Voice Coil Example

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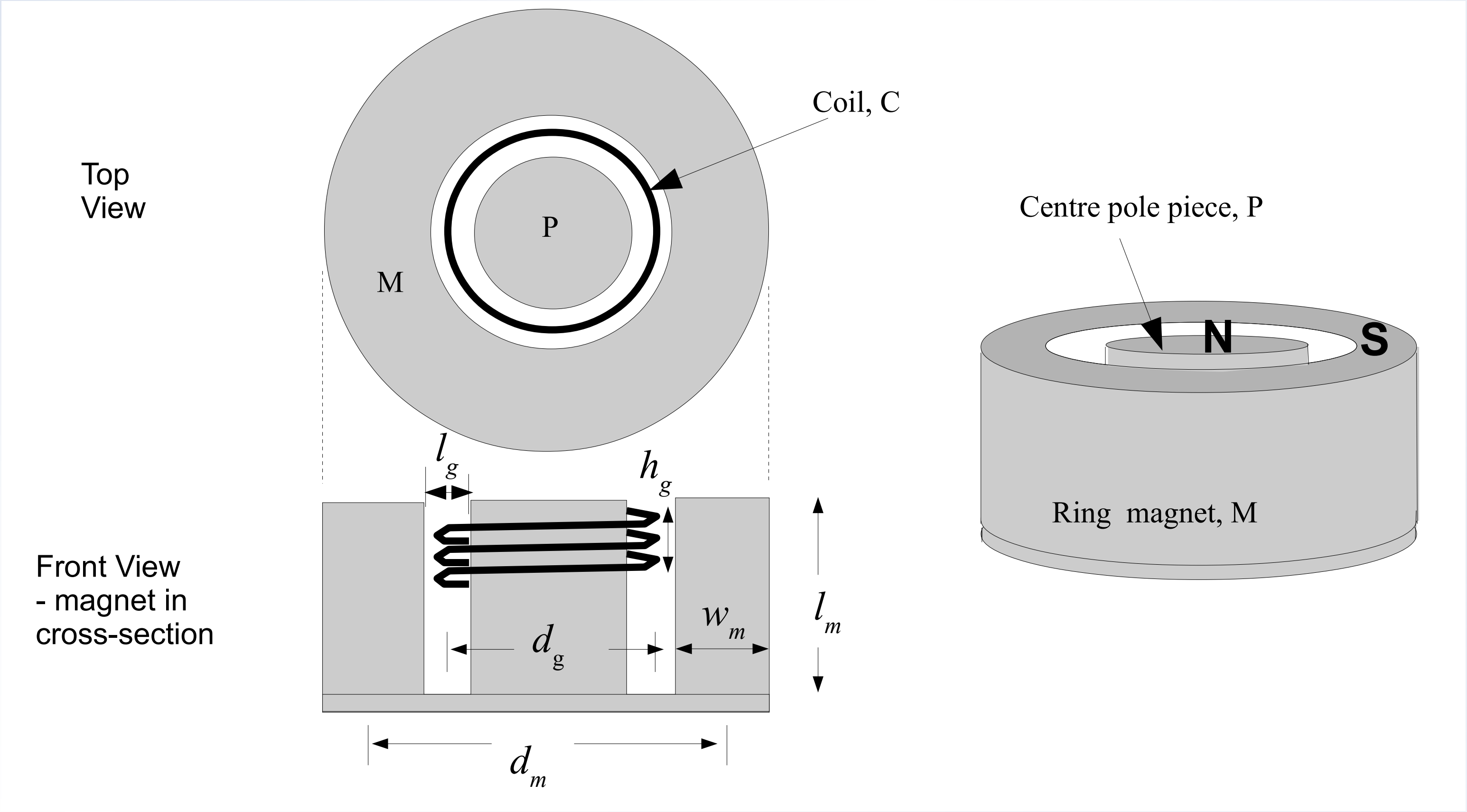
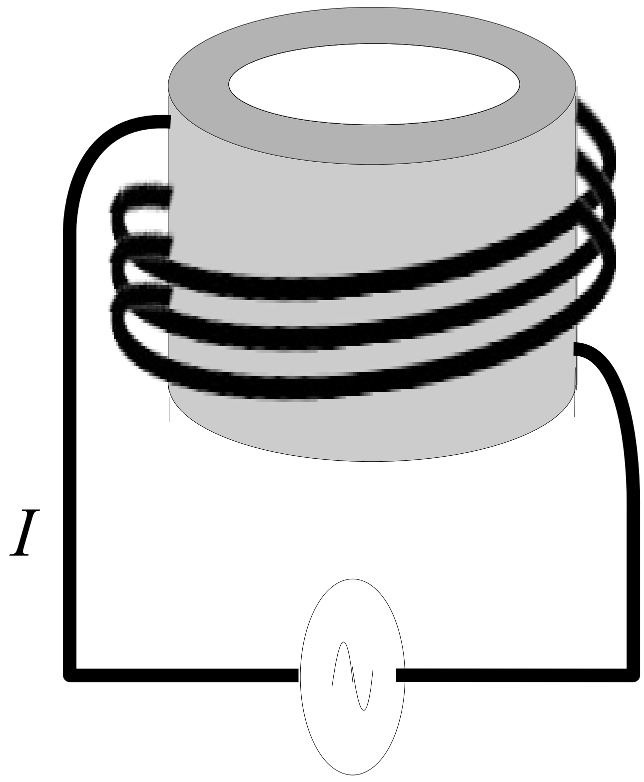
Lecture - Outline

