Measurement (Motion Measurement-2)

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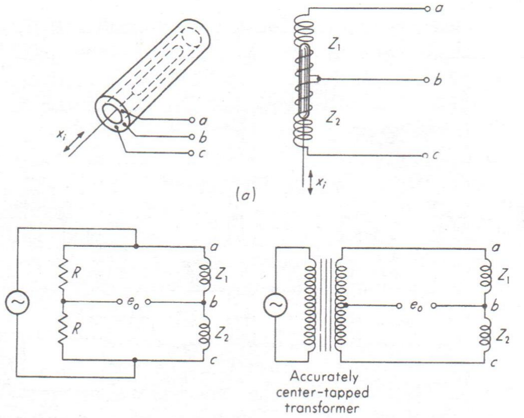
Variable-inductance pickup

- Similar to LVDT – but only two inductance coils
- Inductance coils form two legs of a bridge
- Movable coil provides the mechanical input
- When core at null position, inductance of two coils are equal
- Core motion changes the coil inductances – increasing one and decreasing the other
- Causing bridge unbalance; thus output voltage

Variable-inductance pickup



Two possible methods of exciting transducer and forming bridge circuit

(b)

Variable-inductance pickup

- To get high sensitivity, high excitation voltage is needed
- High voltage however causes higher power loss due to heating
- Center-tapped transformer circuit is used to solve this problem
- Typical range – 2.5-5000 mm; resolution – infinitesimal; non-linearity – 0.02-1% of full-scale; sensitivity – 0.2-1.5 V/mm
- Rotary versions also available

Differential Transformers

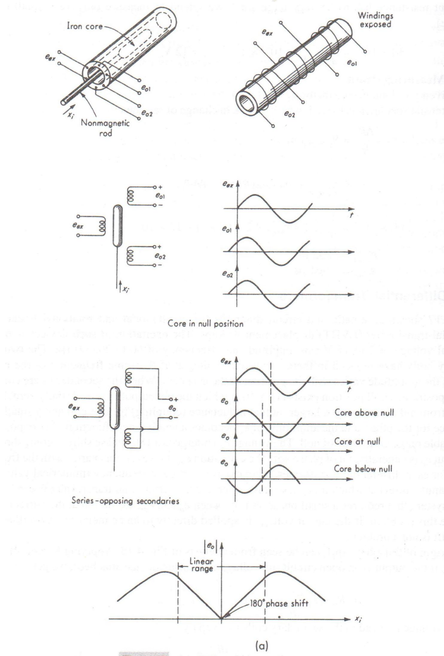


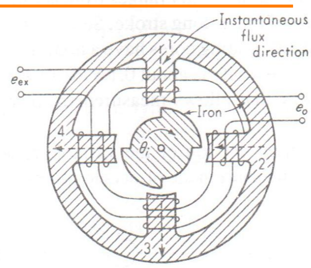
Fig. 4.17 (a) Differential transformer.

Differential Transformers

- Voltage is induced in two identical secondary coils, of the same frequency as excitation (or input)
- The amplitude of induced voltage however varies with the position of the iron core
- The secondary coils are connected in series opposition
- Motion from null position, causes larger inductance for one coil and smaller inductance for the other coil
- Output e_o is out of phase with excitation
- The amplitude e_o is nearly linear over a considerable range on either side of null position
- 180^o phase shift is obtained upon passing through null position

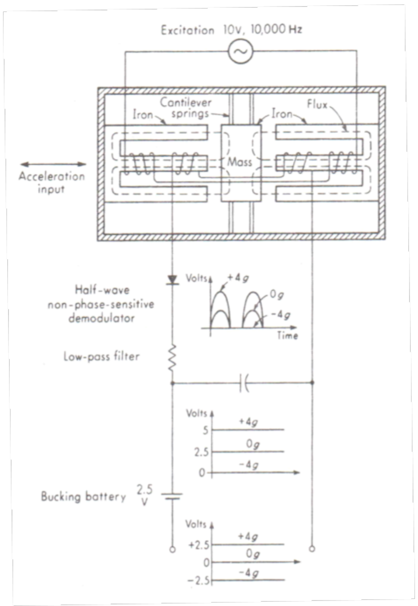
Microsyn

- Based on variable reluctance idea
- Used for measuring rotary motion
- Employed in sensitive gyroscopic instruments
- Motion of shaft induces voltage in coils 1 and 3 (aiding each other) and coils 2 and 4 (which aid each other but oppose 1 and 3)
- Thus a net output voltage is obtained
- Typical values: Sensitivity of 0.2-0.5 V/deg; Non-linearity about 0.5% of full scale; Resolution ~ 0.01 deg



Variable-reluctance accelerometer

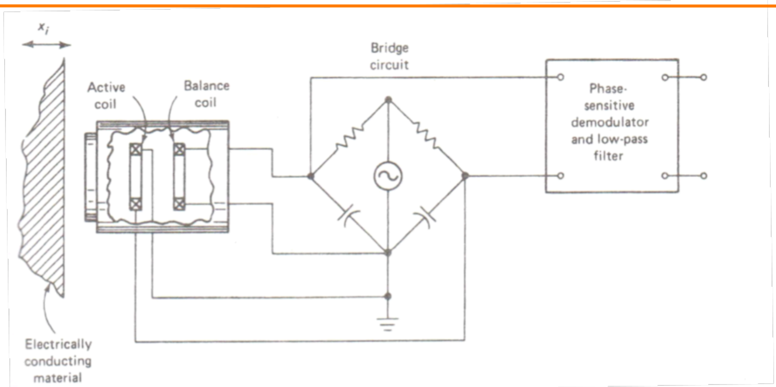
- Here measurement of motion is used to measure acceleration
- Springs supporting the mass deflect in proportion to acceleration



Eddy-current non-contacting transducer

- Here the probe consists of two coils: active (influenced by presence of a conducting target) and second/balance (serves to complete the bridge circuit – also provides temperature compensation)
- Bridge excited at high frequency (~ 1 MHz)
- Magnetic flux lines from the active coil pass into the conductive target, producing eddy currents in the surface (up to a certain depth)

Eddy-current non-contacting transducer



As the target approaches the probe, the eddy currents become stronger – changes the impedance of the active coil and causes a bridge unbalance, which can be related to the target position

Eddy-current non-contacting transducer

- Flat targets, of same diameter as probe or larger are preferred
- Output drops for target size 1/2 of probe diameter
- Curved-surface targets behave as flat surface for shaft-diameter > 4 probe diameter
- Special four-probe systems are available for measuring orbital motions of rotating shafts, and centering and alignment operations

Capacitance Pick-ups

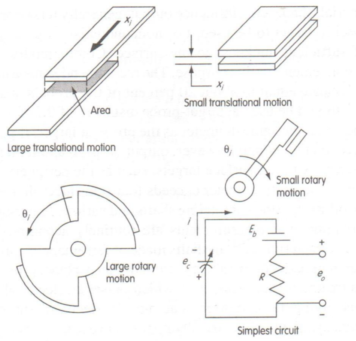


Fig. 4.29 *Principles of capacitive displacement sensing.*

Table 4.1

Configuration	*Range*	*Nominal capacitance*	*Sensitivity*
Long-range linear	10.0 mm	10 pF	0.94 fF/µm
Long-range rotation	1.5 rad	10 pF	6.9 fF/mrad
Short-range linear	100 µm	10 pF	100 fF/µm
Short-range rotation	17 mrad	10 pF	580 fF/mrad

Capacitane Pick-up

- Capacitance is given by: $C = \dfrac{\varepsilon_o \varepsilon_r A}{x}$

  C (capacitance, F), A (plate area, m^2), x (plate separation, m), ε_o is electric constant (8.854 x 10^{-12} F/m), ε_r is relative static permittivity or dielectric constant

- Non-linearity is given by $\eta = \dfrac{\Delta h}{h + \Delta h}$

Example: Capacitance based Transducer

- A capacitance-based displacement transducer of area 200 mm^2 and distance between plates of 5 mm, is filled with air.
- What is the sensitivity of the transducer?
- What is the maximum possible displacement of the plates so that the nonlinearity does not exceed 3%?
- What is the sensitivity if we have the plate of width 14 mm is moving parallel to itself, while maintaining a gap of 5 mm?

Example: Capacitance based Transducer (contd.)

Given: h = 5 mm; w = 14 mm; A = 200 mm^2; ε_0 = 8.85 pF/m; ε_r = 1; η = 3%

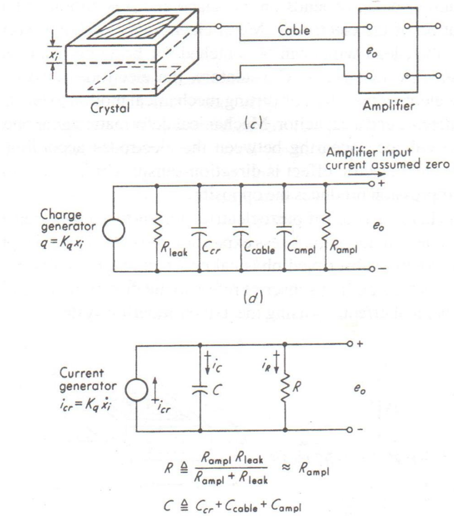
Solution:

- Want sensitivity when plate moved out: $\frac{\Delta C}{\Delta h} = \frac{\varepsilon_o \varepsilon_r A}{h^2}$
- Non-linearity: $\eta = \frac{\Delta h}{h + \Delta h}$
- Want sensitivity when plate moved parallel to itself $\frac{\Delta C}{\Delta A} = \frac{\varepsilon_o \varepsilon_r}{h}; \Delta A = w \Delta l$

Piezoelectric Transducers

- Certain materials (crystal, ceramic or biological matter) generate electric charge within them upon deformation – called *piezoelectric effect*
- The piezoelectric effect is linear and reversible
- The piezoelectric effect is direction sensitive (tension produces certain polarity, compression produces opposite polarity)
- Used in instruments for measuring force, acceleration or pressure
- Material includes:
  - natural crystals (quartz, rochelle salt)
  - synthetic crystals (lithium sulfate, ammonium dihydrogen phosphate)
  - polarized ferroelectric ceramics (barium titanate)
  - some polymer films

Piezoelectric Transducers



Metal electrodes attached on the faces for connecting lead wires

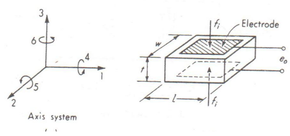
These plates have a capacitance effect

Mechanical effect generates a charge

Piezo-electric element can be thought of as a charge generator and a capacitor

Piezoelectric Transducers (contd.)

- Deformation of the material can occur in many different modes
  - Thickness expansion
  - Transverse expansion
  - Thickness shear
  - Face shear



- The mode of deformation depends on shape and orientation of body relative to crystal axes and location of electrodes
- Two family of constants – *g* constants and *d* constants, are considered
- g_{33} = field produced in direction 3/stress applied in direction 3
- d_{33} = charge generated in direction 3/force applied in direction 3

Homework
(Submit: Tuesday 16/3/21)

- Bring at least 3 examples where the gauges that we have discussed are being used?
- Think of at least one unmet need which can addressed by using one or more of these gauges? Alternatively, come up with an original application for any of the gauges discussed.