Actionneurs et systèmes électromagnétiques II

Moteurs monophasés, applications horlogères

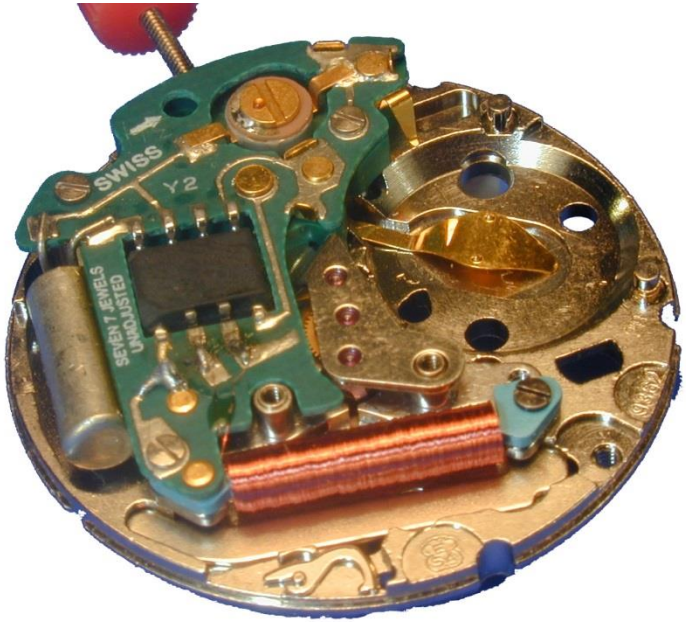
Christian Koechli

Comment tournent les aiguilles?

- Montres mécaniques

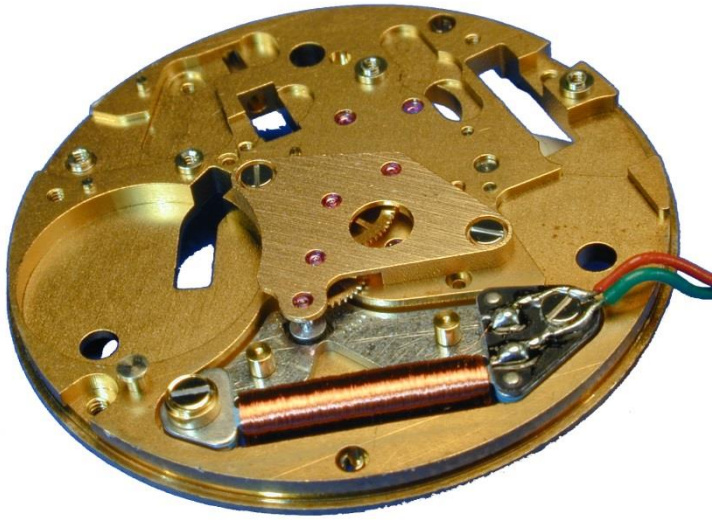
- Montres à quartz

Les types de mouvement

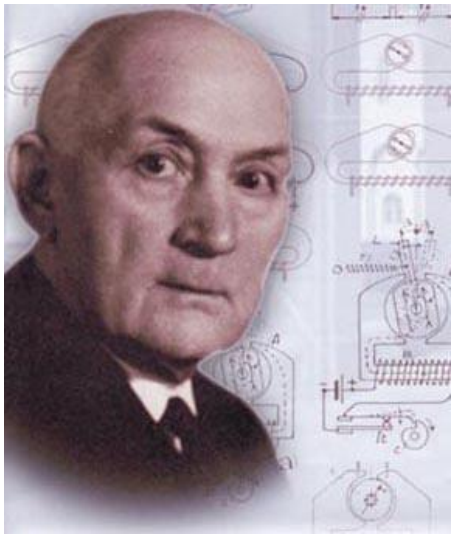


- Montres mécaniques
- Montres à quartz

Moteur actuel

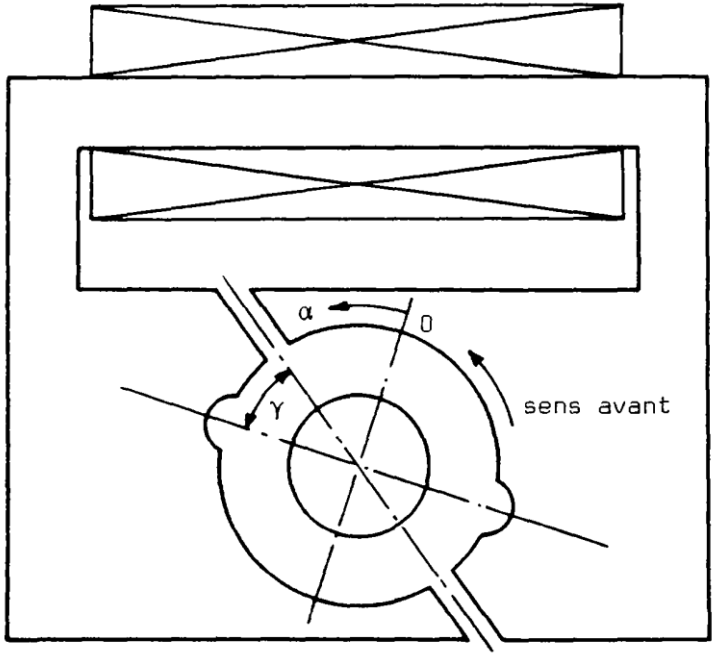


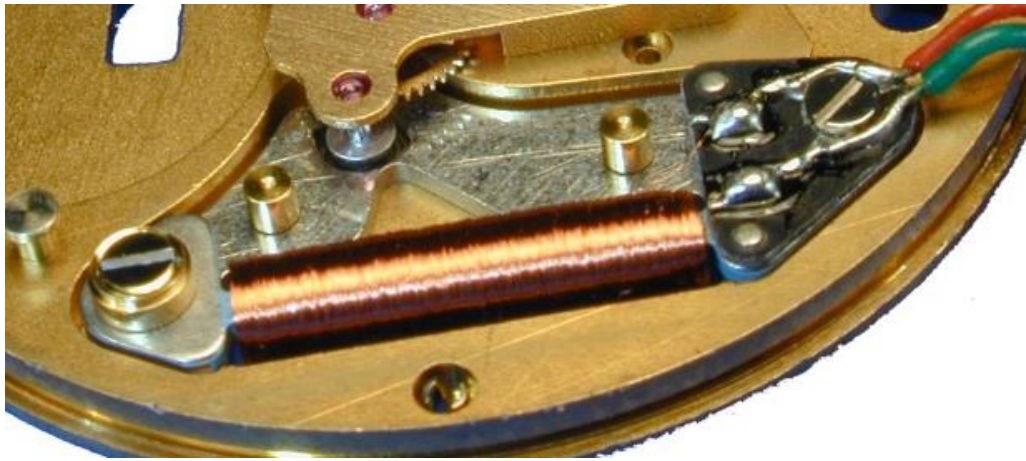
- Marius Lavet (1891–1980)



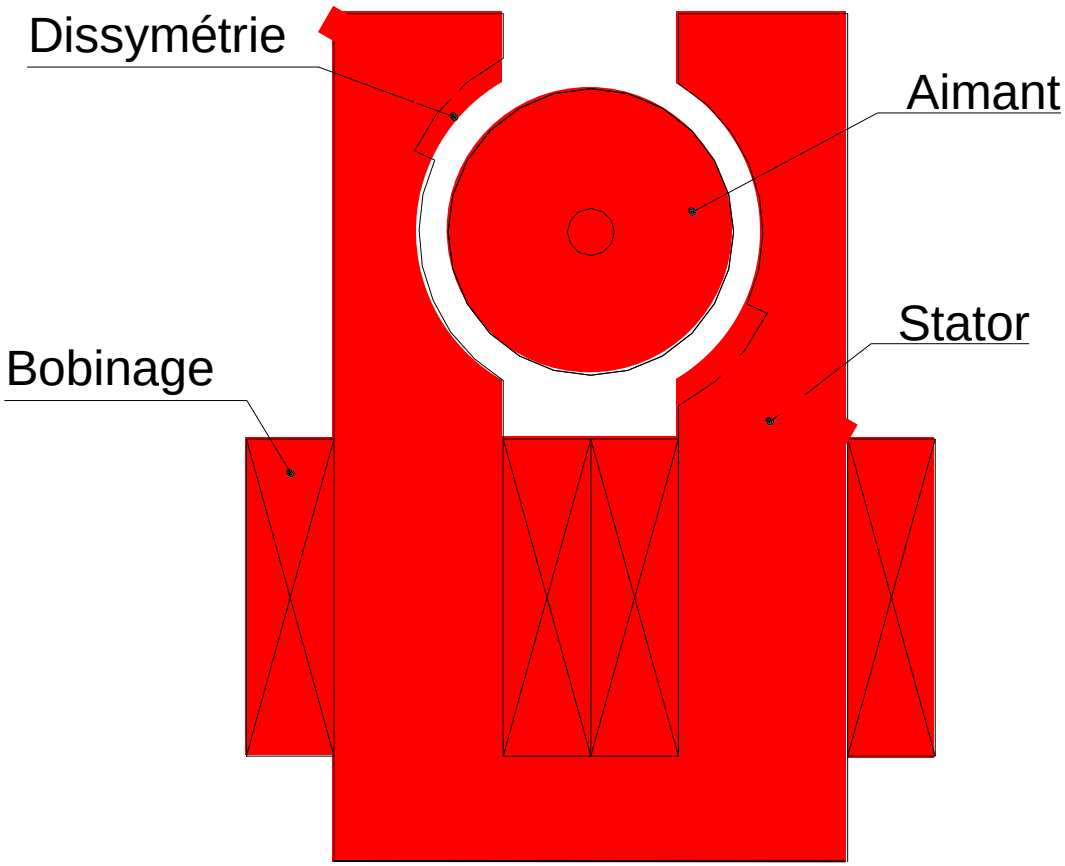
- Le brevet a été délivré le 18 octobre 1937

