ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Imperfections des Amplificateur opérationnel

6.3 Imperfections

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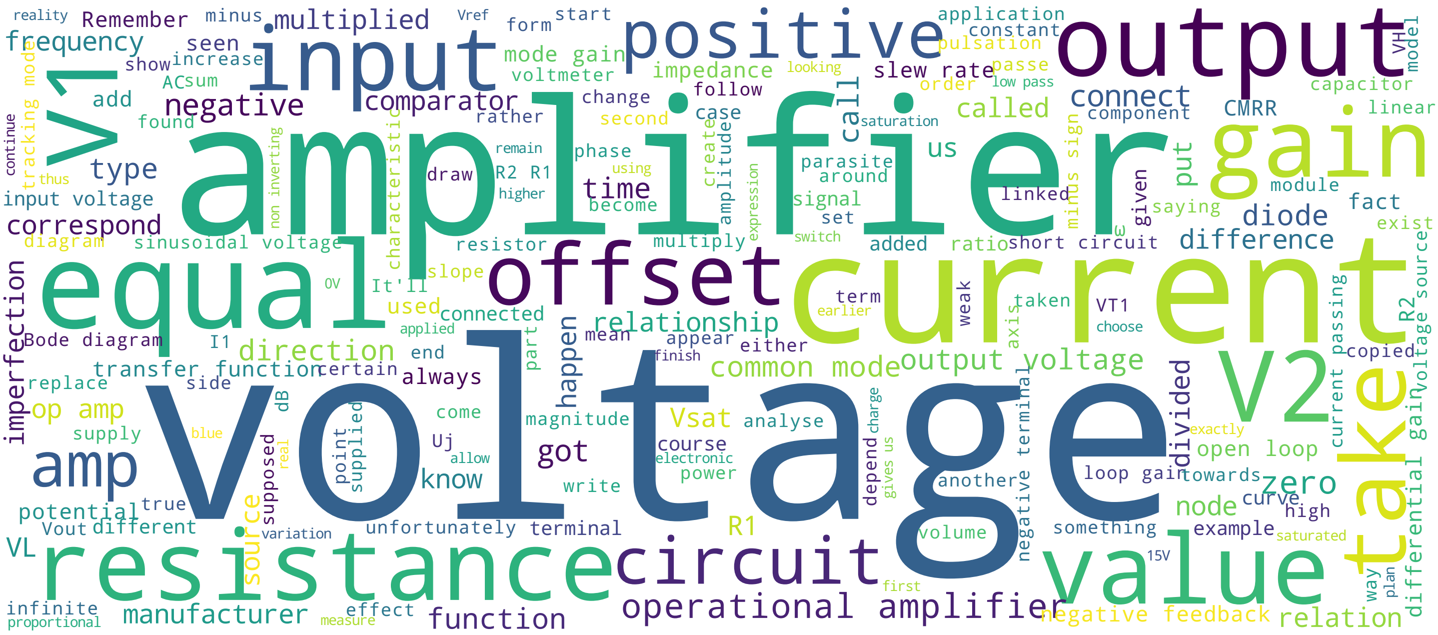
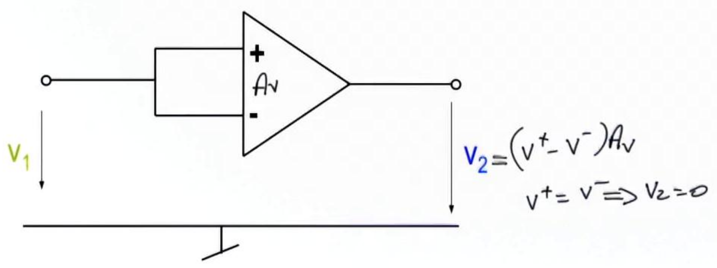


