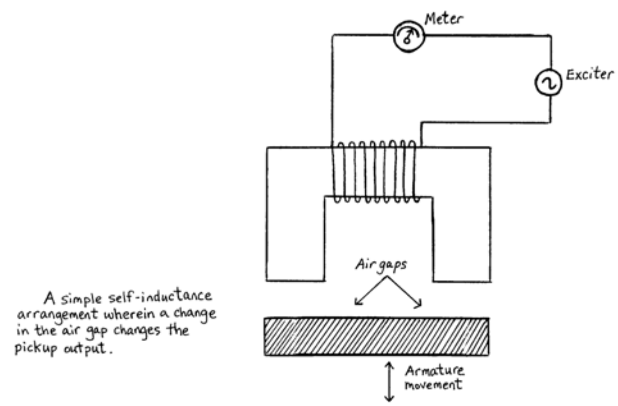
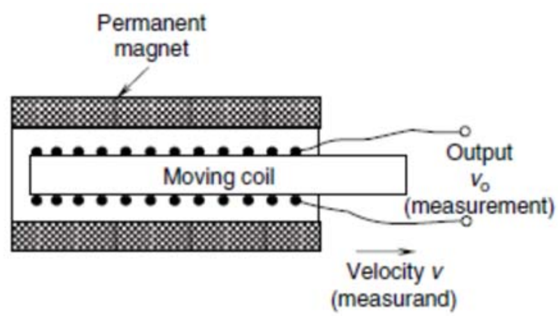
Self-Induction Transducers:

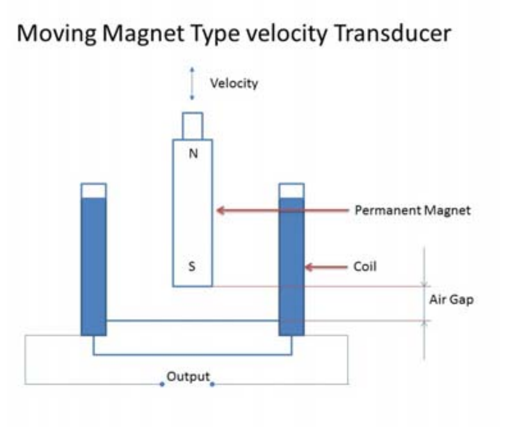


- Unlike mutual-induction transducers, only a single coil is employed.
- This coil is activated by an ac supply voltage V_{ref} of sufficiently high frequency.
- The current produces a magnetic flux, which is linked back with the coil.
- The level of flux linkage (or self-inductance) can be varied by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

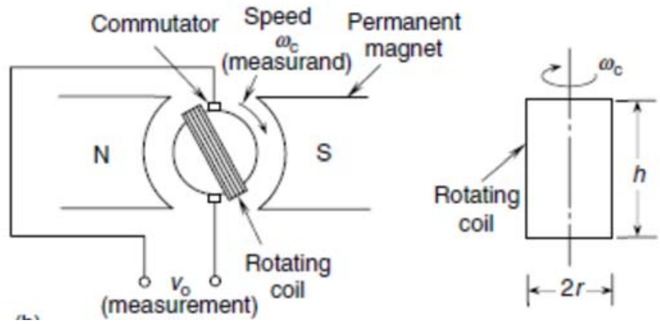


A distinctive feature of permanent magnet transducers is that they have a permanent magnet to generate a uniform and steady magnetic field.

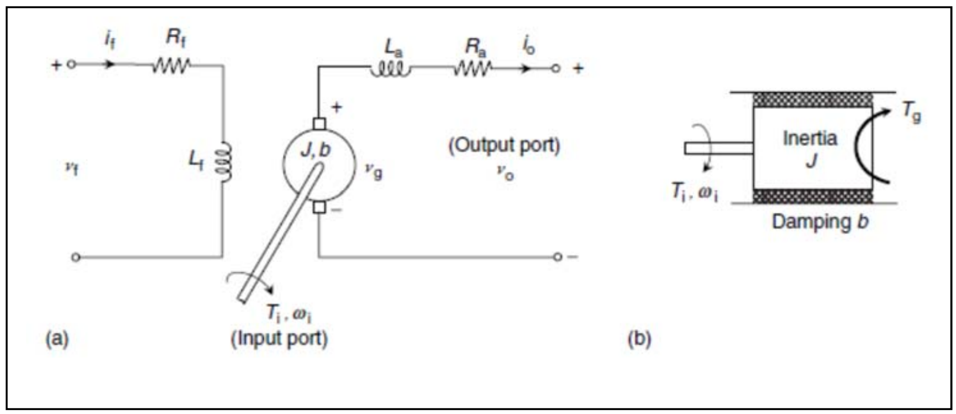


- A relative motion between the magnetic field and an electrical conductor induces a voltage, which is proportional to the speed at which the conductor crosses the magnetic field (i.e., the rate of change of flux linkage).
- In some designs, a unidirectional magnetic field generated by a dc supply (i.e.,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

