Displacement Sensors

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Lecture - Outline

- Inductive Sensors
  - Measuring Inductance
- Capacitive Sensors
  - Measuring Capacitance

Inductance

- Inductance

$$L = N\frac{d\phi}{dI}$$

- With constant permeability

$$L = N\frac{\phi}{I}$$

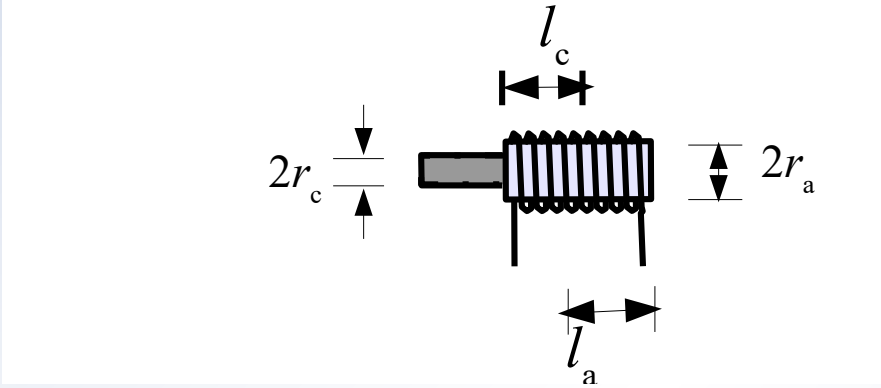
- Reluctance of coil is R:

$$L = N\frac{\phi}{I} = N\frac{NI}{R}\cdot\frac{1}{I} = \frac{N^2}{R}$$

- If l_c is coil length and l_a is length of air, Reluctance:

$$\frac{1}{R} = \frac{1}{R_a} + \frac{1}{R_c} = \frac{\mu_o \pi r_a^2}{l_a} + \frac{\mu \pi r_c^2}{l_c}$$

Variable Inductance Transducer



$$L = \frac{N^2}{R}$$

- Relative permeability:
  - Steel = 30000
  - Ferrite=2500

(Note: Weber/Ampere=Henry)

$\mu_o = 4\pi 10^{-7} H/m$

$$\frac{1}{R} = \frac{1}{R_a} + \frac{1}{R_c} = \frac{\mu_o \pi r_a^2}{l_a} + \frac{\mu \pi r_c^2}{l_c}$$

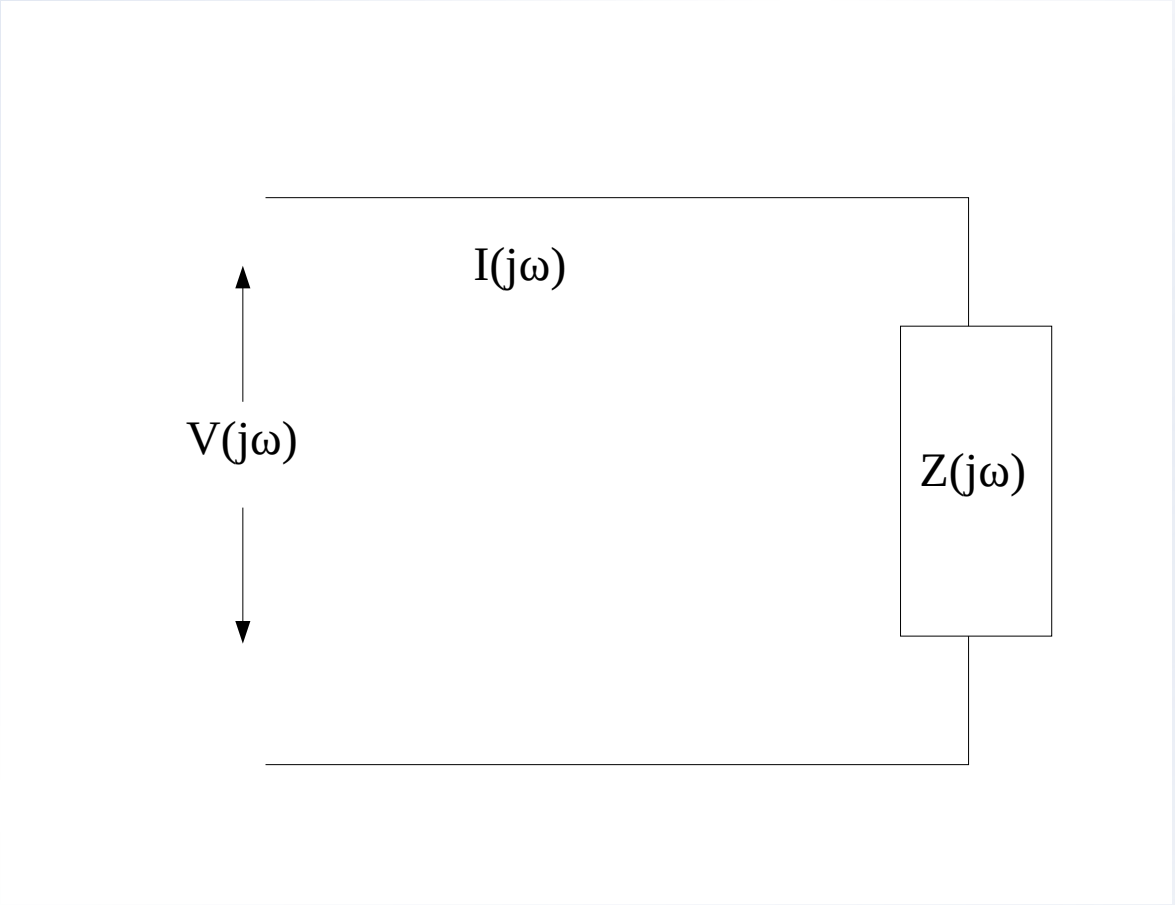
$$L \approx \frac{N^2 \pi r^2 \mu}{l_c}$$

