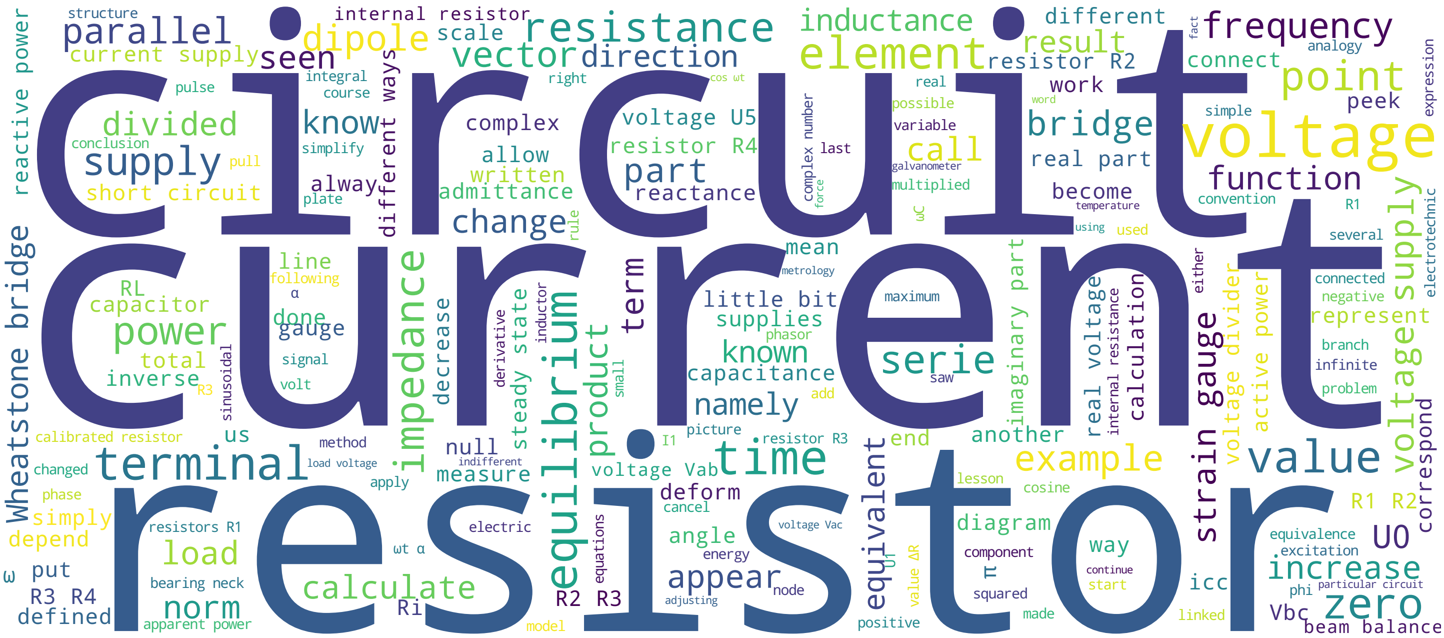
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

LE PONT DE WHEATSTONE

LEÇON 11

Électrotechnique I
Yves PERRIARD & Paolo GERMANO
Laboratoire d'Actionneurs Intégrés



EPFL

Video

Hello, today, we will discuss about a particular circuit much used in metrology: it is the Wheatstone Bridge. This is the content of today's lesson: first of all, we will do an analogy with another measuring device that is the beam balance. Then, we will describe the circuit that builds the Wheatstone bridge. Then we will establish a condition for the bridge to be at equilibrium, and calculate it's equilibrium condition. Finally we will give two application examples and we will end with a conclusion.