Application horlogère: moteur Lavet





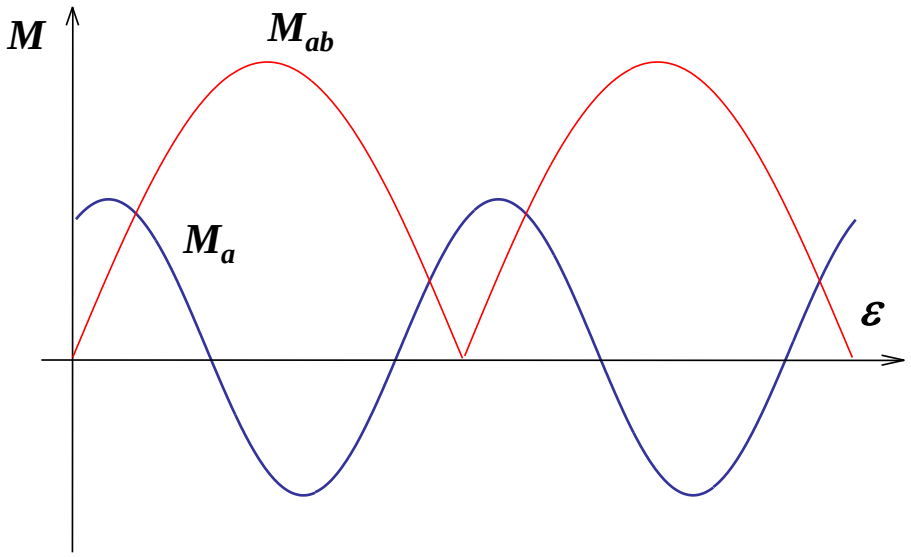
Exemple: moteur bipolaire à rotor interne



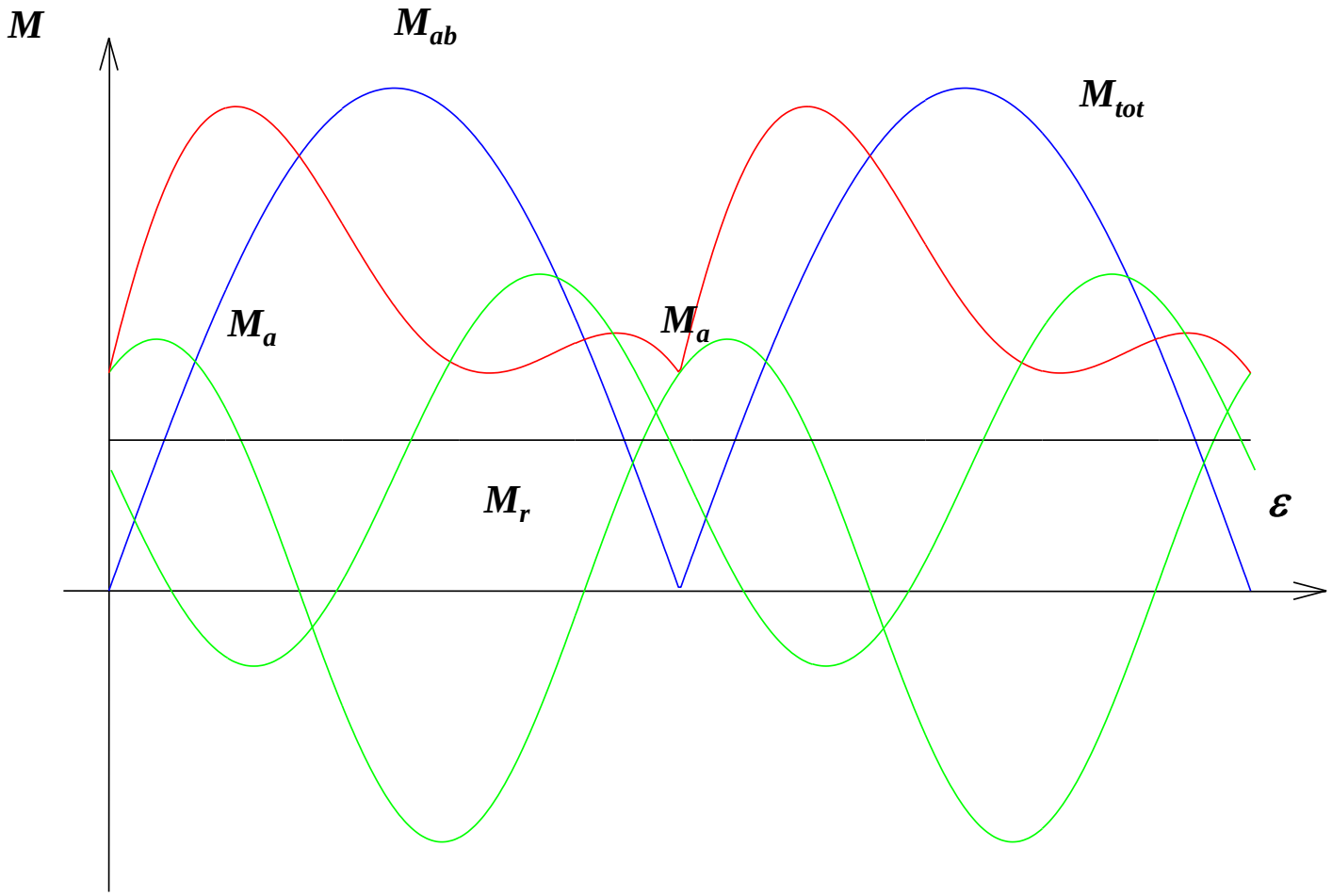
Démo

Couples s’exerçant sur le rotor

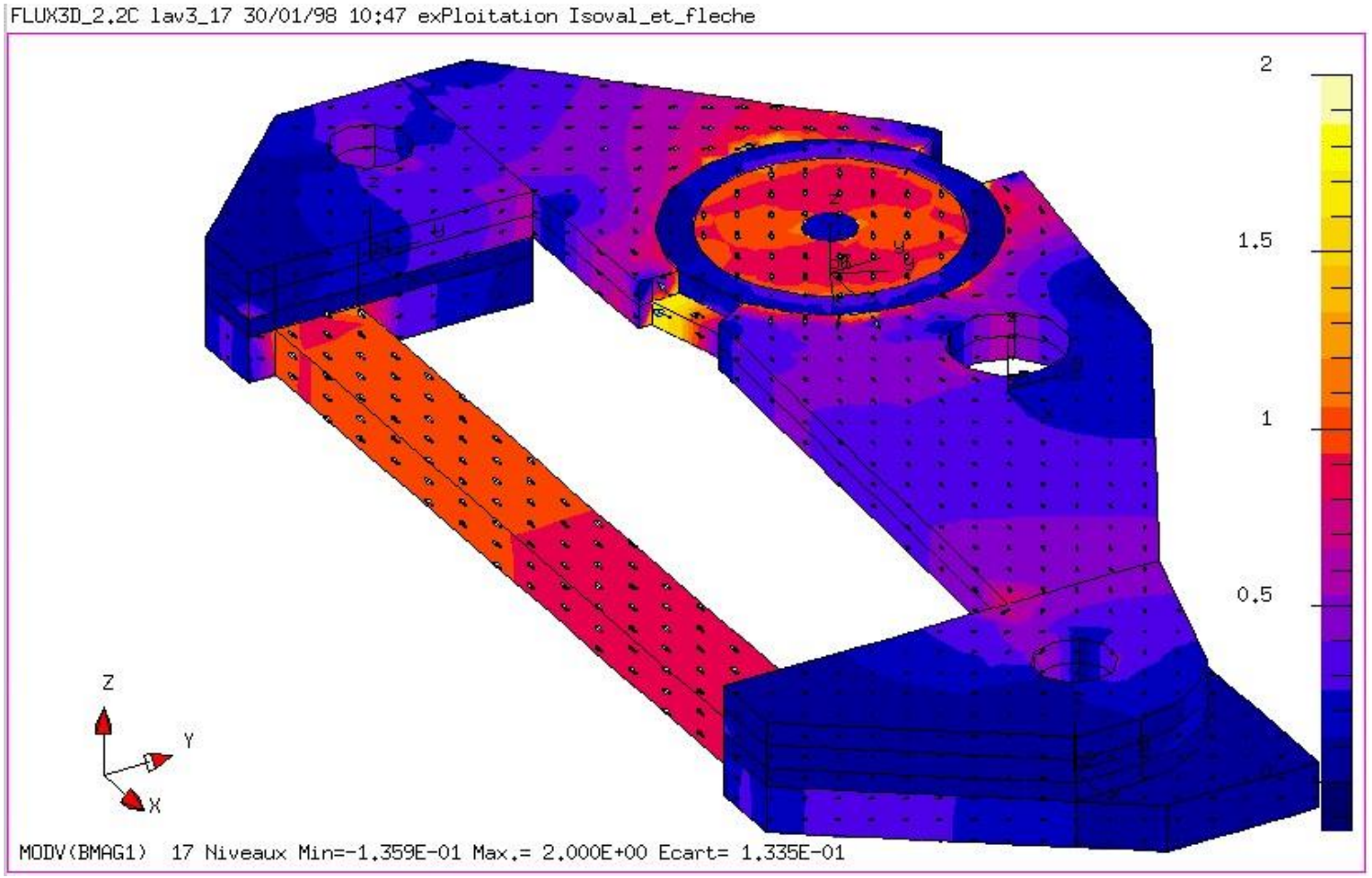
- Couple mutuel
  Interaction aimant- courant dans la bobine
- Couple réluctant ou de positionnement
  Interaction aimant-géométrie du stator



