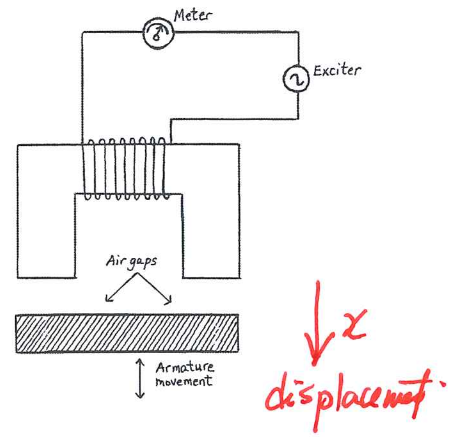
Self-Induction Transducers:

- Unlike mutual-induction transducers, only a single coil is employed.
- This coil is activated by an ac supply voltage V_{ref} of sufficiently high frequency.
- The current produces a magnetic flux, which is linked back with the coil.
- The level of flux linkage (or self-inductance) can be varied by moving a ferromagnetic object within the magnetic field.

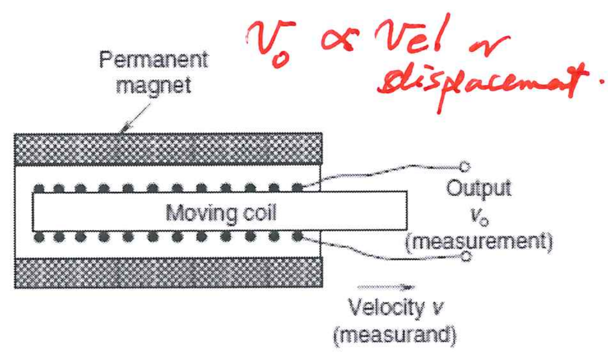


A simple self-inductance arrangement wherein a change in the air gap changes the pickup output.

- This movement changes the reluctance of the flux linkage path and also the inductance in the coil.
- The change in self-inductance, which can be measured using an inductance-measuring circuit represents the measurand (displacement of the object).
- Note that self-induction transducers are usually variable-reluctance devices as well.

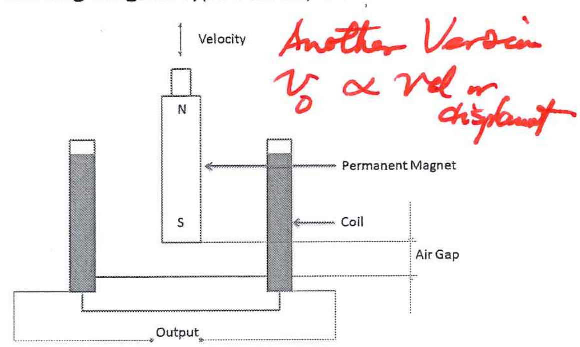
Permanent-Magnet Transducers:

A distinctive feature of permanent magnet transducers is that they have a permanent magnet to generate a uniform and steady magnetic field.



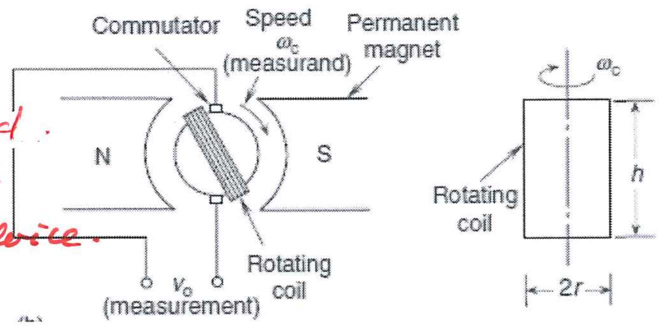
- A relative motion between the magnetic field and an electrical conductor induces a voltage, which is proportional to the speed at which the conductor crosses the magnetic field (i.e., the rate of change of flux linkage).
- In some designs, a unidirectional magnetic field generated by a dc supply (i.e., an electromagnet) is used in place of a permanent magnet.
- Permanent-magnet transducers are not variable-reluctance devices in general.

Moving Magnet Type velocity Transducer



DC Tachometer

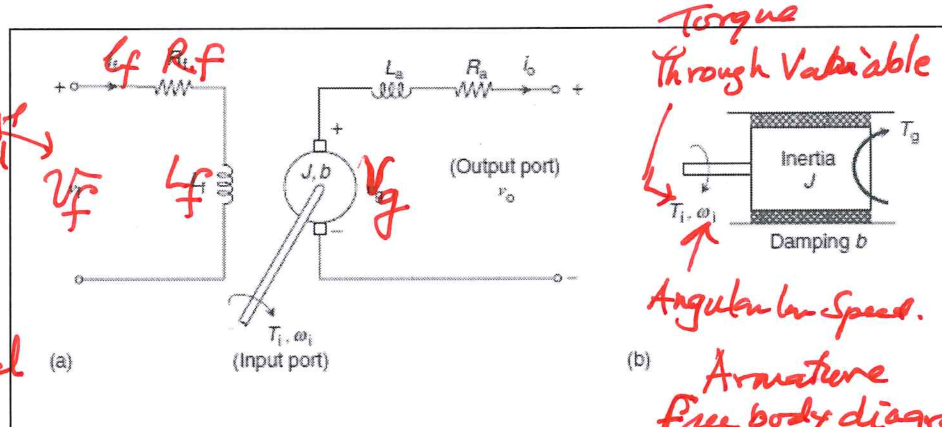
- Measures Angular Velocities
- output signal that is induced in rotating coil is picked up as DC voltage V_o using a Commutator device.