Notes

Summary

0m 03s

LE PONT DE WHEATSTONE

Analogie

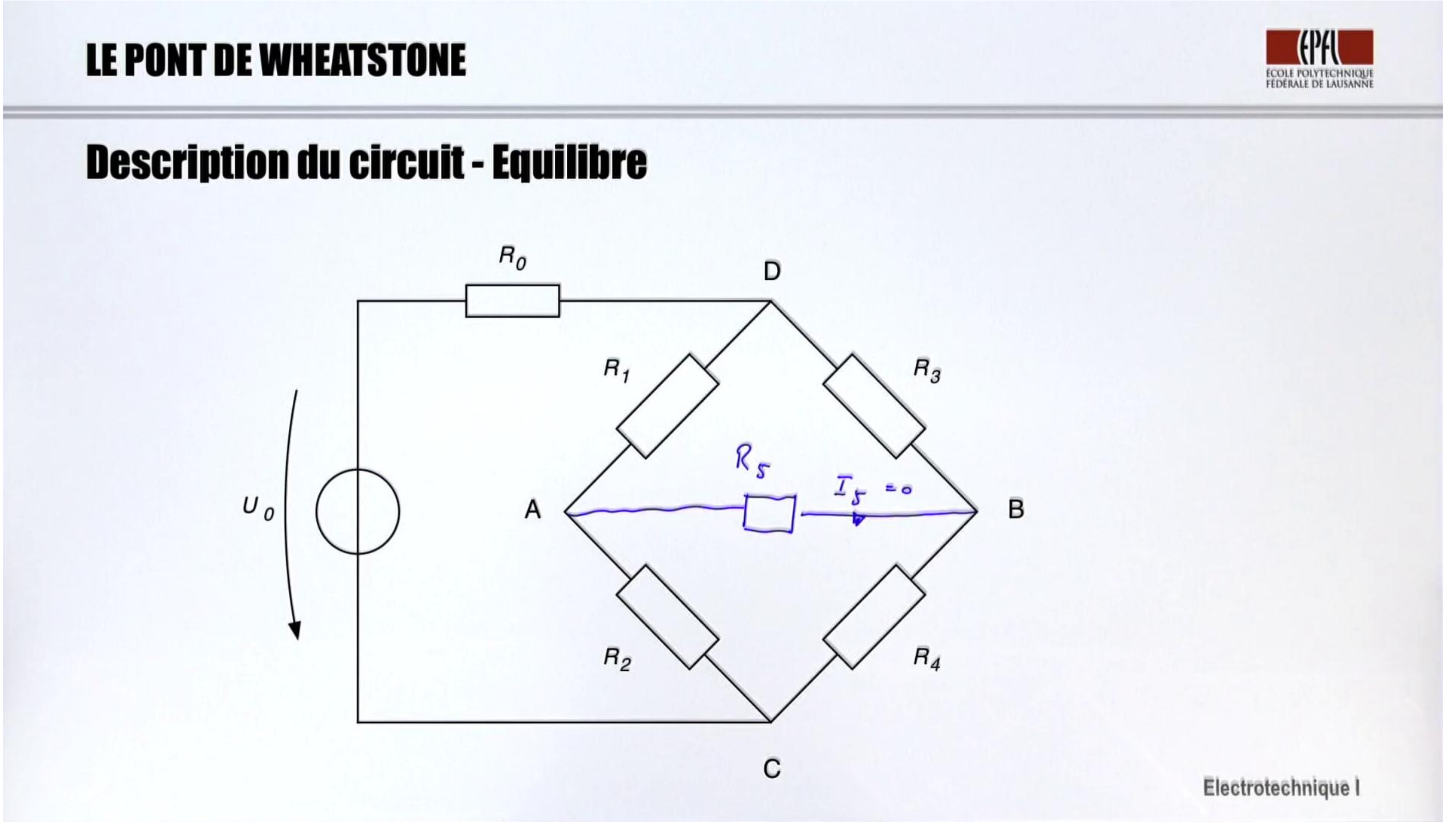
Electrotechnique I

The Wheatstone bridge is an interesting circuit example capable of satisfying, a particular equilibrium condition, a little bit like balance beams.

Notes

Summary

0m 39s

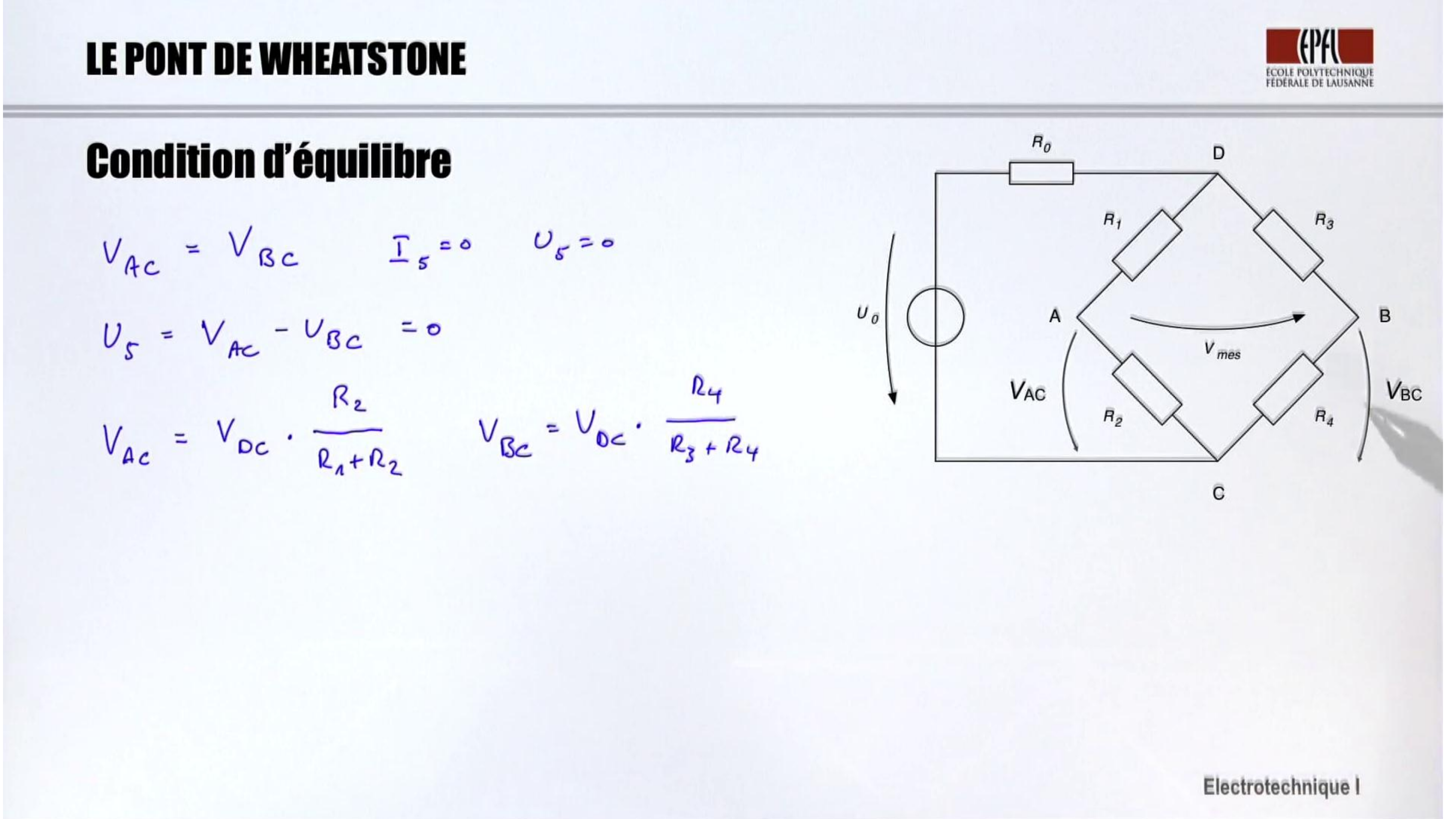


So, here is the Wheatstone bridge. It is a circuit that is essentially made of two branches of two resistors in series. And, the condition for the bridge to be at equilibrium is that the voltage between the points A and B has to be equal to zero. So if we connect a resistor between these two points, resistor that we can name R5 well, the current that crosses this resistor, that we name I5, must be equal to zero, at equilibrium. So if we connect a galvanometer, which is a device allowing the measure of the current. If we connect a galvanometer in series with this resistor her, this last one will indicate a null value. This condition is independent of the value of R0 and of U0. It should be noted that such a principle can be used as continuous current. This is what we are going to work on today, to perform the measurement of an unknown resistor, or generalize an alternative state to define the unknown impedances.

