ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

ÉLECTRICITÉ ET ÉLECTROTECHNIQUE

PRÉAMBULE – BASES DE L'ÉLECTRICITÉ

LEÇON 1

Électrotechnique I

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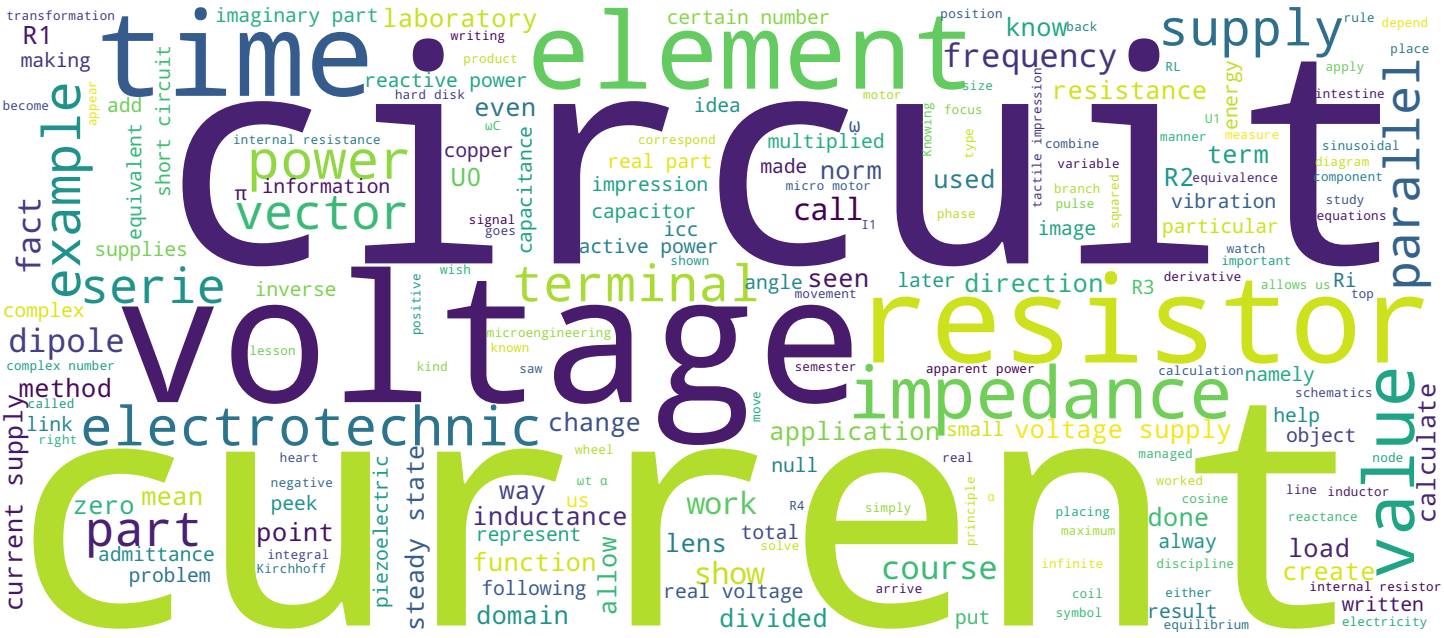
Laboratoire d'Actionneurs Intégrés



Video

INTRODUCTION

Hello, A warm welcome to this MOOC course for electrotechnic 1 that I shall give during this semester with Paolo Germano. Electricity is a relatively recent scientific and technical subject that opened up in the 19th century but that appears in many technical achievements. Several subdomains have appeared that all depend on applications of electricity, ranging from communications to energy. Electronics, which in itself can be distinguished between control electronics and power electronics; the technical information that includes the domain of integrated circuits, the brains of information processing; remote transmission, telephones, televisions and GPS; electrical energy, including generation, transmission, distribution and conversion of energy, the measures, their transmission and their management. All of these domains and subdomains depend upon electrotechnics that we shall discover during this semester. Before starting this course, I would like to give you a preview of what we do here, at EPFL, in a laboratory, the laboratory of integrated actuators, that is part of the Microengineering Institute. What is microengineering ?

Notes

Summary

0m 03s

LA MICROTECHNIQUE

L'automate de Jaquet-Droz (1768 et 1774)

The Writer (6000 pieces) — The Musician (2500 pieces) — The Draughtsman (2000 pieces)

A.L Breguet (1747-1823)

né à Neuchâtel. Plusieurs de ses conventions:

- Montres perpétuelles à remontage automatique
- Ressort-timbre pour les montres à répétition
- Dispositif anti-choc «pare-chute» pour des pivots équilibrés

