
Position, Velocity, & Acceleration

Position, Velocity, and Acceleration

$$v\{t\} = \frac{ds}{dt}$$

$$s\{t\} = s_o + \int_{t_o}^t v\{t\}dt$$

$$a\{t\} = \frac{dv}{dt}$$

$$v\{t\} = v_o + \int_{t_o}^t a\{t\}dt$$

Sensing Principles vs. Measurement Devices

□ Sensing Principles

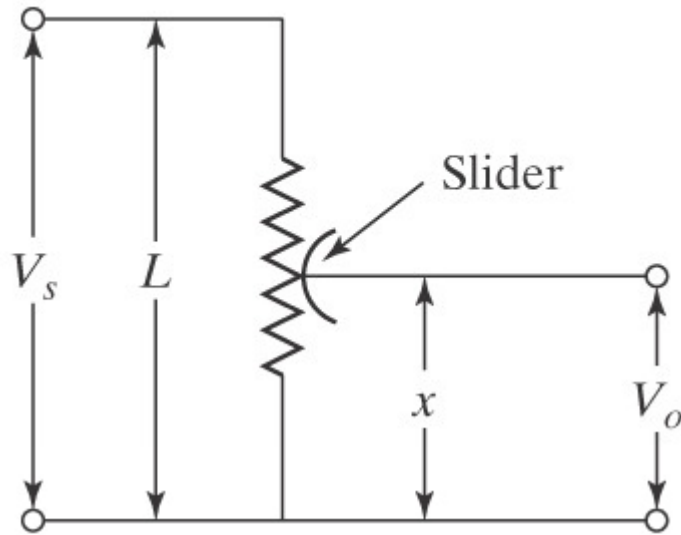
- Electrical resistance
- Electrical capacitance
- Electromagnetism
- Photoelectric effect
- Piezoelectric effect
- Hall effect
- Doppler effect
- Interferometry
- etc.

□ Measurement Devices

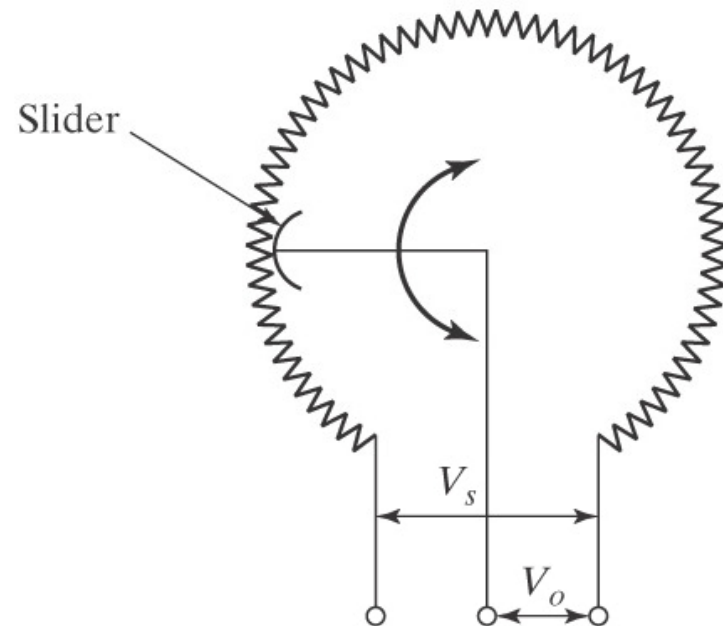
- Potentiometers
- LVDT
- Optical Encoders
- Tachometers
- Accelerometers
- Interferometers
- Triangulation Sensors
- Capacitance Sensors
- etc

