Applications des Amplificateurs opérationnels

7.2 Applications linéaires

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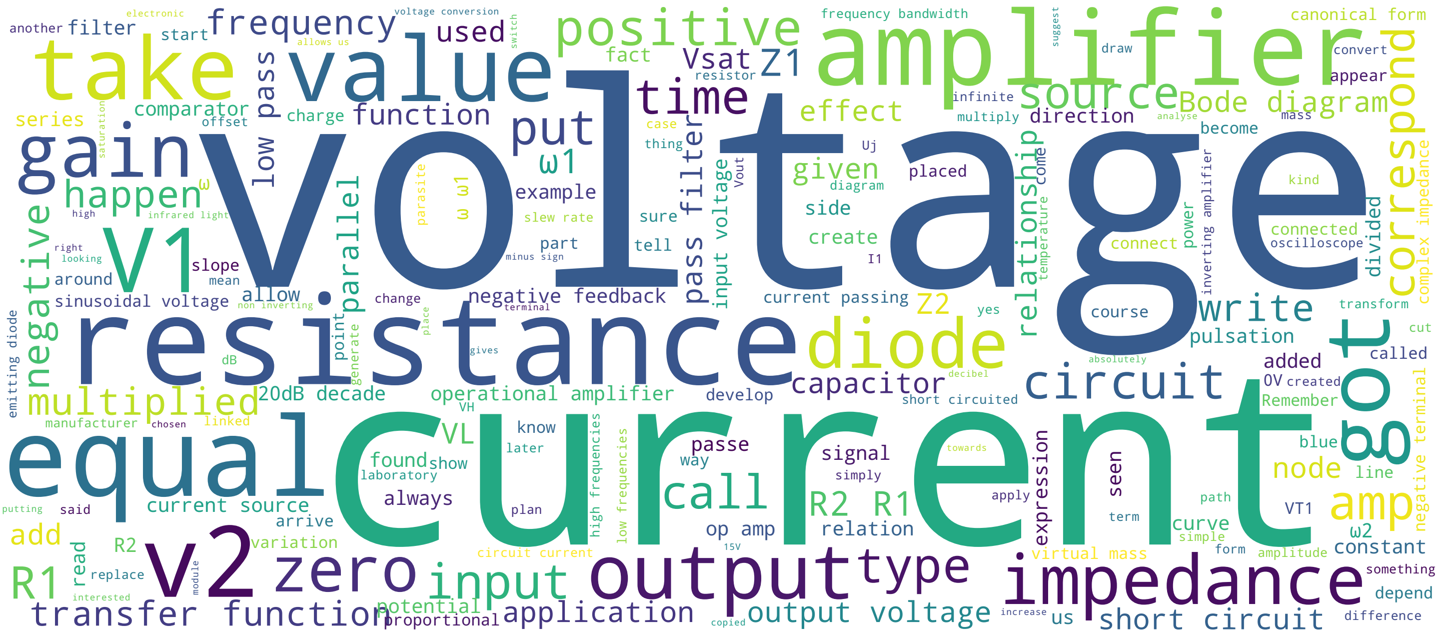
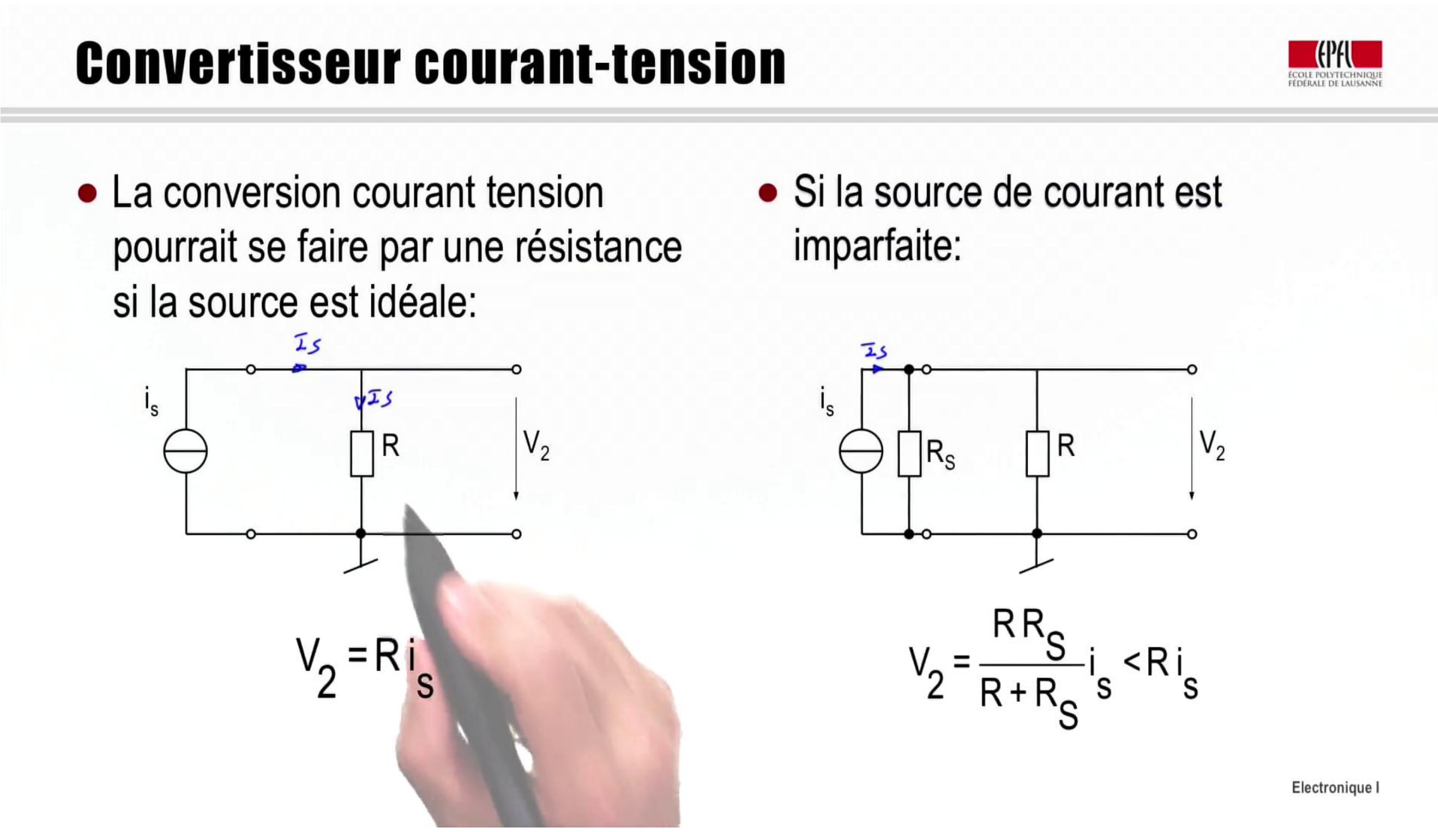


Video



A second linear application will be an application based on something that we've already seen, it's how to convert a current and a voltage. The question seems to be simple because we say that current and voltage are governed by the law of Ohm, voltage is linked to a current by multiplying by a resistance. So you just need to take a current *IS* and inject it into a resistance and this current *IS* will generate a voltage *v2* that is proportional to the resistance multiplied by the current that we would like to see. So we've got a linear relationship between *v2* and *IS*. This is valid if our source is ideal. However, if by chance our source suffers from a resistance parasite, that is placed in parallel and that makes up the structure of the source, we can't take it away, it's internal to the source, it's a parasite. And yes, your current *IS* is here. For this current, all depends on the voltage *v2* that you've got at the output. On this side here, the voltage *v2* is linked to *R*. On this side here, the voltage *v2*, once it has been established, will have *v2* at the resistance terminals *RS* and *v2* at the resistance terminals *R* and you'll have a current passing through here.