Fonctionnement



Simulation



https://www.youtube.com/watch?v=WDP4UURHp9g

Position du rotor à l'arrêt

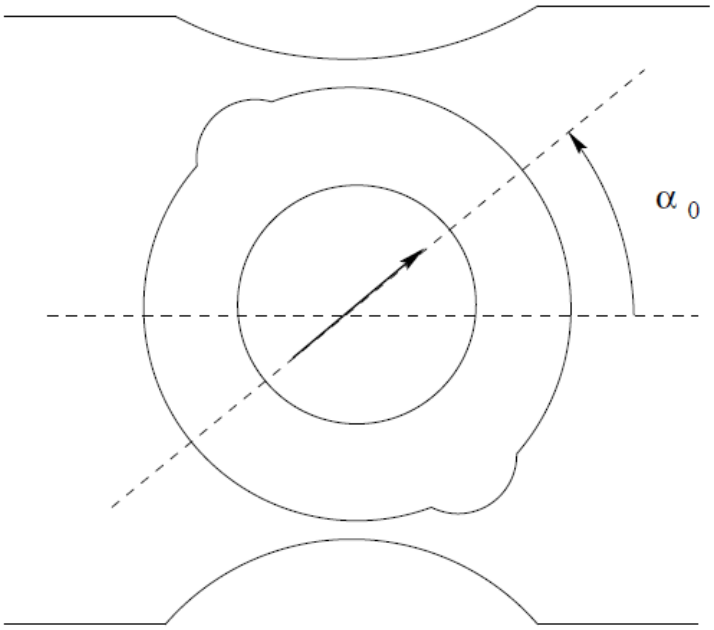
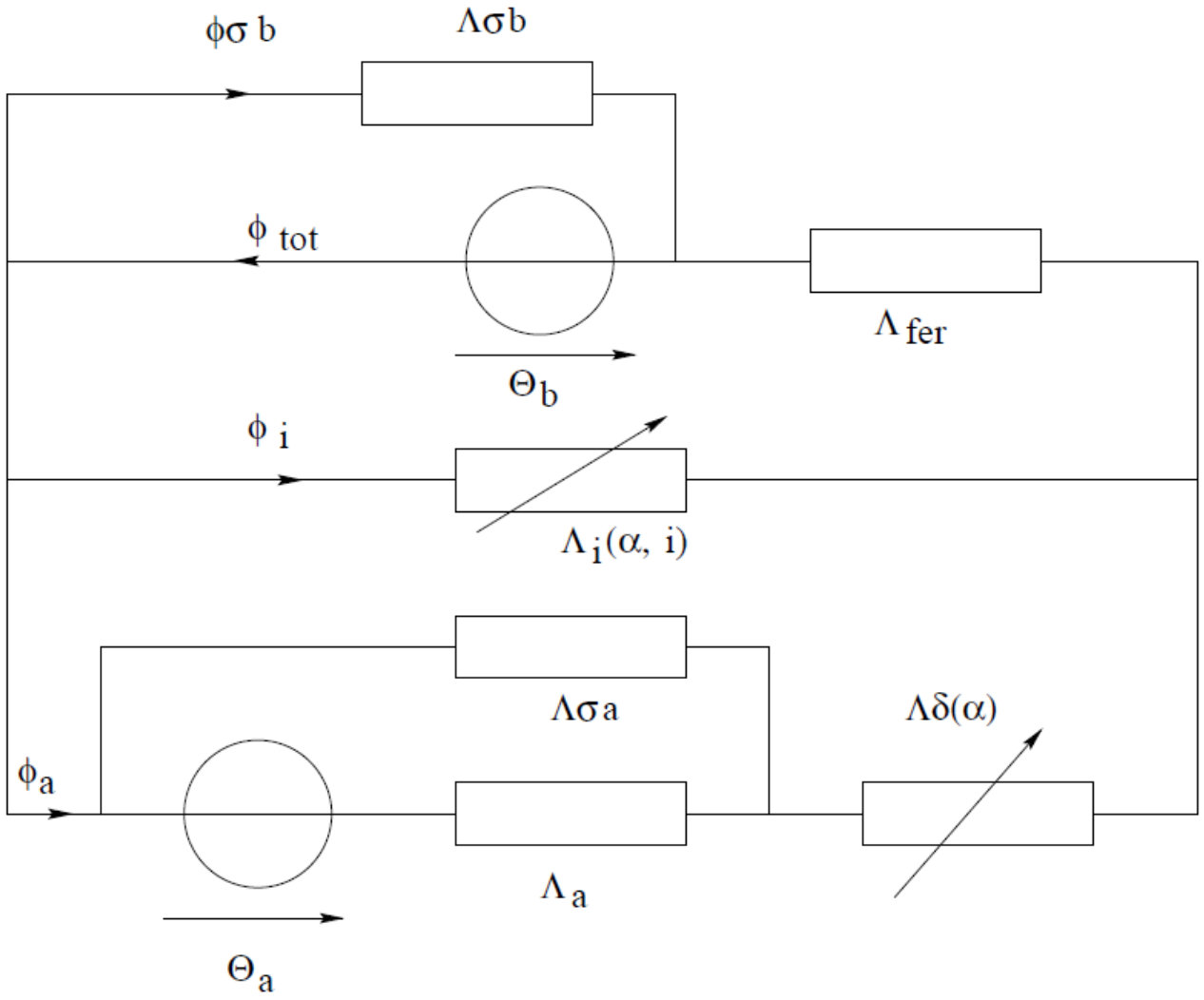


Schéma magnétique équivalent



Equations:couple

$$M = \frac{\partial \Lambda_{aa}}{\partial \alpha}\Theta_a^2 + \frac{\partial \Lambda_{ab}}{\partial \alpha}\Theta_a N i_b$$

$$M = -\hat{M}_a \sin(2\alpha) - \hat{M}_{ab} \sin(\alpha + \alpha_0)$$

$$\begin{aligned} \psi_{ab} &= N\Theta_a \Lambda_{ab} = \widehat{\psi}_{ab} \cos(\alpha + \alpha_0) \\ M_a &= -\widehat{M}_a \sin(2\alpha) \end{aligned}$$

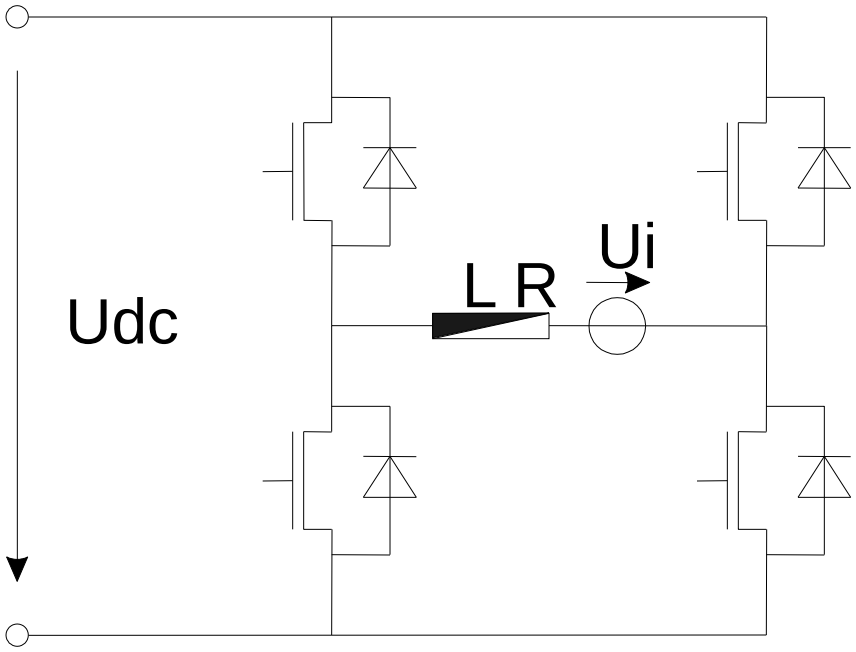
$$M_{ab} = \frac{\partial \Lambda_{ab}}{\partial \alpha} N i_b \Theta_a$$

$$M_{ab} = -\widehat{\psi}_{ab} i_b \sin(\alpha + \alpha_0)$$

Loi de la tension induite

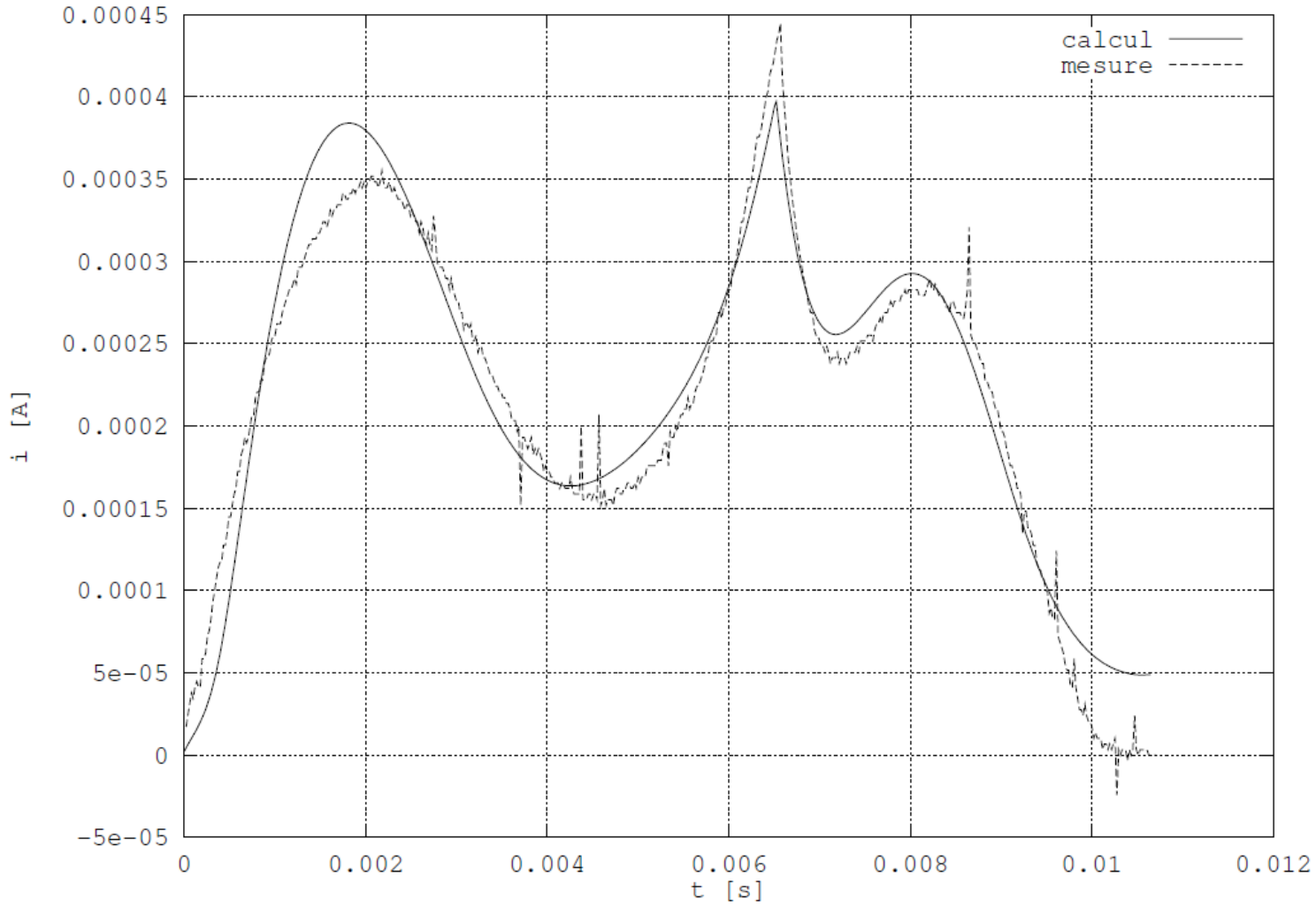
$$
\begin{aligned}
u &= R_b i_b + \frac{d\psi_b}{dt} \\
\psi_b &= L_b i_b + N \Lambda_{ab} \Theta_a \\
u &= R_b i_b + L_b \frac{di_b}{dt} + i_b \frac{dL_b}{dt} + u_i \\
u_{im} &= N \Theta_a \frac{d\Lambda_{ab}}{dt} \\
&= N \Theta_a \left(\frac{\partial \Lambda_{ab}}{\partial i_b} \frac{di_b}{dt} + \frac{\partial \Lambda_{ab}}{\partial \alpha} \omega \right)
\end{aligned}
$$

