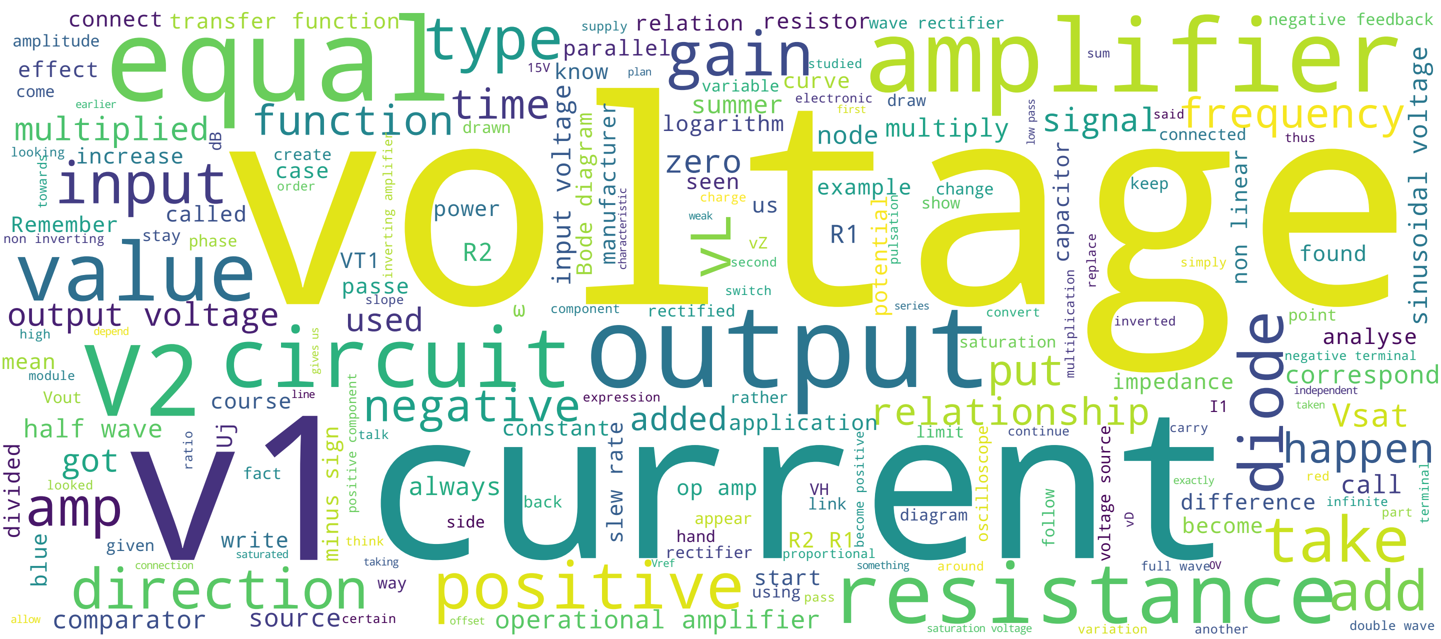
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Applications des Amplificateurs opérationnels