Notes

Summary

0m 49s

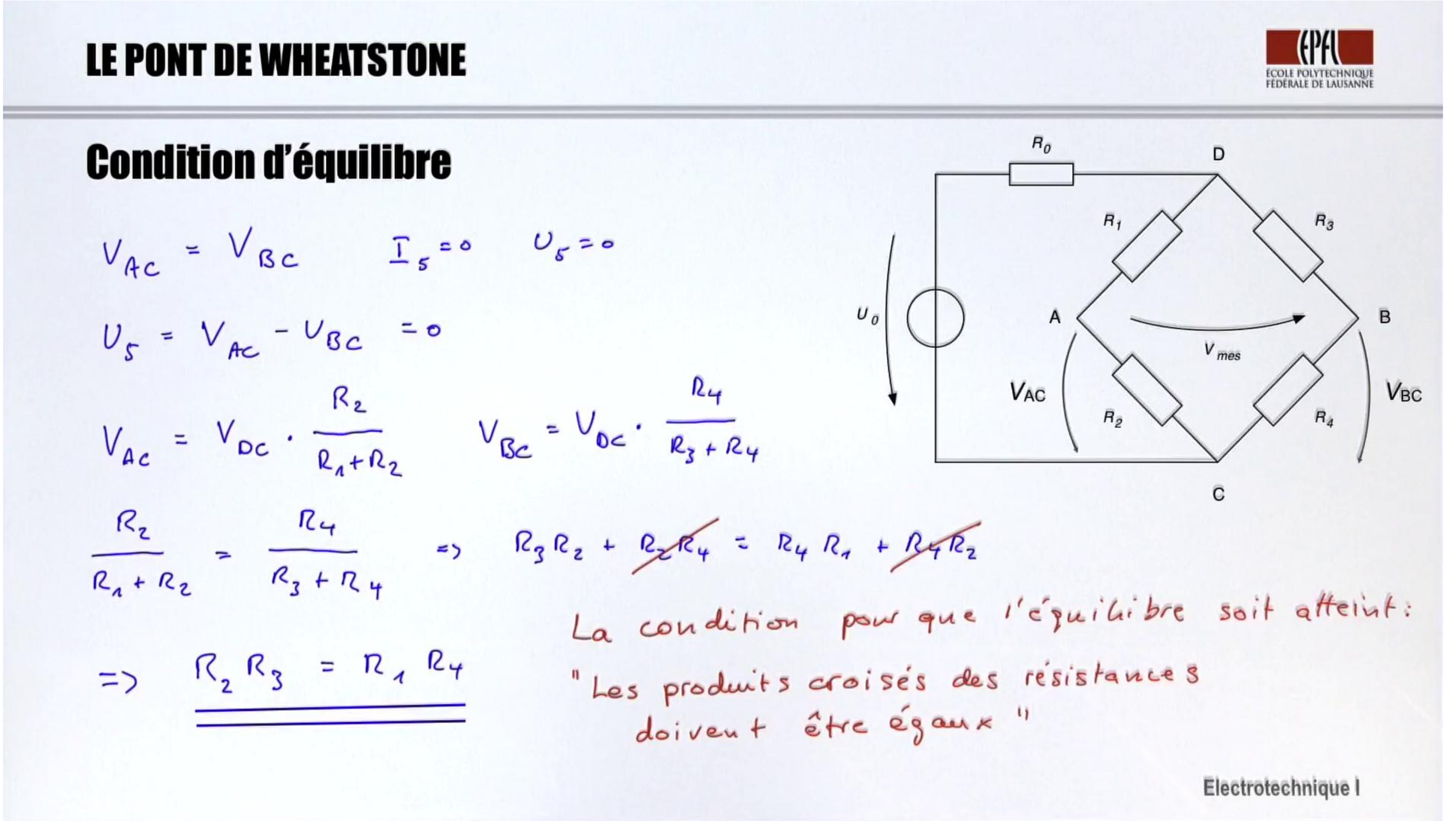


The purpose is to cancel the voltage between the point A and the point B, this voltage U5, whatever the values of U0, R0 and R5 are To get the equilibrium criteria, we will first of all calculate, the voltage that there is between the terminal A and the terminal C, and secondly, the voltage that is between the terminal B and the terminal C and by making these two voltages equal, we will get a voltage U5 that is equal to zero. The equilibrium condition is that Vac must be equal to Vbc which will give a current I5 equal to zero and a voltage U5 also equal to zero. We can also define this voltage U5 between the points A and B as being: U5 = Vac - Vbc This must be equal to zero. The voltage Vac is given by the following relationship: It is the voltage Vdc between the point D and the point C, the voltage Vdc multiplied by the resistor R2 divide by the sum R1 + R2. We recognize the voltage divider. We do the same thing for the voltage at the terminals of B and C. So we have that Vbc is equal to Vdc multiplied by R4, divided by R3 + R4. And again, this expression of the voltage divider. For the equilibrium condition, the voltage Vac needs to be equal to the voltage Vbc.