Alimentation



- Bipolaire (tension positive et négative)
- Impulsion de tension 1.5V puis court-circuit de la phase

Essai: Impulsion de tension 6.5ms



Détection de passage de pas

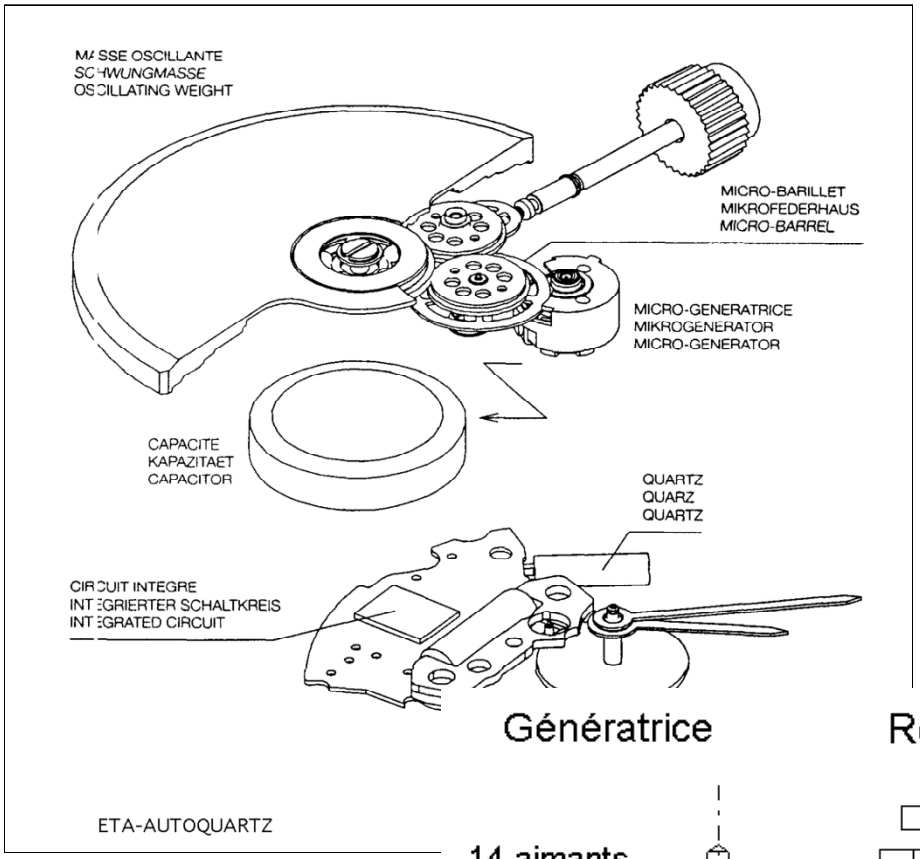
Le moteur a-t-il franchi le pas ?

Choc ?

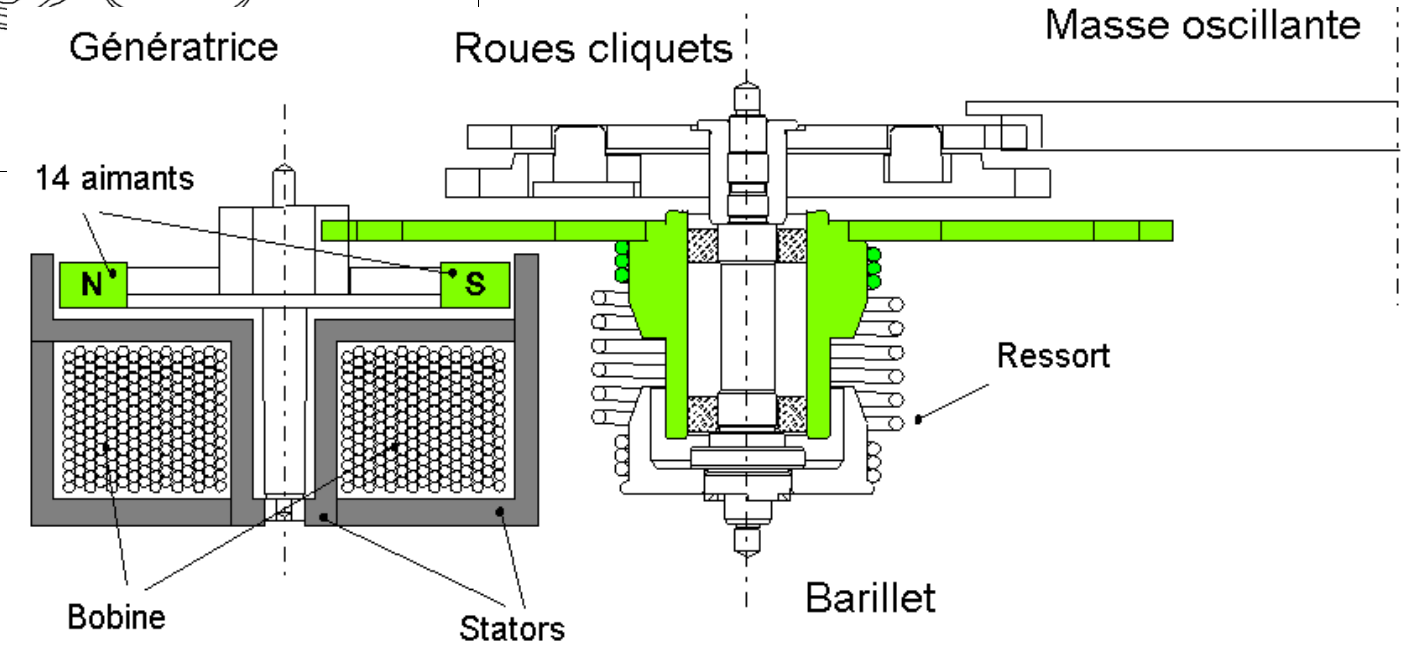
Si détection de pas manqué

Possibilité d’économie d’énergie !

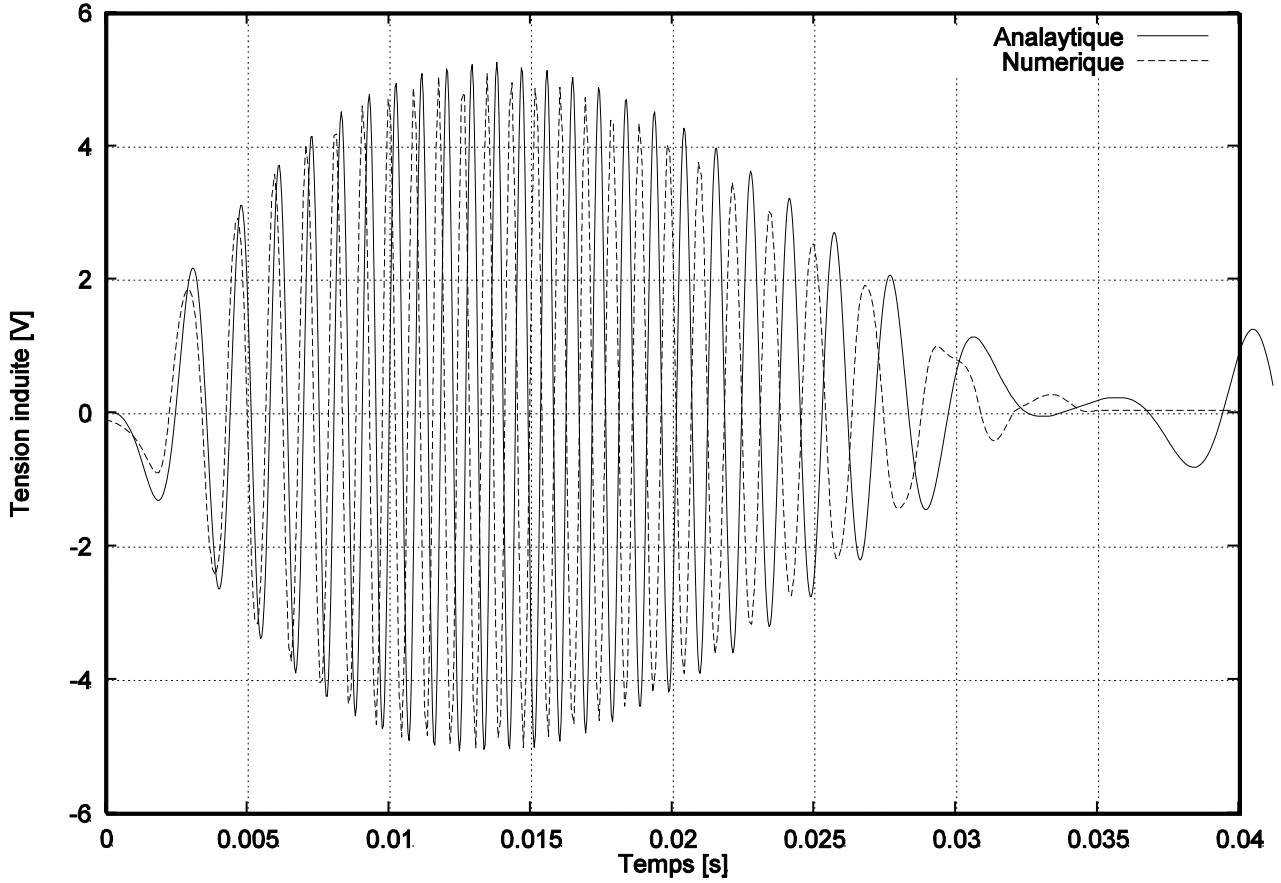
Moteurs monophasés, applications horlogères