Potentiometers

Potentiometer is a variable voltage divider

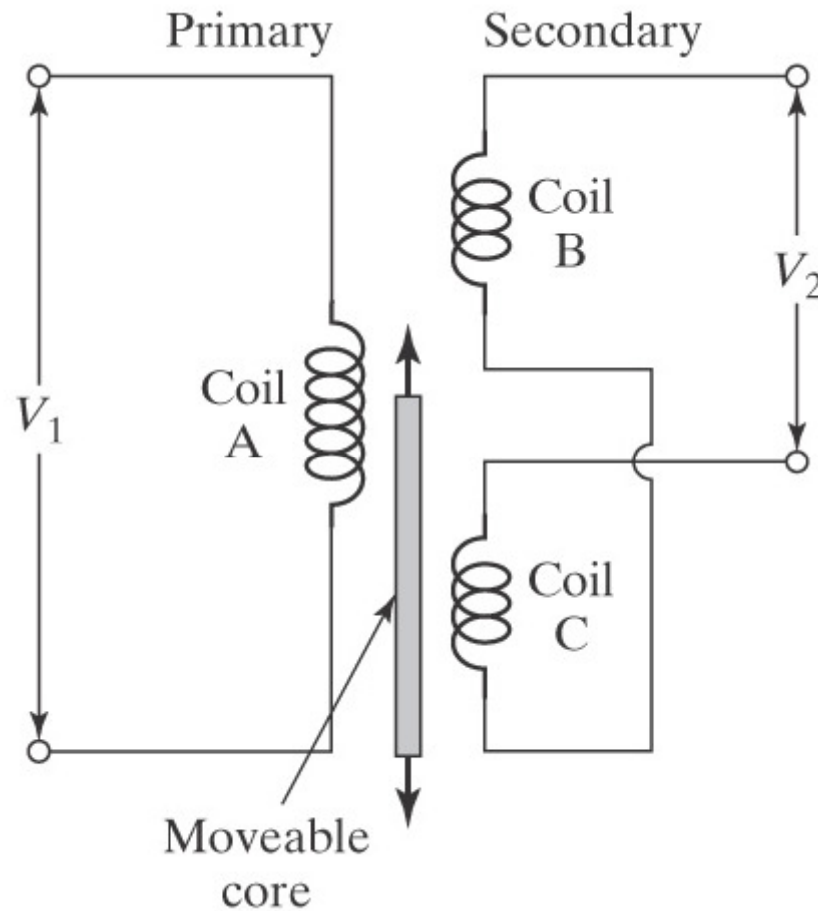


$$V_o = \frac{x}{L} V_s$$



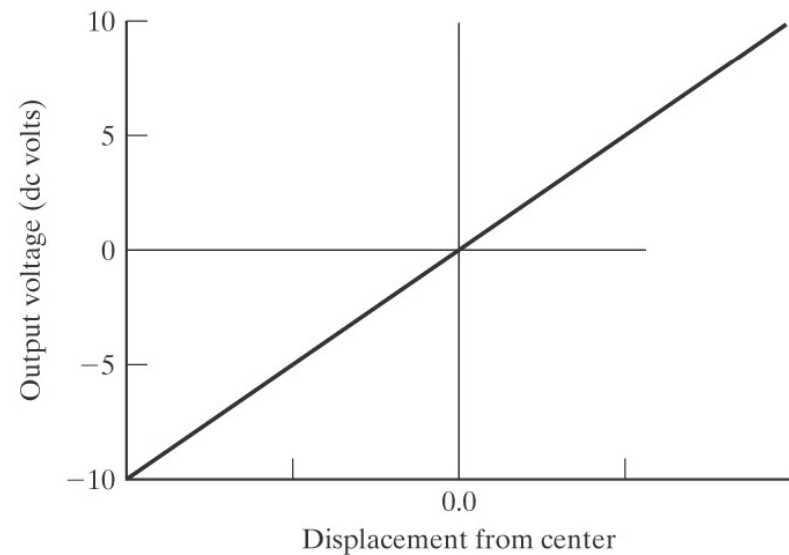
Angular Potentiometers are used in the volume/Tone control of Radio, TV etc.

Linear Variable Differential Transformer (LVDT)