$$V_o = (2nhr\beta)\,\omega_c = k\omega_c$$

Coil turns (n), Coil height (h), Coil width ($2r$), flux density (β), Angular Speed (ω_c), Back emf Constant (k).

Modeling and Design Example:



1. Find Transfer function
2. Assumptions required to decouple this result into practical input/output model for a tachometer.
3. Significance of Mechanical and Electrical Time Constant.

$$v_g = K\omega_i i_f = k\omega_i \Rightarrow v_g = k\omega_i \quad (1)$$

(gen. voltage; constant field current)

$$T_g = k' i_f i_o = K i_o \quad (2)$$

$$v_o = v_g - R_a i_o - L_a \frac{di_o}{dt} \quad (3)$$

(Armature Resistance R_a, Leakage Inductance L_a)

using Newton's Second Law ($F=ma$):

$$J\frac{d\omega_i}{dt} = T_i - T_g - b\omega_i \quad (4)$$

(Armature Inertia J, damping Constant b)

Equation (1) substituted into (3) to eliminate v_g, (2) into (4) to eliminate T_g

Result

$$v_o = k\omega_i - (R_a + sL_a)\,i_o \quad (5)$$

$$(b + sJ)\,\omega_i = T_i - K i_o \quad (6)$$

Note: Laplace Transforms.

i_o in (5) can be eliminate using equation (6)

Finally, i_0 in Equation (5) is eliminated using Equation (6). This gives the matrix transfer function relation:

$$\begin{bmatrix} v_o \\ i_o \end{bmatrix} = \begin{bmatrix} K + (R_a + sL_a)(b + sJ)/K & -(R_a + sL_a)/K \\ -(b + sJ)/K & 1/K \end{bmatrix} \begin{pmatrix} \omega_i \\ T_i \end{pmatrix}.$$

decoupling

$$v_0 = K + \frac{(R_a + sL_a)(b + sJ)}{K}\,\omega_i - \underbrace{\frac{(R_a + sL_a)}{K}}\,T_i$$

* to minimize this K should be Large
⇒ increase # of turns
* Also system will become stable

Electrical terms: $\frac{L_a}{R_a}$

Mechanical terms: $\frac{J}{b}$

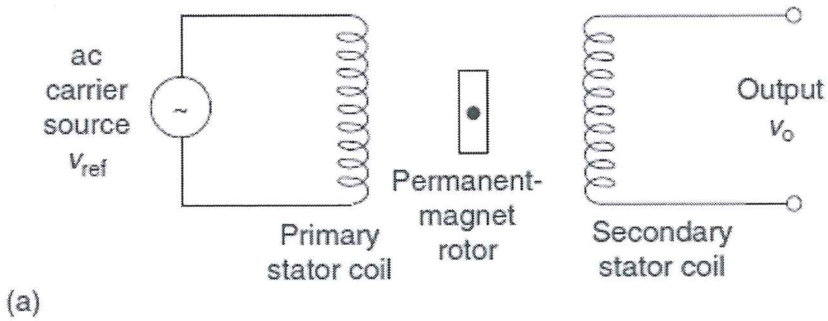
In practical sense $\frac{L_a}{R_a} \ll \frac{J_a}{b}$

Electrical Time constant: $\frac{L_a}{R_a} = \tau_e$

Mechanical Time constant: $\frac{J}{b} = \tau_m$

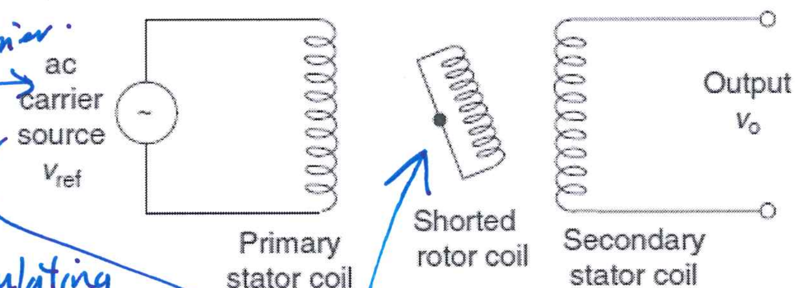
+ * To Reduce τ_m: Decrease Inertia, increase Rotor damping
- * Rotor Inertia ∝ dimensions which determine gain K - Face ↓K
- * Increase b ⇒ Large τ_i for Tachometer, Could Create Loading.
+ * Low K: Reduction of Coupling & Reduction of freq. dep. on system..