Electrotechnique I

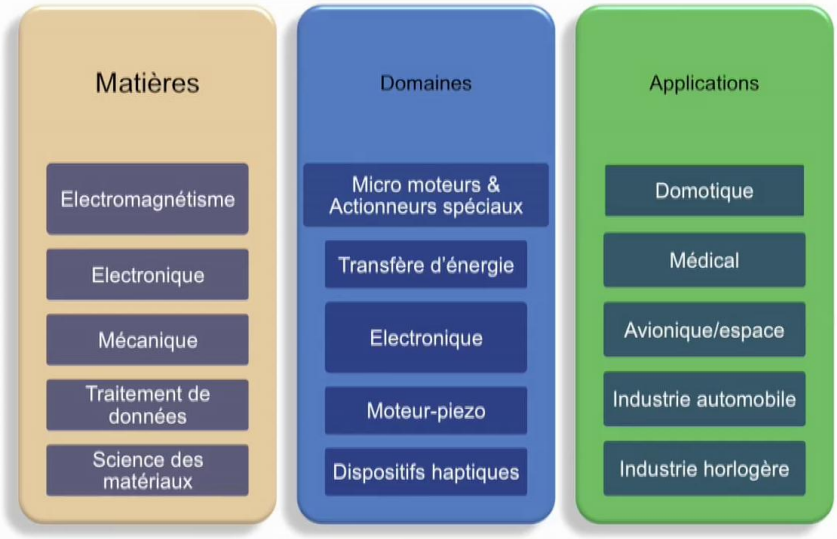
Microengineering is at the heart of a certain number of applications such as watches, robotics, applications that, of course that combine precision, that combine the link between energy, between information, between mouvement between sensors, between optics, etc. You can see here, on the image 3 automata that we call the Jaquet-Droz automata -born in the 18th century- which are, in fact, the first completely mechanical robots, born from the absolutely incredible ingenuity of Mr. Jaquet-Droz. Who was followed by a great man such as Mr. Breguet, who invented the perpetual self-winding watch and whereby, in the Jura part of Switzerland between the Vaud, Neuchatel and Jura cantons we find what is known as the cradle of microengineering, that of course also extends to neighbouring France and where we find a certain number of businesses linked to microengineering that do, even today, very high microengineering.

Notes

Summary

1m 10s

DOMAINE DE COMPÉTENCES



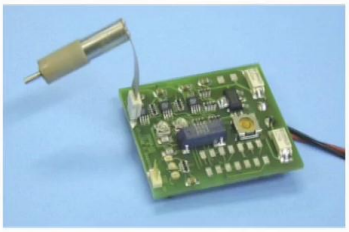
Electrotechnique I

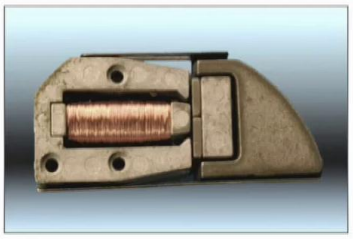
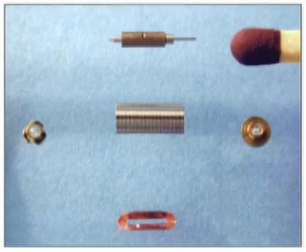
The laboratory finds itself in domains at the heart of different subjects such as electromagnetism, electornics, mechanics, data processing but also material sciences, as we shall see later on. Domains such as micro-motors, energy transfer, electronics, piezoelectric motors, or even haptic devices, are our topics of predilection within the laboratory of integrated actuators.

Notes

Summary

2m 22s

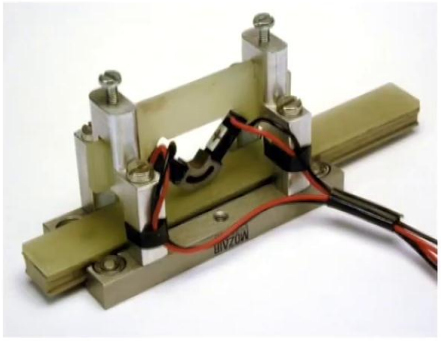
Quickly, we realized that one of the key pieces to enable miniaturisation, is to be able to integrate different movements and different functionalities within a system. You have here several images that show you how these functionalities can be integrated. For example here, the lens of a DVD reader, where the lens must focus the laser beam on the optical disc with a precision better than a micron. And this must be done in the vertical direction but also in the lateral direction, and you have here a microsystem that allows the adjustment of the position of the lens within a micron in two different directions. So here is an actuator. Here as well, a micro-motor of a few millimetres in diameter that can nonetheless turn at 100 000 rotations per minute and its command electronics are much bigger than the motor itself. Or even a hard disk motor, here, alongside a coin just to show you the link between the size and that currently allows us a very powerful miniaturisation.