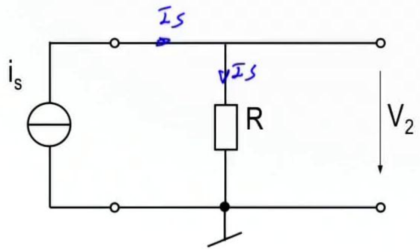
Notes

Summary

0m 04s

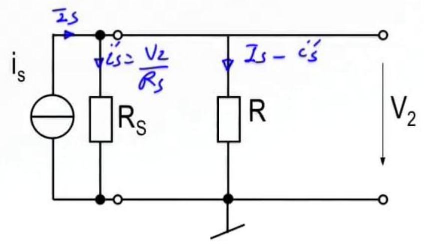
Convertisseur courant-tension

- La conversion courant tension pourrait se faire par une résistance si la source est idéale:



$$V_2 = R\,i_S$$

- Si la source de courant est imparfaite:



$$V_2 = \frac{R\,R_S}{R+R_S}\,i_S < R\,i_S$$

Electronique I

We're going to call it a current *i'S* that is equal to *v2/RS*. But this is a parasite current, that will be taken away from this current *IS* and sent back to your charge. So this current passing through your charge, is absolutely not *IS*, it's a current *IS* that is *-i'S*. So it won't be a direct reading of the variation in current. You'll get a voltage *v2* that will be directly proportional to the fact that there is internal resistance to the source and an external resistance. For sure, you're going to tell me that if this resistance is much bigger than this one here, we won't see any effect, which is true. Sometimes it happens that current sources have resistances so big in relation to the charge resistance, so as to have a minimum current passing through here. But to eradicate this type of problem and to be able to use the current that we draw from a current source completely debited, it is converted to a voltage. Remember from the introductory course on this type of circuit analysis, we said that if you want to read a current, you should read it in a short circuit, meaning that we said to short-circuit a voltage or apply a voltage equal to zero.

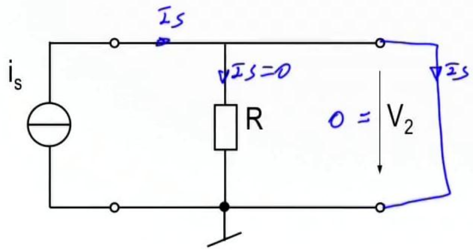
Notes

Summary

1m 24s

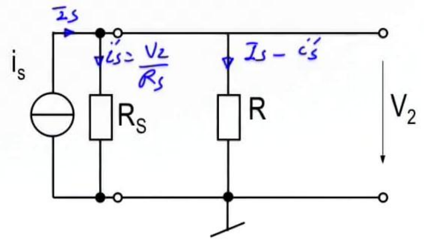
Convertisseur courant-tension

- La conversion courant tension pourrait se faire par une résistance si la source est idéale:



$$V_2 = R\,i_s$$

- Si la source de courant est imparfaite:



$$V_2 = \frac{R R_S}{R + R_S} i_s < R\,i_s$$

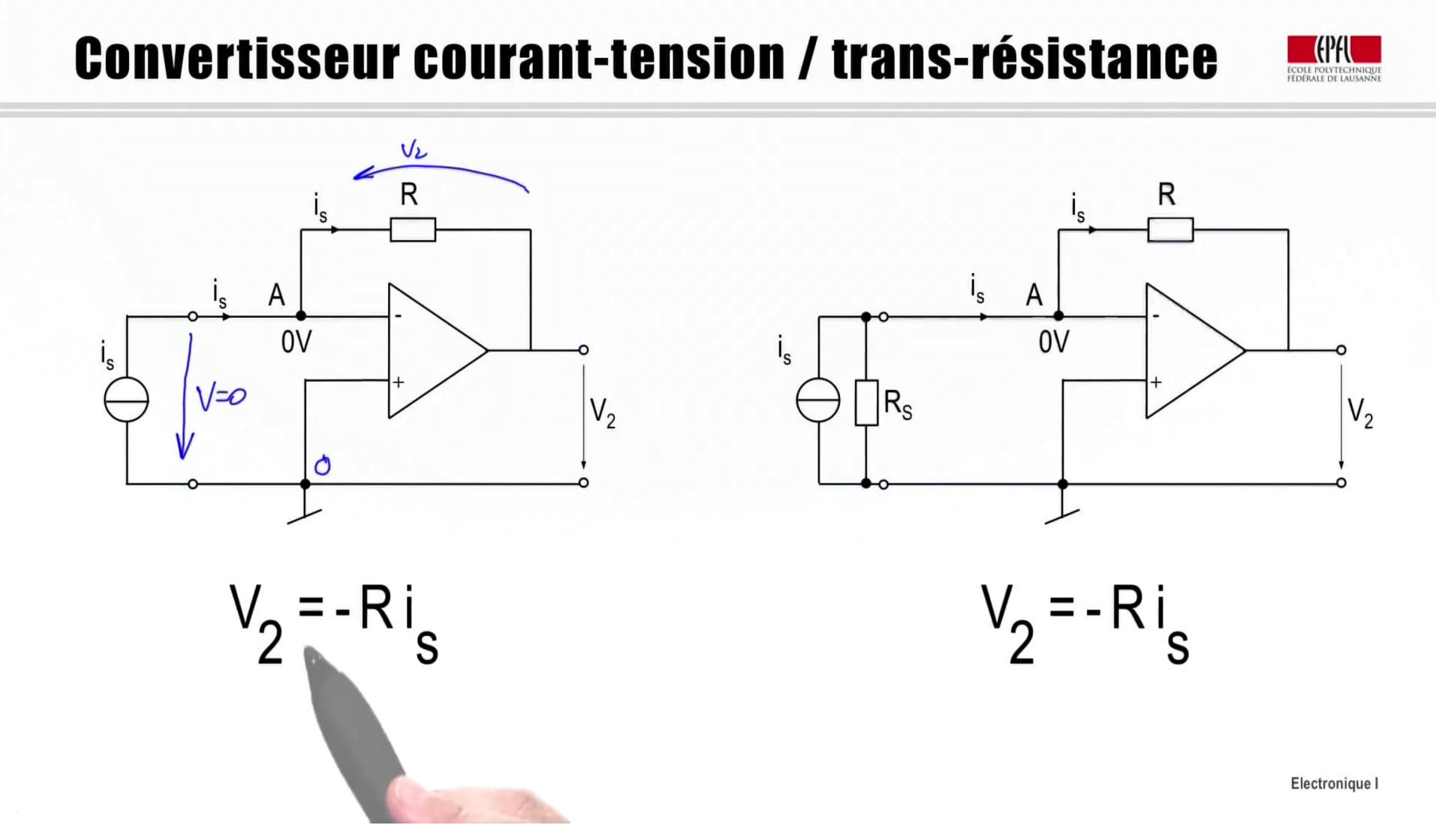
Electronique I

At this present moment, any resistance that is found in parallel with your source won't affect anything. The resistance sees a voltage *v2* equal to zero. So the current here is forcibly equal to zero and your current *IS*, is called a short-circuit current and it's the current that we will take a direct reading from here. But unfortunately here it's a short-circuit current that feeds into the mass and that we've never been able to read in voltage because the voltage was nil. So we can't short-circuit a current source having given that the current reading passes by its voltage conversion. Learn this, each time that we have a current that we want to read, we transform it into voltage. Unfortunately for the current, you will have to put an ammeter and therefore cut the line to be able to read it, or use another effect which is the effect *hall*, and this *hall* effect, isn't used in tri-phase circuits, so we always go through the conversion of a current into a voltage because we can take the voltage in an amplifier and make it bigger or smaller and keep a linear relationship. So, what should we do? We should do the following.