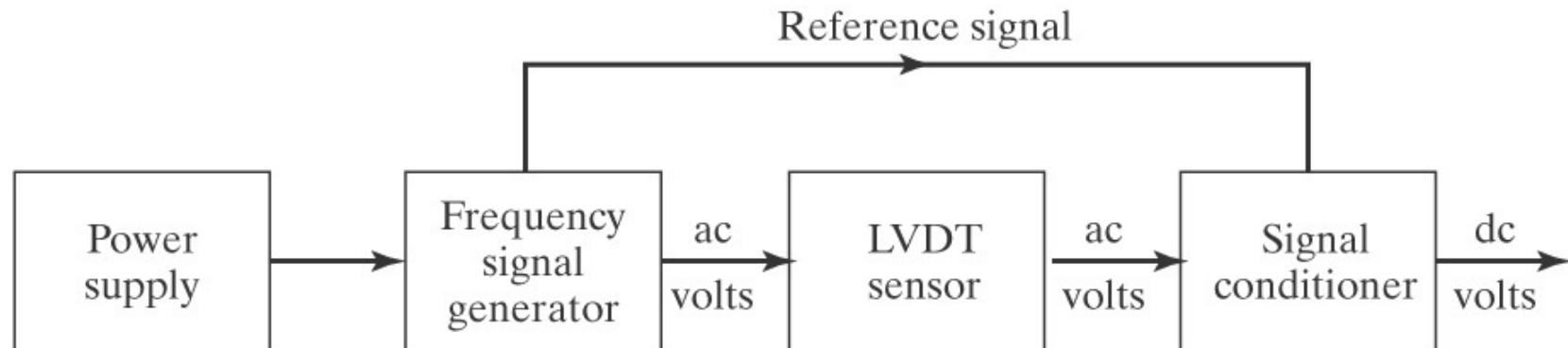


Coil made of Ferromagnetic material

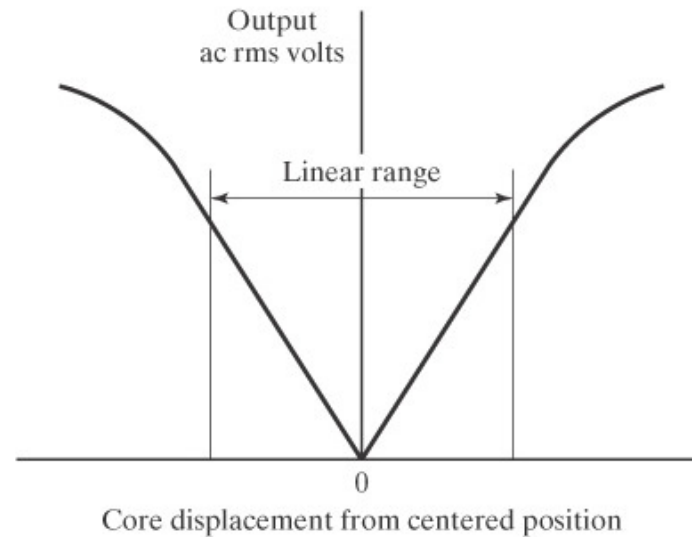
- Smaller Displacement Measurements
- Linear only over a certain range



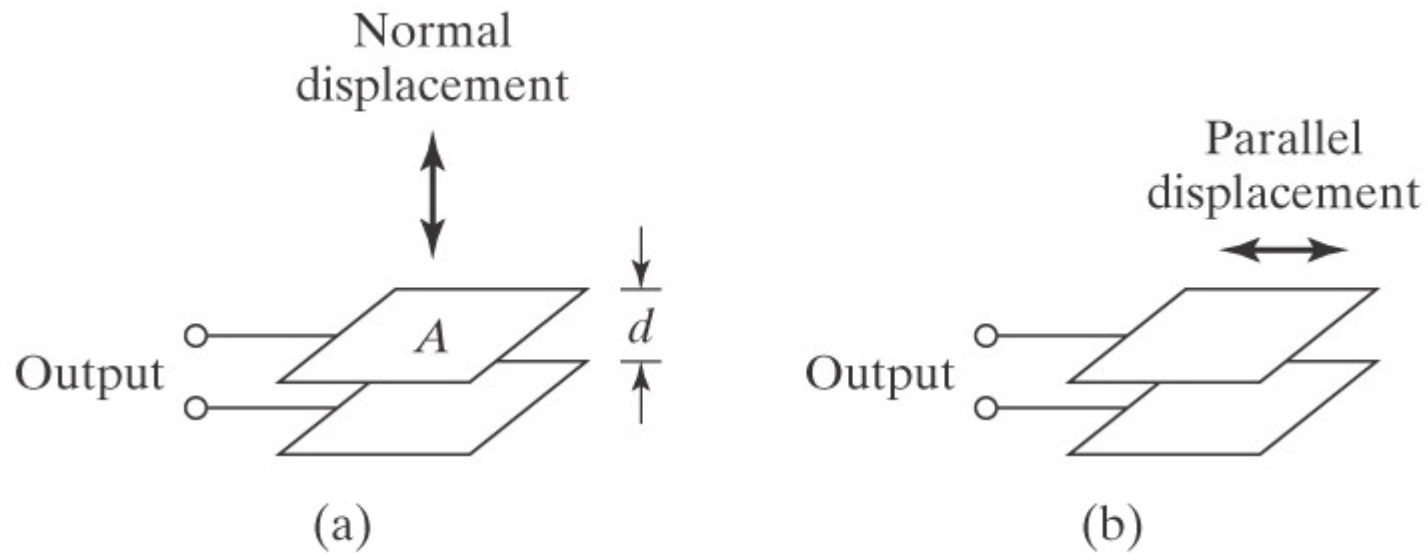
LVDT Signal Output



Phase relation of the output signal with respect to the primary indicates the direction