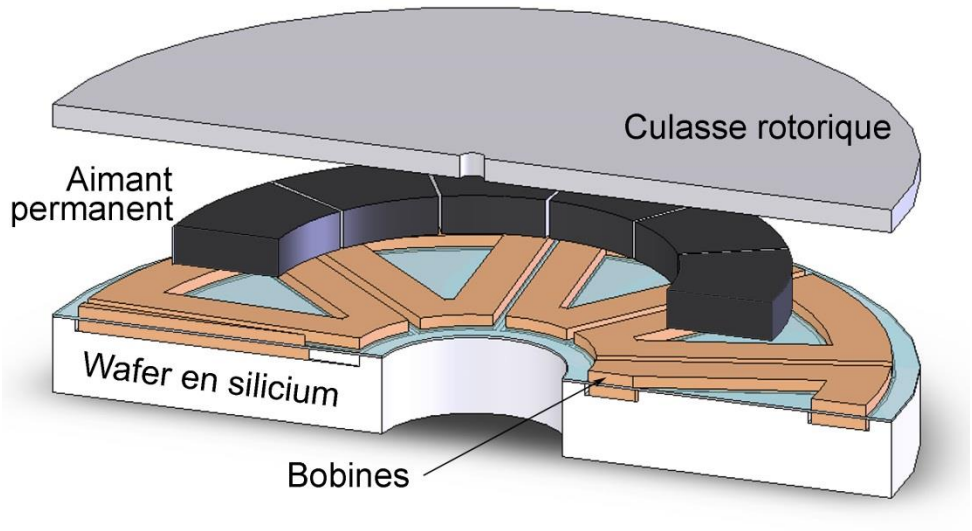
Montre autoquartz



Tension de « shoot »

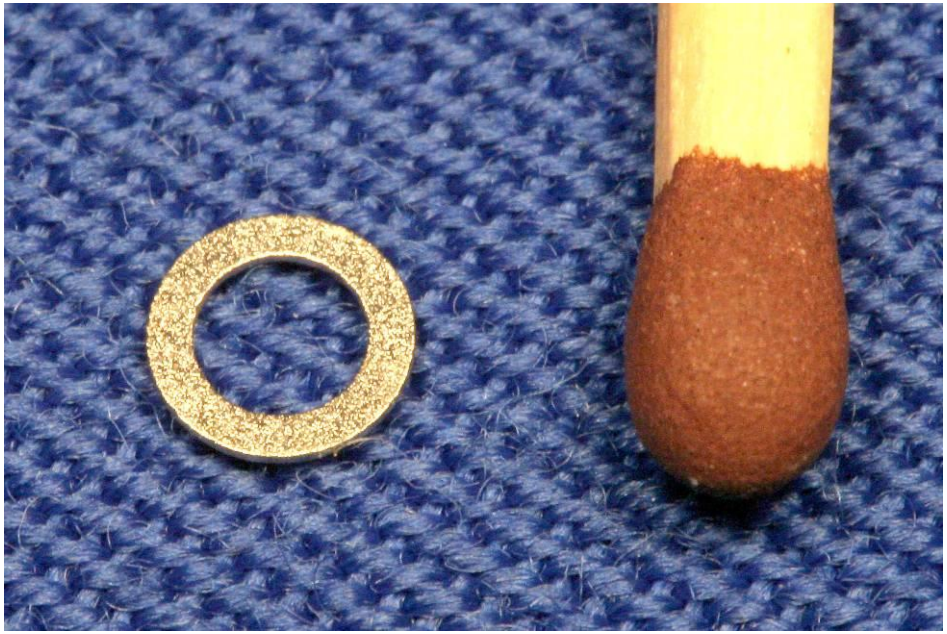


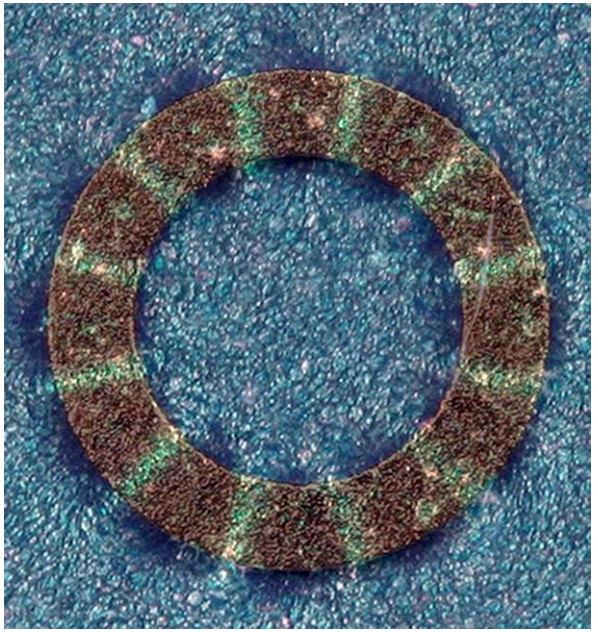
Moteur MEMS



- Diamètre externe: 5.2 mm
- Entrefer: 75 µm
- Epaisseur totale: 500 µm (sans wafer)

L’aimant permanent

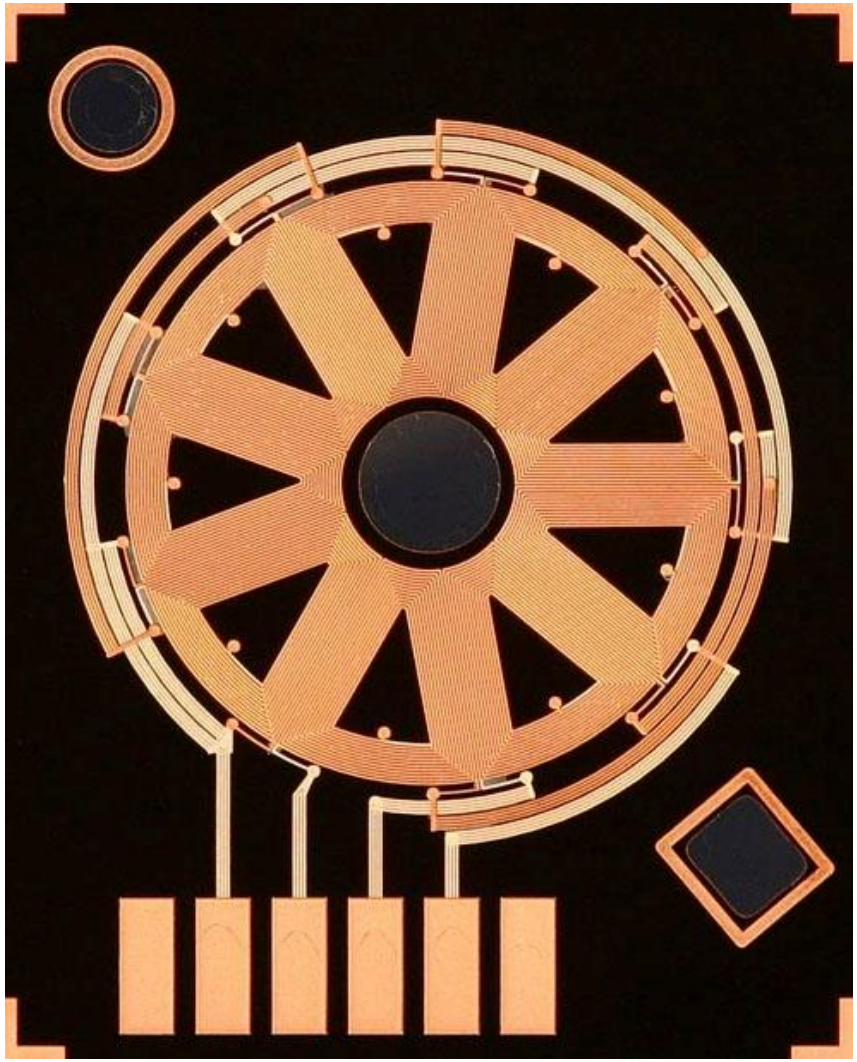




- Diamètre extérieur : 4.0 mm
- Diamètre intérieur : 2.6 mm

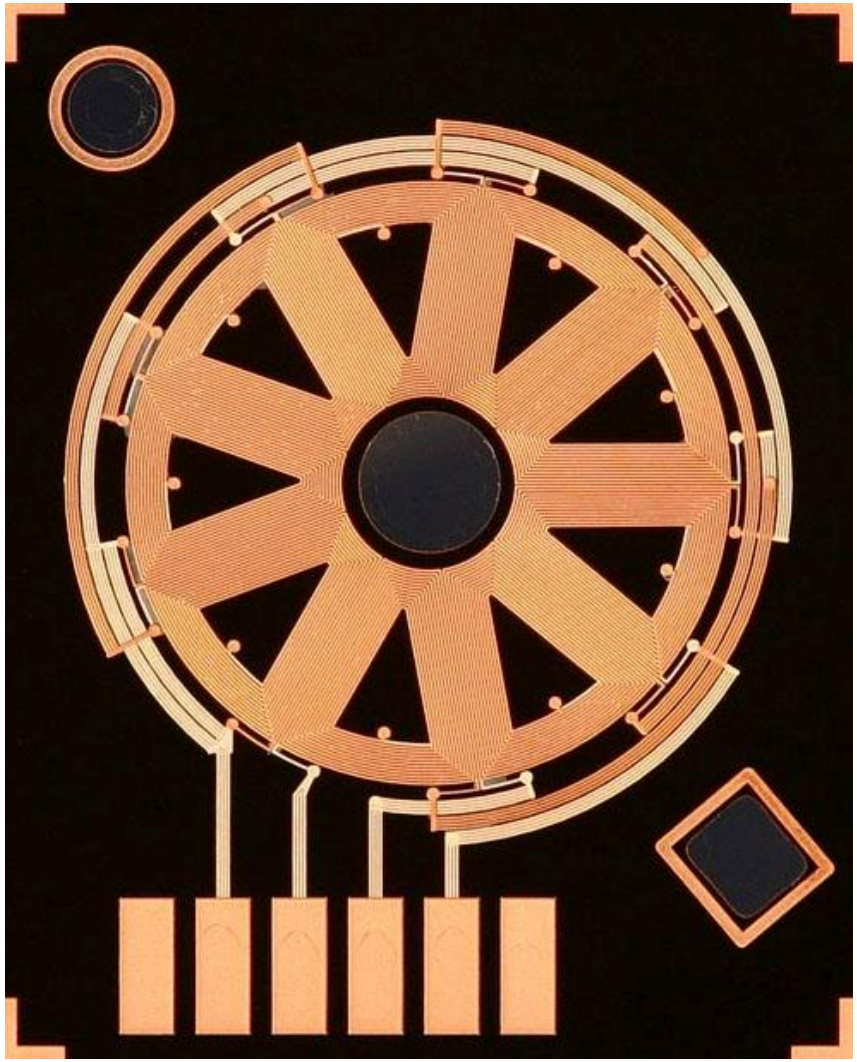
- Epaisseur: 250 µm
- 12 pôles magnétiques

