Electrical and Electronic Measurements, Part 2

Lecture 5: Sensors and Transducers

Velocity, Motion, Force and Liquid Level Sensors

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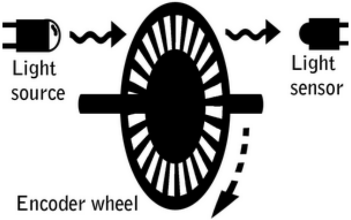
Velocity Sensors:

[1] Incremental Encoders:

- The incremental encoder used for displacement sensing can be used for the measurement of angular velocity.
- The velocity could be determined by counting the number of pulses produced per second.
- Two tracks of slots could be used to determine the direction of velocity (clockwise or counter clock wise).



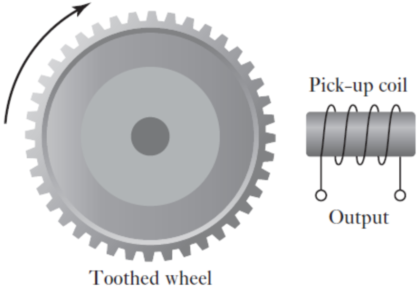
Velocity Sensors:

[2] Tachogenerators:

- The tachogenerator is used to measure angular velocity. It has two forms:

1. Variable Reluctance Tachogenerator:

- A toothed wheel of ferromagnetic material is attached to the rotating object.
- A pick-up coil is wound on a permanent magnet. As the wheel rotates, the air gap between the coil and the ferromagnetic material changes.
- The flux linked by a pick-up coil will be changed due to the change in the air gap. The resulting cyclic change in the flux produces an alternating e.m.f. in the pickup coil.



Velocity Sensors:

[2] Tachogenerators:

The flux ϕ changes with time as:

$$\phi = \phi_0 + \phi_a cos(n\omega t)$$

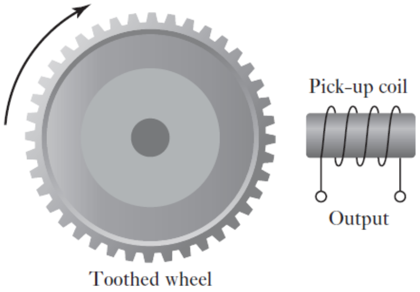
ϕ_0: The mean flux.
ϕ_z: Flux variation amplitude.
ω: Rotation speed
n: No. of teeth.

$$e.m.f = -N\frac{d\phi}{dt} = N\phi_a n\omega sin\omega t$$

N: No. of turns of pickup coil.

$$\boxed{e.m.f = E_{max} sin\omega t} \quad E_{max} \propto \omega$$

The induced e.m.f. could be shaped to a series of pulses that could be counted as a measure of angular velocity.



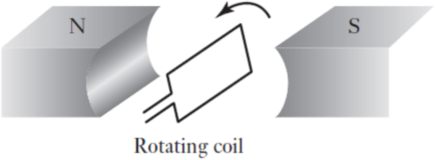
Velocity Sensors:

[2] Tachogenerators:

- The tachogenerator is used to measure angular velocity. It has two forms:

2. A.C. Generator:

- It consists of a coil, termed the rotor, which rotates with the rotating shaft inside a magnetic field produced by a stationary permanent magnet.
- When the coil rotates, an alternating e.m.f. is induced in it.
- The amplitude or frequency of this alternating e.m.f. can be used as a measure of the angular velocity of the rotor.
- The output may be rectified to give a d.c. voltage with a size which is proportional to the angular velocity.



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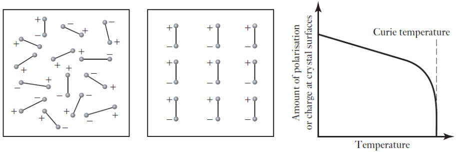
Motion Sensors:

[1] Pyroelectric Sensors:

Motion sensors: sensors used to detect the human motion.

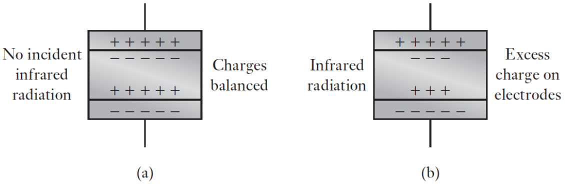
- Pyroelectric materials are crystalline materials which generate charge in response to heat flow.
- When a pyroelectric material is heated to the Curie temperature ($\approx 610^o c$) in an electric field and the material cooled while remaining in the field, electric dipoles within the material line up and it becomes polarized.
- When the field is then removed, the material retains its polarization.
- When the pyroelectric material is exposed to infrared radiation, its temperature rises and this reduces the amount of polarization in the material and the dipoles losing their alignment.