Capacitive Displacement Sensing



$$C = \epsilon_0 \epsilon_r \frac{A}{d}$$

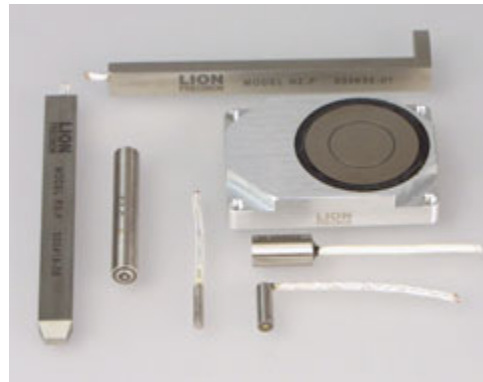
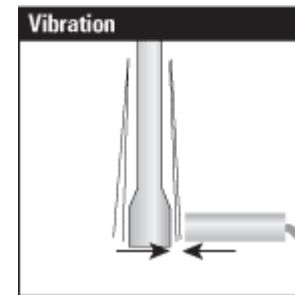
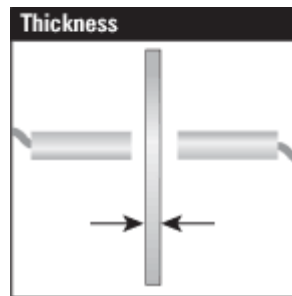
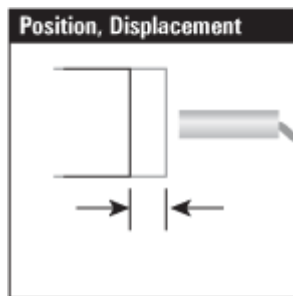
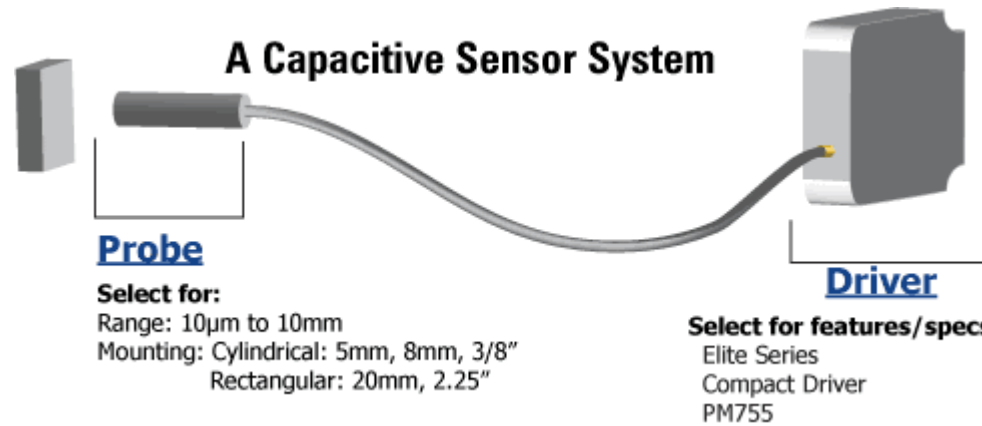
C : capacitance