Notes

Summary

2m 43s



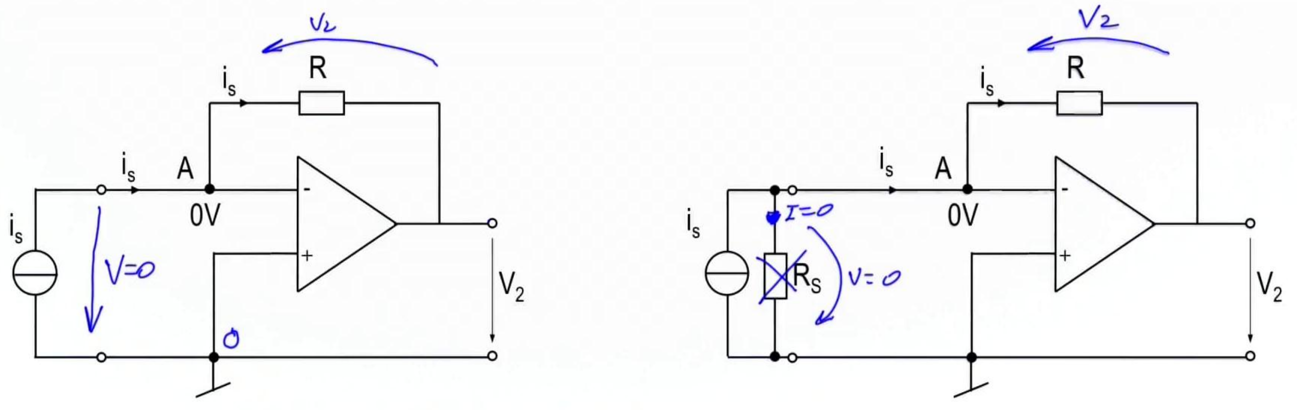
We need to take advantage of the fact that an amplifier has a mass... the plus connected to the mass corresponds to an amp that creates virtual mass. The real mass of 0V is copied by the amp and placed on this node here. A potential equal to zero is created on the node *A*, which tells you that the difference in voltage between here and here is equal to zero by the fact that the amp has an infinite gain. And there you go, your current source, in terms of voltage has been short-circuited. The voltage here is nil. You've got voltage *V* equal to zero. So, your short-circuit current that was shown before, is the current *iS*. The current source sees the short-circuit current so the current continues on its path and can pass through the negative feedback resistance. And your voltage *v2*, that is between this node and the mass, is also found between this node here and the virtual mass because it's got the same potential. So, we've got *v2* that's here. You're going to tell me that it's obvious. Yes, but it's interesting when it happens.