- Voice Coil
  - Ring magnet
  - Centre pole piece
  - Air gap
  - Coil in air gap
  - Spring to position coil

Voice coil - actuator



Ring magnet



- Ferrite ring

Length=20mm

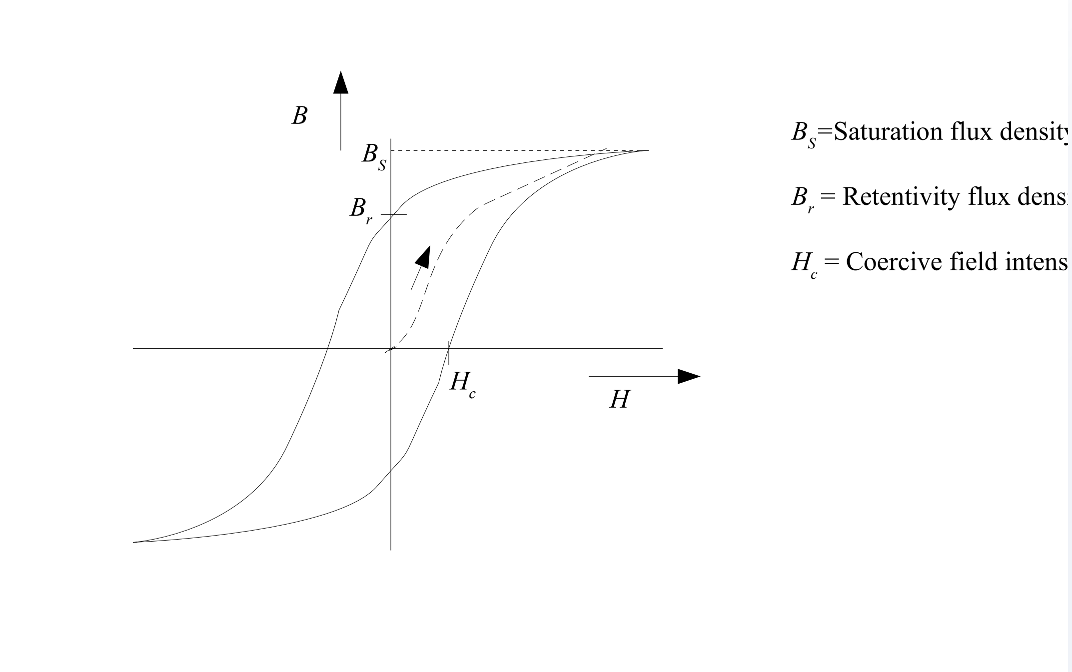
outer diameter=20mm, inner diameter=15mm.

Place it in a coil of wire (e.g.,20 turns; current 1A)

Ferrite => H_c=60 Amp-turn/m, B_r = 0.15 Weber/sq.m

Ferrite ring is saturated and fully magnetized.