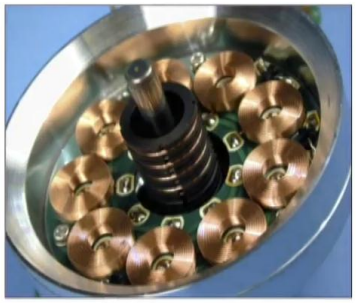
Notes

Summary

2m 51s

- Multiplication des fonctions
- Utilisation du «contactless»
- Analyse globale de l'entraînement





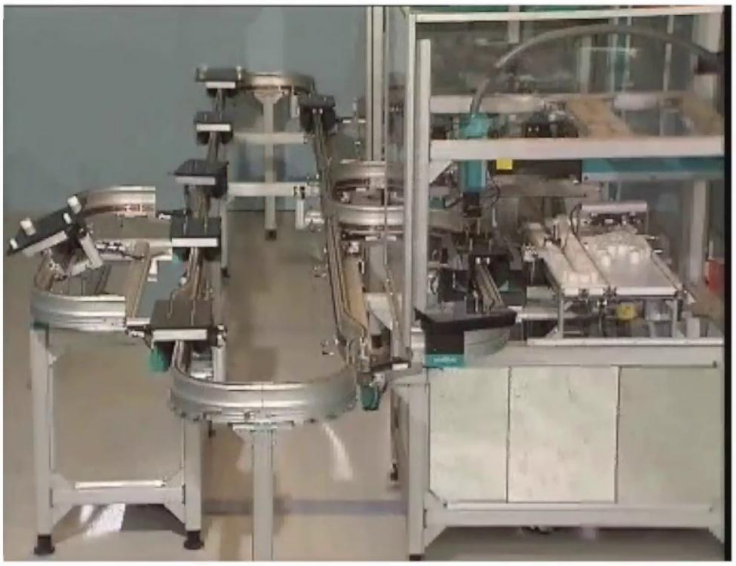
As I have mentioned, integration is at the heart of our activities to allow - not for this lens of a DVD for example, to add two systems one upon the other to make an XY table - but to combine two systems together allowing the combination of ingenuity and microengineering to solve a problem in proper manner. Or even here, you can see a motor. Here, a motor of an ancient belt DVD with four coils that you can clearly see here that are in fact a transformation of the information of the belt sensor that transfers without contact the information within the motor.

Notes

Summary

4m 04s

Transmission d'énergie et d'information sans contact, travail en salle blanche



Electrotechnique I

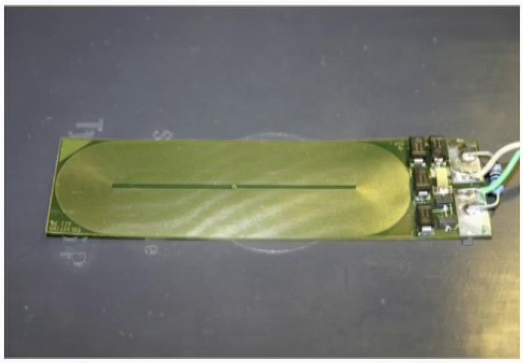
Another element that we work on is transmission of energy without contact, here, a project that we have worked on where we can see the belts a lateral belt here - we can see them better here - with a test bus that allows supplying power to the cart. These carts, as we can see, move along an assembly line. Thus, the goal is to make assembly lines with these small independent modules. And to go to the cleanroom, well, the rubbing of these brushes on these bands creates too much dust. Thus, the idea here was to create an entirely contactless system.

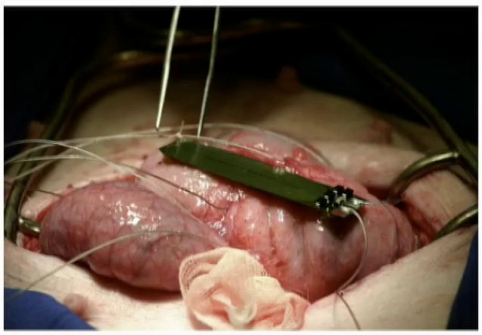
Notes

Summary

4m 50s

TRANSFERT D'ÉNERGIE





Electrotechnique I

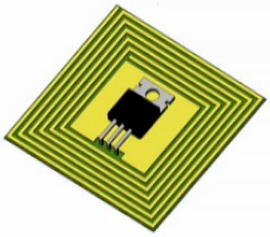
This contactless system is reused here for a project with a local business, that we've managed to implement with the help of the CHUV hospital of Lausanne with problems where energy need to be transmitted within the human body. You can see here an in vivo experiment where we placed a "secondary", It's a coil, here, on a flex print, directly attached to the intestine. We close the intestine and, from the outside, we will activate the intestine for people who have chronic constipation problems or severe problems of gut motility.