Notes

Summary

2m 00s

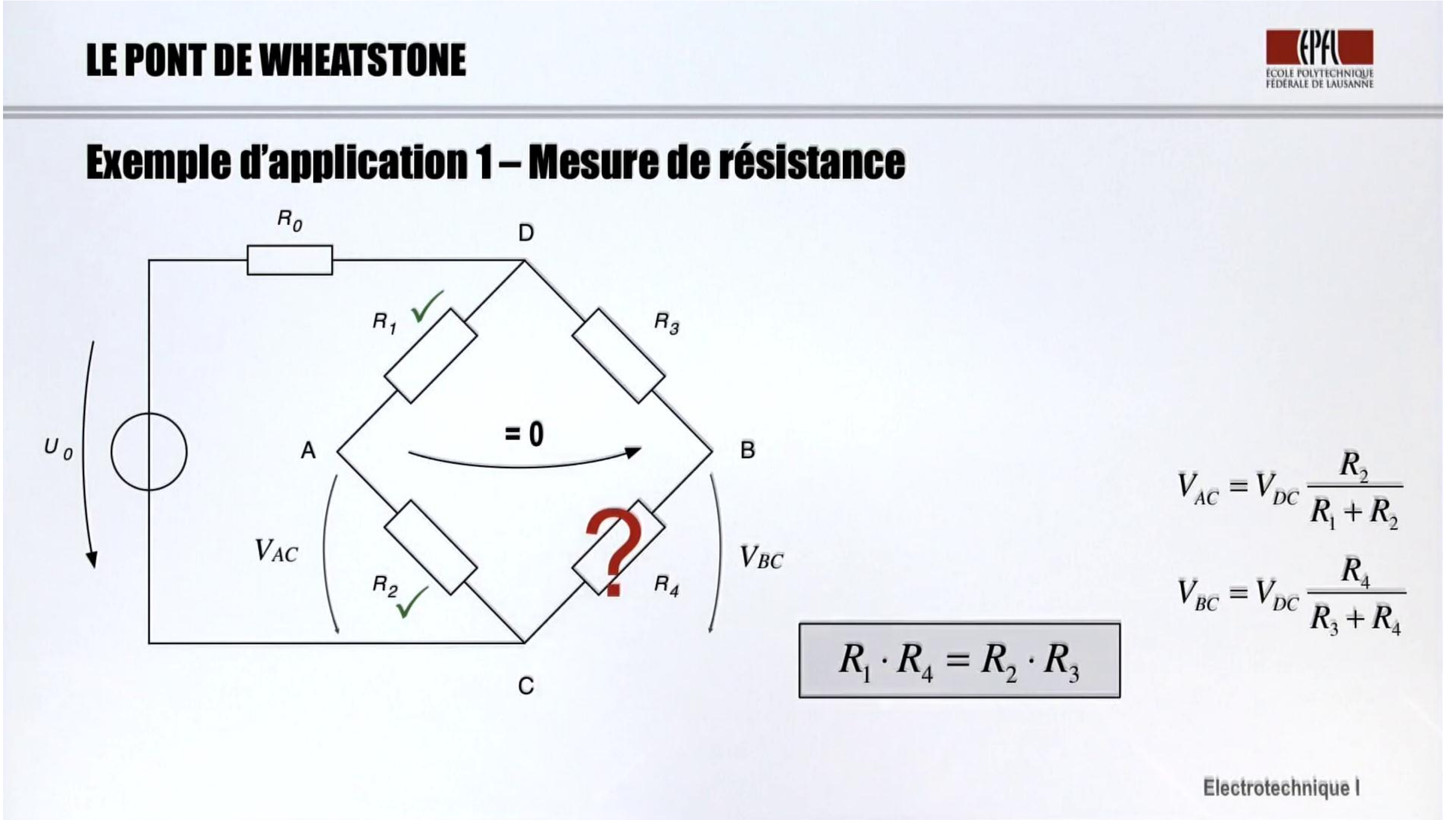


We can rewrite this equation the following way: [Silence] that we can expand and that gives: [Silence] We can simplify this equation by deleting these two products. Which gives us the following relationship: The product R2 * R3 must be equal to the product of R1 * R4 so that the bridge is in equilibrium. Rather than embarrass ourselves with indices which are, moreover, not from a conventionality we can clearly see here that the indices R1, R2, R3, R4 can be arbitrarily chosen we will then remember the following rule, that says that: the equilibrium condition of the bridge is reached when the cross products of the resistors, R1 * R4 is equal to the product of the resistors R3 * R2 [Silence] Now that we have defined the equilibrium condition we can see that we can use this circuit, or this bridge, in two different ways: either by adjusting the resistors R1, R2, R3, R4 so that the voltage Vab is equal to zero, or by the equilibrium of the circuit, that satisfies this equation her, we look at the voltage that appears at the terminals Vab when we change one or several of the four resistors.

Notes

Summary

3m 53s

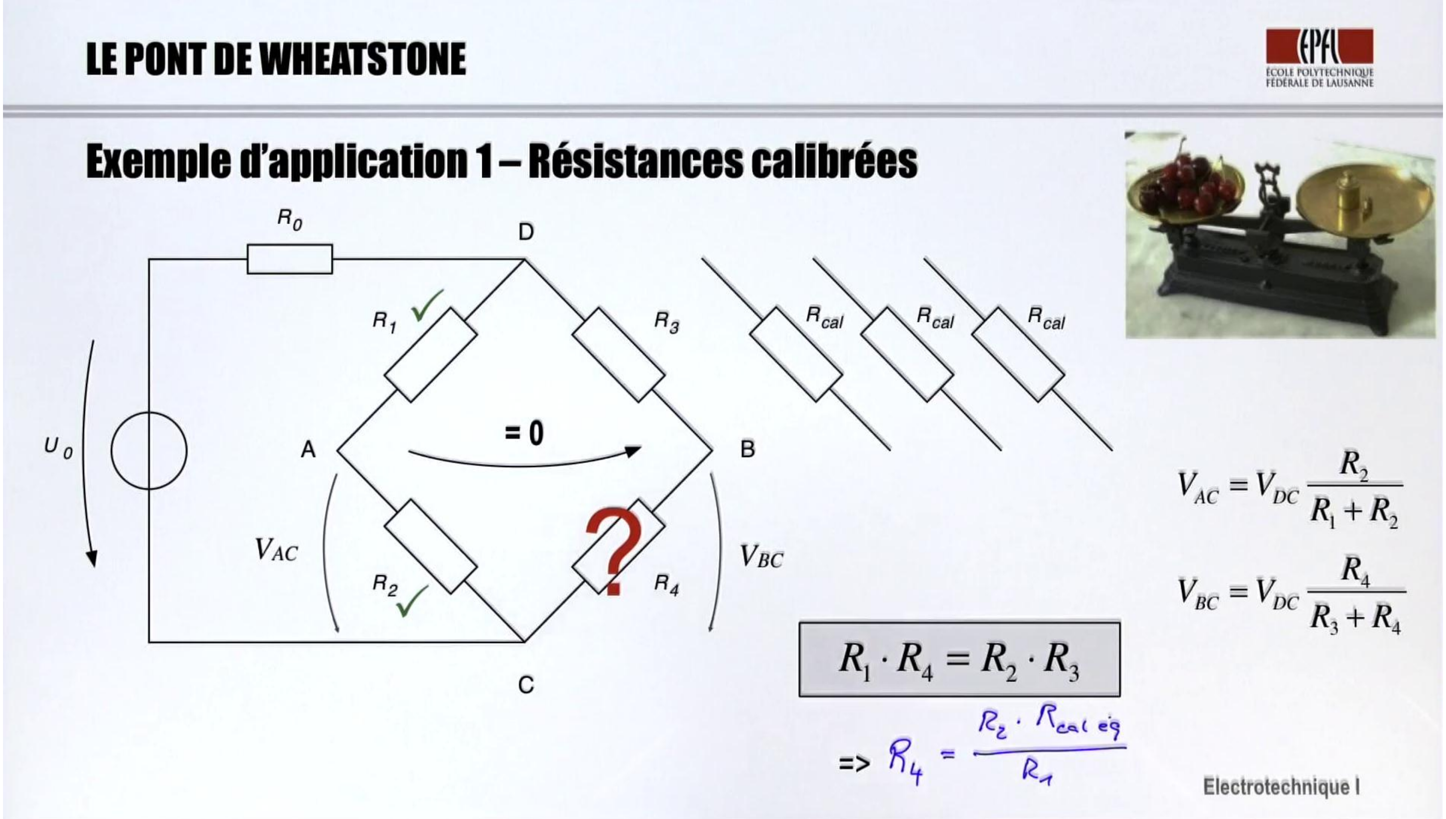


So the first mode of use, is the resistance measuring. If we start with a circuit where a first resistor is known and a second resistor, we can get the result, the computation of a fourth resistor simply by adjusting the resistor, here, R3, in a way that the voltage Vab, that appears between these points, becomes equal to zero, namely that we satisfy this equation here.