ϵ : permittivity

A : plate area

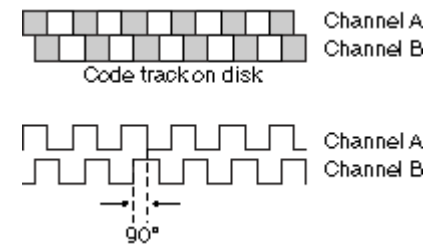
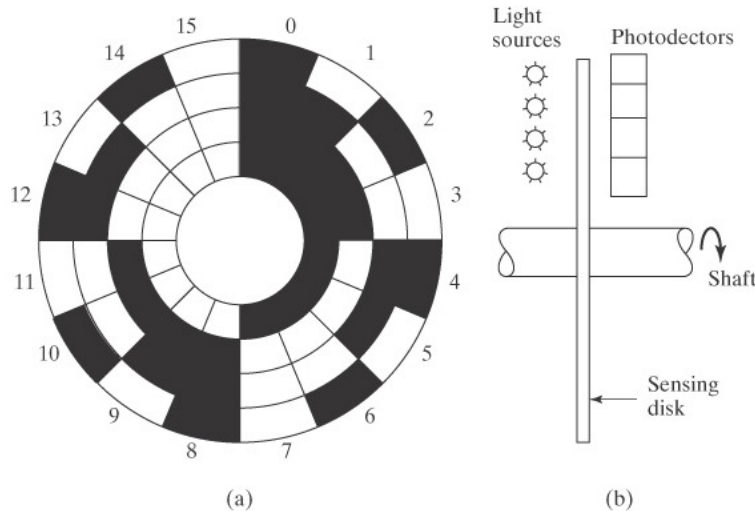
d : distance between plates

Capacitance Sensor



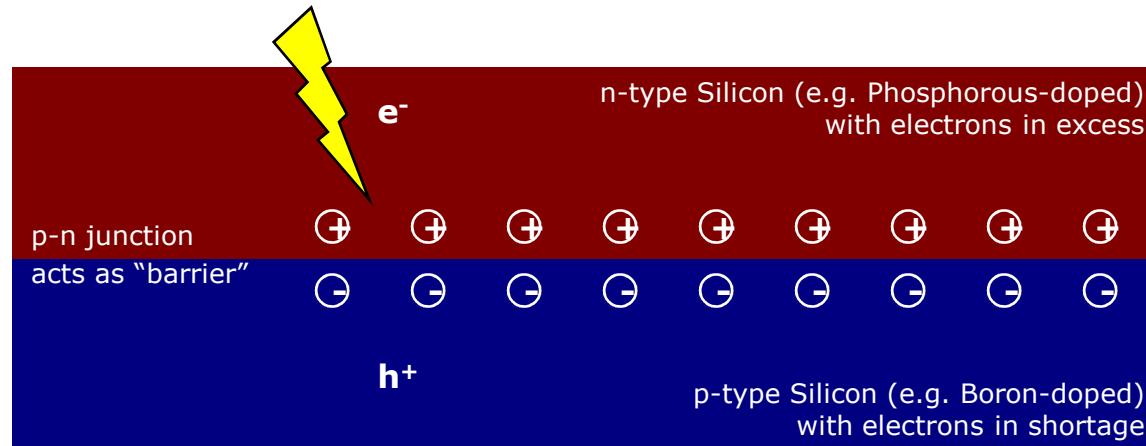
Position Encoders

- ❑ May be arranged in **linear** or **rotary** configuration.
- ❑ **Optical** detection is common, but may also be capacitive, resistive, magnetic, etc.
- ❑ May be **absolute** or **incremental** (counting from a reference).
- ❑ Arranging in **quadrature** provides finer resolution (by monitoring transitions rather than states) as well as direction.



