Motion Sensors

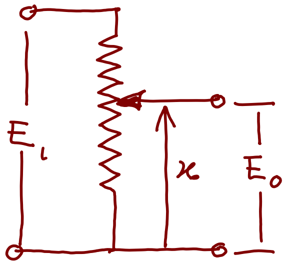
2103-602
Measurement and
Instrumentations

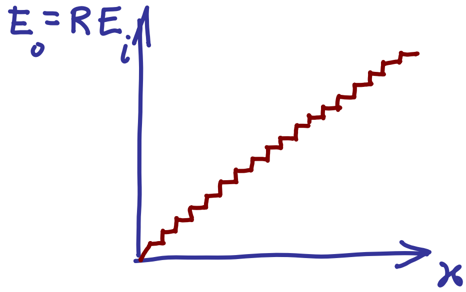
Elements of Motion Transducers

- Variable-resistive type
- Capacitive type
- Variable-inductive type
- Interferometer
- Piezoelectric type

Potentiometer (Variable-Resistive)

The pin tracks the object and moves along the resistive element. The output voltage is linearly related to the variable resistance or the position.





– Simple

– Rugged

– Low precision

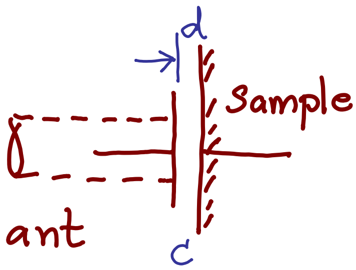
– Sensitive to electrical noise

Capacitive type

The output voltage is related to the capacitance that depends on a separation of the conductive plates.

$C = f(K, A, d)$

$K \sim$ dielectric constant



– Very high precision (nm or better) and small range

– Medium response time (bandwidth)

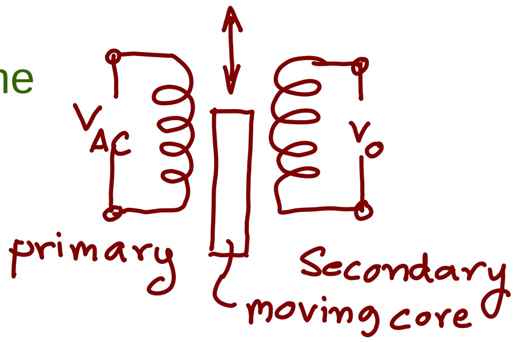
– Non-contact and alignment is critical

– Need charge amplifier

Inductive type

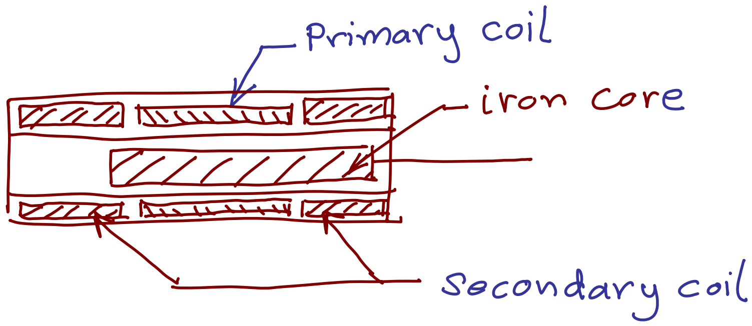
EMF voltage induced in the secondary coil varies with the moving position of the ferromagnetic core in between.

- Quite rugged due to non-contact components
- Medium resolution (better than microns) and range less than meters
- Medium to low response time
- Complex electronics



Linear Variable Differential Transformer (LVDT)

Real world design of inductive displacement sensor

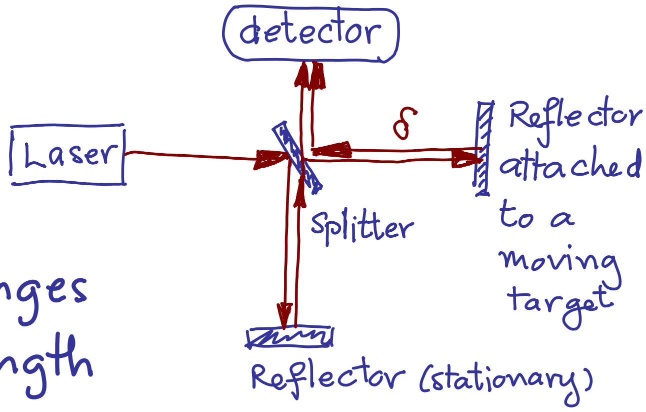


Interferometer

A very precise instrument that relates the displacement of the object with the wavelength of light.

– High sensitivity (nm or better) but small range (tens of microns)

– Non-contact sensor



$$2\delta = N\lambda$$

$N \sim$ # of fringes

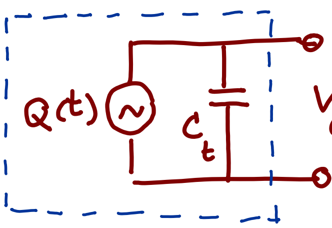
$\lambda \sim$ wavelength

Piezoelectric Type

A piezo-material generates a significant electrical charge when it deforms. So it can be used as acceleration sensors.

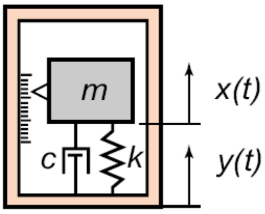
– High natural frequency, good for accelerometer

– Need charge amplifier



$$V_o(t) = \frac{Q(t)}{C_t}$$

Operating Frequency vs. Natural Frequency of Motion Sensors



By measuring motion of mass $x(t)$, base motion $y(t)$ can be determined.

Accelerometer

Seismometer

Frequency Response

Mathematics:

EOM: Defining $w(t) = x(t) - y(t)$, we have

$$m\ddot{w} + c\dot{w} + kw = -m\ddot{y} \text{ or}$$

$$\ddot{w} + 2\zeta\omega_n\dot{w} + \omega_n^2 w = -\ddot{y}$$

For harmonic motion of the base and mass,

$y(t) = Re[Ye^{j\omega t}]$ and $w(t) = Re[We^{j\omega t}]$

Finally, we get

$$\left|\frac{W}{Y}\right| = \frac{r^2}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$$

where $r = \omega / \omega_n$.