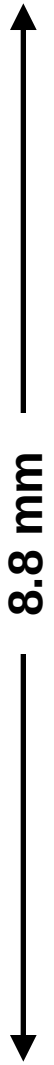
Stator

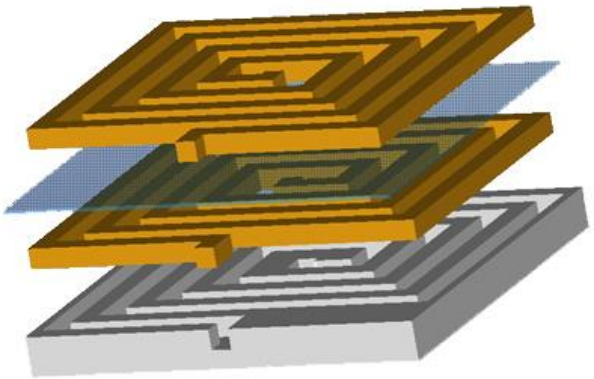


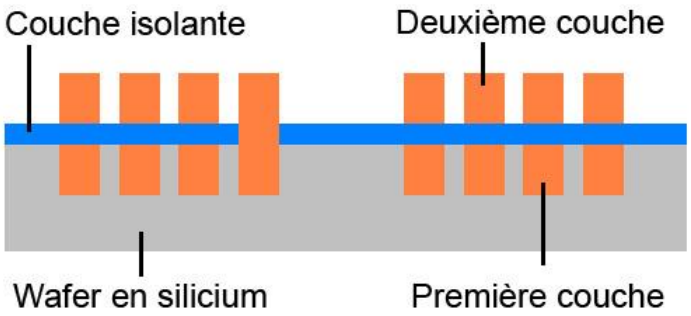
- 3 phases (étoile)
- 3 bobines par phase
- 2 niveaux de cuivre
- 24 spires par bobine
- 69 stators par wafer