Notes

Summary

5m 49s

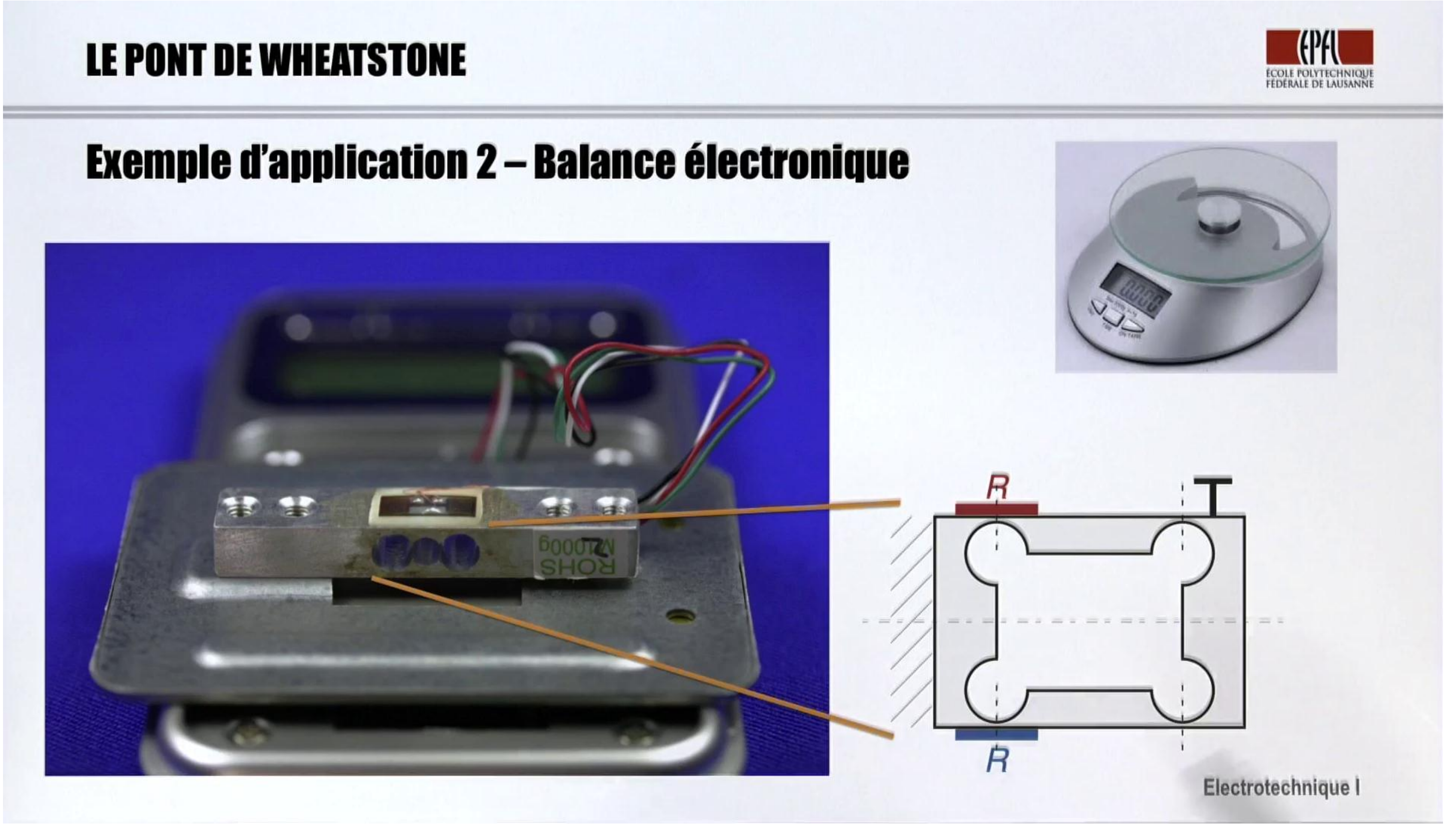


So the analogy with the beam balance is total. We have here an unknown that we will like to know the mass, we will simply add here calibrated weights such that the beam balance comes back to equilibrium. This is what we do here with the bridge. If we know the reistor R1 and the resistor R2 The resistor R4 can be obtained by adding or replacing R3 by known calibrated resistor values, so that the voltage AB becomes equal to zero. Which makes that the resistor R4 will be equal to the product of the resistor R2 multiplied by the equivalent calibrated resistor, divided by R1. R1 and R2 are known and also the calibrated resistors.

Notes

Summary

6m 26s



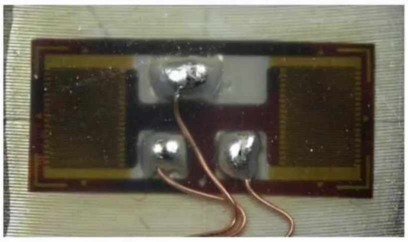
The second application example is an electronic scale, a scale such as the ones in trade, that allows to measure a force, or a weight, by using strain gauges. This scale, here disassembled, is made of a deformable mechanical structure where a part is linked to the stationary part of the balance, the table, and another part that is connected to the plate. Schematically, here, this element here, is what we call a bearing neck, that is a deformable structure with the four necks that are here very thin, and so we put a resistance here on the part that deforms itself, and when we will push here on the plate all the structure will deform itself and change the resistance.