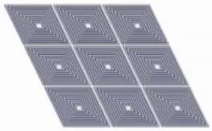
Notes

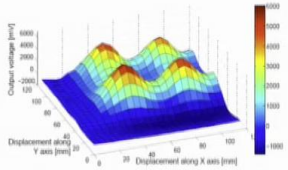
Summary

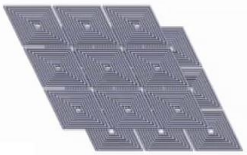
5m 27s

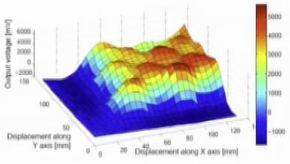
TABLE POUR LOGITECH

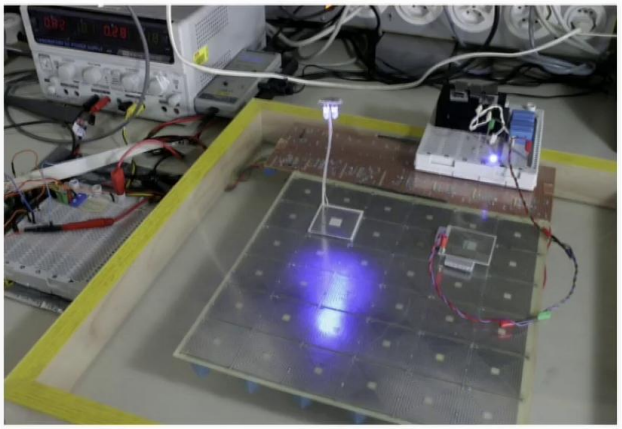












Electrotechnique I

Another application that we've managed to do for the company Logitech is here a testing bench, a table, upon which we can place any object and this object will be supplied in energy.

Notes

Summary

6m 06s

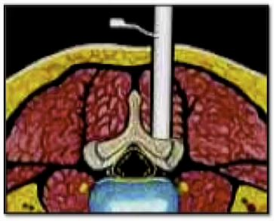
The laboratory also works on micro-motors or very special motors. We've also had the opportunity of working for very ambitious projects on artificial hearts. You have here one of the in vivo experiments that has been done. This has been done in collaboration with Montreal, with, here, a motor with its titanium shell. Blood is used to cool down the motor and this part here, of the motor will find itself completely immersed within the left ventricle.

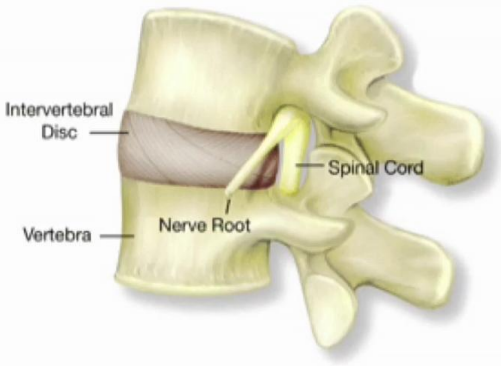
Notes

Summary

6m 17s

BISTOURI PIEZO-ÉLECTRIQUE





Electrotechnique I

Several other applications : we've worked on a piezoelectric bistoury, we shall see later on what we mean by "piezoelectric". It's a crystal that we vibrate and we got the idea of making a bistoury that can choose the tissue that it is in the process of cutting, in particular for high risk operations, like for example, working on the intervertebral disks with the spinal cord that is very close here, thus the risk of harming the patient is relatively high and to be able to have a bistoury capable of selecting a soft or hard tissue, endues an immense advantage for the surgeon that is operating.

Notes

Summary

6m 49s

ACTIONNEUR PIEZO-ÉLECTRIQUE

Electrotechnique I

Here is a piezoelectric actuator as I was describing it earlier and that can thanks to its vibrations and to the fact that we are acting based on a contact between the vibrating part and the stationary part, finally create movement.

Notes

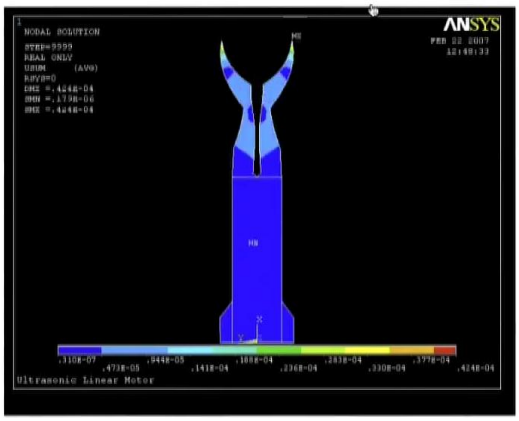
Summary

7m 35s

SÉQUENCE DE DÉFORMATION D'UN RÉSONATEUR

Le phénomène stick-slip induit un mouvement

Mouvement retour : 69 kHz



Mouvement pour avancer : 84 kHz

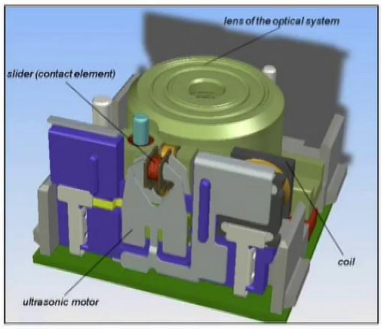
Thus you have here a small linear actuator that was created in our laboratory and that make you better understand how this system works, we have prepared a small animation, to show you how, by increasing the vibration at the tip of the system, you can see here how it vibrates "in the same manner as a fin", like a fish in fact and the tip of this "fin" will touch the stator and induce a movement. And for two different frequencies, we can create a going movement or a coming movement.