Measuring Inductance using simple V-I

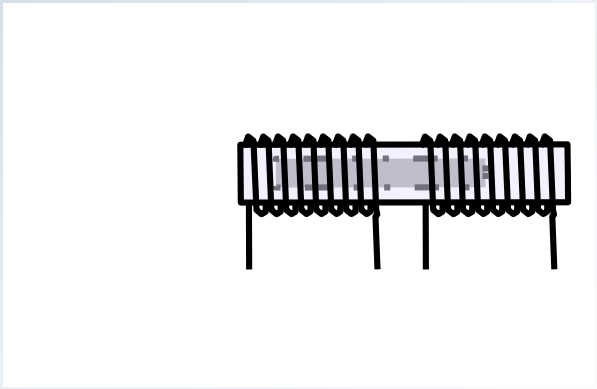
$$I(s) = \frac{V(s)}{R + Ls}$$

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

$$L\,\omega = \frac{|V(j\omega)|}{|I(j\omega)|} - R$$

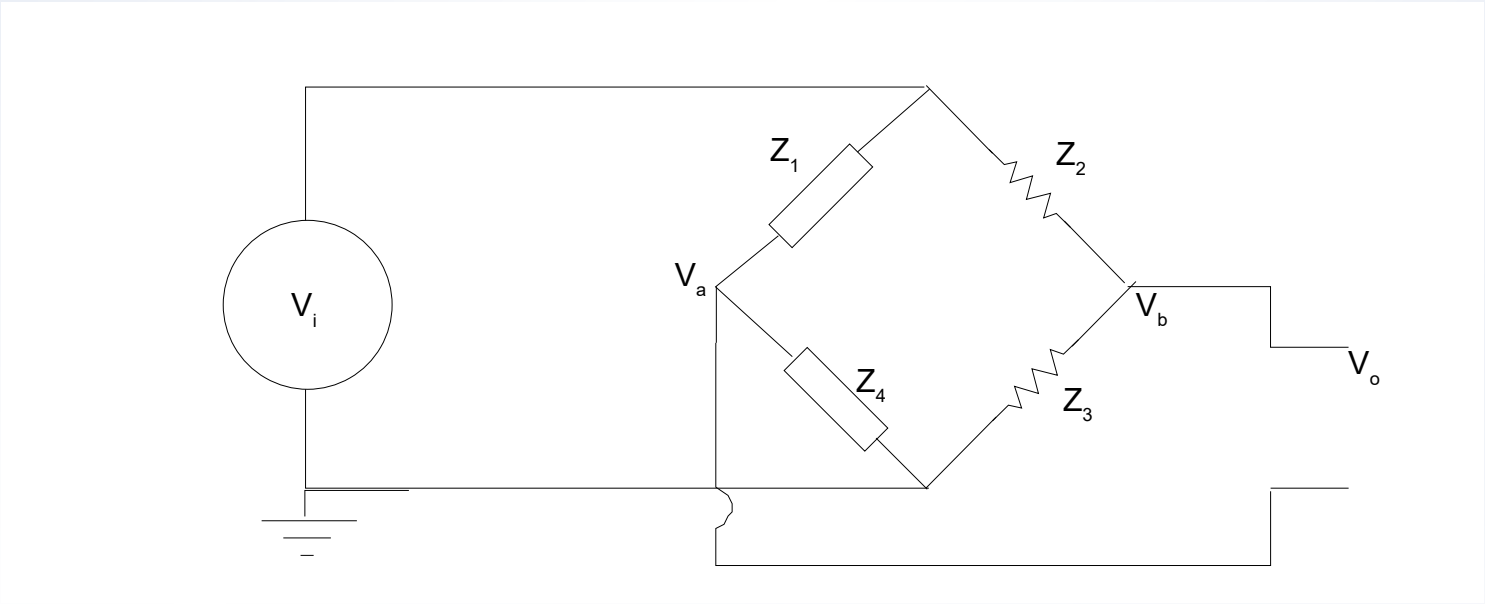