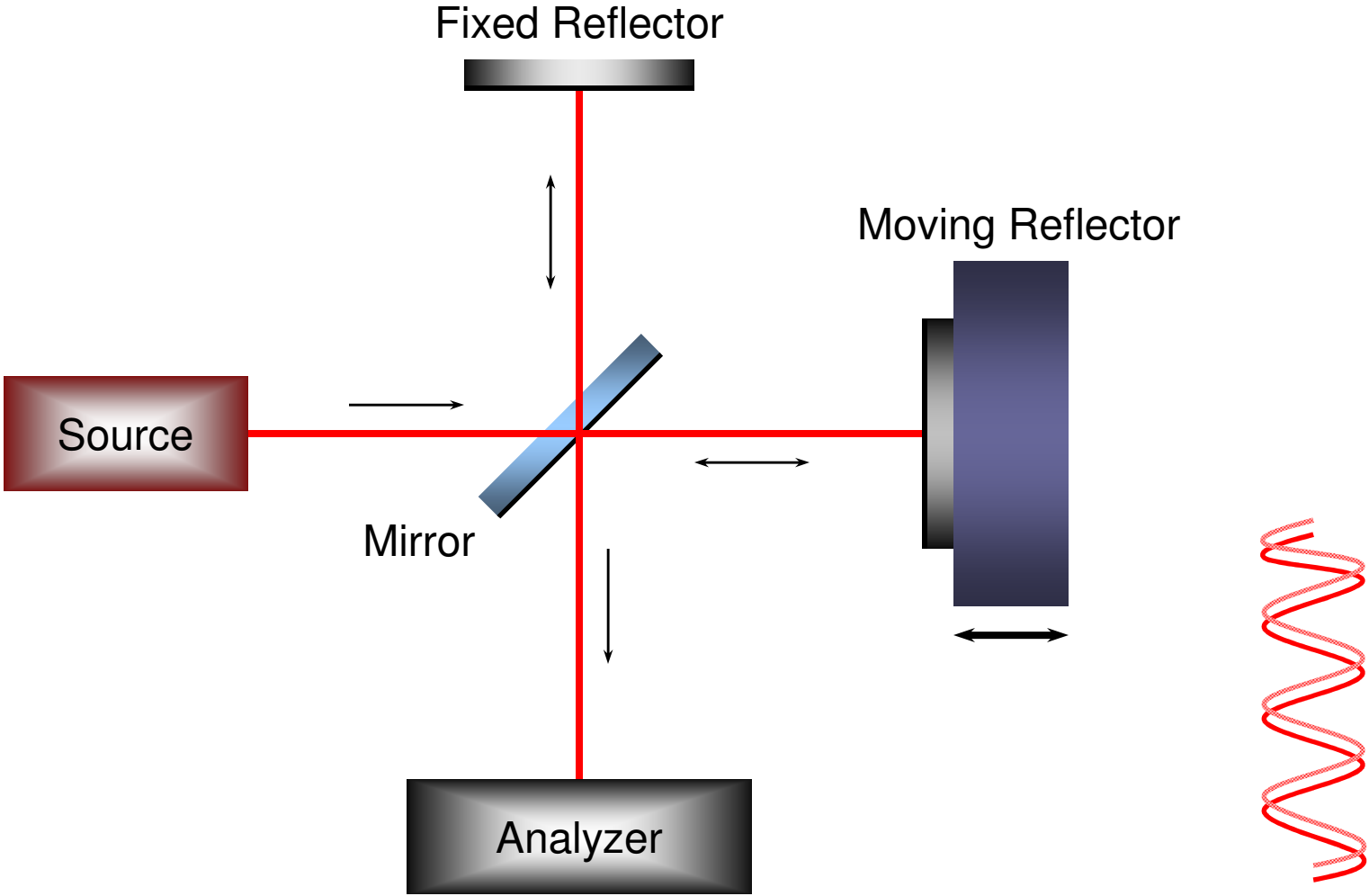
<http://zone.ni.com/devzone/cda/tut/p/id/4763>

Photoelectric Effect

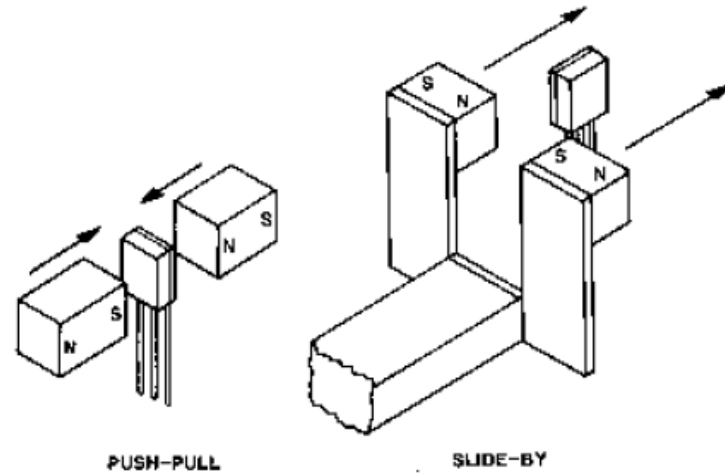
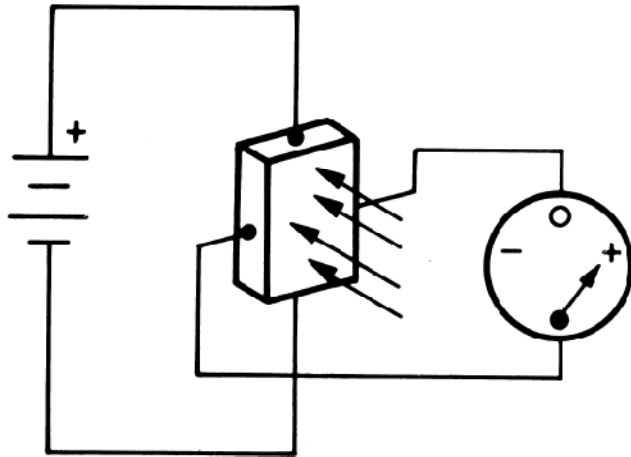