Video

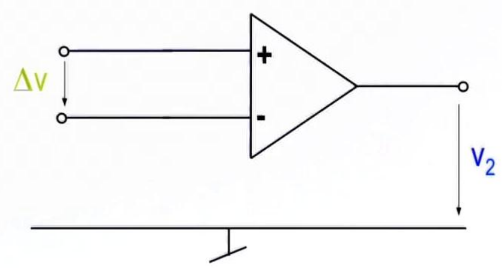
EPFL

Taux de réjection du mode commun

- Gain de mode commun
- Gain en mode différentiel



$$A_C = \frac{v_2}{v_1}$$



$$A_D = \frac{v_2}{\Delta V}$$

Taux de réjection du mode commun: CMRR

$$CMRR = \frac{A_D}{A_C}[dB]$$

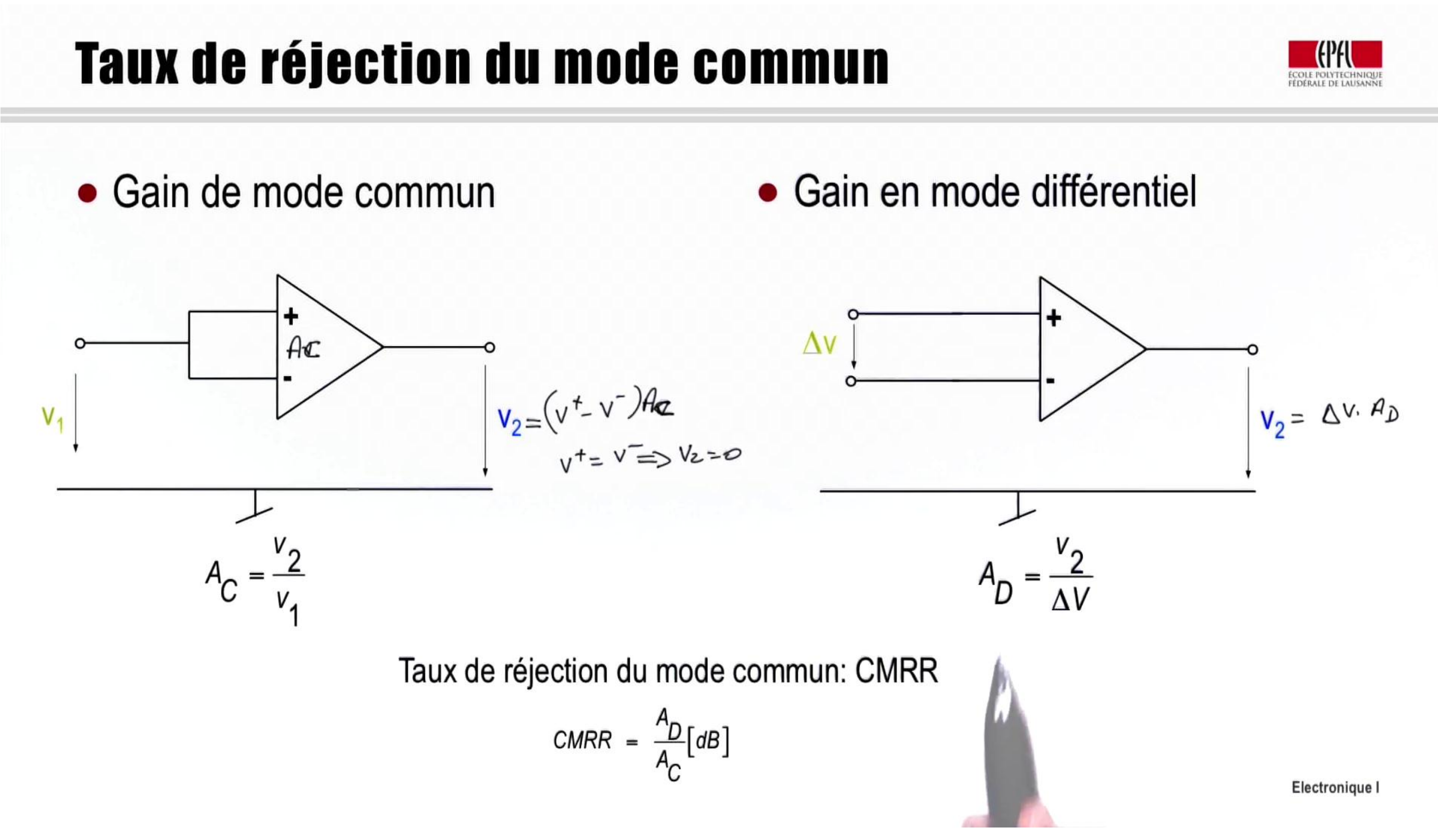
Electronique I

Another imperfection of the amplifier: the common-mode of the amplifier. Take a look at this schematic here. I've taken an operational amplifier and created a short circuit at the input by connecting the plus to the minus. So I've applied the same voltage to the *V+* and to the *V-*. Remember that the voltage *v2* is equal to *V+* - *V-* multiplied by the gain in open loop to the amp, When there is a gain in open loop. If *V+* is equal to à *V-*, which is the case here, this... So if we've got *V+* equal to *V-*, this should give us a voltage *v2* equal to zero. But unfortunately, an amp wouldn't give you a voltage *v2* equal to zero. You will end up with a tension that is not nil. It's the voltage that you've connected on the two terminals, the positive and negative ones, because the amplifier shows a gain which called the common-mode gain, and this value is also supplied by the manufacturer who informs you that your amplifier has got a slight gain and that this slight gain will follow the ratio *v2/v1* and has a certain value which is supplied to you by the manufacturer. and is equal to the *AC* we discussed earlier.

Notes

Summary

0m 03s



So you'll have *v2* which isn't equal to zero, despite the fact that by default, we expect that that this will be the case. So it will take *v2* equal to *ΔV* multiplied by the differential gain. This differential gain is a given gain and it is the same as the open-loop gain of your amplifier. In contrast, the common-mode gain... Sorry, here I've written *V*, but it should be *C*. In contrast, the common-mode gain of your amplifier, is a gain