Notes

Summary

3m 51s

Convertisseur courant-tension / trans-résistance



$$V_2 = -R\,i_s \qquad\qquad V_2 = -R\,i_s$$

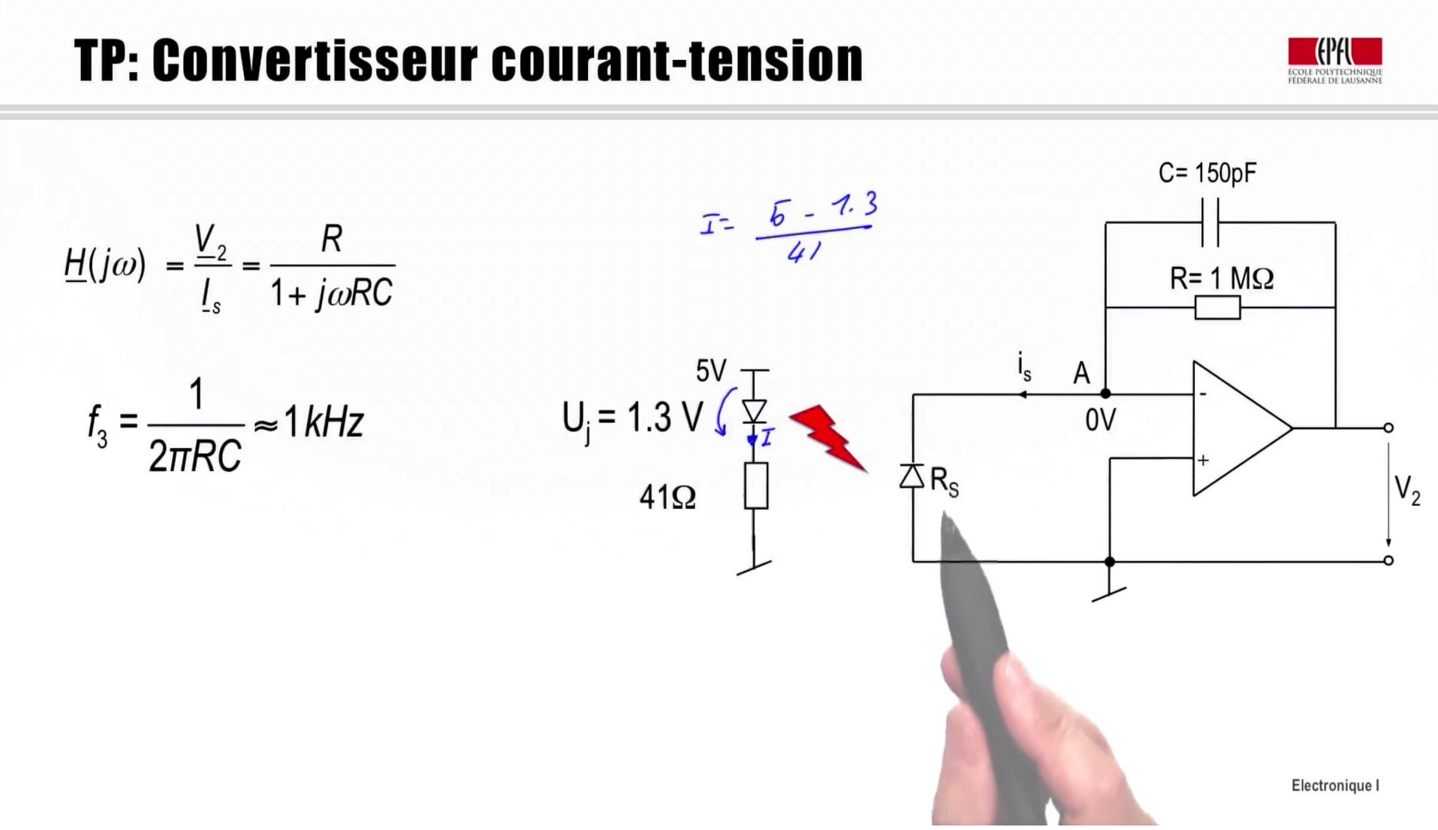
Electronique I

You take a current source that isn't ideal like this, which has a parallel resistance *RS* and this resistance, we don't know its value and it can fluctuate with a phenomenon linked to the temperature, with age, or any other type of physical phenomenon. And yes, it will always be short-circuited by the virtual mass, 0V here, 0V there, therefore a potential difference *V* equal to zero. So the parasite current passing through your resistance, this current *I* is equal to zero. So you've got your current *IS - 0* continuing on its path, it remains *IS*. This parasite resistance therefore has no more effect on the negative feedback amplifier having a virtual mass because the voltage *v2* always remains here and the current *IS* passes through the *R* and will give you a relationship where *v2 = -RiS*. There are lots of applications for this type of circuit and I'd like to show you some of them, how we have captors that convert physical variables into current. And this current here, we'd like to be able to read it and convert it into a voltage. And here's an example of an application in which, we'd like to be able to use a set-up like this one.

Notes

Summary

5m 05s



I suggest that you go into a laboratory if you have the possibility and to make a current-voltage conversion and to take a diode, an infrared diode, that converts infrared fluxes, of infrared light, that arrive at a junction with a proportional current at the light intensity that arrives here. You can create a light flux via an emitting diode. You can get diodes that emit in the infrared spectrum. So, I suggest that you take an emitting diode, a receptive diode and apply a current. Here, we've applied a continuous current. This current is equal to the power voltage, therefore it's 5V, minus the voltage drop at the terminals of this diode here that you will have chosen from the market. Generally, it's around 1,2-1,3V. I've put a resistance of 41Ω to generate a certain current *I*, such as *I = (5 - 1,3)/41Ω*, that will give you the current here and this current, once passed through this diode, will generate you infrared light that you can't see if this diode here is infrared. And here, you're going to place a receptive diode. And often, there's an infrared filter so it filters certain components outside of this spectrum here and a diode of this type converts this intensity into current.

Notes

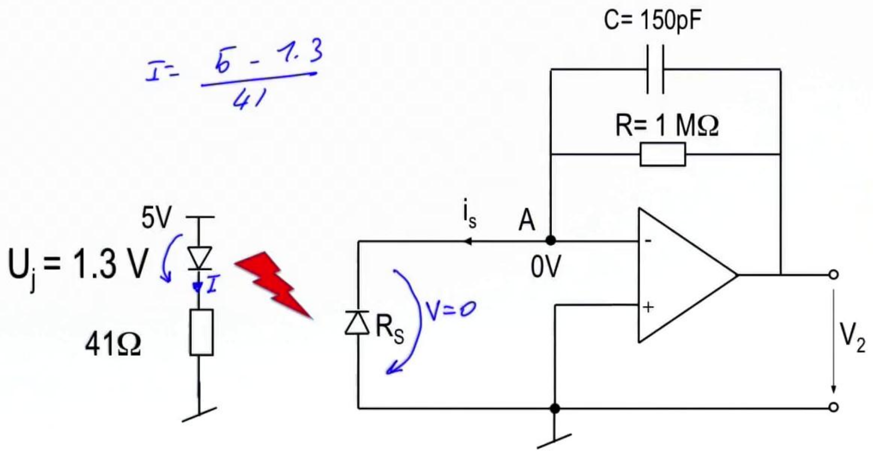
Summary

6m 31s

TP: Convertisseur courant-tension

$$\underline{H}(j\omega) = \frac{\underline{V}_2}{\underline{I}_s} = \frac{R}{1 + j\omega RC}$$

$$f_3 = \frac{1}{2\pi RC} \approx 1\,kHz$$



Electronique I

I'd like to read this current here in a resistance. And I've put two, quite big resistances of 1MΩ, and this resistance here will transform a voltage *v2 = IS x R*, that we saw before. So, it's this relationship of current-voltage conversion but the diode that you've added here, will become polarised with a voltage *V* that is equal to zero, it being given that this zero and this zero are the same, so your diode is completely short-circuited even if the resistance is in parallel, so the source resistance that is in parallel with it guarantees the integrity of the current that exits the diode, it being given that it's a very weak current and that we can't tolerate a current leakage that passed through any parallel resistance. You're going to ask what this capacitor is for. If you are in a laboratory and you want to filter a certain range of frequencies, because don't forget that this diode will maybe also receive lamps that are lit around you or someone passing through. And yes, with a resistance like this, I try to create a filter of around 1kHz with the *R* and the *C* that are here to make a low-pass filter so that some parasite components are filtered out by this negative feedback that has a complex impedance and that creates a low-pass filter with an integrating amplifier with a gain or resistance of 1MΩ in parallel with the resistance *C*.

Notes

Summary

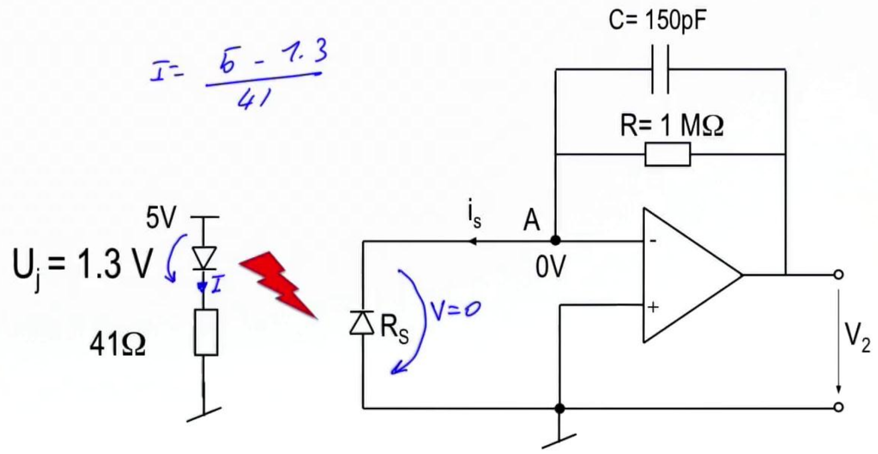
8m 11s

TP: Convertisseur courant-tension

$$\underline{H}(j\omega) = \frac{\underline{V}_2}{\underline{I}_s} = \frac{R}{1 + j\omega RC}$$