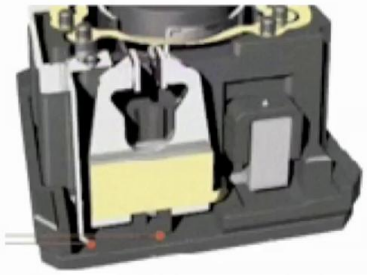
Notes

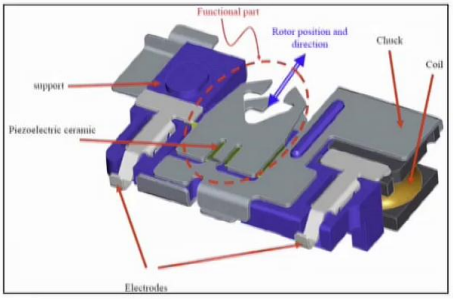
Summary

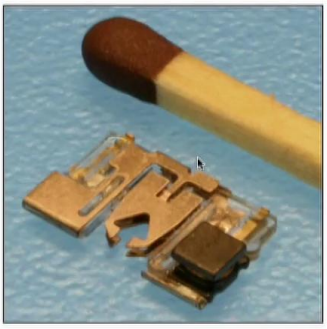
7m 48s

LENTILLE DE FOCALISATION









Electrotechnique I

We've also worked on focusing lenses. You can see here this lens in green, with a small box that doesn't measure more than 5 by 5 millimetres. And within, you have a small piezoelectric system described here, or even with a picture here, with a matchstick to give a sense of the size of this object that will in fact, this small actuator, make the lens go up and down to focus on the image. And here are some piezoelectric elements that are used in the industrial domain.

Notes

Summary

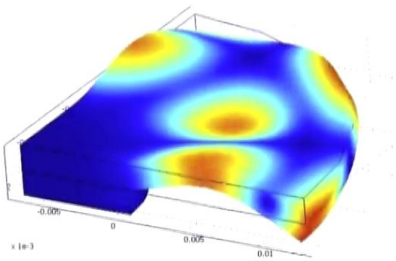
8m 25s

ACTIONNEUR PIÉZOÉLECTRIQUE TACTILE

Sentiment d'un changement local de la surface en fonction de la position du doigt

Dimensionnement multiphysique:

- Piézoélectricité
- Mécanique des structures
- Dynamique des fluides



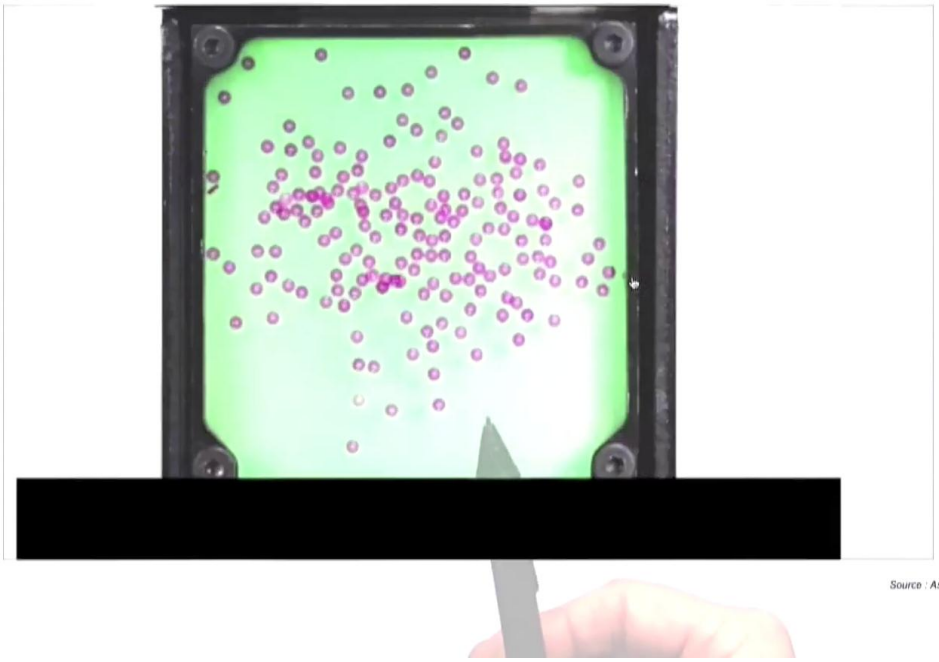
Electrotechnique I

And finally, the use of piezoelectrics can also be done to create tactile impressions. We've made here - on an Ipod, a fake Ipod - a wheel under which there is a piezoelectric crystal that is put in vibration. The quarter, here, is shown to you and you can see a wave from this piezoelectric that will happen on this wheel. By placing a finger on this wheel, the piezoelectric, through its vibration, creates a film of air that will give you the impression that your finger is sliding. When in fact, the matter has not changed. By actuating and by stopping this principle, we can create an impression of sliding, rubbing, sliding, rubbing, and thus, give a tactile sensation or a tactile impression to the user and thus create a sort of virtual tactile system. Knowing that there are also several modes of vibration, we intend to continue work for the next several years to even give an impression of patterns to this tactile impression and not just an on/off change of the state of impression of sliding and not sliding.

