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Sensors, actuators and displays

Objectives

To review the construction and operation of
1. mechanical sensors
   - the strain gauge and its use in bridge circuits
   - capacitance transducers
   - the linear variable differential transformer
   - the synchro and resolver
2. temperature sensors
   - resistance temperature detectors
   - the thermistor
   - the thermocouple
   - semiconductor sensing devices
3. radiation detectors
   - the pyrometer
   - optical sensors
   - sonic transducers
   - nuclear radiation sensors
4. chemical activity detectors
   - the pH probe
   - gas sensors
5. output actuators
   - relays
   - stepper motors
6. displays
   - light-emitting diodes
   - liquid crystal displays

In this chapter we look at some of the numerous types of transducer which are commonly available. As a first step we have already differentiated between input and output transducers and we now further subdivide, but still in broad terms. Input transducers, or sensors, can be grouped according to the physical quantities that are to be detected and, in many cases, quantified. The main categories are:

1. mechanical sensors for force, pressure, position, proximity, displacement, velocity, acceleration, vibration and shock;
2. sensors for temperature;
3. radiation detection;
4. chemical activity.
Output transducers are grouped according to their purpose:

1. actuators for control;
2. displays for information.

**Mechanical sensing**

When one considers the demand for weighing and pressure sensing in modern equipment, it is not surprising that force sensors are probably the most common of transducers, and almost all sensors designed to detect and measure force rely upon the transformation of the force into the deformation of an elastic medium. For example, the application of a longitudinal force to a steel rod will result in an extension of that rod by an amount

\[ \Delta x = \frac{E \Delta F}{A} \]

where \( E \) is Young's modulus for the rod material, \( F/A \) is the applied force per unit area, i.e. the stress, and \( X \) is the original length of the rod.

Provided that the force applied is not so great that the rod is permanently deformed, then the above expression applies and the extension, \( \Delta x \), bears a linear relationship to the applied force. The variable to be measured now becomes a more tangible physical displacement, or strain, where strain is defined as the change in length per unit length.

Thus

\[ \frac{\Delta x}{X} = \frac{E F}{A} \]

or

\[ \text{strain} = \text{Young's modulus} \times \text{stress} \]

**The strain gauge**

First developed in the USA in the late 1930s, the strain gauge is now the most widely used device for the measurement of force. It consists of a resistive material, initially a length of fine wire but now usually a metal foil, only a few microns in thickness, made by etching a grid pattern in copper-nickel or chrome-nickel (Fig. 2.1). The foil can be produced in many sizes

Micrometres are also known as 'microns'.

![Fig. 2.1 The strain gauge; these are commonly fabricated on a polyester film which is then glued to the specimen under test](image)