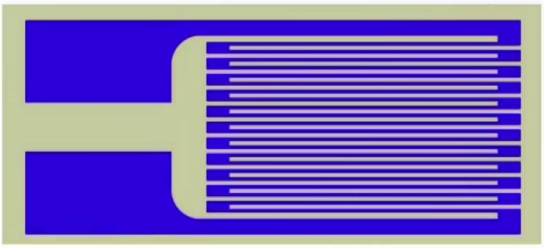
Notes

Summary

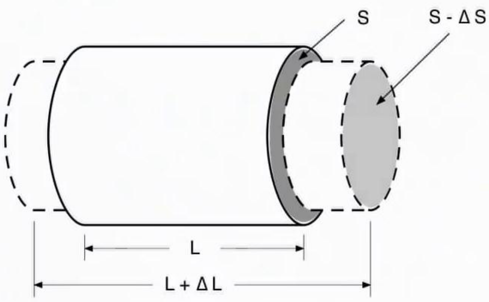
7m 25s

Exemple d'application 2 – Jauge d'extension





$$R = \rho \cdot \frac{L}{S}$$



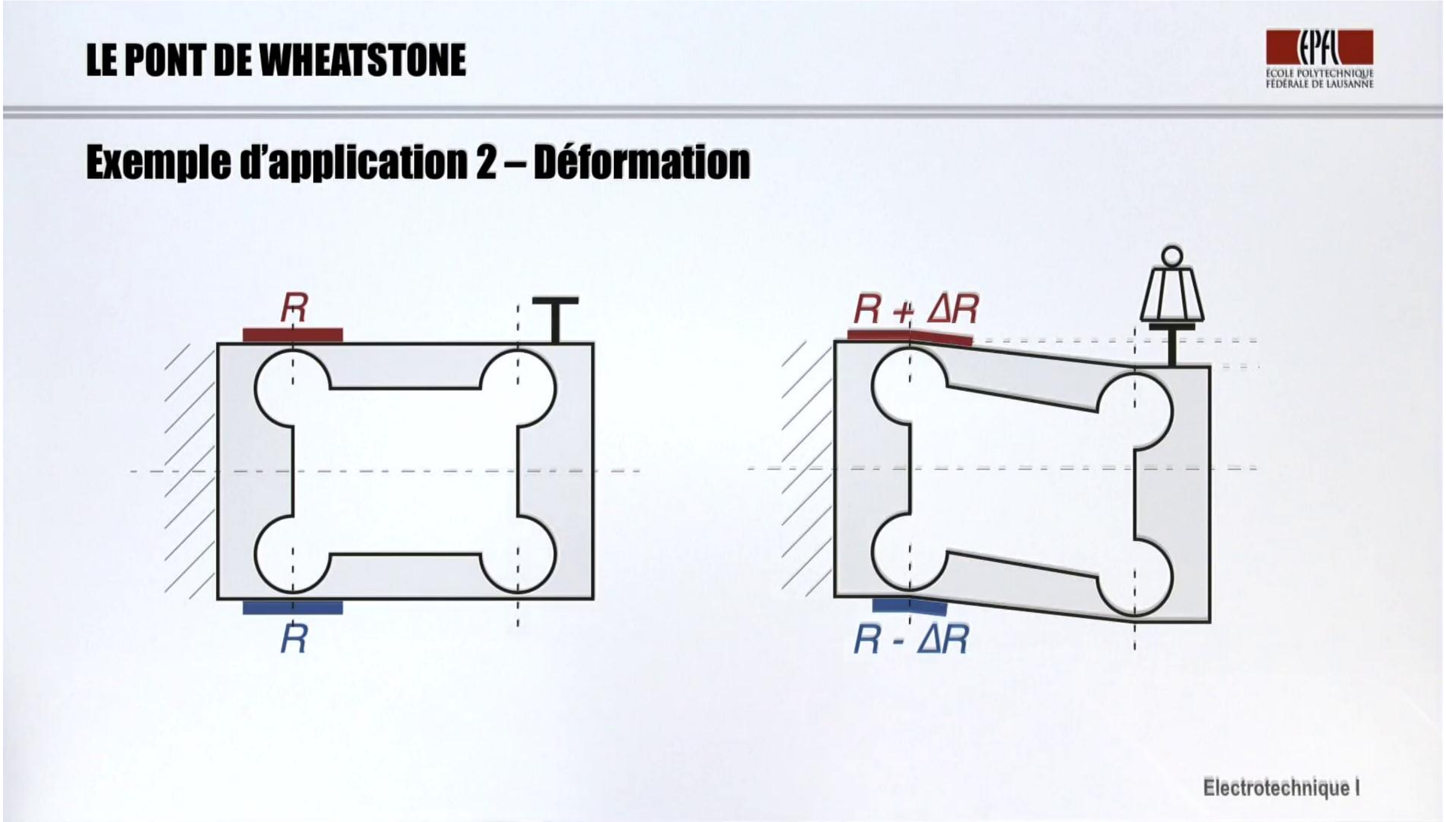
Electrotechnique I

We can see here a picture a little bit more detailed of such strain gauges. Here, schematically, to picture the element in a better way, we see that it is a coil with L times the length of a copper cable and if we pull on this gauge her, each of these strands will lengthen and the section will decrease so the volume remains the same So we have a resisitance that will change. If we pull on the strain gauge, the resistance will increase and if we compress the strain gauge, the resistance will decrease.