Notes

Summary

8m 59s



Electrotechnique I

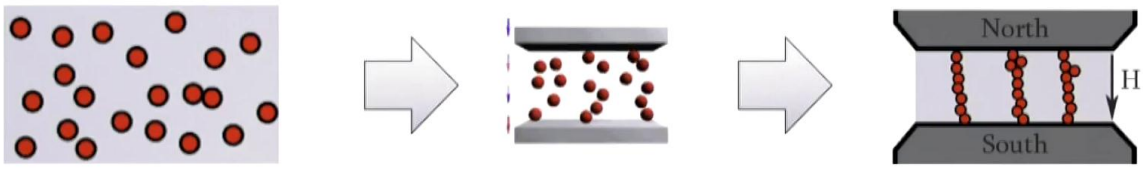
You also have here an image of a robotic system that takes pieces on a part, here in color - you have pieces, here, that arrive on this part, that are dispersed - we wish to, with the help of this piezoelectric system, move these pieces in a given direction and to know very precisely the position of this small pieces of balls that are included here in the video.

Notes

Summary

10m 18s

FLUIDE MAGNETORHEOLOGIQUE (MRF)



"Sachiko Kodama, Yasushi Miyajima, "Morpho Towers"

Electrotechnique I

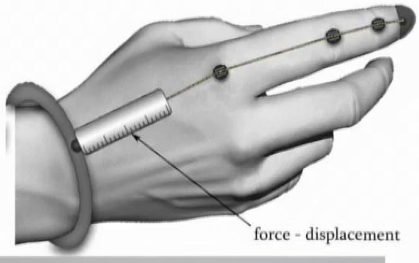
A few other elements : magnetic fluids. You can see, here on top, a fluid known as "magnetorheological", this means that its viscosity will depend on the magnetic field that goes through this fluid. We are researching actuators that use this principle. And below, an small amusing video to show that we can also work with these magnetic fluids and make them climb, like so, this conic structure.

Notes

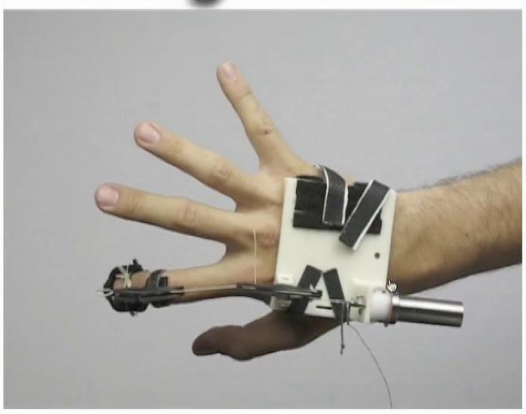
Summary

10m 44s

MR GANTS HAPTIQUES



Réduire la masse de l'actionneur et permettre d'obtenir un système compact pour la rééducation



Electrotechnique I

You can see here, an explanation of a haptic glove where we've used - here on this haptic glove - a small system that works with magnetorheological liquids.

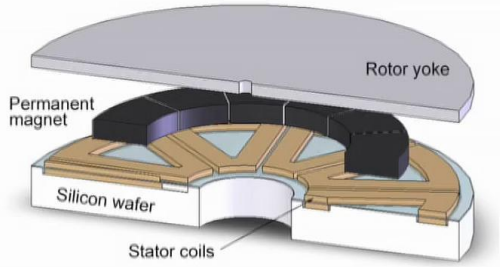
Notes

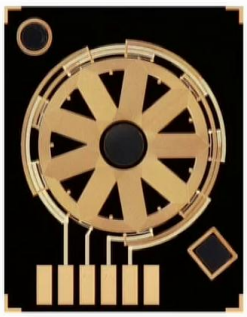
Summary

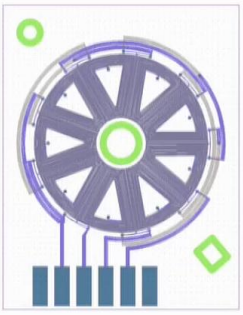
11m 13s

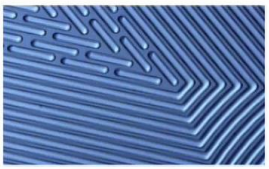
MOTEUR HYBRIDE MEMS

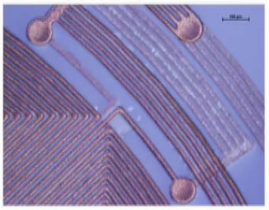
- Développement d'un moteur triphasé miniature
- Fabrication du stator en salle blanche