Permanent Magnet



$$R_m = \frac{H_c}{B_m}\frac{l_m}{A_m} = 400\left(\frac{0.02}{137.5\,x\,10^{-6}}\right) = 58.2\,x\,10^{3}\,Amp - turns/Weber$$

Magnetic circuit

Iron Pole piece: length = 20mm, diameter = 13mm.

Fe permeability: $\mu = 6\,x\,10^{-3}$

$$R_p = \frac{1}{\mu}\frac{l_p}{A_p} = \frac{10^3}{6}\frac{0.02}{530\,x\,10^{-6}} = 6.3\,x\,10^3$$

$$R_g = \frac{1}{\mu_o}\frac{l_g}{A_g} = \frac{1}{4\pi 10^{-7}}\frac{2\,x\,10^{-3}}{880*10^{-6}} = 1800\,x\,10^3$$

$$B_g = \frac{H_c}{R_m + R_p + R_g} R_g = H_c\,x\,0.965 = 58\,Wb/m^2$$

Coil

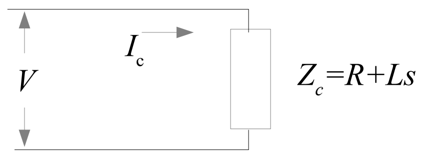
- Coil: 40 gauge (diameter 0.08 mm), 125 turns. Length of coil=10mm.

Diameter of coil = 14 x 10^{-3} m. Length of wire=1.75 m

Resistance of coil = 5.8 Ω

Inductance (iron core inductor):

$$L = \mu N^2 \frac{A}{l} = 6\,x\,10^{-3}\,x\,15625\,x\,\frac{154\,x\,10^{-6}}{10\,x\,10^{-3}} = 1.44\,H$$



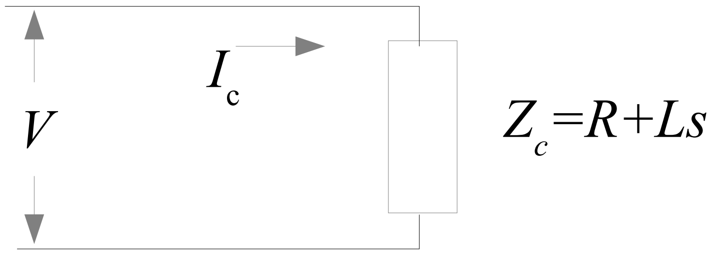
Static case

- Excitation voltage = 6V

Current = 1.03 A

Force:

$$F = BIl = 105\,N$$



Dynamic case

- Excitation voltage is time varying: V(t)

$$V(t)=R\ \ I(t)+L\frac{dI(t)}{dt}$$

$$I(s)=\frac{V(s)}{R+Ls}=\frac{V(s)}{Z_e(s)}$$

Mechanical Aspect

- When coil is moving, EMF due to moving conductor in magnetic field:
  - Back EMF
  - Velocity determined by mechanics