$$f_3 = \frac{1}{2\pi RC} \approx 1\,kHz$$

$$I = \frac{5 - 1.3}{41}$$



Electronique I

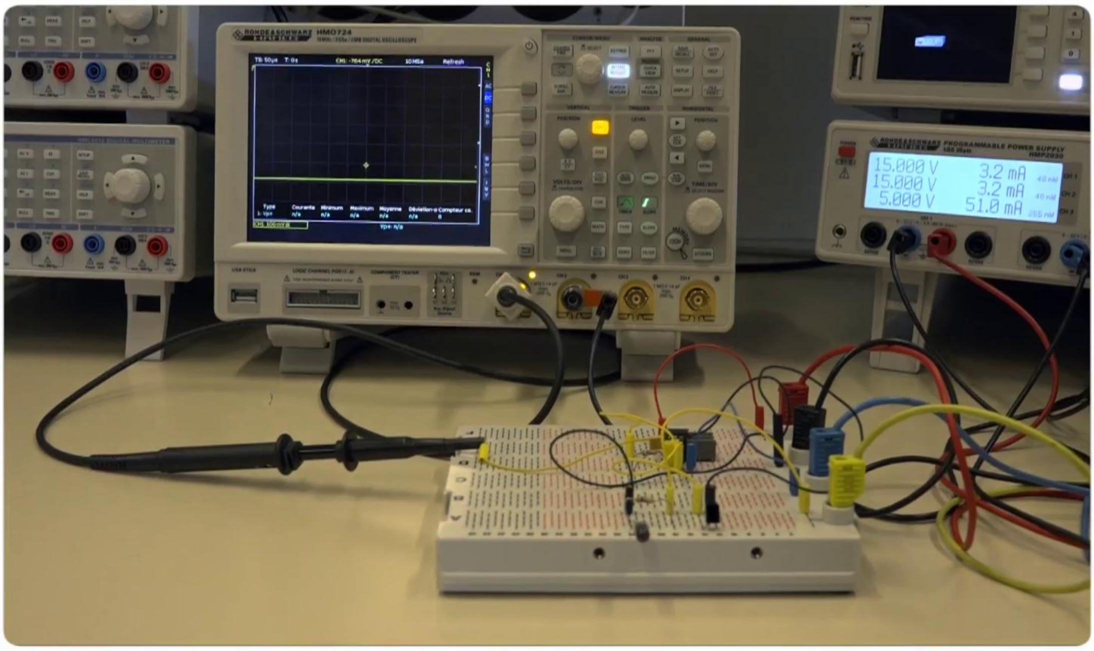
We call this type of circuit transresistance because it converts current and voltage. Remember this term, it will be used again. This type of circuit is used in a variety of applications.

Notes

Summary

9m 41s

TP: Détecteur d'objet



Electronique I

So we're going to look at what happens with an emission of infrared light with this emitting diode and another receptor of the same light and later on, we'll try putting an obstacle in the way. And here is that obstacle, that is simply a hand that will reflect the light onto the diode. Watch how the hand movement affects the oscilloscope. It's an object detector that is used in industrial applications. Watch the line where, every time the hand gets closer and the light intensity increases, we can see the line going up and down.

Notes

Summary

9m 56s

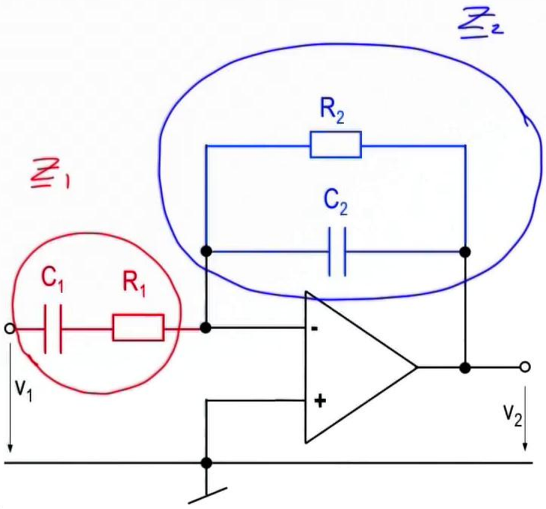
Filtrage

- $\underline{Z}_1 \rightarrow R_1$ série avec C_1
- $\underline{Z}_2 \rightarrow R_2$ parallèle avec C_2

$$\underline{Z}_1 = R_1 + \frac{1}{j\omega C_1} = \frac{1 + j\omega R_1 C_1}{j\omega C_1}$$

$$\frac{1}{\underline{Z}_2} = j\omega C_2 + \frac{1}{R_2} = \frac{1 + j\omega R_2 C_2}{R_2}$$

$$\underline{Z}_2 = \frac{R_2}{1 + j\omega R_2 C_2}$$



$$\underline{H}(j\omega) = -\frac{\underline{Z}_2}{\underline{Z}_1} = -\frac{j\omega R_2 C_1}{(1 + j\omega R_2 C_2)(1 + j\omega R_1 C_1)} = -\frac{R_2}{R_1}\frac{j\omega R_1 C_1}{(1 + j\omega R_2 C_2)(1 + j\omega R_1 C_1)}$$

Electronique I

We've just completed a whole series of amplifier applications where we've been interested in the relationship between input and output voltage multiplied by a certain constant. So we've done the voltage difference multiplied by a gain. We've covered a current multiplied by a resistance with the transresistance. And we've already looked at applications that make use of filters. And here, I'm going to give a very simple example on how we make a filter application with an operational amplifier. Here's a plan of a negative feedback op-amp where instead of putting in a simple resistance, I've put in a resistance and a capacitor. And here too, I've put in a resistance and a capacitor. So I've got a complex impedance, that I've coloured blue. So, if you take this and you call this impedance *Z2*, that is complex, you'll find it here. And I've noted that it's the placement in parallel of *R2* with *C2*. Now take the series *R1* and *C1*, and it's this impedance here, and I call it *Z1*. So here, I've got the impedance *Z1*. And you've got an amplifier with an impedance *Z2*, an impedance *Z1*, which constitutes the two impedances of an inverting amplifier.

Notes

Summary

10m 32s

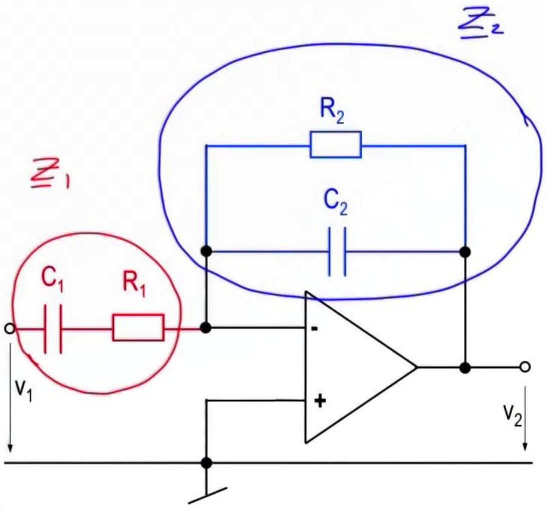
Filtrage

- $\underline{Z}_1 \rightarrow R_1$ série avec C_1
- $\underline{Z}_2 \rightarrow R_2$ parallèle avec C_2

$$\underline{Z}_1 = R_1 + \frac{1}{j\omega C_1} = \frac{1 + j\omega R_1 C_1}{j\omega C_1}$$

$$\frac{1}{\underline{Z}_2} = j\omega C_2 + \frac{1}{R_2} = \frac{1 + j\omega R_2 C_2}{R_2}$$

$$\underline{Z}_2 = \frac{R_2}{1 + j\omega R_2 C_2}$$



$$\underline{H}(j\omega) = -\frac{\underline{Z}_2}{\underline{Z}_1} = -\frac{j\omega R_2 C_1}{(1 + j\omega R_2 C_2)(1 + j\omega R_1 C_1)} = -\frac{R_2}{R_1} \frac{j\omega R_1 C_1}{(1 + j\omega R_2 C_2)(1 + j\omega R_1 C_1)}$$

Electronique I

But this time here, it's not a pure reality for a resistance on either side. There is a capacitive element that adds a complex number. And it will help us to create a transfer function which relays the output voltage to the input voltage and allows us to, once traced onto the Bode diagram here, to see that there's a frequency range that could be affected by the values of these two impedances. We've already seen, if we look at a capacitor that comes between the positive and negative terminals, and we've spoken about the integrating effect, and we've shown that this can become a low-pass filter, and we've seen that if we put a series resistance here as input impedance of this amp, we create a derivative effect and we've seen that this capacitor here allows the making of a kind of high-pass filter if we also add a resistance *R1* in series with it. So this time here, we've cumulated both effects. We've got an effect that cuts out high frequencies, we've got an effect that cuts out low frequencies, and we've put the two impedances on either side of an inverting amplifier that will allow us to make a frequency, or to let past a frequency bandwidth.