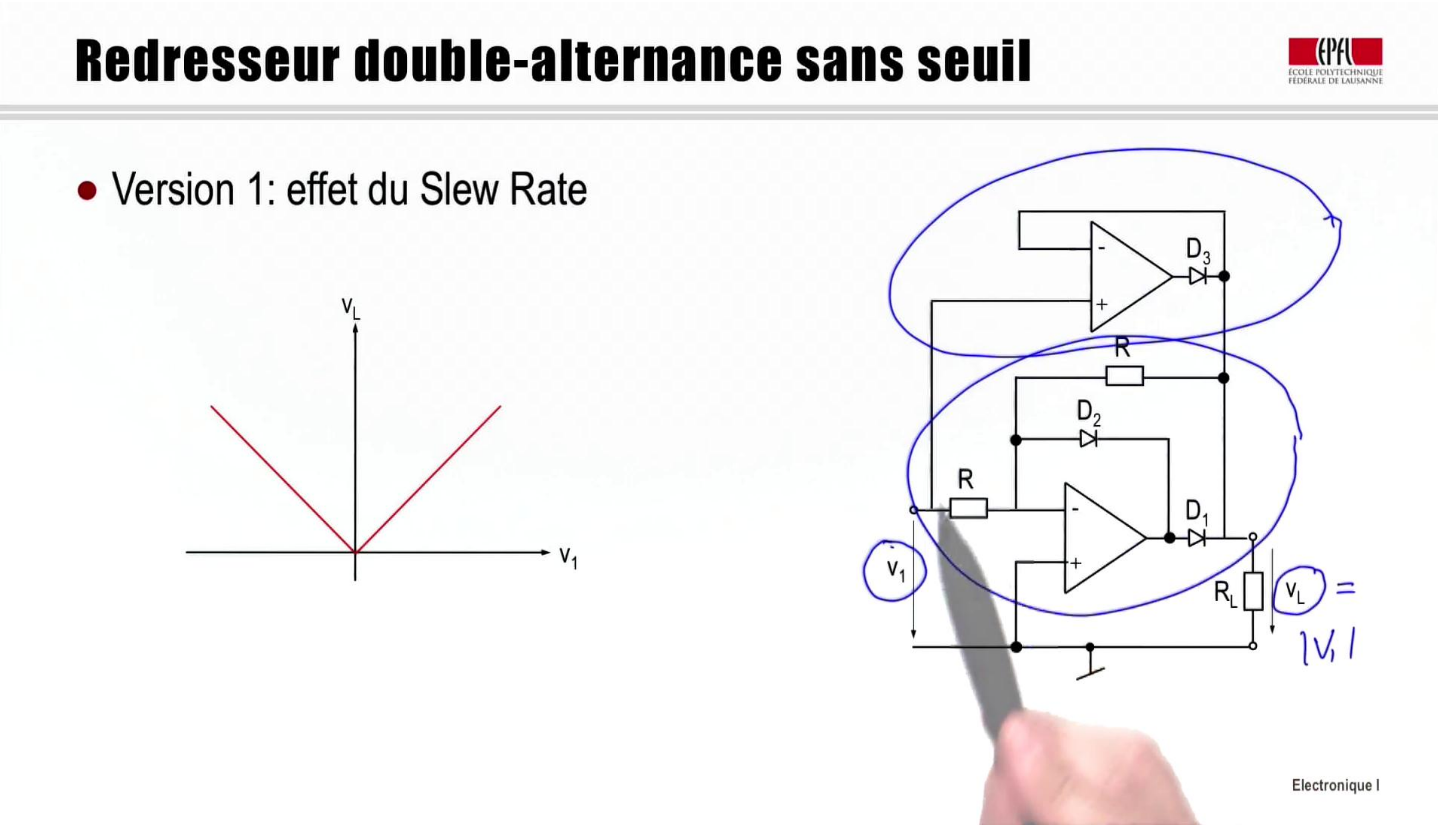
8.3 Applications non-linéaires

Prof. Maher Kayal
Electronics Laboratory-ELAB



Video

EPFL



Suppose that now we want to do a full-wave rectifier. So a full-wave rectifier means that the positive component at our input, it is sent to the output, and it will remain positive. On the other hand, the negative component is rectified and becomes positive. So this is a full-wave rectifier. The voltage *vL* is equal to the absolute value of *v1*. So this voltage *v1*, whether it's positive or negative, will always become positive at the output. So we direct everything towards the upper level. *vL* is always positive, we can never have *vL* as a negative, regardless of the value of *v1*. When *v1* becomes negative, the circuit rectifies the positive position. We can do this easily by taking the two circuits that we have seen before and putting them in parallel. Here is a half-wave rectifier circuit. This here is positive. So what is positive will remain positive. This here, which is negative, will be made positive. To put in parallel will generate this type of behaviour. Unfortunately, when you put the two in parallel, you'll benefit from this type of circuit. We've just said that the *slew rate* effect of the amp is less visible compared to the first circuit.