$$V_b(s) = B_g l_c u(s)$$

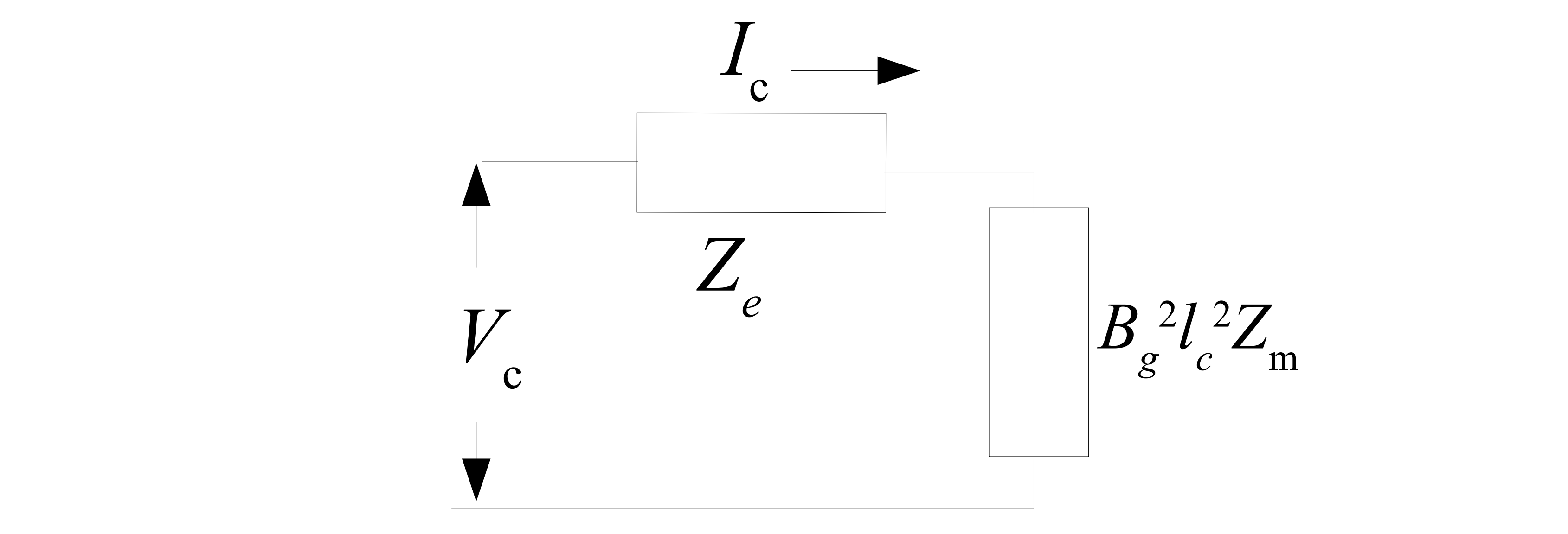
$$\begin{aligned} V(s) &= V_e(s) + V_b(s) \\ &= I(s) Z_e(s) + B_g l_c u(s) \end{aligned}$$

$$F(t) = m\dot{u}(t) + k_b u(t) + k_1 \int u(t)\,dt$$

$$u(s) = F(s) / [ms + k_b + k_1/s]$$

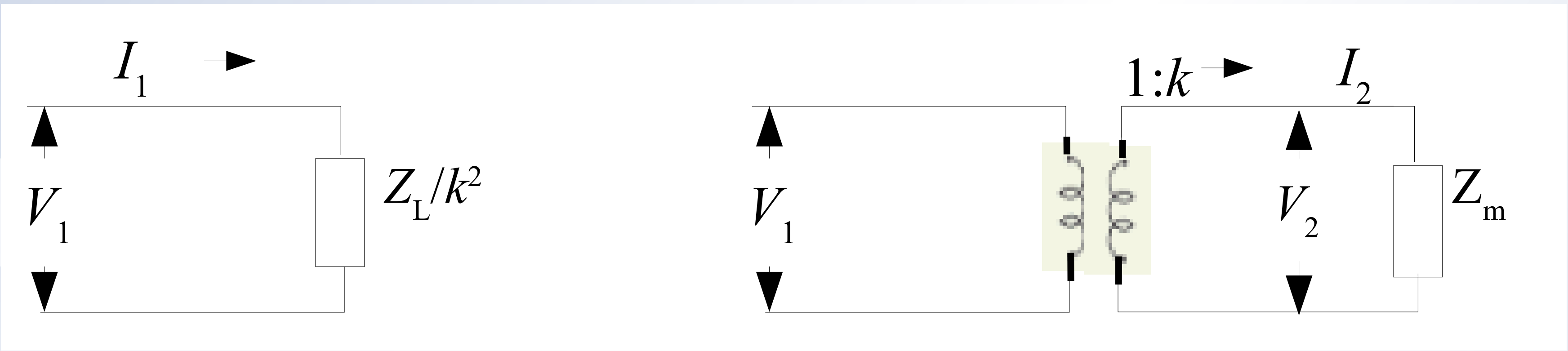
$$u(s) = \frac{B_g l_c I(s)}{ms + k_b + k_1/s}$$