Notes

Summary

8m 29s

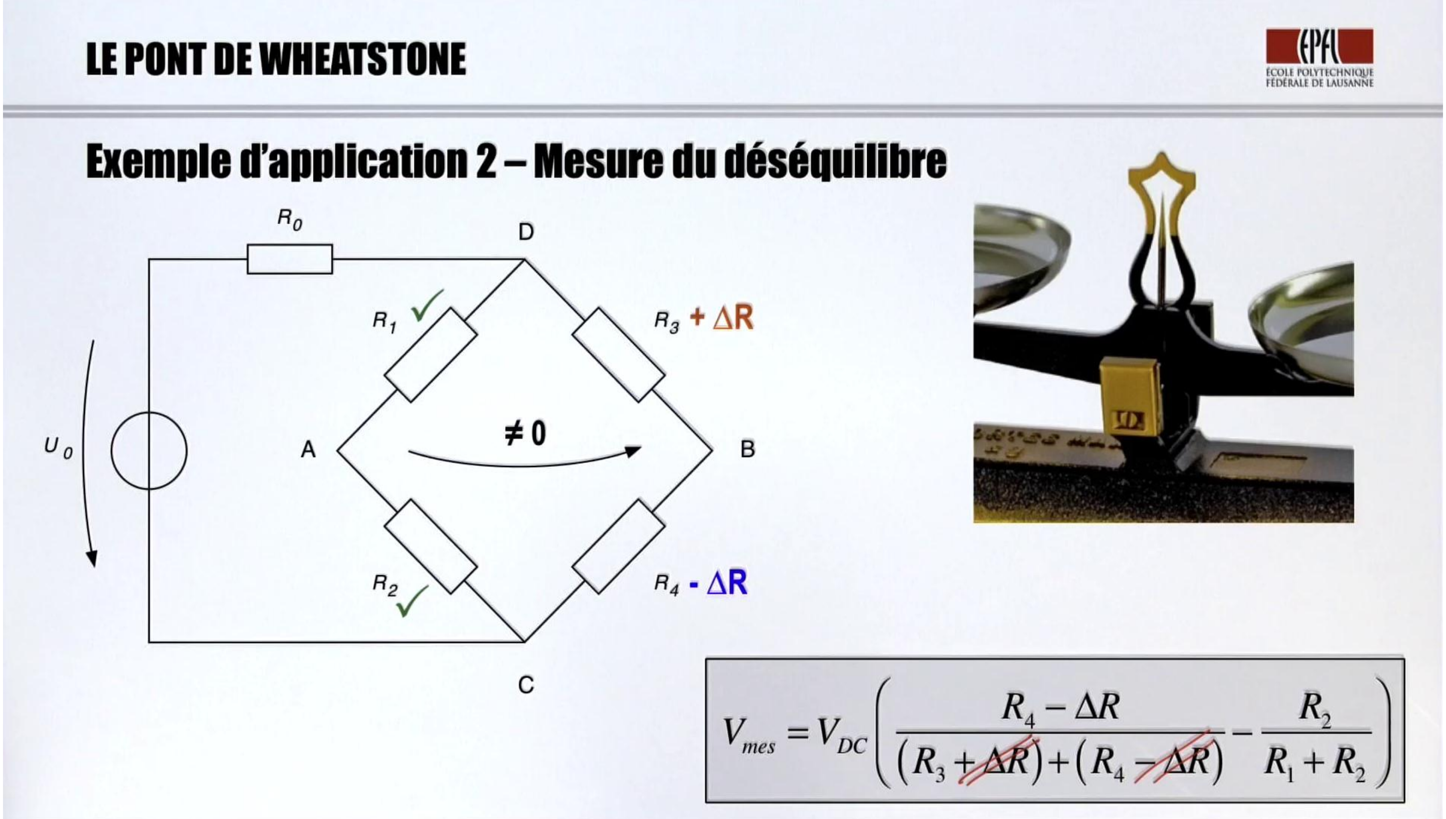


We see here on these two sketches the bearing neck in its equilibrium position and when we apply a force on the plate so we deform this extremity here the other one remaining stationary and so the resistance, or the strain gauge, that is positioned at this place will elongate, so we will increase its resistance, while this one will be compressed. We will decrease its resistance of a value ΔR.