Permanent-Magnet AC Tachometer:



- When the rotor is stationary or moving in a quasi-static manner, the output voltage is a constant amplitude signal much like the reference voltage, as in an electrical transformer.
- As the rotor moves at a finite speed, an additional induced voltage, which is proportional to the rotor speed, is generated in the secondary coil.
- This is due to the rate of change of flux linkage into the secondary coil as a result of the rotating magnet. The overall output from the secondary coil is an amplitude-modulated signal whose amplitude is proportional to the rotor speed.
- For transient velocities, it becomes necessary to demodulate this signal in order to extract the transient velocity signal (i.e., the modulating signal) from the overall (modulated) output.
- The direction of velocity is determined from the phase angle of the modulated signal with respect to the carrier signal.

AC Induction Tachometer:



- Primary stator Coil → Carrier. Induces a voltage in Rotor coil. Modulated Signal
- Rotor spin provides modulating signal
- which is ∝ spin (speed of Rotation
- Non-Energized stator: Secondary coil provides o/p of Tachometer.
  $V_o \propto$ stator field & speed of Rotor. coil
- Demodulation required to extract component ∝ angular speed of Rotor.
- No slip rings, no brushes, (No voltage ripple as in DC + Brush Noise.)

Variable-Capacitance Transducers:

Variable-inductance ($j\omega L$) devices and variable-capacitance ($1/j\omega C$) devices are variable-reactance devices.

$L\frac{di}{dt} = v$ and $C\frac{dv}{dt} = i$

Capacitance $= K\frac{A}{x}$; x : gap between plates
K = dielectric constant $= \epsilon = \epsilon_r \cdot \epsilon_0$ (in Vacuum)
A : overlapping Area of Two plates (Fixed & Rotating)
Results in varying ϵ.?

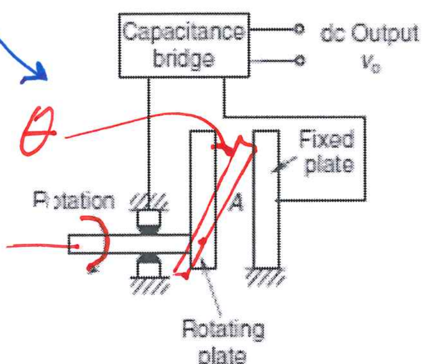
Capacitive Rotation Sensor: (fig a)

1-stationary plate + 1-Rotating plate
$A \propto \theta$; K: Sensor Constant

$C = K\theta$

Sensitivity of this angular displacement sensor is:

$$S = \frac{\partial C}{\partial \theta} = K$$

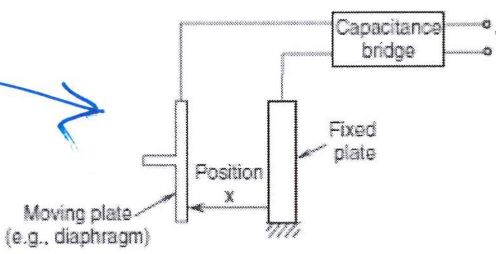


(a)

Capacitive Displacement Sensor: (fig b)

- Sensor for Measuring transverse displacements and proximities
- Cap. Plate attached to Moving plate

Sensor Relation is $C = \frac{K}{x}$

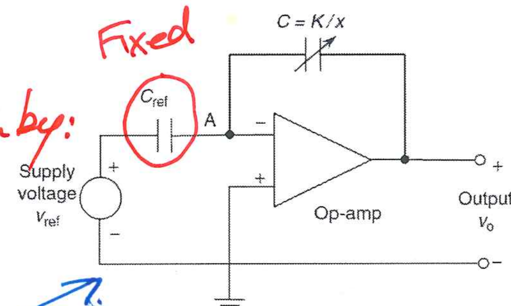


(b)

- Corresponding Sensor Sensitivity is given by:

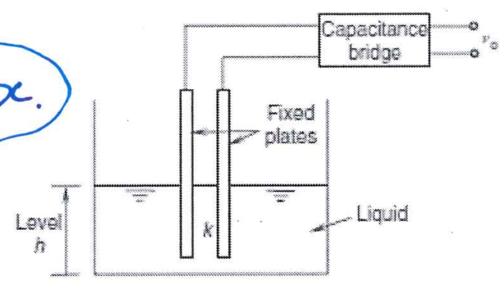
$$S = \frac{\partial C}{\partial x} = -\frac{K}{x^2} \quad \leftarrow \text{NON LINEAR}$$

- To Linearize, use inverting Amp.



Node-A: $v_{ref}\, C_{ref} + v_o C = 0$

$\because C = K/x \therefore$ $\therefore v_0 = -\frac{v_{ref} \cdot C_{ref}}{K}\, x$.



- Solid Di-Electric element, free to Move in Longitudinal direction of Capacitor plates
- Di-Electric Const. changes due to Motion $\therefore$ Level detection.