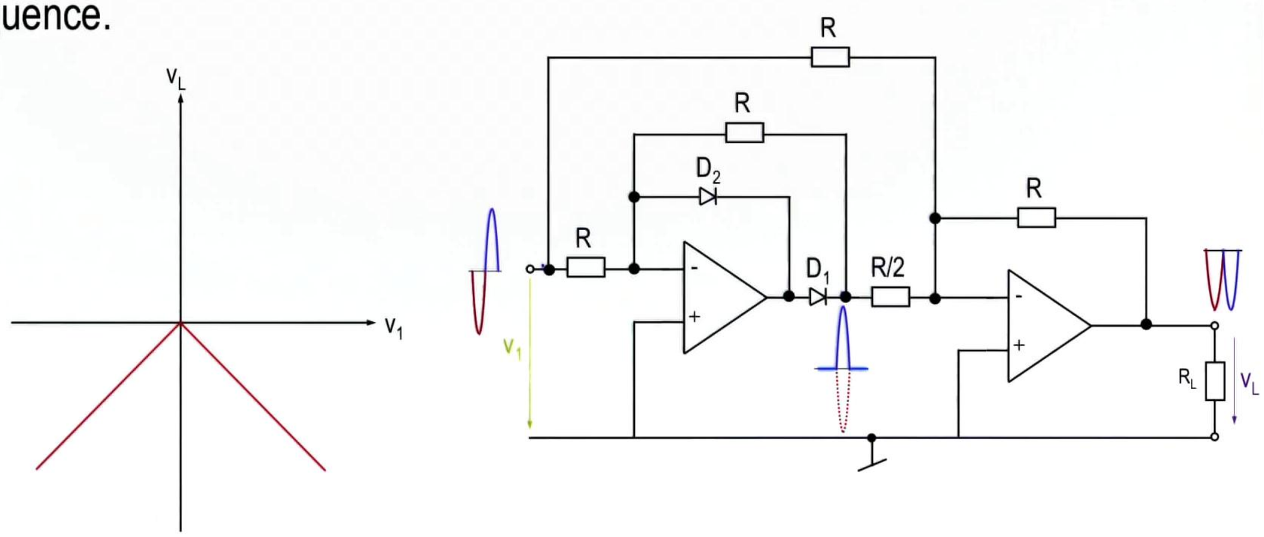
Notes

Summary

0m 04s

Redresseur double-alternance sans seuil

- Version 2: Meilleure réponse en fréquence.



Electronique I

Putting them in parallel means that this here will limit your frequency. On the other hand, here, it will limit your frequency less. So we don't take advantage of the benefit of one against the other. We're quite annoyed by the existence of this circuit. Are there any other solutions to resolve this problem? Yes. So here is a very well-known technique. This technique consists in using this type of diagram. So there, just to give another example, of course by inverting the diodes, we can go back to the previous diagram but just to illustrate another example, I have used an inverting amplifier, so this is an inverting rectifier, with a summer. I think you remember that this type of connection from here to here is a summer. We will take a voltage there and a voltage here and add them in. The voltage that is added here, is multiplied by this resistor divided by this with a negative sign to which we add the ratio of this resistor over this resistor with a minus sign, and send this to the output. We can analyse this circuit by focussing on a sinusoidal voltage. We have a sinusoidal voltage here. I have drawn the negative component in red, and the positive component in blue.