DC Tachometer



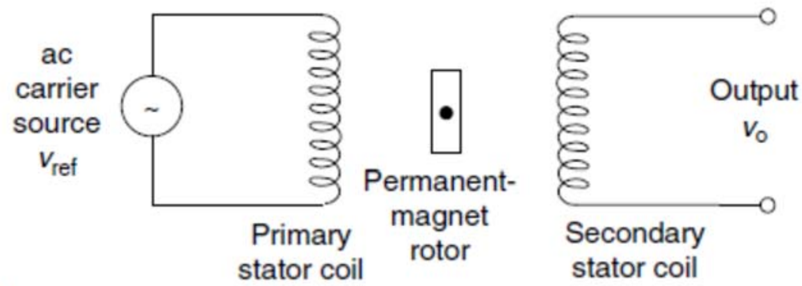
Modeling and Design Example:



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

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

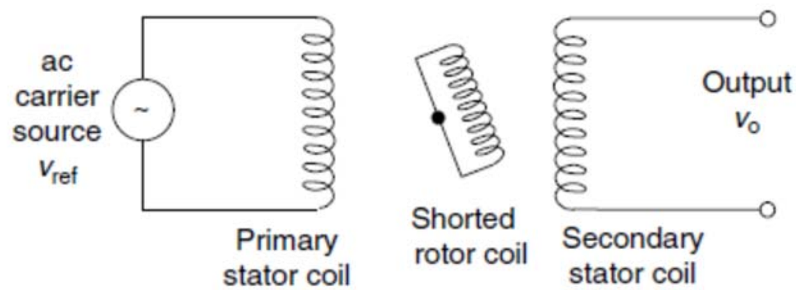
Permanent-Magnet AC Tachometer:



(a)

- 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 is powered by an ac supply which induces a voltage in the rotor coil and it is a modulated signal.
- High frequency (carrier) component of this induced signal is due to the direct transformer action of the primary ac.
- The other (modulating) component is induced by the speed of rotation of the rotor, and its magnitude is proportional to the speed of rotation.
- The non-energized stator (secondary) coil provides the output of the tachometer. This voltage output is a result of both the stator (primary) field and the speed of rotor coil. As a result, the tachometer output has a carrier ac component whose frequency is the same as the primary signal frequency, and a modulating component, which is proportional to the speed of rotation. Demodulation would be needed to extract the component that is proportional to the angular speed of the rotor.

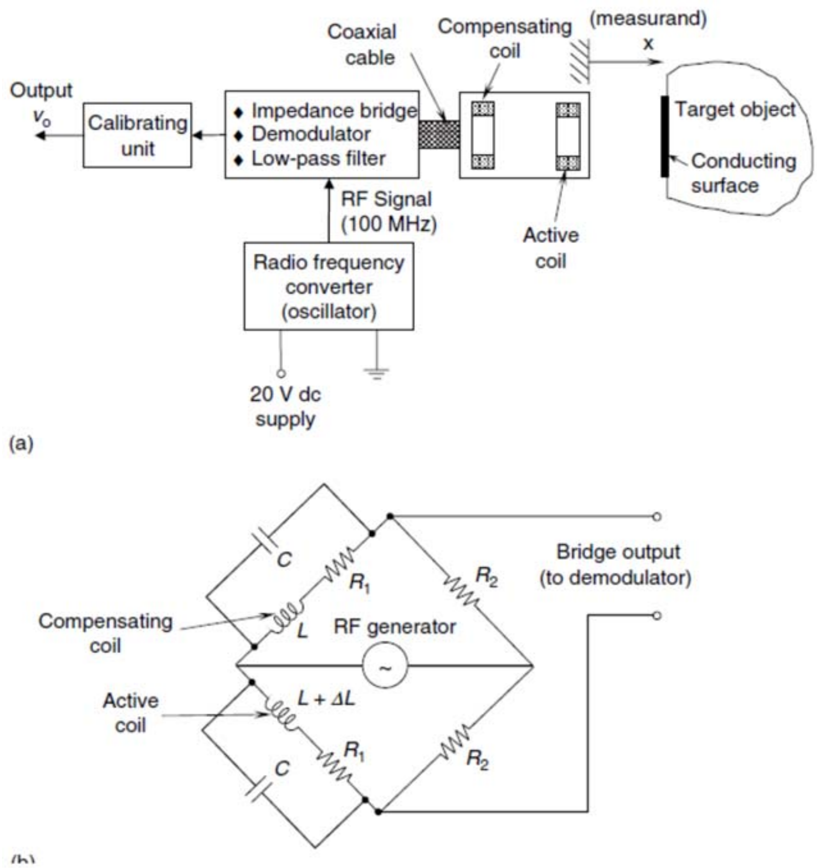
Eddy Current Transducers:

- If a conducting (i.e., low-resistivity) medium is subjected to a fluctuating magnetic field, eddy currents are generated in the medium.

- The strength of eddy currents increases with the strength of the magnetic field and the frequency of the magnetic flux.

- This principle is used in eddy current proximity sensors.

- When the target object is moved close to the sensor, eddy currents are generated in the conducting medium because of the radio-frequency magnetic flux from the active coil.



- The ***magnetic field of the eddy currents opposes the primary field***, which generates these currents.

- Hence, the ***inductance of the active coil increases***, ***creating an imbalance in the bridge***. The resulting ***output from the bridge is an amplitude-modulated signal containing the radio-frequency carrier***. This signal can be demodulated by removing the carrier.

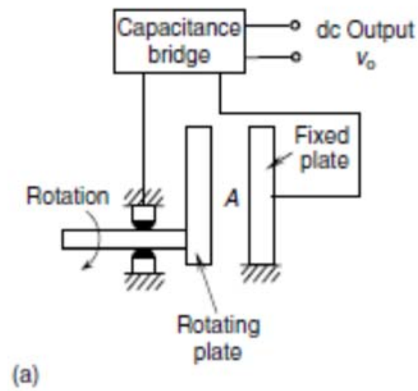
- The resulting signal (modulating signal) measures transient displacement of the target object.

-------End – of – Inductive- Sensors ----

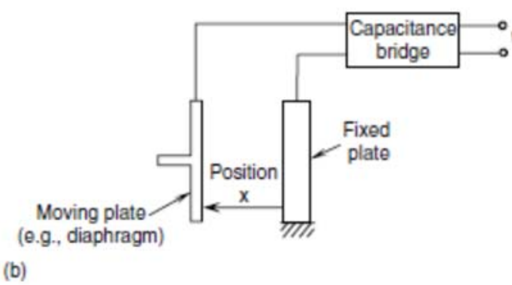
Variable-Capacitance Transducers:

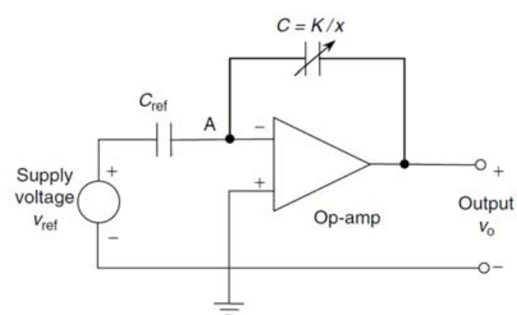
Variable-inductance devices and variable-capacitance devices are variable-reactance devices.

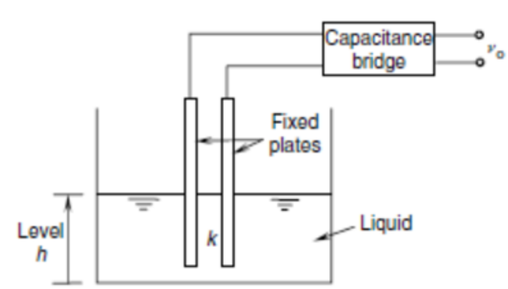
Capacitive Rotation Sensor:



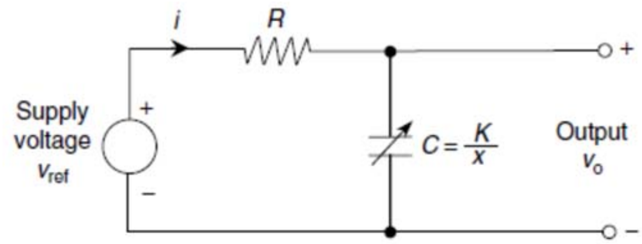
Capacitive Displacement Sensor:



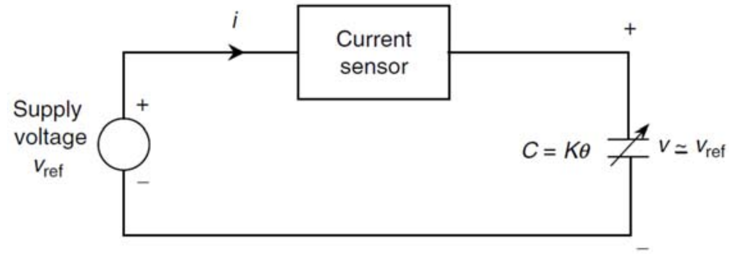




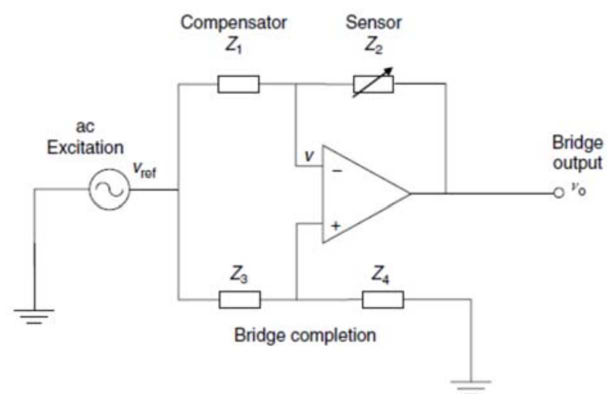
Example:
Consider the circuit shown, examine how this arrangement could be used to measure displacements.



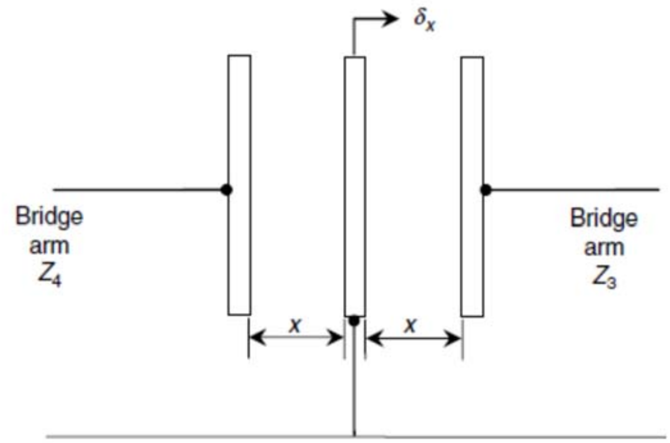
Capacitive Angular Velocity Sensor:



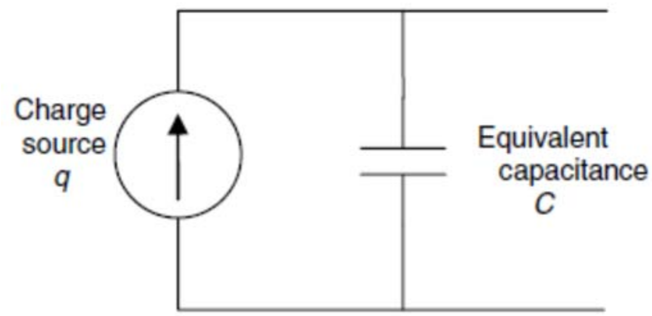
Capacitive-Bridge Circuit:

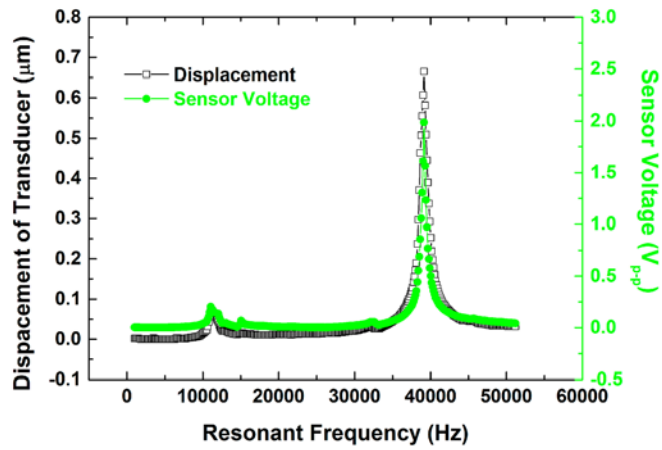


Differential (Push–Pull) Displacement Sensor:

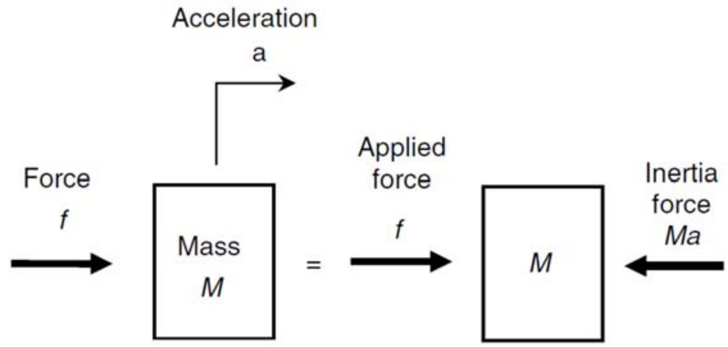


Piezoelectric Sensors:
Some substances, such as barium titanate, single-crystal quartz, and lead zirconatetitanate (PZT) ***can generate an electrical charge and an associated potential difference when they are subjected to mechanical stress or strain***. This piezoelectric effect is used in piezoelectric transducers.



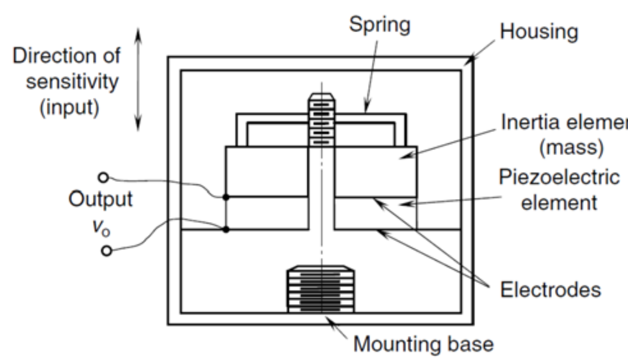


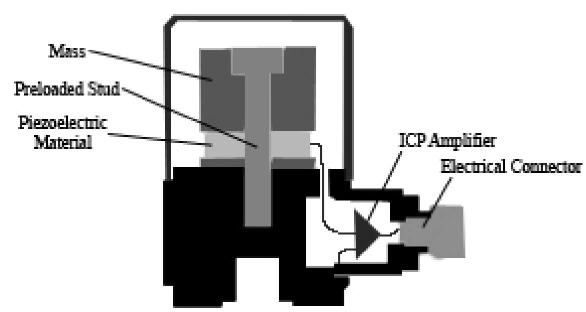
Accelerometers:



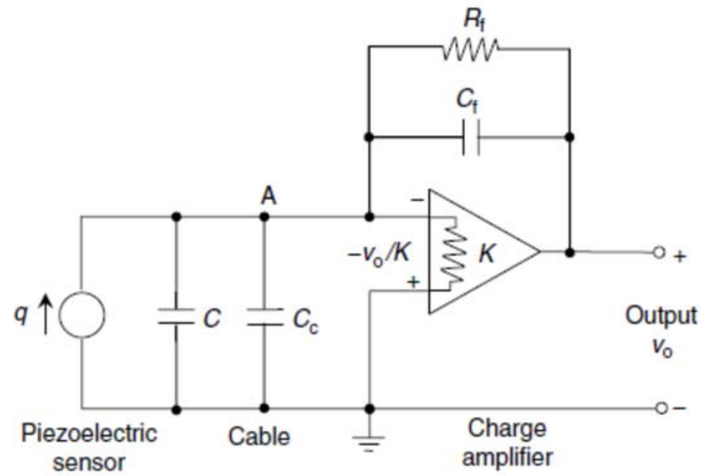
Piezoelectric Accelerometer:

A piezoelectric velocity transducer is simply a piezoelectric accelerometer with a built-in integrating amplifier in the form of a miniature integrated circuit.





Charge Amplifier:



Piezoelectric signals cannot be read using low-impedance devices. The two primary reasons for this are:

1. High output impedance in the sensor results in small output signal levels and large loading errors.
2. The charge can quickly leak out through the load.

A charge amplifier is commonly used as the signal-conditioning device for piezoelectric sensors, in order to overcome these problems to a great extent.

- Because of impedance transformation, the impedance at the ***output of the charge amplifier becomes much smaller than the output impedance of the piezoelectric sensor***. This virtually eliminates loading error and provides a low-impedance output for purposes such as signal communication, acquisition, recording, processing, and control.
- Also, by using a charge amplifier circuit with a ***relatively large time constant, the speed of charge leakage can be decreased***.