Differential Inductance Sensor – bridge measurement

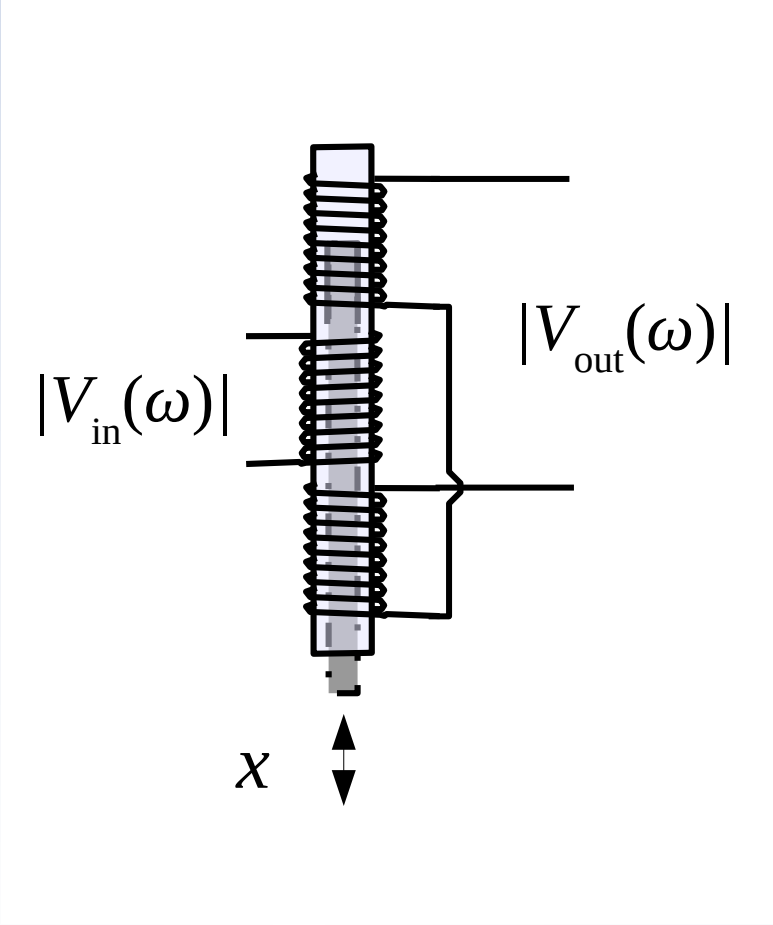


$$Z_1 = L + \Delta L \quad , \quad Z_4 = L - \Delta L$$

$$V_o(s) = \frac{V_i}{2} - \frac{V_i}{2Ls}(L + \Delta L)s$$



Linear Variable Differential Transformer (LVDT)