Equivalent Electrical Impedance due to mechanical components



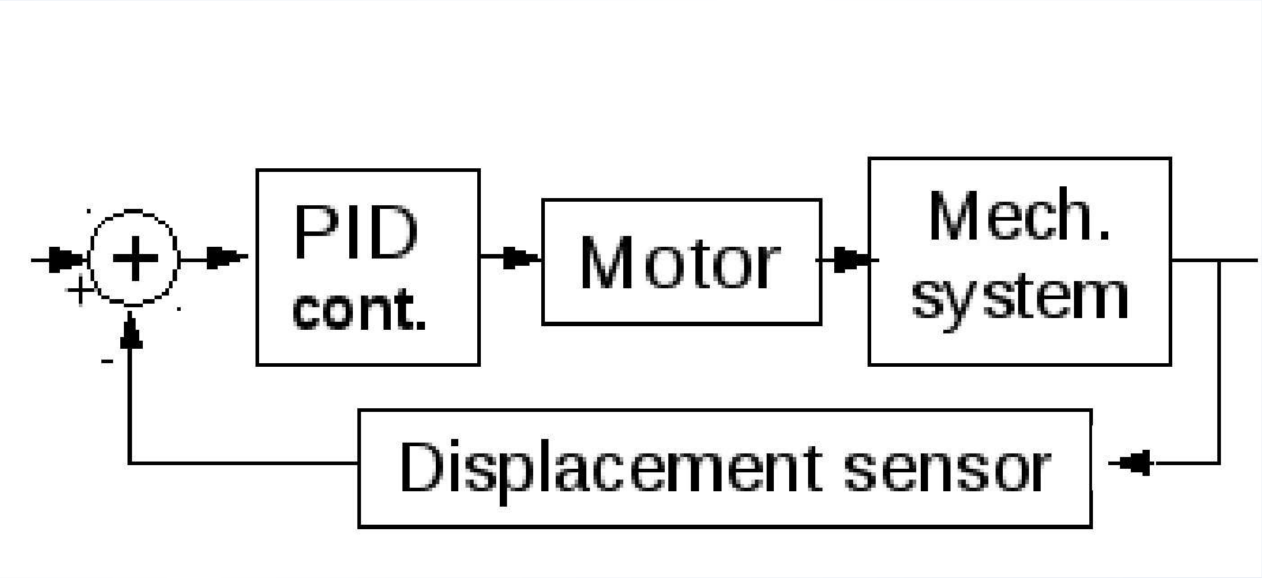
$$\frac{V_b(s)}{I(s)} = -B_g^2\, l_c^2\, Z_m(s)$$