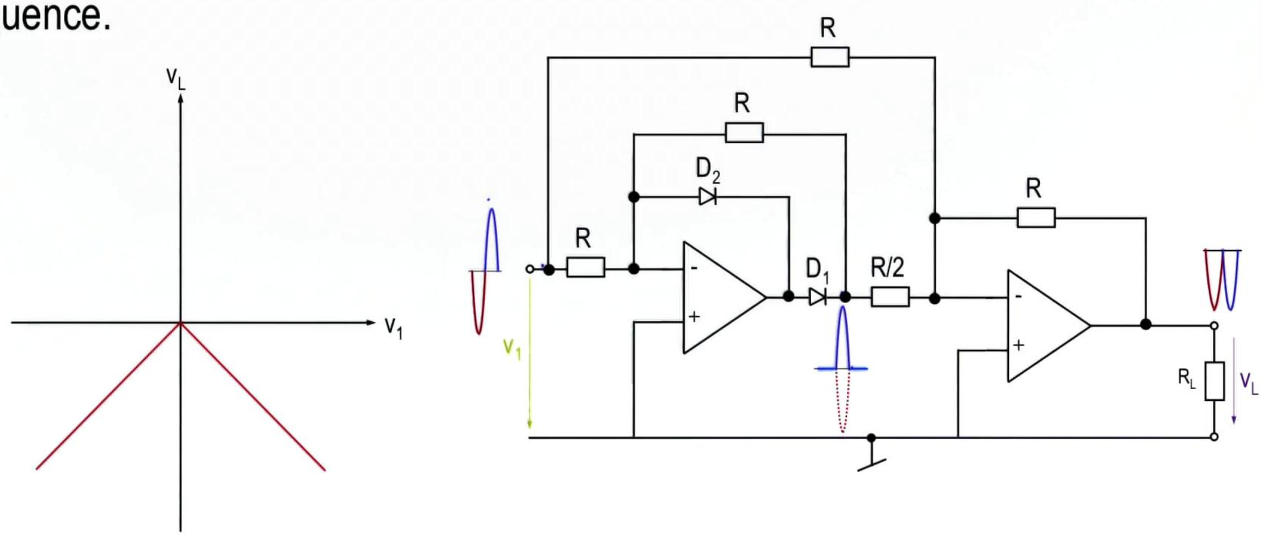
Notes

Summary

1m 38s

Redresseur double-alternance sans seuil

- Version 2: Meilleure réponse en fréquence.



Electronique I

I will analyse what first appears at the output of the rectifier. And well, at the output of the rectifier, there is a gain equal to -1. So I will take the negative part in red, which I've drawn in a dotted line here, and I will multiply it by -1, so I keep the same amplitude and I rectify it. So the negative part has become positive. This is what we have just analysed and studied. Now, I put this in a summer and I multiply it by 2. So I take this positive part and I multiply it by 2. I have doubled this and I add a minus sign. So what is drawn in blue will find itself inverted again and multiplied by 2. It will be doubled and inverted. And I have just added all of my signal to it. I will take all this, invert it and add it in. I will let you do this little exercise for yourself so you realise that at the output, you will find yourself with the negative, and positive components that are found on the same side in this case, on the negative side. So all the sinusoidal input signal that we have added is now rectified at a double wave. So we don't lose the half-wave of our voltage at all but all the half-waves are brought back to a value less than zero which is clearly explained.

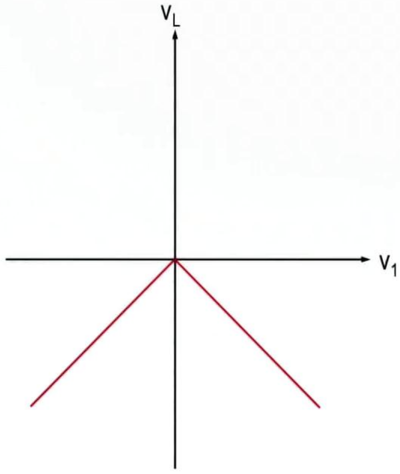
Notes

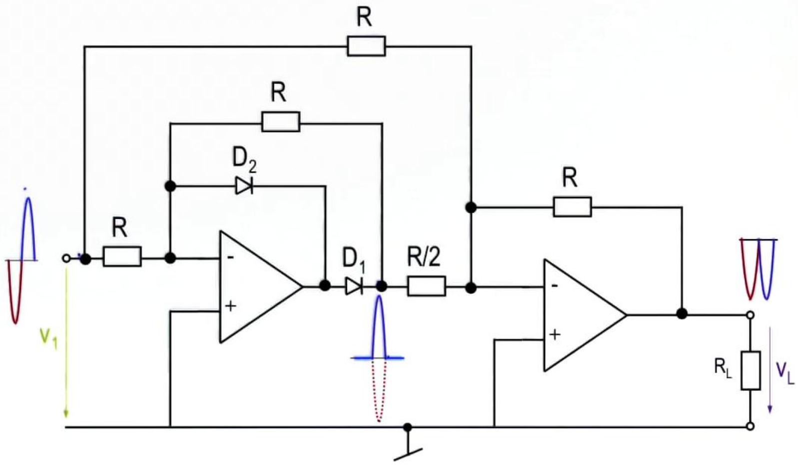
Summary

3m 01s

Redresseur double-alternance sans seuil

- Version 2: Meilleure réponse en fréquence.