For example, consider a piezoelectric sensor and charge amplifier combination, as represented by the circuit above. Let us examine how the rate of charge leakage is reduced by using this arrangement.

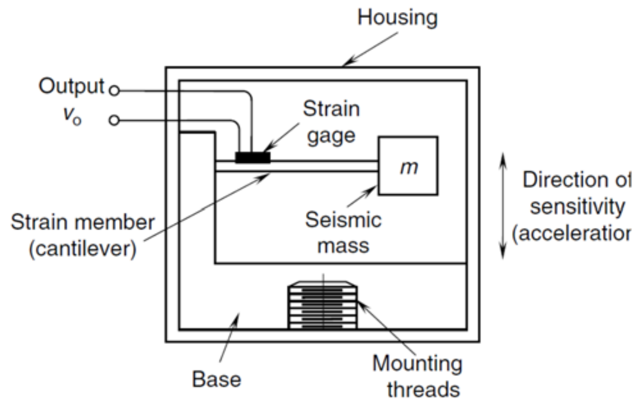
Strain Gages:

- Many types of force and torque sensors are based on strain-gage measurements.
- Although strain gages measure strain, the measurements can be directly related to stress and force. Therefore, it is appropriate to discuss strain gages under force and torque sensors.
- Note, however, that strain gages may be used in a somewhat indirect manner (using auxiliary front-end elements) to measure other types of variables, including displacement, acceleration, pressure, and temperature.

Equations for Strain-Gage Measurements:

Examples:

- Acceleration may be measured by first converting it into an inertia force of a suitable mass (seismic mass) element, then subjecting a cantilever (strain member) to that inertia force and, finally, measuring the strain at a high-sensitivity location of the cantilever element.



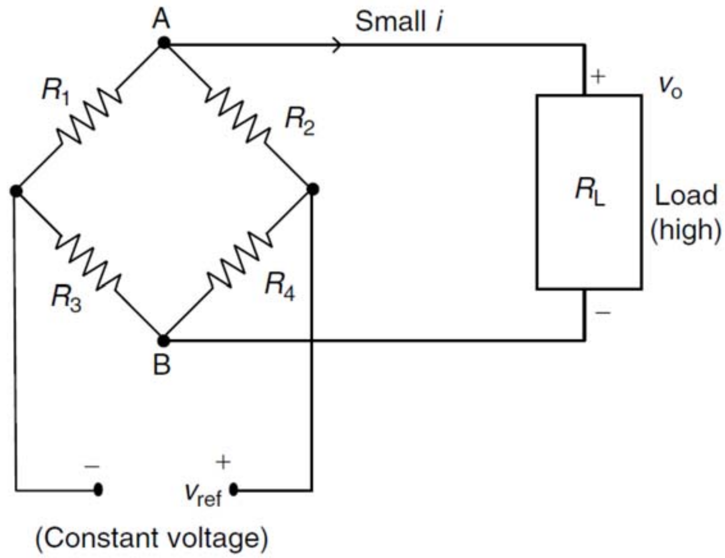
- Temperature may be measured by measuring the thermal expansion or deformation in a bimetallic element.
- Thermistors are temperature sensors made of semiconductor material whose resistance changes with temperature. Resistance temperature detectors (RTDs) operate by the same principle, except that they are made of metals, not of semiconductor material.
- Note that these temperature sensors, and the piezoelectric sensors, should not be confused with strain gages.
- Resistance strain gages are based on resistance change as a result of strain, or the piezo-resistive property of materials.

A direct way to obtain strain-gage measurement is:

- To apply a constant dc voltage across a series-connected pair of strain-gage element (of resistance R) and a suitable (complementary) resistor R_c, and
- To measure the output voltage V_0 across the strain gage under open-circuit conditions (using a voltmeter with high input impedance).
- It is known as a potentiometer circuit or ballast circuit.

Bridge Sensitivity:

- Strain-gage measurements are calibrated with respect to a balanced bridge.
- When the strain gages in the bridge deform, the balance is upset.
- If one of the arms of the bridge has a variable resistor, it can be changed to restore balance.
- The amount of this change measures the amount by which the resistance of the strain gages changed, thereby measuring the applied strain.
- This is known as the *null-balance method* of strain measurement.



The Bridge Constant and the Calibration Constant:

If more than one strain-gage is active, the bridge output may be expressed as: