we are less irritated by the *slew rate* of the amplifier because the variation of *v2*, when we pass from a positive voltage, when the *v1* voltage passes through zero, we see a variation in size order from 1.2 to 1.4V because it's equal to two times *Uj*, contrary to what we saw earlier which was 15V plus 0.7V. So the difference is clearly minimal and the impact on the output voltage of a limitation of the amplifier, which is the *slew rate*, is lower. So we always wish, as much as possible, to appeal to this type of montage rather than the alternating simple rectifier when the output is positive, we prefer to use this montage to take advantage of this effect that we've just discussed.

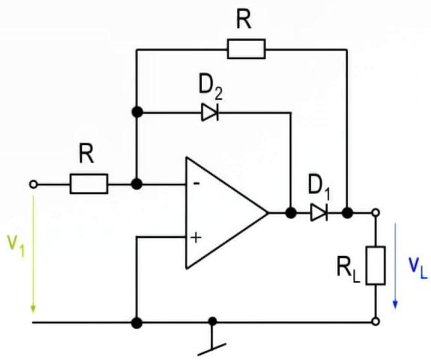
Notes

Summary

10m 01s

TP: Redresseur inverseur simple-alternance





Electronique I

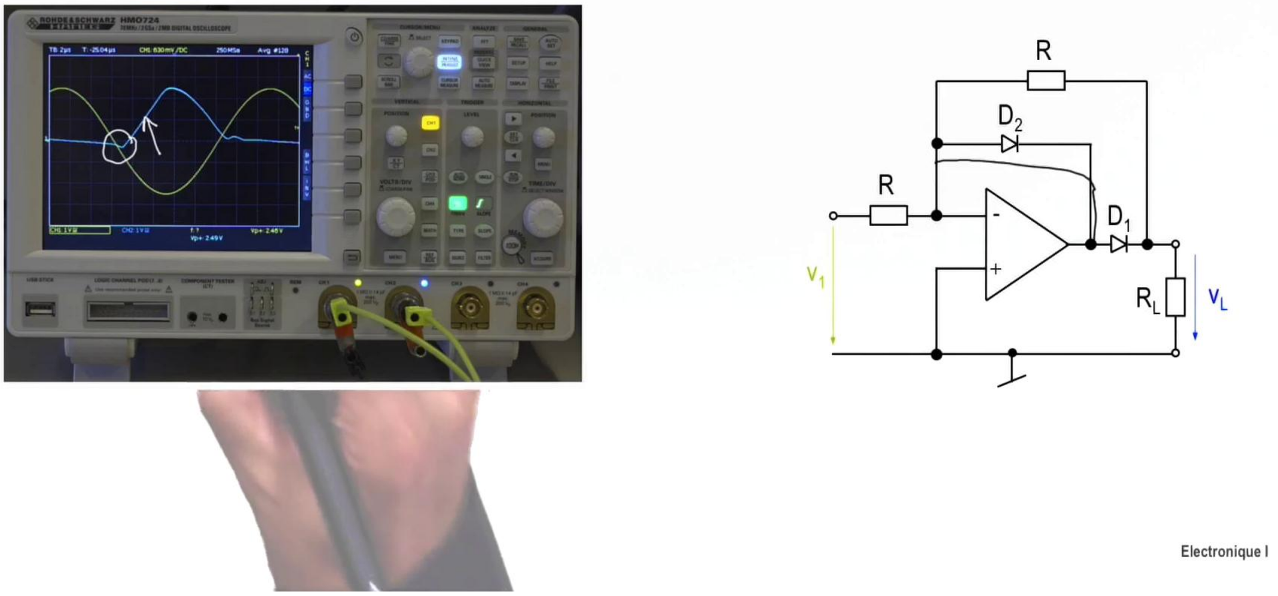
Here is our input voltage which is in yellow and certainly, we will see the rectified voltage at the output, i.e. the positive alternation will give us a zero, however, our negative alternation will be rectified and that is what we can see now on this oscilloscope. I would really like, at this stage, to illustrate what will happen with this type of amplifier when it passes through zero and see what problems will occur, linked to the *slew rate*. So remember that an operational amplifier suffers from an imperfection when we have a voltage deviation at the output and with this voltage deviation, when it has to do be done quickly, there is a phenomenon called the *slew rate*, as it's called in English. And this voltage deviation limits the voltage variation at the output that we can see there. So you see the blue curve. When the voltage in yellow passes through zero, of course, this diode there, is the one that was conducting, the amplifier is counter reacted by the two resistances, but when it passes through zero, it will rectify the voltage and it will pass from *-Uj* to *+Uj* and we can see this phenomenon here.