Notes

Summary

12m 01s

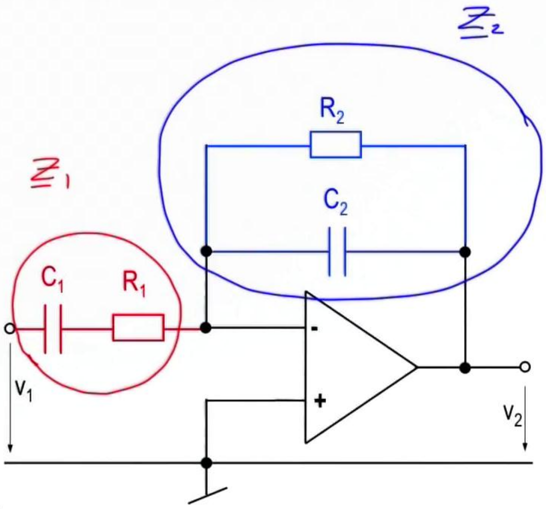
Filtrage

- $\underline{Z}_1 \rightarrow R_1$ série avec C_1
- $Z_2 \rightarrow R_2$ parallèle avec C_2

$$\underline{Z}_1 = R_1 + \frac{1}{j\omega C_1} = \frac{1 + j\omega R_1 C_1}{j\omega C_1}$$

$$\frac{1}{\underline{Z}_2} = j\omega C_2 + \frac{1}{R_2} = \frac{1 + j\omega R_2 C_2}{R_2}$$

$$\underline{Z}_2 = \frac{R_2}{1 + j\omega R_2 C_2}$$



$$\underline{H}(j\omega) = -\frac{\underline{Z}_2}{\underline{Z}_1} = -\frac{j\omega R_2 C_1}{(1 + j\omega R_2 C_2)(1 + j\omega R_1 C_1)} = -\frac{R_2}{R_1}\frac{j\omega R_1 C_1}{(1 + j\omega R_2 C_2)(1 + j\omega R_1 C_1)}$$

Electronique I

To broach this type of exercise, or this way of doing things, we call it a filter because we're going to only allow one frequency to pass that will be multiplied by a gain. And for certain frequencies, we'll dampen the signal, the high frequencies and the same for the low frequencies. And it's the impedances *Z2* and *Z1* that will do this. So, we're going to start by writing down the impedance *Z1*. The impedance *Z1*, is placed in series with the resistance *R1* and a capacitor *C1*. So, we just have to write down the complex impedance of each of these. The impedance of a resistance is a pure real number, it's *R1*. The impedance of a capacitor is *1/jωC1*. So, I've placed in series *R1 + 1/jωC1* that will give me the value of *Z1*. I just have to develop it to see it in a different way. On the other side, I've placed a resistance *R2* in parallel with a complex impedance, *1/jωC2*. They are in parallel. So I write down the same thing. I write *1/Z2*, that allows me to write *jωC2 + 1/R2*. I develop it and inverse it to find *Z2*. And I find an impedance *Z2* which is equal to the expression.

Notes

Summary

13m 20s

Filtrage

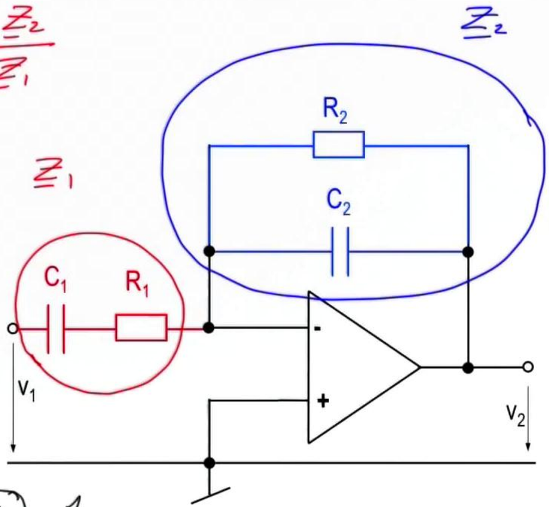
- $\underline{Z}_1 \rightarrow R_1$ série avec C_1
- $\underline{Z}_2 \rightarrow R_2$ parallèle avec C_2

$$\underline{H}(j\omega) = -\frac{\underline{Z}_2}{\underline{Z}_1}$$

$$\underline{Z}_1 = R_1 + \frac{1}{j\omega C_1} = \frac{1+j\omega R_1C_1}{j\omega C_1}$$

$$\frac{1}{\underline{Z}_2} = j\omega C_2 + \frac{1}{R_2} = \frac{1+j\omega R_2C_2}{R_2}$$

$$\underline{Z}_2 = \frac{R_2}{1+j\omega R_2C_2}$$



$$\underline{H}(j\omega) = -\frac{\underline{Z}_2}{\underline{Z}_1} = -\frac{R_1}{R_1}\frac{j\omega R_2C_1}{(1+j\omega R_2C_2)(1+j\omega R_1C_1)} = -\frac{R_2}{R_1}\frac{j\omega R_1C_1}{(1+j\omega R_2C_2)(1+j\omega R_1C_1)}$$

Electronique I

So I've got my expression *Z2* and of *Z1* and my amplifier that's got *Z2* here and *Z1* here, there's a gain *H(jω)* that is equal to -*Z2/Z1* and that's what I write down here. So, I write down the impedance to the numerator, that's in blue, by the impedance that is at the denominator divided by *Z1* and I develop it. So I take this expression here and this expression here and I develop them. And here, to get a canonical form... The canonical form, is to find the easy expressions to transform into a Bode diagram. I see *R2/R1* is a known canonical form. It's a constant. I see *jωR1/C1*. And I see *1/1 + jωR1C1* and *1/1 + jωR2C2*. To make it easier, to see this, if you develop the expression *Z2/Z1*, you will find: *jωR2C1*. And I've given a little calculation tip, in multiplying this, to the numerator and to the denominator, by *R1* and I've divided by *R1*. So I don't modify the expression but this will allow me to write down *R2/R1*, which I find here, and *jωR1C1* that I find here. So it allows me to find simple expressions and here they are.