that's called *AC* and this gain *AC* will multiply the difference between *V+* and *V-*. And the gain *AD<difference /i>, the differential gain, will multiply this V+* - *V-* by a gain that corresponds to the open-loop gain of the amplifier. It is referred to by manufacturers as the common-mode rejection ratio that is *CMRR*, which is a ratio between the differential gain divided by the common-mode gain. And this gain *CMRR*, or rather this ratio *CMRR* between *AD* and *AC* is supposed to be a very high value because the differential gain of an amp is supposed to be extremely high. Remember, it's supposed to be infinite. And the common-mode gain is supposed to be very weak.

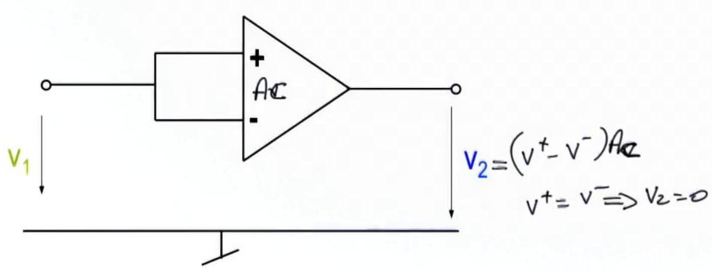
Notes

Summary

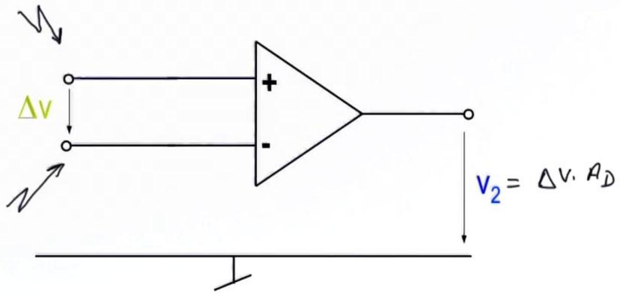
1m 25s

Taux de réjection du mode commun

- Gain de mode commun
- Gain en mode différentiel



$$A_C = \frac{V_2}{V_1}$$



$$A_D = \frac{V_2}{\Delta V}$$

Taux de réjection du mode commun: CMRR

$$CMRR = \frac{A_D}{A_C}[dB]$$

Electronique I

And obviously, the ratio of something very big over something that is very weak is supposed to give us a *CMRR* that is very, very high. So, it's better to have an amplifier with a very high *CMRR*, so it is capable of rejecting the common-mode, and therefore not respond in such ways that if you set up your amplifier and it receives external parasites on the positive and negative terminals and that these parasites are the same as on the + and the -, we wouldn't like to see the differential mode affected by these parasites and would prefer that the differential gain dominated over this common-mode gain. So what we're saying is that when we have an amplifier and we have the same external parasites arriving onto the + and the -, these parasites will have an effect and it's the *CMRR* that allows us to detect the quantity of parasites that will remain and continue to effect the output of our amplifier.