Electronique I

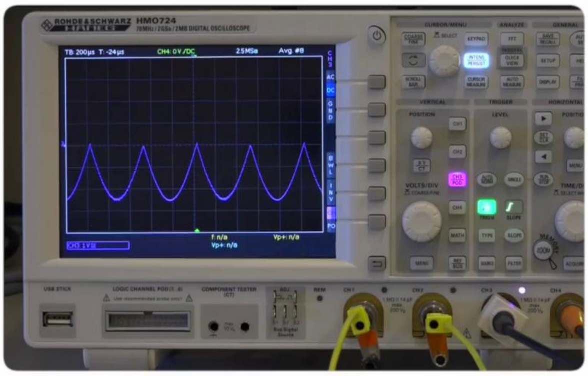
So the voltage *vL* is always negative and the value *vL* is always negative, regardless of *v1*. When *v1* becomes negative, it will stay that way until the output. And when *v1* becomes positive, the output *vL* will become negative. So we are going to connect it and look at what happens on an oscilloscope which shows us that this type of circuit essentially gives us a double wave such as this one.

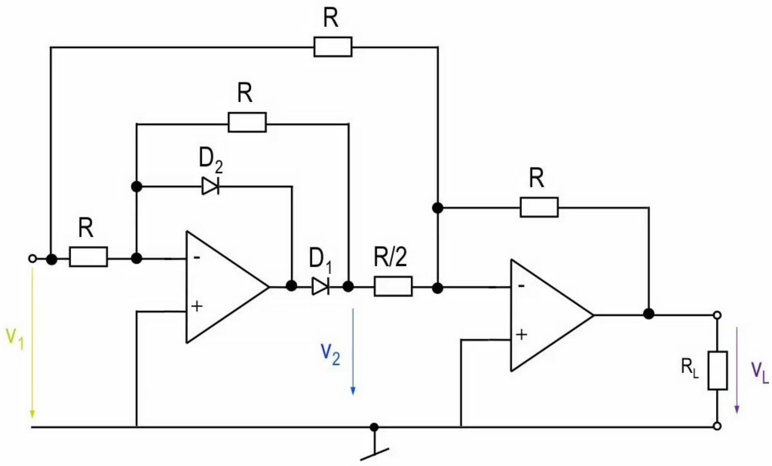
Notes

Summary

4m 35s

Redresseur double-alternance sans seuil





Electronique I

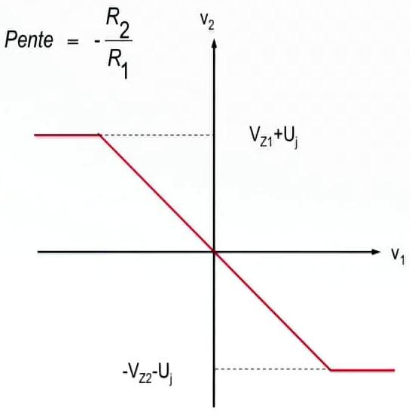
Here is our input voltage. As usual, we have a voltage, which we can track in yellow. And there, we will observe it after the first stage of rectification. So we see the negative half-wave which is rectified and has become positive. And the positive half-wave which has become equal to zero. And we will see what happens at the output of the summer. It's difficult to see what is going on on this oscilloscope because there are several lines which are confused, but we can see the output of the summer. It's enough to delete the other lines and keep the only voltage source at the output of the summer. And there, we have a negative double wave. So what will stay with us at the output, is an entirely negative voltage, as well as the positive part, the positive half-wave and the negative half-wave.