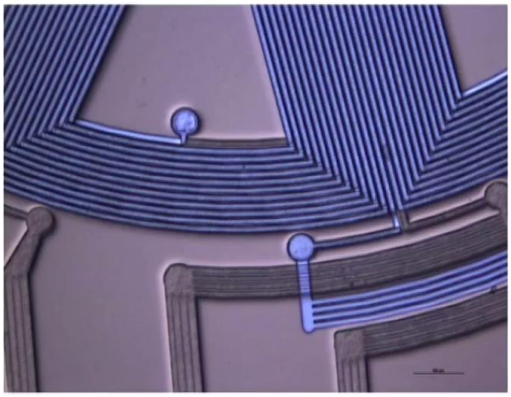
Electrotechnique I

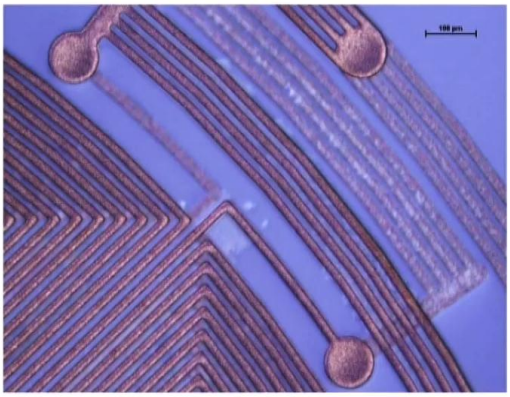
The hybrid MEMS motor can also show you the integration on which we are working. We had the idea of making a stator printed on silicon with a magnet, we'll say "classical", that we place above, here, the silicon. Why ? To make an extremely tiny motor and thus, finally, stators can be made like hotcakes.

Notes

Summary

11m 28s





Electrotechnique I

You can see here a nice photograph where we can see a layer of copper and behind, transparent, the other layer of copper and we can like this, sandwich different layers of copper on each other with here canals that are used to link the different layers together to create a true winding.

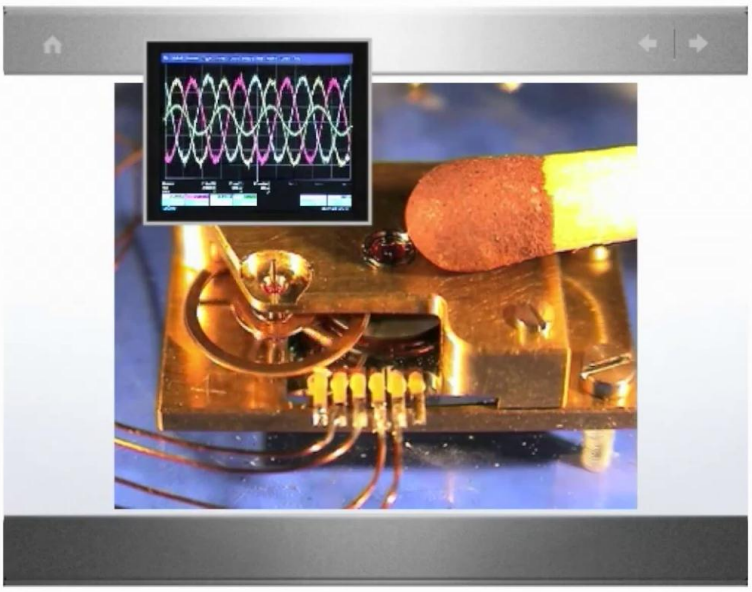
Notes

Summary

11m 54s

MOTEUR HYBRIDE MEMS

Rendement de plus de 45% ! Soit une durée de vie de la batterie passant de 2 ans à 6 ans



Electrotechnique I

You have here the finished motor along with a matchstick, again to show you the size. The efficiency is of more than 45%, which, compared to the currently used 15% motor enables us to extend the battery life cycle from two years to about six. Thus, the ecological impact by making these kind of changes or these type of integration studies is phenomenal.

Notes

Summary

12m 14s

ELECTROTECHNIQUE I

- Une des premières branches de l'ingénieur dans la formation microtechnique
- Définition:

  Utilisation technique de l'électricité soit en tant que support d'énergie, soit en tant que support d'information.
- Application à un grand nombre d'autres disciplines qui utilisent le circuit électrique comme schématisation de base

This allows me to arrive - now that you have seen all that can be done in electrotechnics and it's not an exhaustive - all of this applications that I've shown you use the basis of electrotechnics. And thus, it is one of the first engineering branches in the microengineering course. but just there : mechanics, materials, robotics... All of these courses do and use electrotechnics. We can thus make a definition : it would be "the technical use of electricity, either as a energy support, or as an information support ". And, as you have seen it, an application to a very large number of other disciplines that use electric circuits as a basic mapping.

Notes

Summary

12m 41s

L'ÉLECTROTECHNIQUE : ÇA N'EST PAS ...