Notes

Summary

9m 14s

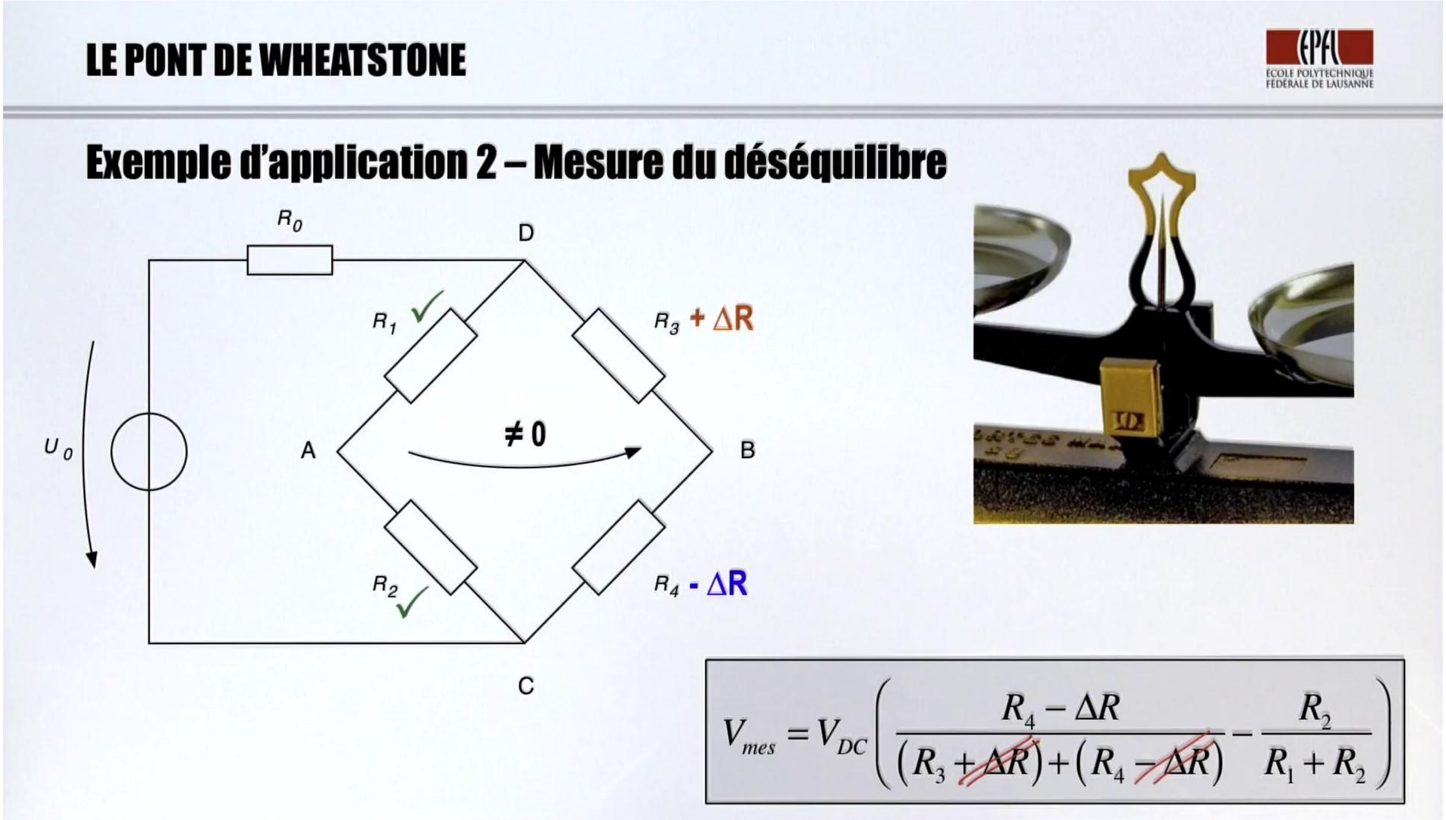


Here is the circuit used within the electronic balance. We have four resistors where two of them are known and fixed. The two others are the strain gauge resistors, and that are capable to fluctuate. At equilibrium, these resistors are equal and so the bridge is at equilibrium the voltage Vab is equal to 0. Under stress, the bearing neck will change. The resistor R3 will increase, the resistor R4 decreases, and so at equilibrium Uab will be broken and a voltage between these two points will appear. We find the equation that we have expanded before, with the crossed products that must be equal, the resistor R4 will be changed of a value -ΔR, the resistor R3 will be modified of a value + ΔR. We see in this equation that ΔR can simply be changed here, compensate itself. And the voltage that appears at the terminals, between the terminals A and B namely given bay this equation that depends on the fluctuations of the resistor and therefore the deformation that has been done on the scale. There will the be a voltage between the points A and B that will appear, it is a little bit like the needle of the balance, here that will deviate from the equilibrium position if we continue our analogy.

Notes

Summary

9m 42s

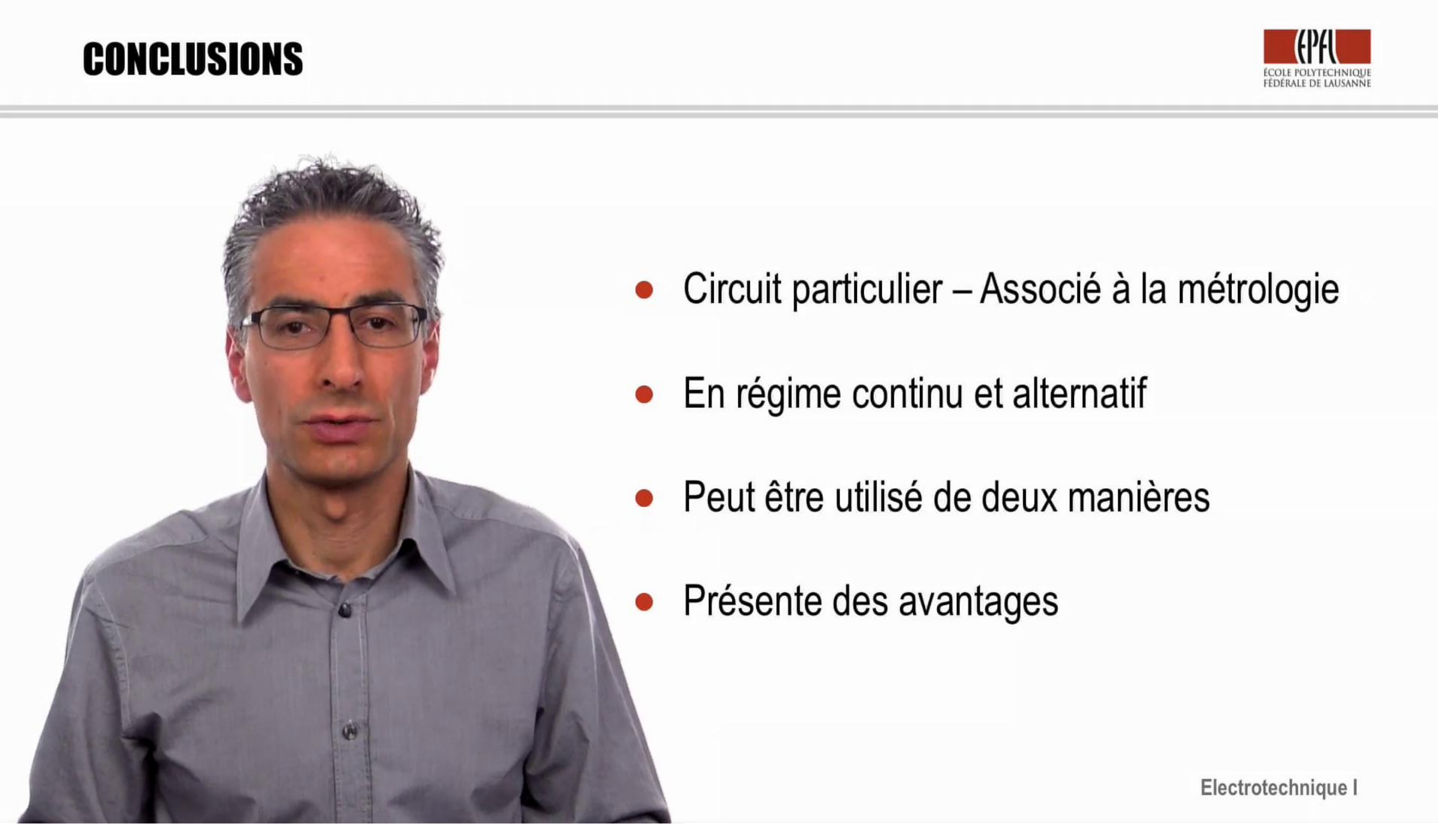


Note that we can arrange the resistors in different ways to increase the sensibility of the circuit, eventually go from two gauges to four gauges. But anyway, the big advantage of this set up, is that it is indifferent to external disturbances, for example the temperature. At equilibrium, if the circuit's ambient temperature increases, then the bridge stays at equilibrium because all the resistors will increase because of the temperature. And therefore, the equilibrium will be guaranteed.

Notes

Summary

11m 18s



So we have seen a particular circuit linked to metrology, it is the Wheatstone bridge. We have done the expansion of the functioning in DC mode but it is also valid for the alternative mode. We have seen that we could use this bridge in two different ways either by searching for the equilibrium either by starting at equilibrium, and moving away from this equilibrium and calculate the resistance fluctuations. This circuit has a lot of advantages, as being indifferent to the temperature. It is clear now that, there are many electronic devices that allow to measure the resistances, and that make the circuit a little bit obsolete, but the structure of the bridge remains used in many assemblies, even in embedded electronics, when it is not possible to add another device.

Notes

Summary

11m 50s