Notes

Summary

14m 29s

Filtrage

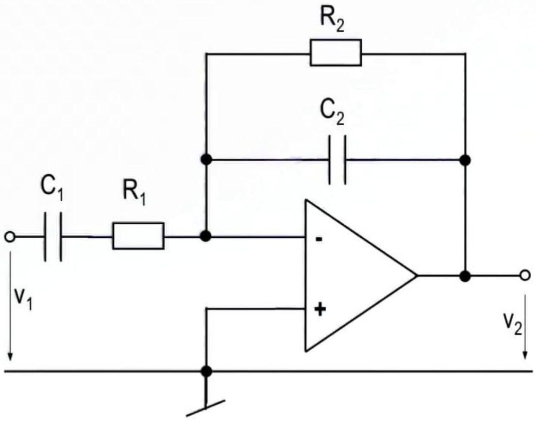
$$\underline{H}(j\omega) = -\frac{R_2}{R_1}\,\frac{1}{1+j\omega R_2C_2}\,\frac{j\omega R_1C_1}{1+j\omega R_1C_1}$$

1 2 3 4

$$\underline{H}(j\omega) = -\frac{R_2}{R_1}\,\frac{1}{1+j\dfrac{\omega}{\omega_2}}\,\frac{j\dfrac{\omega}{\omega_1}}{1+j\dfrac{\omega}{\omega_1}}$$

1

$$\omega_1 = \frac{1}{R_1C_1} \text{ et } \omega_2 = \frac{1}{R_2C_2}$$



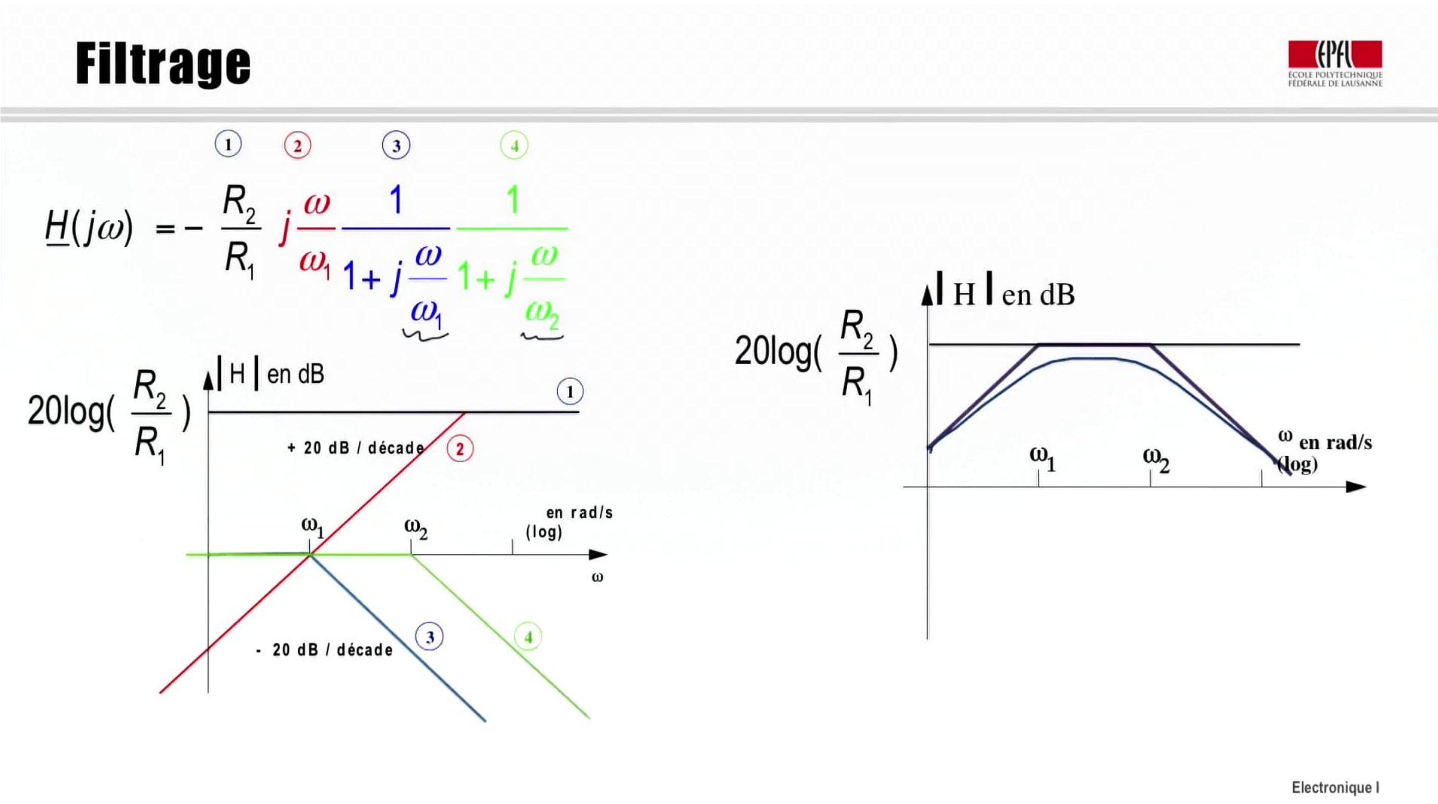
Electronique I

Here, once I've subdivided this into difference canonical forms and I've simplified it to see the forms that we know, a gain *R2/R1*, a low-pass filter *1/(1 + j(ω/ω2))*, a second low-pass filter *1/(1 + j(ω/ω1))* and a derivative function *j(ω/ω1)*. by replacing *ω1* with *1/R1C1* and *ω2* with *1/R2C2*, we come to what is here. So this will give us different canonical functions that we'll transfer into a Bode diagram. We've got a function a second function, a third function and a fourth function if we look at *1/(1 + j(ω/ω1))* and we've got four functions that we need to trace into a Bode diagram to see the frequency characteristic of this transfer function of an amplifier with an impedance *Z2* and *Z1* added around the amplifier which is in the centre.