Notes

Summary

2m 42s

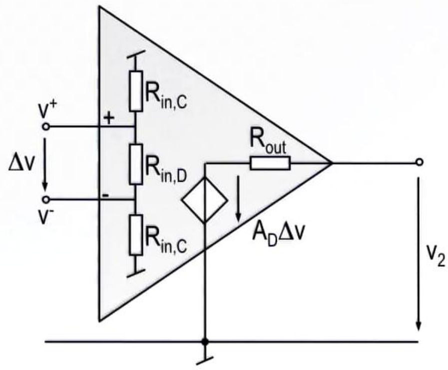
Impédance d'entrée et de sortie

Ordres de grandeur

$R_{in,C}$ » 100 MΩ

$R_{in,D}$ » 1 MΩ

R_{out} » 75 Ω



Electronique I

Quite briefly, we're going to look at a real op-amp in terms of input and output impedance. We've always said that there isn't any current entering the amplifier via the terminals + and -. It isn't true. If there hadn't been any impedance at the input of the amp, then yes, we would have had a current equal to zero. The exact model of an amplifier such as the one that was presented at the beginning, didn't have any resistor, Neihter did this one or that one. It had a controlled voltage source and an output resistor *Rout* and we considered that *Rout* was equal to zero, that it didn't exist. In reality, a complete operational amplifier does have an output resistor. This output resistance is weak. And when the amp is in negative feedback, it is divided by the negative feedback rate, so it is even weaker that the value supplied by the manufacturer because it will be improved by the negative feedback rate. And the nature of the electronics that we've used in the interior to create the input and output could have a certain current that would be absorbed. And this absorbed current would be presented by a resistance called i>RinC and *RinC*.

Notes

Summary

3m 45s

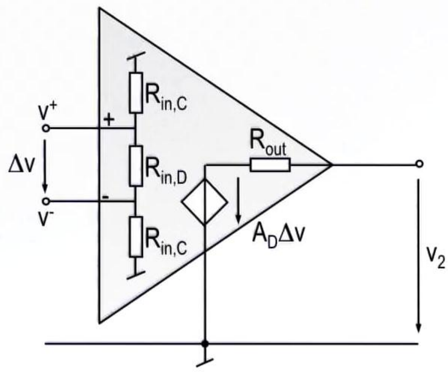
Tension de décalage ou d'offset

Ordres de grandeur

$R_{in,C}$ » 100 MΩ

$R_{in,D}$ » 1 MΩ

R_{out} » 75 Ω



Electronique I

So both these resistances are common-mode resistances. And a differential resistance between the + and the - which corresponds to the scales of magnitude of an amplifier when it is designed with bipolar technology. So, if the transistors used are bipolar transistors, we get this type of magnitude for the input resistance and the output impedance, or the output restance of the amp, it could be much weaker than these 75 Ω that are shown here. And all of that depends on the practical implementation in the form of microelectronics. You need to know that when the manufacturer sells you an amplifier, he will supply you with three values and these three values can be modelled in this way to take into account this type of imperfection.

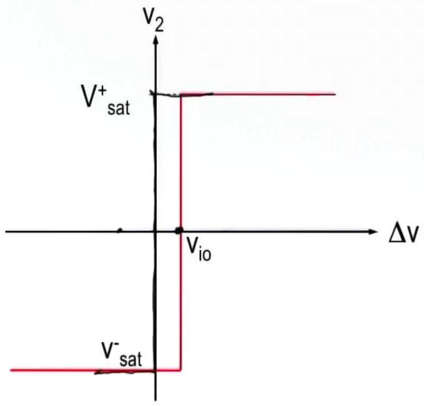
Notes

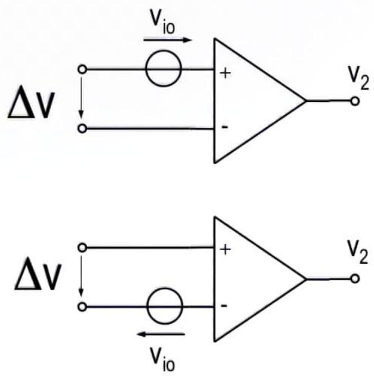
Summary

5m 08s

Tension de décalage ou d'offset

- Tension d 'offset V_{io} ramenée à l 'entrée et de quelques mV à quelques µV, selon le type de l'AO
- Modèles





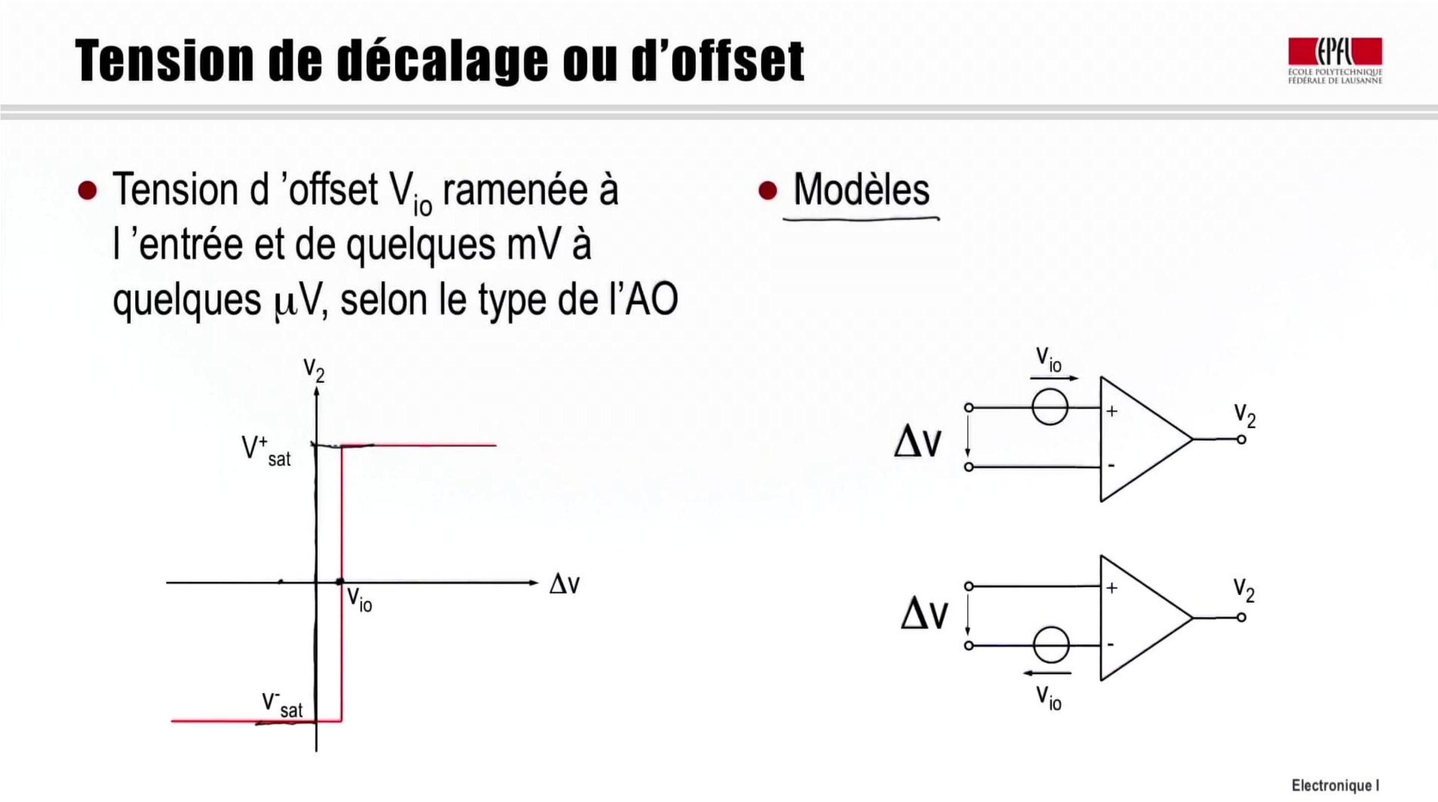
Electronique I

Another source of imperfection is called the offset voltage or the '*offset* voltage. When we considered the output voltage specification in relation to the difference *V+ - V-*, we got this curve here, which was completely confused with this axis here. So this curve went through the origin. However, what we're saying here is: "No, there's an offset voltage." So, instead of being like this, this curve follows the red curve. So it can be offset, either in this direction, or in that direction, by the value *Vi0*, that we call the *offset* voltage of the amplifier. So this voltage is uncertain. It has a Gaussian distribution. It could be either like this, or like that. In the same batch, fabricated in the same microchip factory, there can be amplifiers that have positive *offset* voltages and negative *offset* voltages. This is linked to the manufacturing process and to what is called impendence matching or to what extent the transistors fabricated inside an amplifier are compatible and are able to compensate for each other without creating an offset voltage. Unfortunately, we can only get rid of this voltage by using quite advanced electronic techniques and that it's a voltage model.

Notes

Summary

5m 53s



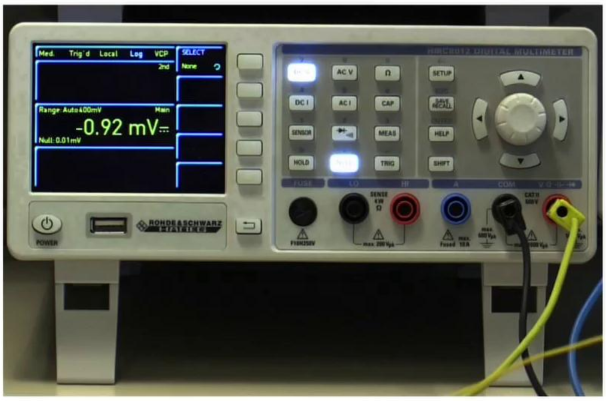
This voltage isn't measured in this way. You can't come and connect a voltmeter from one part to another because it doesn't exist. It's a model. It's a model to simply show that all of the electronic effects brought to the input can show up as a form of voltage that we call the *offset* voltage. And that the manufacturer supplies us with a typical value, a minimum and maximum value with a Gaussain distribution of this *offset* voltage.

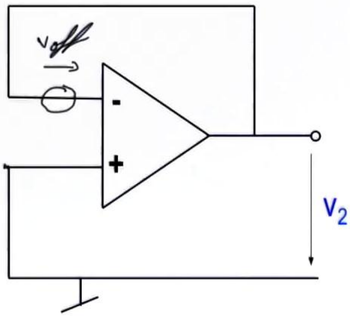
Notes

Summary

7m 36s

MESURE DE L'OFFSET





Electronique I

If we want to measure the *offset* voltage of an operational amplifier, it is sufficient to connect it in tracking mode. You take an operational amplifier, and you connect it to tracking mode. So you take the positive input, and connect it to the volume and you connect a voltmeter at the output, as I am doing here. I've taken a 741 amplifier. I've connected it in tracking mode. So it's an amp that will yield a very high open-loop gain. So this voltage here, which should be at zero, when we've physically connected it to zero, this *offset* voltage, should either be here, or on the other side. Put simply, it appears modelled at the input and this *offset* voltage, is the offset between this node here, copied to this node here, and added and brought to the output and when I measure the output voltage *v2* in relation to the volume, that's what my voltmeter is showing now, and here, I see that I've got an order of magnitude of 1mV *offset* of this amplifier that I am now measuring. Of course, if I change circuits and connect a different one, It'll have a different *offset* voltage. Of course, if I change circuits and connect a different one, It'll have a different *offset* voltage.