Principe de fabrication

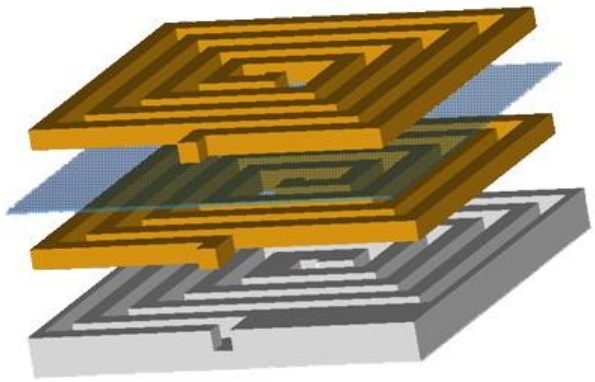


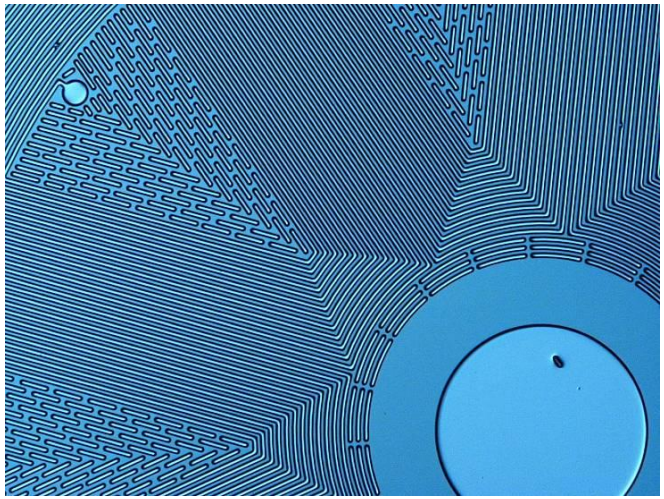


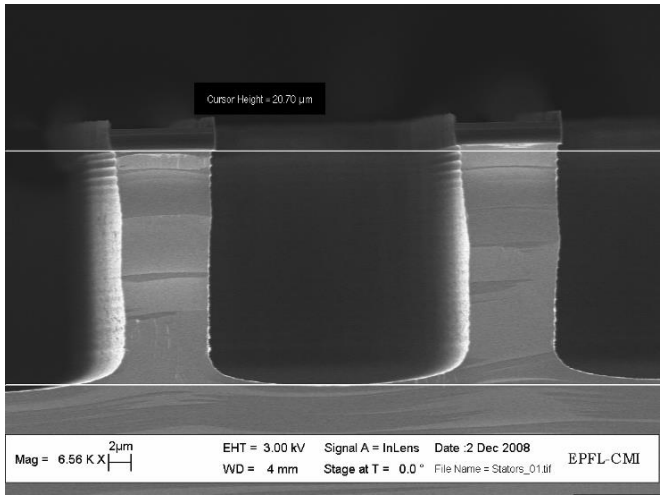




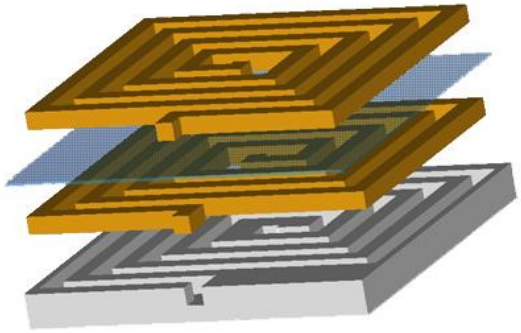
Gravure du silicium

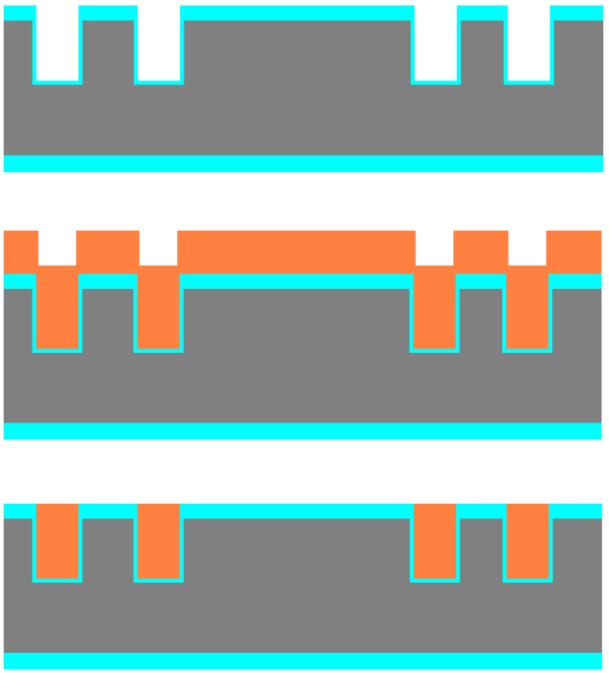


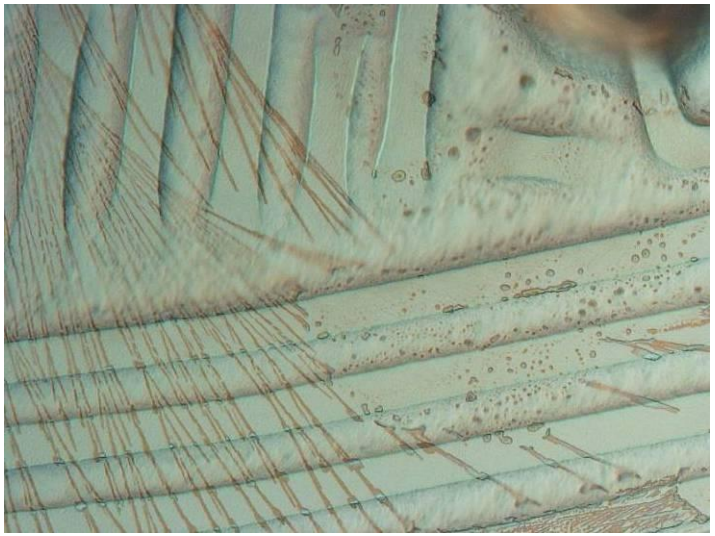


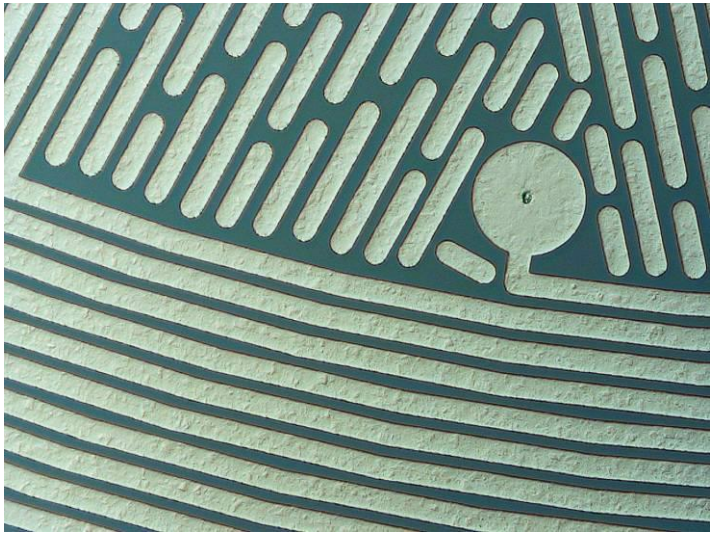


Electrodéposition et CMP

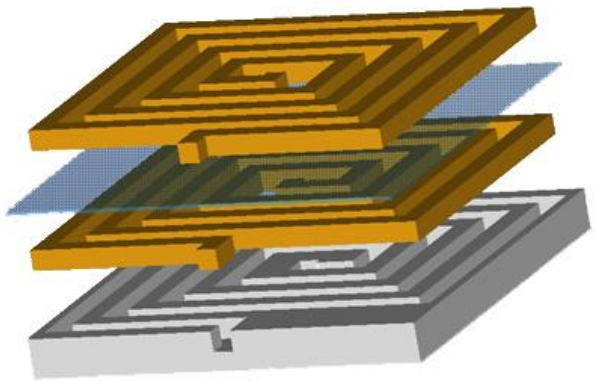


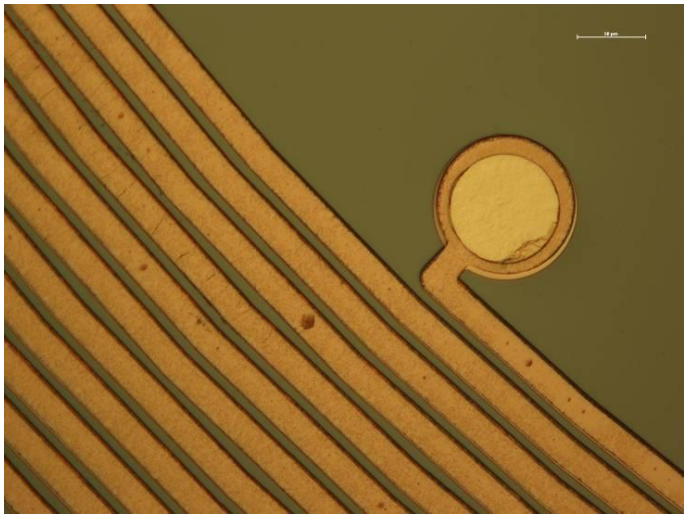


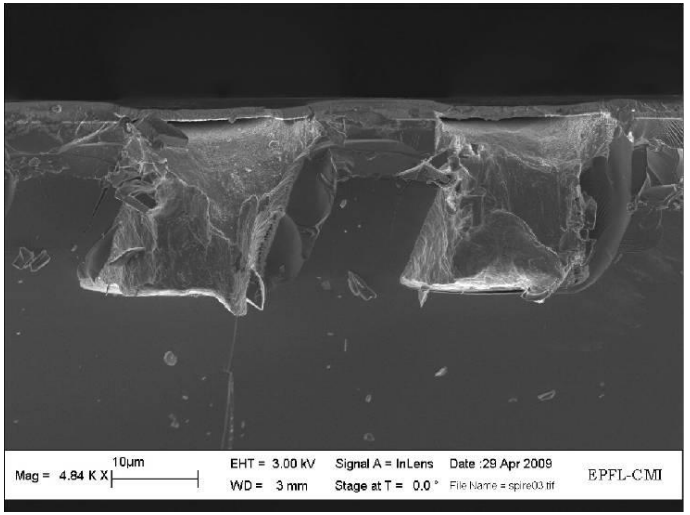




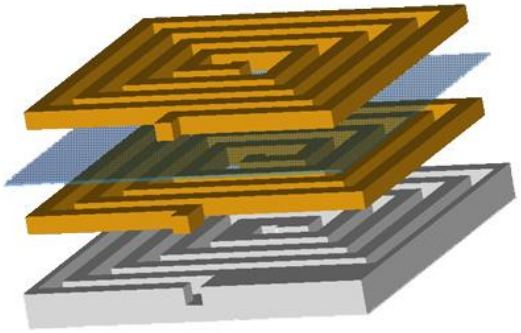
Isolation

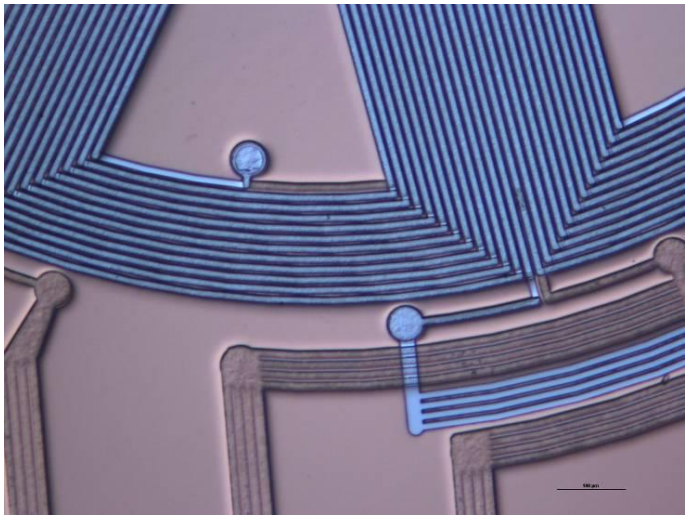


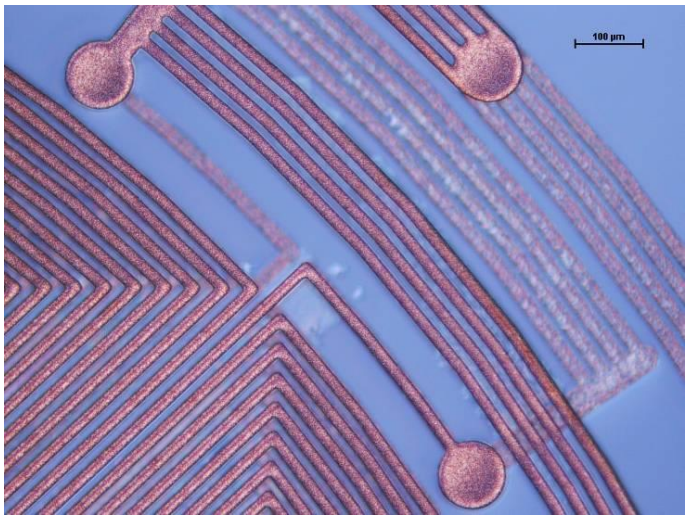



10µm
Mag = 4.84 K X
EHT = 3.00 kV
WD = 3 mm
Signal A = InLens
Stage at T = 0.0 °
Date :29 Apr 2009
File Name = spire03.tif
EPFL-CMI