- ❑ The *photoelectric effect* is a phenomenon in which photon energy (i.e. from light) releases electrons from their otherwise more stable state on a surface.
- ❑ In a *photodiode*, photon energy produces free charge carriers (electron-hole pairs) to overcome the otherwise current-impeding junction between p-doped and n-doped semiconductor layers.

Laser Interferometer



Hall Effect



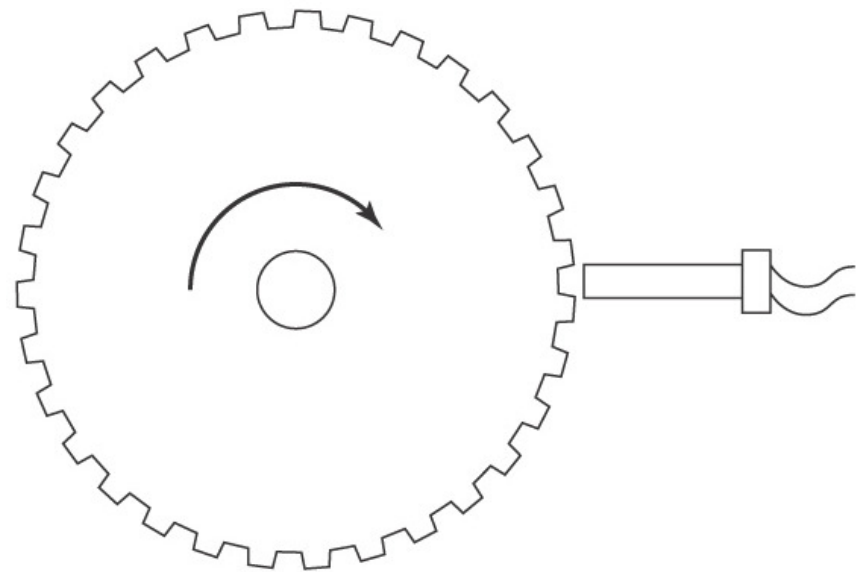
- ❑ The *Hall effect* is a disruption to the “ordinary” flow of current and charge distribution across a thin sheet (typically semiconductor) by the presence of a magnetic field oriented perpendicular to it.
- ❑ The electrons traveling across the sheet are displaced by the magnetic component (\mathbf{B}) of the Lorentz force:

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

- ❑ A wide variety of Hall effect sensors can thus measure magnetic field strength or subtle changes in field by outputting a voltage that is proportional to it.