Notes

Summary

16m 12s

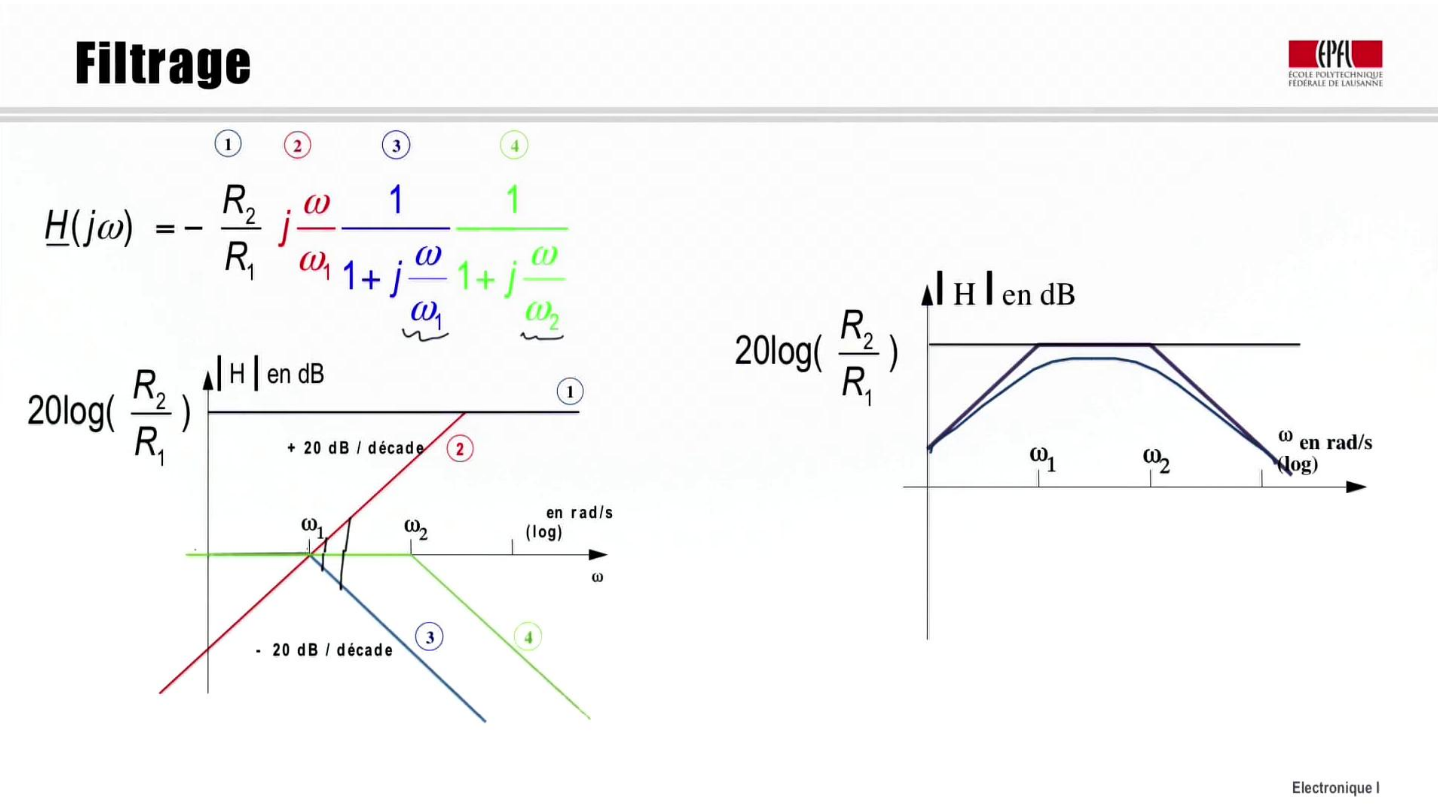


The global transfer function, which I've coloured in to distinguish the functions *1*, *2*, *3*, *4* that I mentioned earlier on. So, when we want to take a constant *R2/R1*, knowing that in a Bode diagram, the asymptotes of the transfer function are brought over here. *R2/R1*, it's a constant. *20log(R2/R1)* allows us to put it into decibels that corresponds to a right that is independent to the variation in frequency. So here, I've brought back the pulsations. So remember, *ω = 2πf*, *f* being the frequency. If I look at *j(ω/ω1)*, *1/(1 + j(ω/ω1))*, *1/(1 + j(ω/ω2))*, I recall that *ω1* and *ω2* are known, it depends on the values *R* and the *C* that we've used. I bring back *ω1* and *ω2* and I start taking *j(ω/ω1)* and I trace the transfer function module that is a right of a slope equal to +20dB/decade that passes through *ω1* that corresponds to the Bode diagram of this. These two functions are the same. It corresponds to a low-pass filter. One fixed on a pulsation *ω1*, the other on a pulsation *ω2*. So one of them will give an asymptotic diagram which has 0dB up to *ω1* and will give a slope of -20dB/decade starting from *ω1*.

Notes

Summary

17m 24s



So, I've got attenuation, I lose a facture of 10 each time that I go up a multiple of 10 over the ω, over the pulsations. So I lose 20 decibels each time I multiply the pulsation by 10. The same for the green function, but it's a low-pass filter where *ω2* is much higher than *ω1* in the example that I've chosen here and we find ourselves with this. So, we've learned that when we've got a Bode diagram and we want to make the diagram of the whole of this amplifier, given that we're working to a logarithmic scale, it suffices to add these curves. So I've got a constant that is here, that I've maintained. I've got +20dB/decade from this red curve and -20dB/decade from the blue one, corresponding to this, they'll cancel each other out. So I've got +20dB, -20dB, that is cancelled out. This amount here is always equal to this one here, etc., etc. So it will give me a plateau but just before *ω1*, I've got a slope equal to +20dB/decade therefore I see it here. Up until *ω1*, I'm going to see this part that appears here, offset from the constant part that corresponds to *R2/R1*, for sure by 20log of this value to arrive in decibels. Now, if we carry on, we get to around *ω2*.

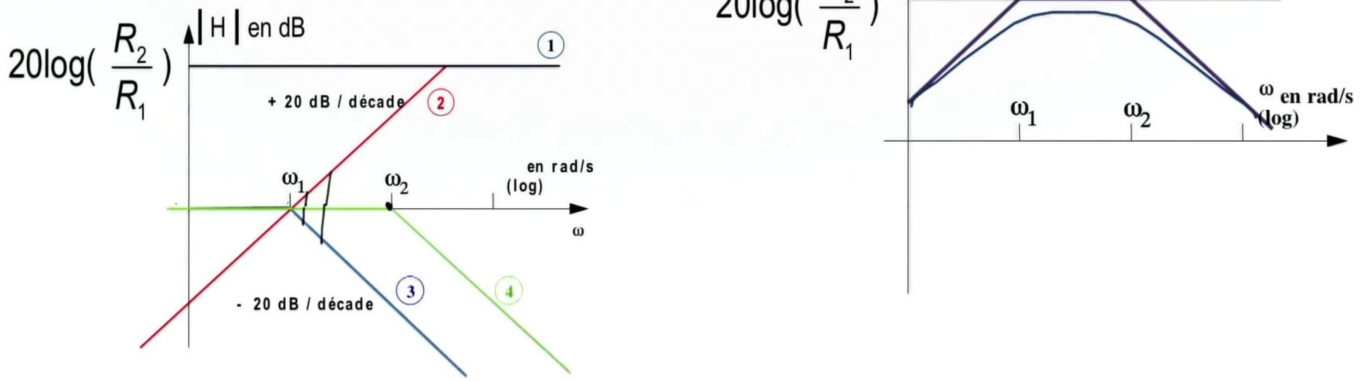
Notes

Summary

19m 08s

Filtrage

$$\underline{H}(j\omega) = -\frac{R_2}{R_1}\, j\frac{\omega}{\omega_1}\, \frac{1}{1+j\dfrac{\omega}{\omega_1}}\, \frac{1}{1+j\dfrac{\omega}{\omega_2}}$$



Electronique I

Around $\omega 2$, for sure, these slopes of +20dB, -20dB are cancelled out, which is what gives me this plateau. But from this point here, we reduce again -20dB/decade from this amount, which will give us this slope here. And we see this type of filter that we can call a band-pass filter because it allows pulsations to go through. For sure, we've got a true curve that corresponds to three decibels and three decibels below the asymptotic value and we see this true curve that corresponds to what we would have seen if we had measured here, everything displaced and multiplied by a gain *éR2/R1*. And we see that we've got the low frequencies that will be dampened by this attenuation that appears here and the high frequencies. And we've got a frequency bandwidth that is multiplied by the gain just between the two. So, we've created a pass-band filter. So here you have an extremely well-known application of an amplifier that corresponds to making amplifiers that we're interested in to a frequency bandwidth that we multiply by a gain and other frequency bandwidths that we dampen down. It's called filtering. There's a whole range of courses that cover the subject of filters and that explains how to develop filters of all kinds to work on frequencies and to eliminate certain frequency components of a given signal.

Notes

Summary

20m 38s