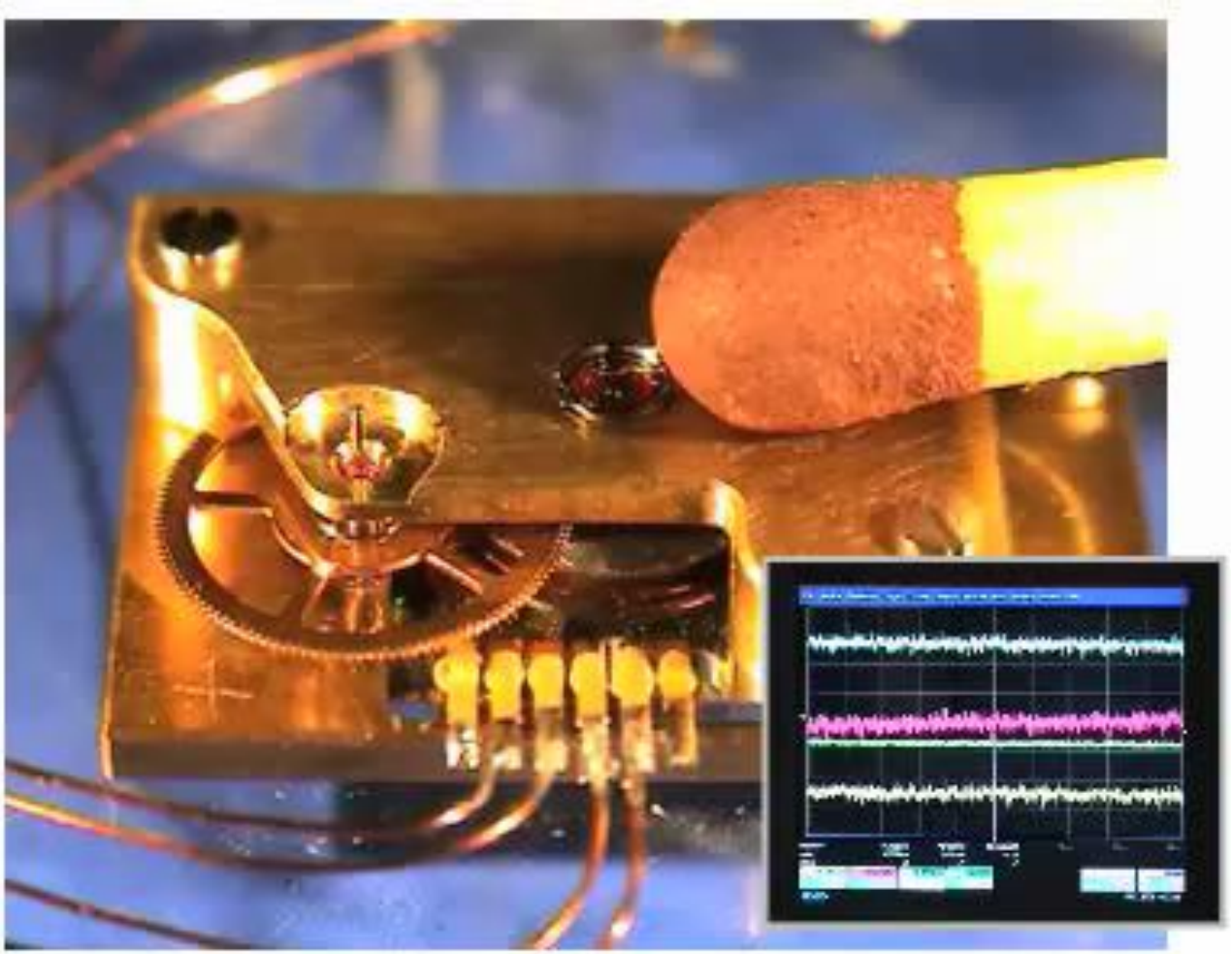
Le deuxième niveau de spires



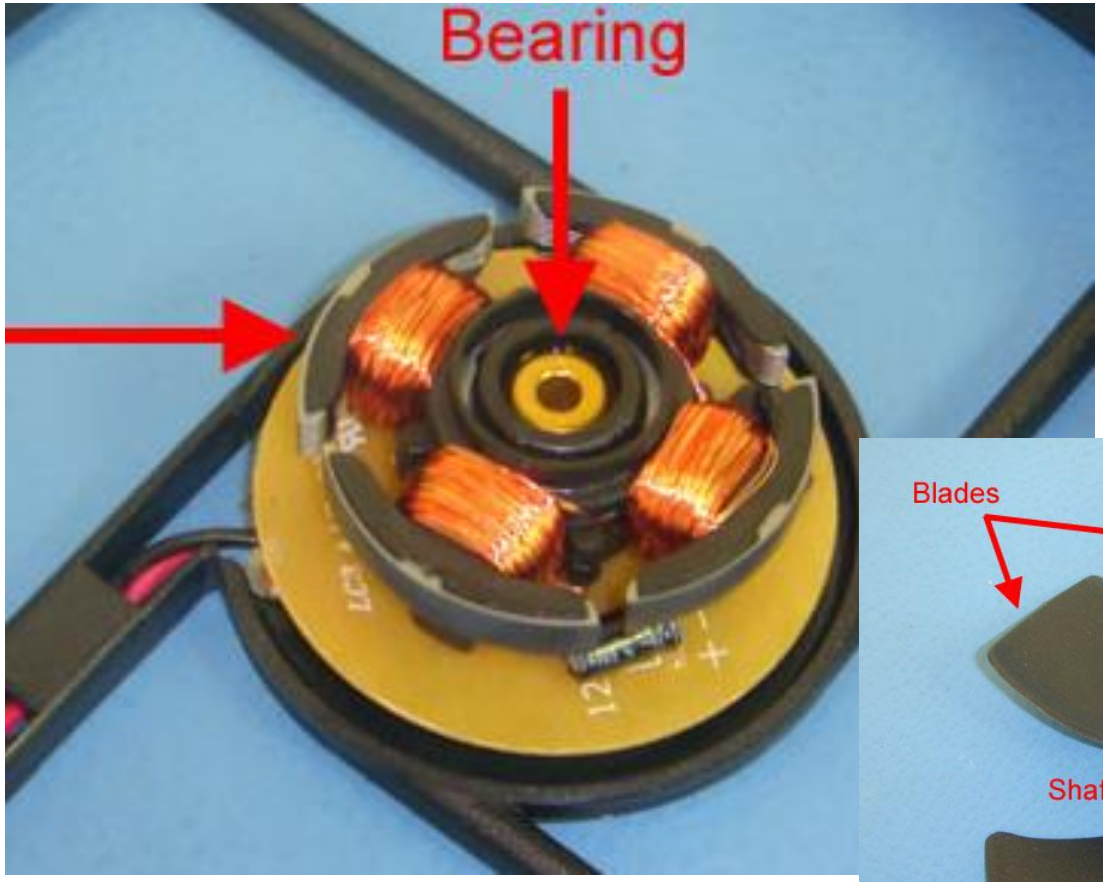


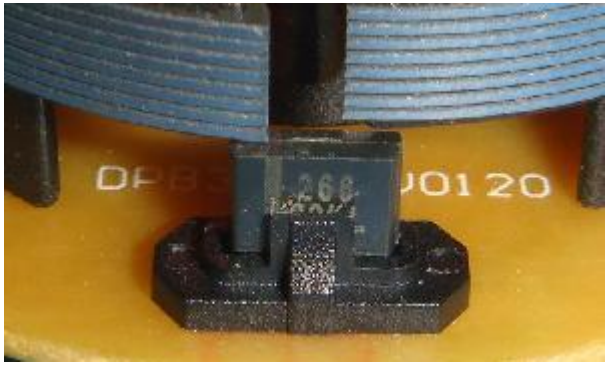


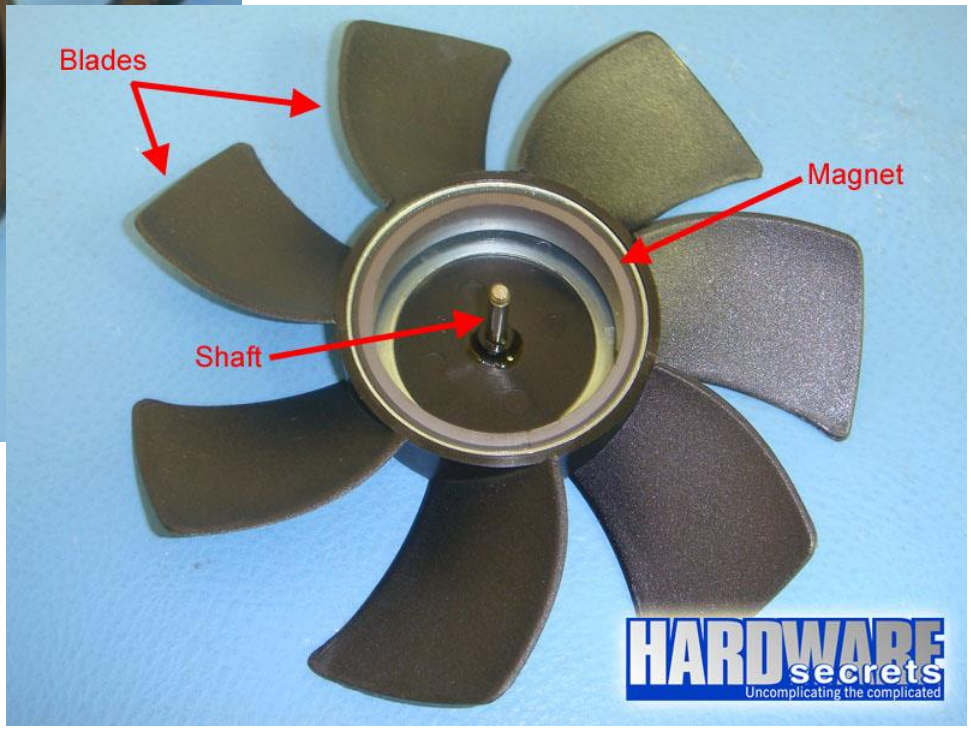
Moteur assemblé



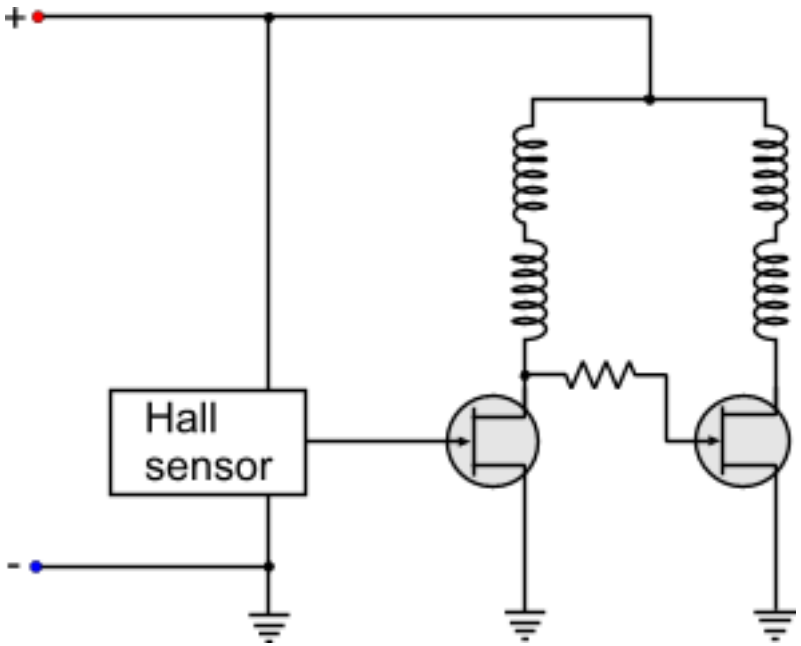
Ventilateur d’ordinateur (moteur biphasé)

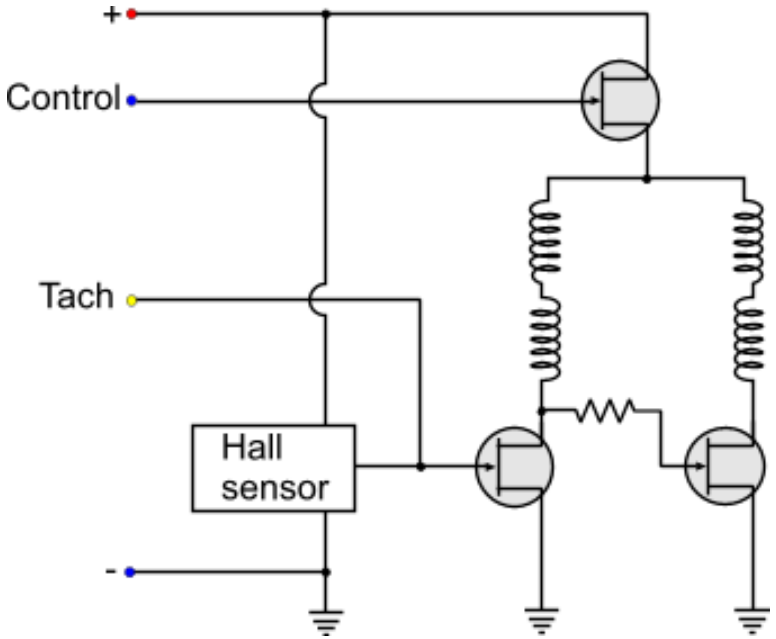


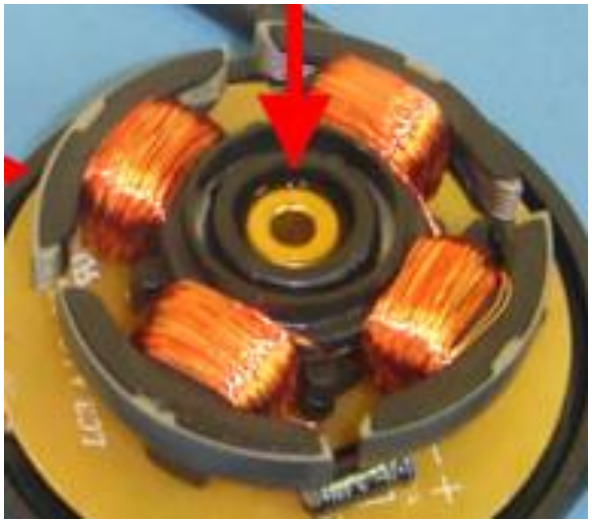




Commutation







Source: pcbheaven.com