Electrotechnique I

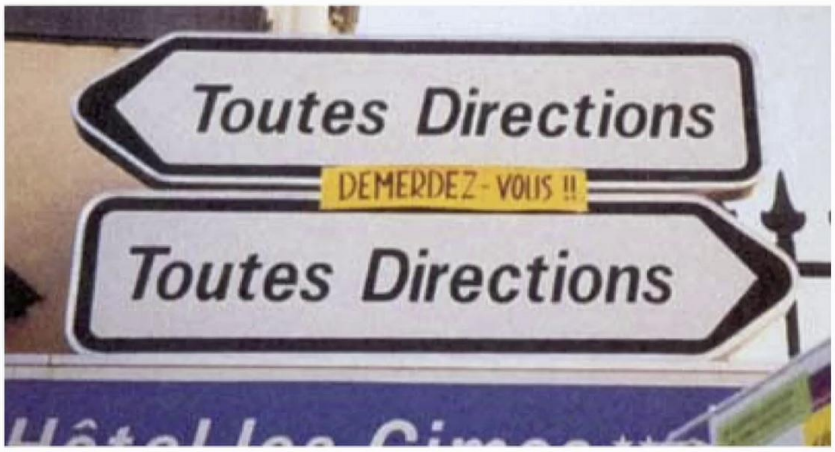
Electrotechnic isn't that kind of image where you can see that to go straight, you have to go left.

Notes

Summary

13m 28s

ÇA N'EST PAS NON PLUS



Electrotechnique I

And you also shouldn't think to yourself "Absolutely go here !", no. We will try to give you clues, provide you with methods that will allow you to make the best choice when faced with a electrotechnic problem.

Notes

Summary

13m 34s

APPLICATIONS, EXEMPLES

- Calcul de circuits électriques
- Electronique
- Machines électriques et micro-actionneurs
- Mécanique et thermique
- Formalisme de l'ingénieur:

  Ecriture et symbolique

Electrotechnique I

And what you must also know, is that electrotechnic, as a discipline of electricity, does not only apply to electricity but as I've mentioned to electronics, but also to electric machines, to micro-actuators, thus to electromagnetism. And also, this may seem strange, to mechanical and thermal engineering, because, in fact, we can model thermal flow by equivalent electric diagrams and thus reuse all this formalism and methods studied in electrotechnics, with the help of the basics of electrotechnics that we shall see here. Thus, the writing, symbolic and schematics that we shall see here will be fundamental elements to be able to make a coherent engineer's language for all disciplines.

Notes

Summary

13m 50s

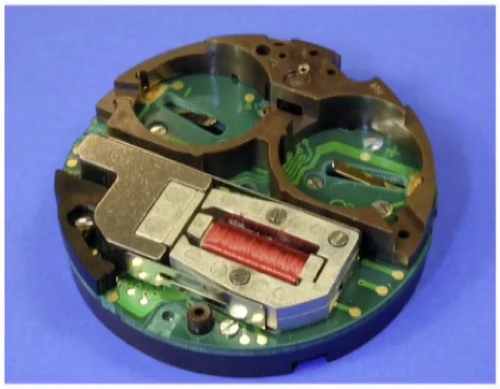
Here again, for example, a wonderful application of the engineer that benefited from the works of electrotechnics and electromagnetism. This is a hard disk motor relatively ancient, from the 1990s, and that shows you here two actuators : one that enables the rotation of the hard disk, and one that will actuate, you can see here the linear actuator, the playhead or playheads the support the sensor.

Notes

Summary

14m 46s

TISSOT : «TOUCH»



Electrotechnique I

Another example of miniaturisation that again calls for all of this it's a watch that is made by a Swiss company, that's called the touch and you have here, in fact two actuators on this same watch, on the front and back. So first two-phased motors that will allow each to command a needle -since these needles are independent from each other for the different functionalities that are presented - and then, a small vibrator, here, that will allow to give out a silent alarm within the watch.

Notes

Summary

15m 13s

Electrotechnique I

Other natural phenomena, such as here, this magnificent double lightening on Lake Leman, can be explained or can be formalised by what we will see in electrotechnics. But also, here, three micro-tornadoes on Lake Neuchâtel, in Switzerland, that can also be, using fluid mechanics, approached by simplified models that call for the schematics of electrotechnics.

Notes

Summary

15m 46s

PROGRAMME DU COURS I

- Conventions et symboles
- Lois de Kirchhoff
- Analyse de circuits
- Régime sinusoïdal
- Puissance

Electrotechnique I

This is the program of the course I shall be offering you, it's to first tackle conventions and symbols, very important, since around the world we don't all have the same way of writing or conceiving the schematics. Thus, to agree for the beginning of this course. Then, we shall see the laws of Kirchhoff, the basis of electrotechnics and electricity. Afterwards we shall study the analysis of circuits that will lead us to offer you a certain number of methods that will allow you to solve circuits. You will have the choice of the methods, and it is through the exercises that we will offer that you will better feel the way and which methods to finally use for your own circuit solving. Finally, we will move on to sinusoidal steady state that will later bring us to the study of power to finish the first course. To conclude I wish you all the best and will re-join you in lesson number two of this MOOC 1.

Notes

Summary

16m 14s