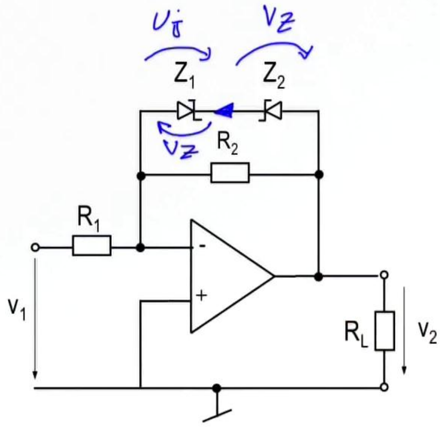
Notes

Summary

5m 02s

Amplificateur écrêteur





Electronique I

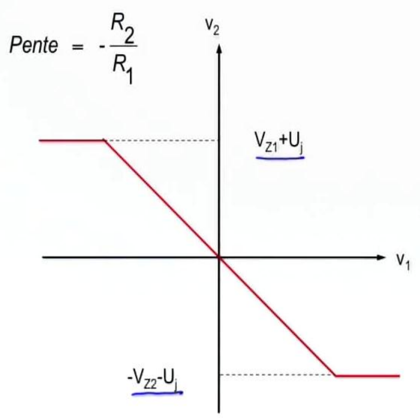
To continue with non-linear circuits, here is also a technique that we use by adding in diodes that we call Zener diodes. A Zener diode is a diode that we draw with a small *Z* which is added here. It has a forward-bias direction. So in this forward-bias direction, it is like a normal diode. So if I have a positive voltage in this direction here, I will have a voltage of *Uj*, like a normal diode. So this is a junction voltage to the order of 0.6 to 0.7 per silicon. On the other hand, when the current crosses it in this direction here, you will find yourself with a voltage in this direction here which is equal to the voltage *vZ*. We have taken two similar diodes and we have put the two diodes head-to-foot. So there will be a current in this direction or in this direction. And if you look if the current is positive in this direction here, you will see *Uj* and a voltage here equal to *vZ*. If you follow a current that will pass in the direction of this arrow here, you'll find yourself with a voltage equal to *Uj* and a voltage *vZ* in this direction.

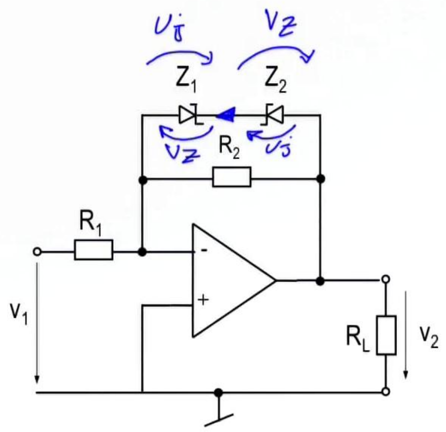
Notes

Summary

5m 50s

Amplificateur écrêteur





Electronique I

Which means that your amplifier, instead of overloading the voltages to saturation, it will linearly amplify the voltage *v1* and multiply it by a gain *R2/R1* and these two diodes here, will never intervene. But when we start to exceed *vZ1+Uj* and *-vZ2-Uj*, your amplifier will cap the signal and give an effect similar to a saturation effect but which is independent from the saturation of the amp. So if you want to avoid the feeder voltages of the amp finding themselves at the output, you can add this type of circuit and it's you who decides on the saturation voltage of the amp, not the power of your amplifier.