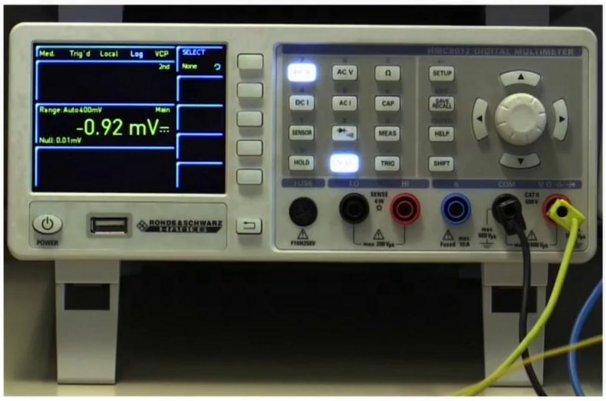
Notes

Summary

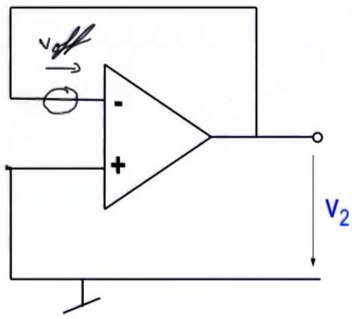
8m 04s

MESURE DE L'OFFSET

- Courant d'entrée pourrait être entrant ou sortant



- Modèle:



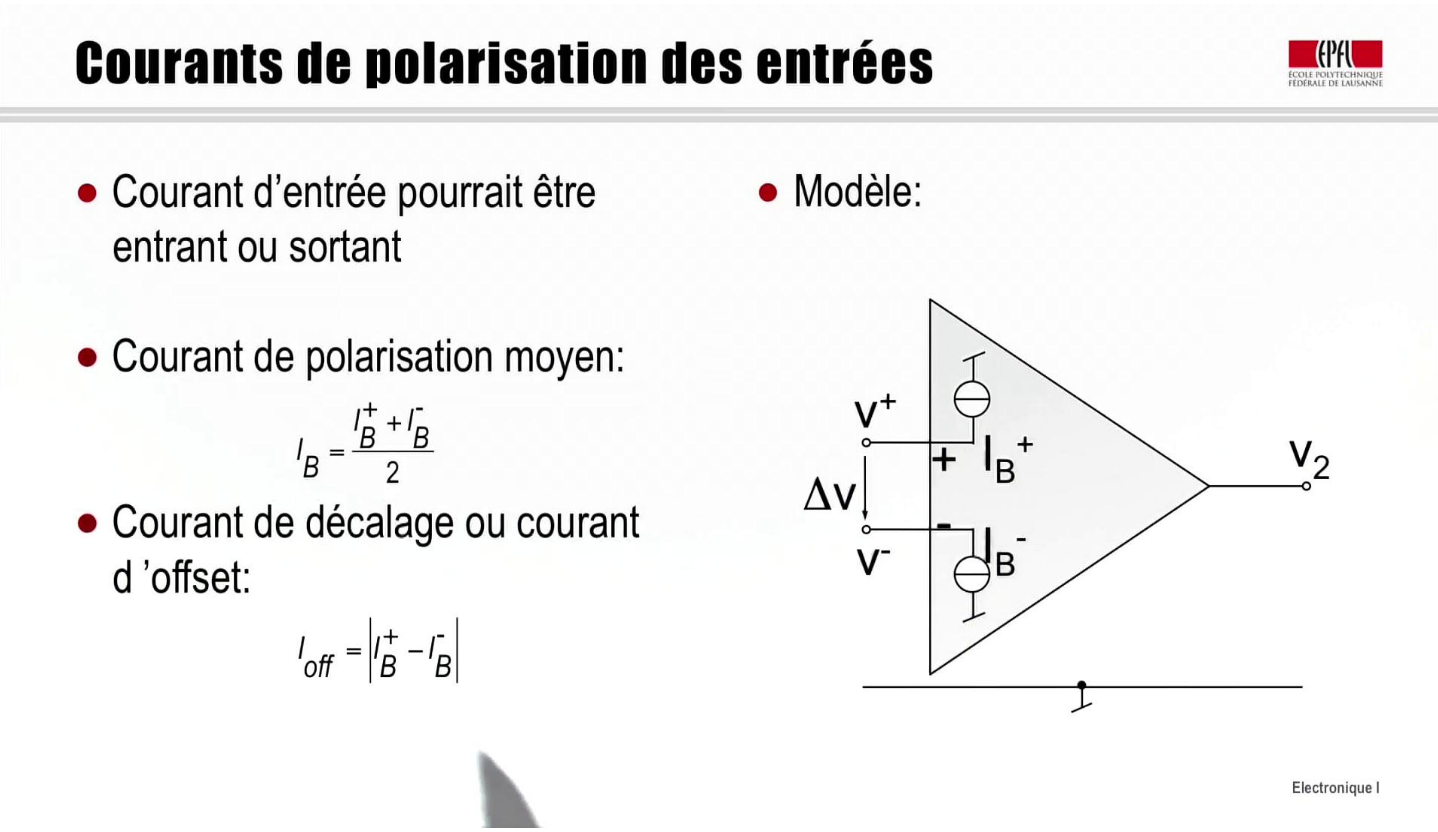
Electronique I

Manufacturers provide two terminals. And physically, on these two terminals, we can connect an external potentiometer and we can set the potentiometer to reduce this voltage. But you need to know that this voltage *drifts*, and changes. We can't hold it at a given value because it changes in relation to different parameters, especially temperature. So we can't compensate for, or hold the *offset* You need to always work on the amplifier to wipe out the voltage *offset*.

Notes

Summary

9m 25s



So, to finish with the imperfections of an operational amplifier, we're going to look at the fact that the current passing through the positive and negative terminals isn't exactly equal to zero. In reality, a current does exist. It depends on the specifications of the internal transistors which are used. Sometimes, this current can go up to some nanoamps or there can be weak leakages in the current. Sometimes, this current can go up to some nanoamps or there can be weak leakages in the current. So, the manufacturers of these operational amplifiers will always talk about two imperfection parameters. They'll provide the value of current *IB+* and of current *IB-*. They present it as an average polarisation current. So, they'll take the sum of both of them and divide it by two and that gives us an average value for the current passing through one or the other. You should remember that, as for the voltage *offset*, this current always differs from one and the other. We can't guarantee that the current is equal to that, that one equals the other. However, an average value is given by the manufacturer.

Notes

Summary

9m 57s

Conclusion

Electronique I