$$\frac{V_{out}}{V_{in}} \approx k\,x$$

Capacitive transducers

- Capacitor

$$C = \epsilon \frac{A}{l}$$

- Microphone

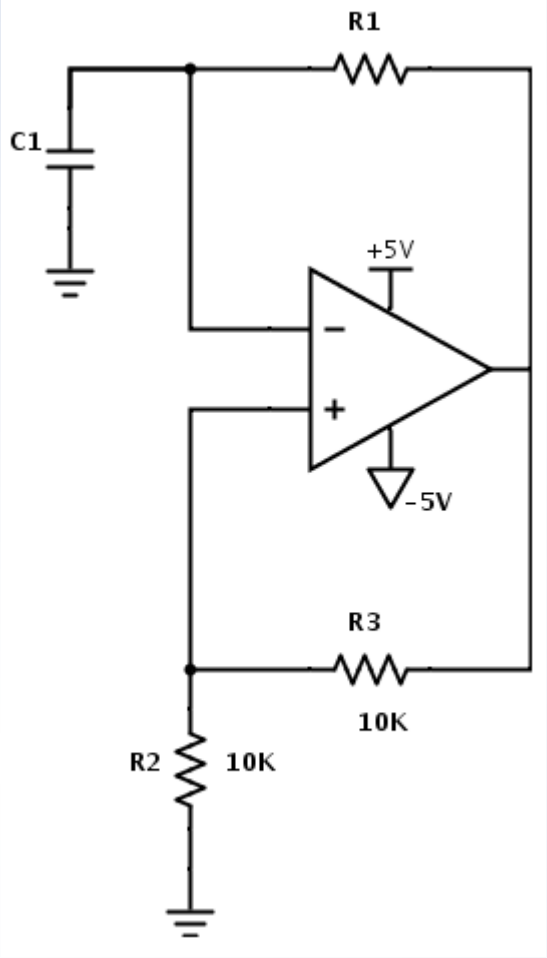
$$\frac{dC}{dl} = \epsilon \frac{A}{-l^2} = \frac{-C}{l}$$

$$\frac{\Delta C}{C} = \frac{-\Delta l}{l}$$

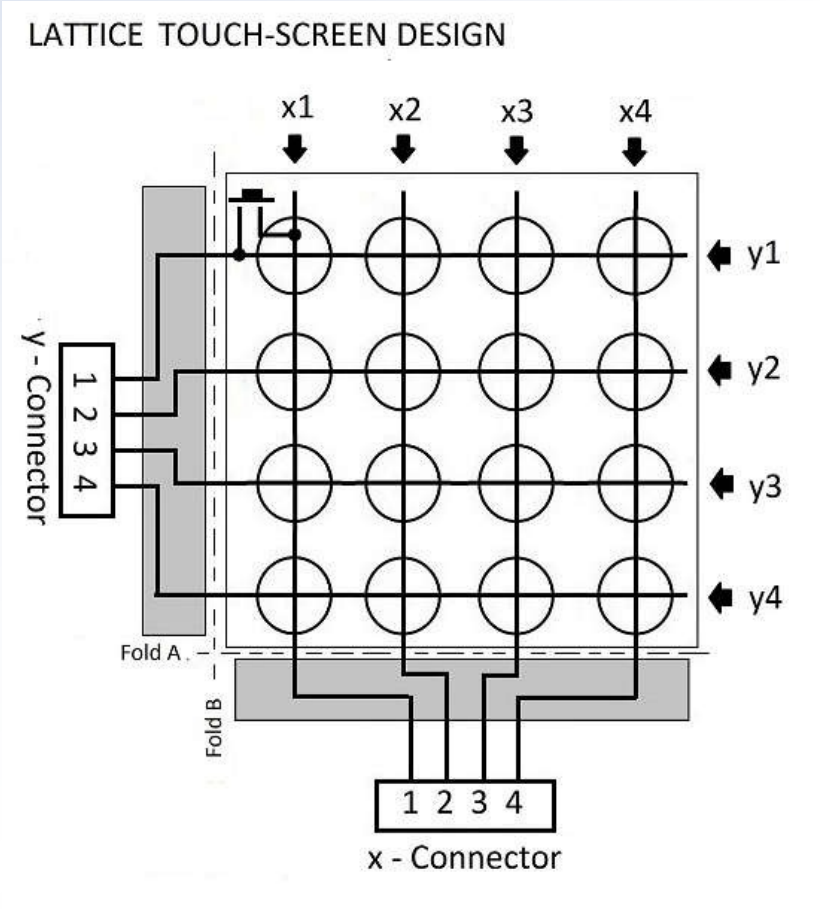
Capacitance measurement

- Simple V-I measurement
- Bridge measurement
- Oscillator measurement
- Charge transfer or switched capacitor measurement

Relaxation Oscillator for capacitance measurement



Capacitive grid sensor



End of Lecture