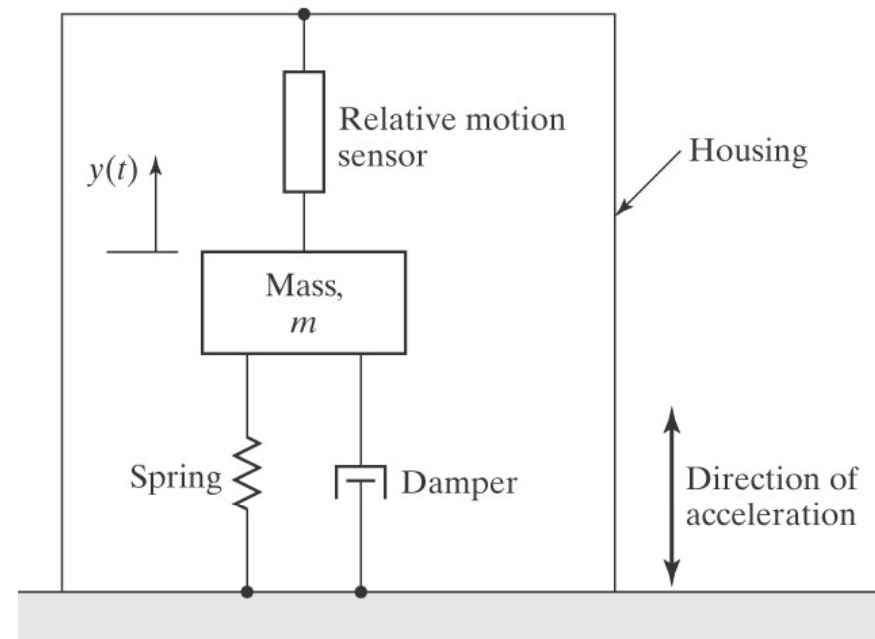
Tachometer

- ❑ A **tachometer** is a device that measures angular velocity.
- ❑ Some implementations may include electromagnetic generators, magnetic pickups, and photo-detectors.

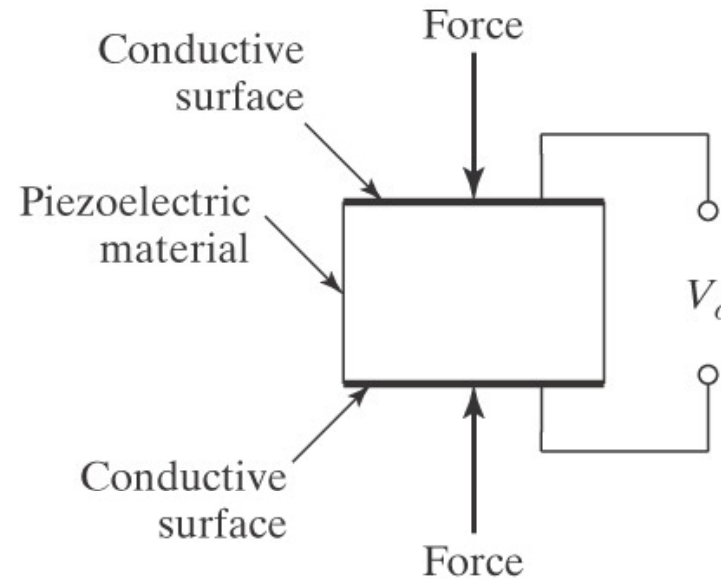


Accelerometer

- ❑ Senses acceleration (i.e. changes in velocity) by measuring position as a function of time.
- ❑ A mechanical vibration system having spring-mass-damper elements.
- ❑ Commonly expressed in multiples or fractions of g (9.81 m/s^2).



Piezoelectric Effect

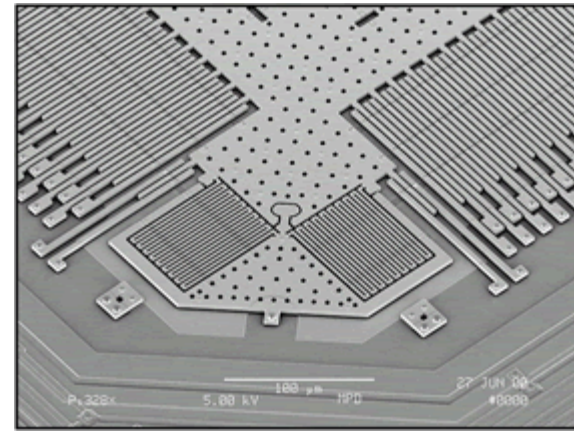


- ❑ *Piezoelectricity* is a two-way relationship between mechanical stress and electric potential exhibited by some materials, based on changes in the crystalline ionic structure along internal asymmetries.
- ❑ Based on related phenomena, *piezoresistive* materials exhibit change in electrical resistance when experiencing mechanical strain.

MEMS Accelerometers (Analog Devices ADXL)

□ Features

- 2-Axis Acceleration Sensor
- ~ 5mm x 5 mm chip
- 2-100 g operating ranges
- milli-g resolution
- mA power consumption
- ~ 1000 g Shock Survival



□ Applications

- Inertial Navigation
- Portable Device Security
- Motion Detection
- Camera Image Stabilization
- Game Controller Feedback



Some Useful Criteria for Position/Motion Sensors

- ❑ Contact vs. Non-Contact
- ❑ Range
- ❑ Resolution
- ❑ Accuracy
- ❑ Repeatability
- ❑ Frequency Response
- ❑ Signal Conditioning Requirements
- ❑ Environmental Robustness
- ❑ Cost