Motion Sensors:

[1] Pyroelectric Sensors:

- A pyroelectric sensor consists of a polarized pyroelectric crystal with thin metal film electrodes on opposite faces.
- At normal states, the sensor has a balanced surface charge.
- If infrared radiation is incident on the crystal and changes its temperature, the polarization in the crystal is reduced.
- Consequently, there is an excess of charge on the metal electrodes over that needed to balance the charge on the crystal surfaces.
- The pyroelectric sensor behaves as a charge generator which generates charge when there is a change in its temperature as a result of the incidence of infrared radiation.

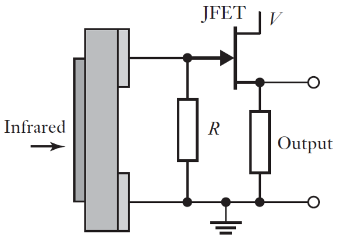


Motion Sensors.

[1] Pyroelectric Sensors:

- The change in charge is Δq is proportional to the change in temperature Δt:

$$\Delta q = k_p \Delta t \qquad k_p \text{ is the crystal sensitivity constant}$$



- To detect the motion of a human or other heat source, a pyroelectric sensor with two separated back electrodes is used. The two sensors receive the same heat signal when there is no motion.
- When a heat source moves, the heat radiation moves from one of the sensing elements to the other, resulting alternating current through a resistor.
- A transistor is included in the circuit as a voltage follower to reduce the output impedance.

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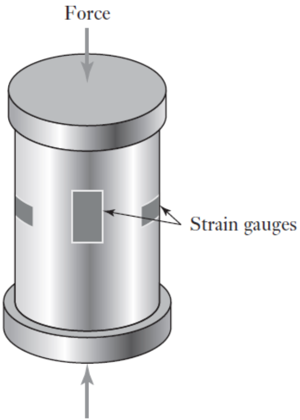
Force Sensors:

[1] Strain Gauge Load Cell:

- Forces are commonly measured by the measurement of displacements.
- Strain gauges are used to monitor the strain produced in some member when stretched, compressed or bent by the application of the force.
- The arrangement for measuring the force is generally referred to as a **load cell**.
- Load cell is a cylindrical tube to which strain gauges have been attached. When forces are applied to the cylinder the resistance will change which is a measure of the applied force.
- A signal conditioning circuit is required to eliminate the effect of temperature change on the strain gauge.



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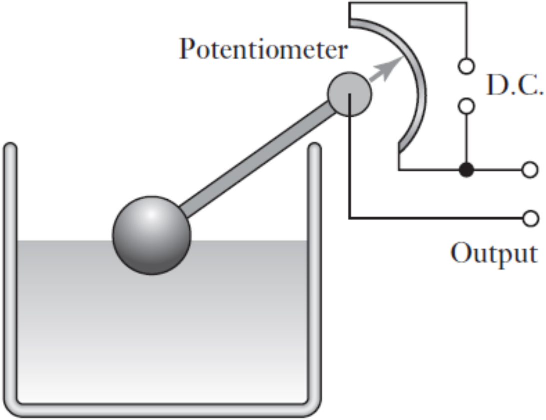
Liquid Level Sensors:

[1] Floats:

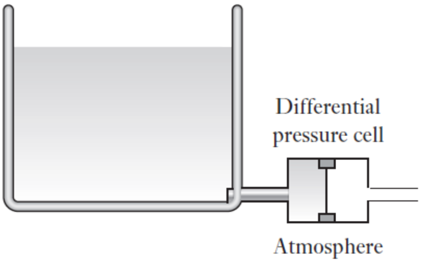
- A direct method of monitoring the level of liquid in a vessel is by monitoring the movement of a float inside that vessel.
- The displacement of the float causes a lever arm to rotate and so move a slider across a potentiometer.
- The result is an output of a voltage related to the height of liquid.

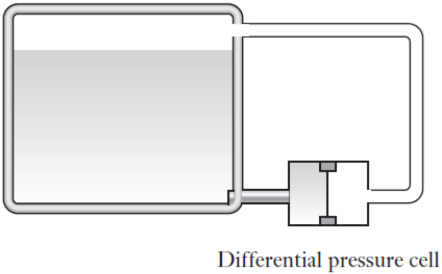


Liquid Level Sensors:

[2] Differential pressure:

- An indirect method for measuring the level of a liquid is measure the liquid which is changed according to the liquid level.
- The differential pressure cell can be used to monitor the difference in pressure between the base of the vessel and the atmospheric pressure.
- In case of closed vessel, the differential pressure cell monitors the difference in pressure between the base of the vessel and the air above the surface of the liquid.





End of Lecture

Best Wishes