And to finish off, they also give a type of distribution statistic too, of the difference between the two, that we call the current *offset*. So, it's the difference between this current minus this current. You also need to know that for this current, we can't know if it's input or output. It can go in both directions. We have now seen the imperfections of an amplifier It seems to be that that as long as the amplifier is performing its function within a circuit, one only has to take the amp and use it while imagining that its imperfections are true to the ideal characteristics of an amp. Unfortunately, in the real world, when we take an operational amplifier and we want to use it at very high frequencies, we are very quickly confronted to the fact that finding an amplifier with a very high frequency, will result in a very weak gain. And vice versa. The same for the *slew rate*. If you choose an amplifier with very low consumption you need to know that the *slew rate* will also be very high. And the more energy an amplifier is wasting the more the *slew rate* will improve. and your amplifier will be able to cope with higher and higher output variations.

Notes

Summary

10m 59s

Courants de polarisation des entrées

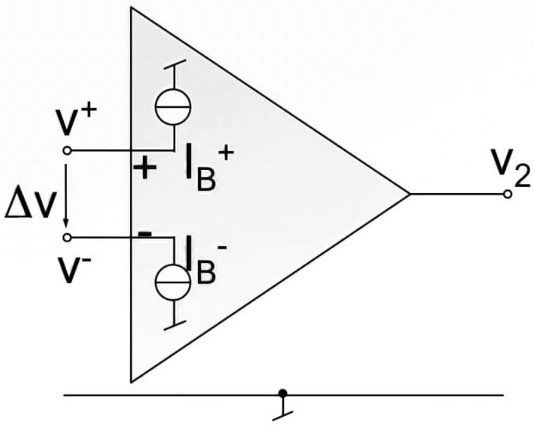
- Courant d'entrée pourrait être entrant ou sortant
- Courant de polarisation moyen:

$$I_B = \frac{I_B^+ + I_B^-}{2}$$

- Courant de décalage ou courant d'offset:

$$I_{off} = \left| I_B^+ - I_B^- \right|$$

- Modèle:



Electronique I

and so on, and so forth... All of these imperfections are related to one another and are linked to the technical implementation within the amplifier. And unfortunately, there isn't one existing amplifier presenting all these characteristics There are some advantages and disadvantages, presenting all these characteristics depending on what it's being used for. presenting all these characteristics depending on what it's being used for. So, this chapter on the imperfections of an amplifier is one of the most important ones because it's based on these values, that we can choose the correct amplifier for the right application.

Notes

Summary

12m 21s