Using a transformer representation

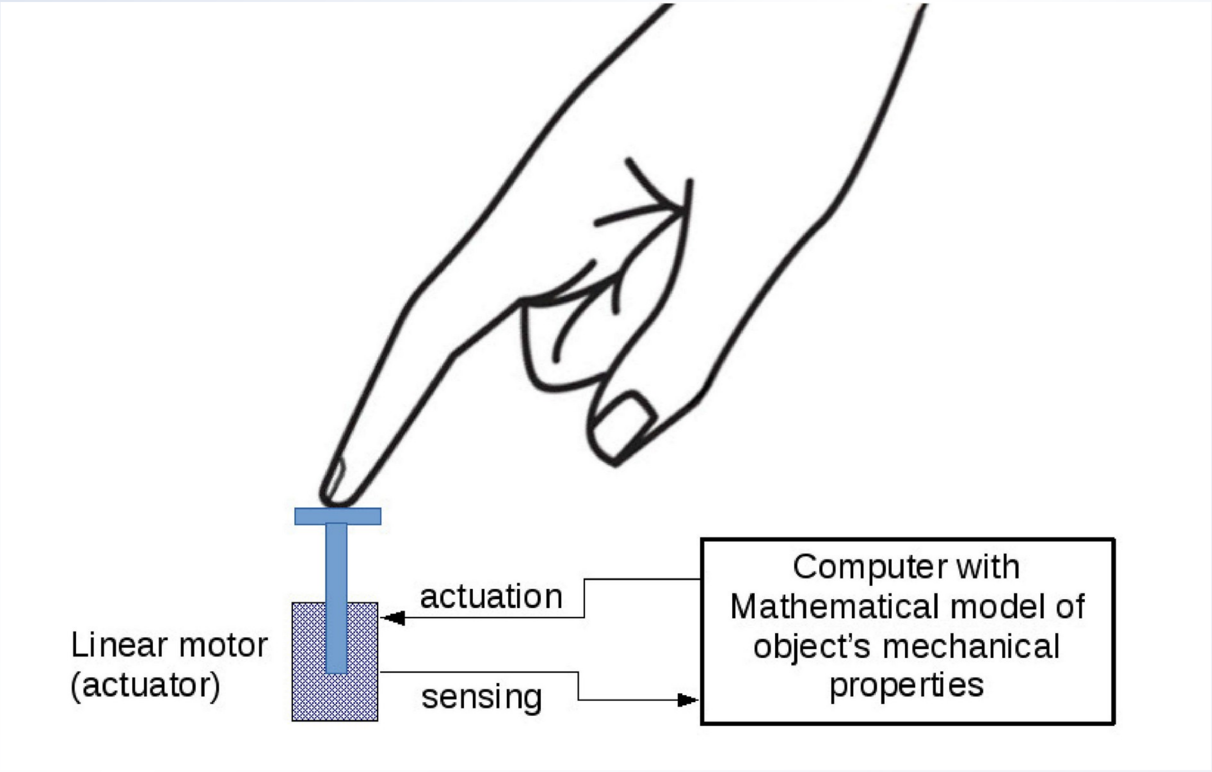


$$V_2 = k\,V_1 \ , \qquad I_2 = \frac{I_1}{k} \ , \qquad \frac{V_2}{I_2} = k^2 \frac{V_1}{I_1} \ , \qquad Z_L = \frac{V_2}{I_2} \ , \qquad \frac{V_1}{I_1} = \frac{Z_L}{k^2}$$

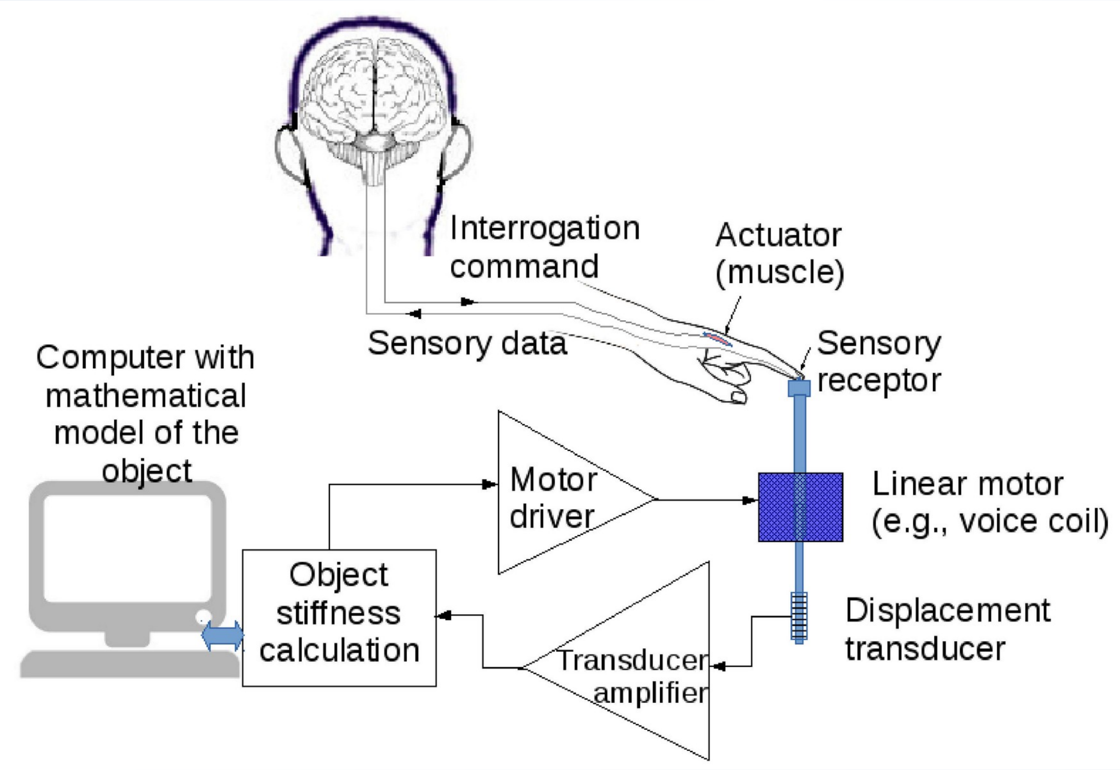
Servo Motor



Application of Servo motor in Haptics



Haptics – Feeling in Medical Devices



End of Lecture