Notes

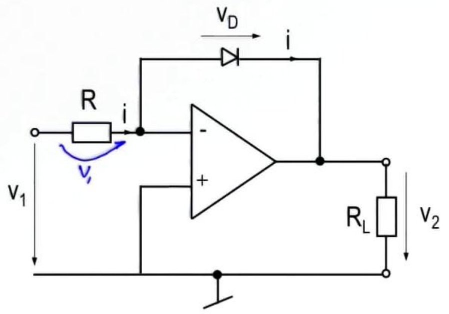
Summary

7m 10s

Convertisseur linéaire-logarithmique

$$i = \frac{v_1}{R} = I_S e^{\frac{vD}{nUT}} = I_S e^{\frac{-v2}{nUT}}$$

$$v_2 = -n\,U_T \ln \frac{v1}{R\,I_S}$$



Electronique I

To finish, we're going to analyse a circuit which is called a linear-logarithmic converter. This type of converter is used to amplify, or rather to convert the signals between *v1* and *v2* which will have a logarithmic relationship. But it acts only on increases on smaller signals. So when *v1* is very weak, a *Δv1*, you'll find with your *Δv1* voltage, I'm talking about an increase, so this weak amplitude here, which will give you a current *i* equal to *v1/R*. This current will cross through a diode. So the increasing diode, when the diode is reversed, which is found around an operating point of this diode, it has an exponential law which will link the current that flows through to the voltage to its terminals *vD* through this exponential law. The current *iS* is a current which is provided by the manufacturer of the diode. The variable *n* is a variable of correction for this relationship and it must be known. The thermodynamic voltage, as we knew it, is 26mV at room temperature. So when the voltage *v2*, which is also an increase that appears here, equal to *-vD*, we have replaced *vD* with *-v2*.

Notes

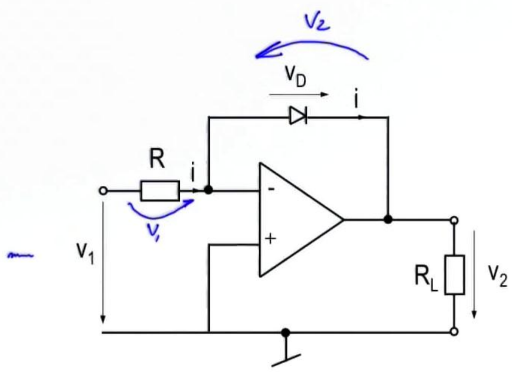
Summary

7m 56s

Convertisseur linéaire-logarithmique

$$i = \frac{v_1}{R} = I_S e^{\frac{vD}{nUT}} = I_S e^{\frac{-v2}{nUT}}$$

$$v_2 = -n\,U_T \ln \frac{v1}{R\,I_S}$$



Electronique I

And we can develop this. And we will find a relationship which links the voltages *v1* and *v2* by a logarithmic law. So *v2* is in reality proportional to the logarithm of *v1*. This circuit doesn't seem interesting or difficult to use, which is true. Having to add increases poses a problem. There are variants that I won't talk about now but which use transistors, which exacerbate this effect. But on the other hand, suppose that you have this type of convertor which converts a voltage *v1* with the logarithm of this voltage, know that it's an extraordinary measure to use when we want to carry out a multiplication operator because until today we used the op amplifier to add them together. We used the op amplifier to subtract. And if you want to multiply, the ideal is to use two sorting circuits like this with a summer. Why? Because the sum of a function where we have the logarithm, and well, if we add two logarithms to the output, we can transform this into a multiplication by looking for an inverse conversion, which means looking for the exponential of this. We know very well that the logarithm, when we add it in, we have the advantage of carrying out multiplications between the voltages when we add in two logarithms.

Notes

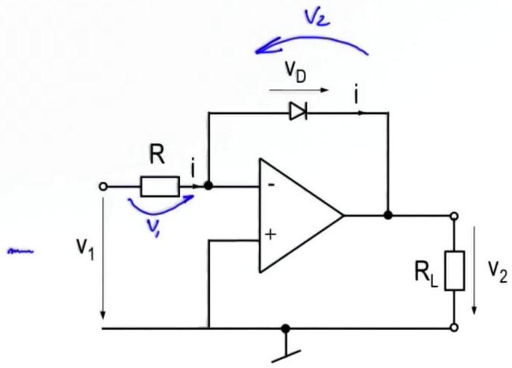
Summary

9m 21s

Convertisseur linéaire-logarithmique

$$i = \frac{v_1}{R} = I_S e^{\frac{vD}{nUT}} = I_S e^{\frac{-v2}{nUT}}$$

$$v_2 = -n\,U_T \ln\frac{v1}{R\,I_S}$$



Electronique I

I'll just mention this idea in passing. But this type of circuit can be used to carry out a multiplication operator and a division operator that haven't been present here, because they go through a logarithmic conversion. Ok, we've just finished a series of examples with non-linear sorting circuits. We have especially focussed on rectifiers and we have looked at different types of rectifiers. We have also looked at how to achieve saturation values which are limited. We have just finished looking very quickly at the logarithmic converter without giving examples, while there are still other non-linear functions with the operational amplifier I think that the listener now has the capacity to analyse this type of circuit.

Notes

Summary

10m 55s