Notes

Summary

11m 29s

TP: Redresseur inverseur simple-alternance



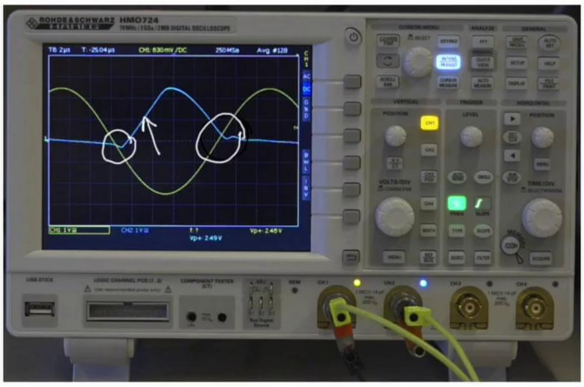
This phenomenon shows us that there's a small change and then, we have this slope and this slope isn't exactly a sinusoidal voltage. It's the tangent slope to the passing through zero of a sinusoidal voltage because the amplifier will take time to follow *-Uj* to *Uj* and it will affect the linearity of the rectified voltage at the output. And to solve that, as we saw when we studied the chapter on imperfections, you can lower the voltage and have fewer deviations. There is another phenomenon that I would like to comment on, it's what happens when this diode there will conduct. So this diode here will conduct, it will make a counter reaction. So it will rejoin the current which will pass directly by a counter reaction through the diode by having a drop in *Uj* voltage in this direction there. That means that at the moment when this diode will conduct, the amplifier will act like a voltage follower it has a plus here, it will place it there, the zero, it will place it here and we would have a follower. And the voltage follower corresponds exactly to what happens there. The amplifier is counter reacted by the *D2* diode.

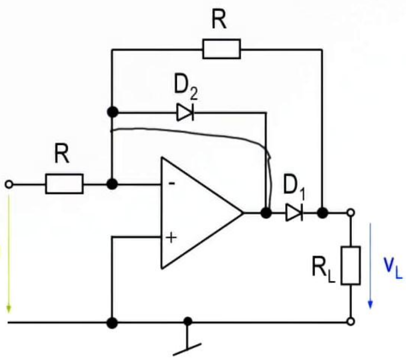
Notes

Summary

12m 46s

TP: Redresseur inverseur simple-alternance





Electronique I

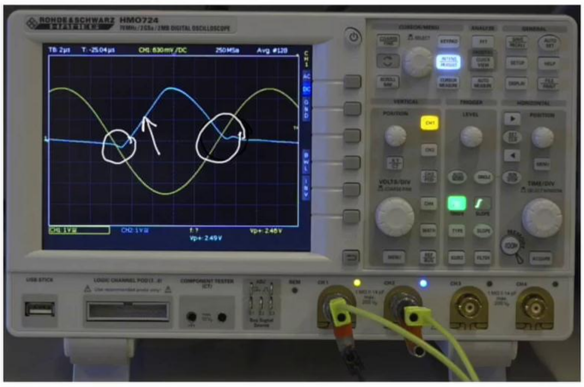
And rightly, when it arrives there, when it arrives here, the amplifier is changing the type of counter reaction. At the start, it was counter reacted by this *D1* diode. And then, it is counter reacted by the *D2* diode. And we can see small oscillations that appear here because this amplifier can't quickly follow this passage from one diode to the other and it will take a certain amount of time to counter react and we can see it here by an oscillation which is quite common for these components. To resolve this and to have fewer oscillations which appear here, you need to increase the amplifier's gain and the amplifier's bandwidth, if possible. And that's it, with that, we were able to see that using an active amplifier, which has stability rules that aren't yet studied at this level in electronics, we would still have a rectified voltage which can sometimes suffer from the amplifier's imperfections. And it was the right moment to mention them. And what we've just seen with this amplifier by using the two diodes is much more drastic and has a much more limiting effect when the amplifier is non-inverting.

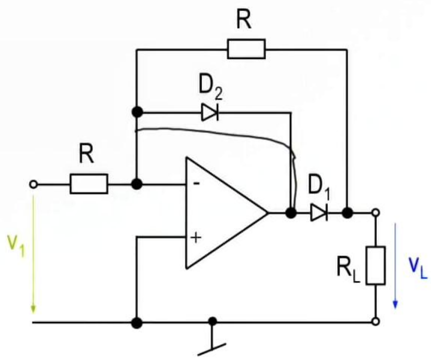
Notes

Summary

14m 05s

TP: Redresseur inverseur simple-alternance





Electronique I

I understand that the montage that we studied at the start, where it's a non-inverting rectifier, this type of phenomenon is much more drastic and strongly limits using this amplifier with applications that have very, very weak frequency and the output voltage deviation is extremely weak, especially when passing through zero. I remind you that when the rectifier is non-inverting, the output voltage of the amplifier has to leave from -*Vsat* to +*Uj*. And there, we already see this phenomenon when it leaves from -*Uj* to +*Uj* so in size order from 1.4V, and in the case of the non-inverter, there's a lot of voltage which passes and the *slew rate* sometimes has to change from voltages like -15V to 0.7V, which is enormous.

Notes

Summary

15m 21s