Displacement, Proximity and Position sensors

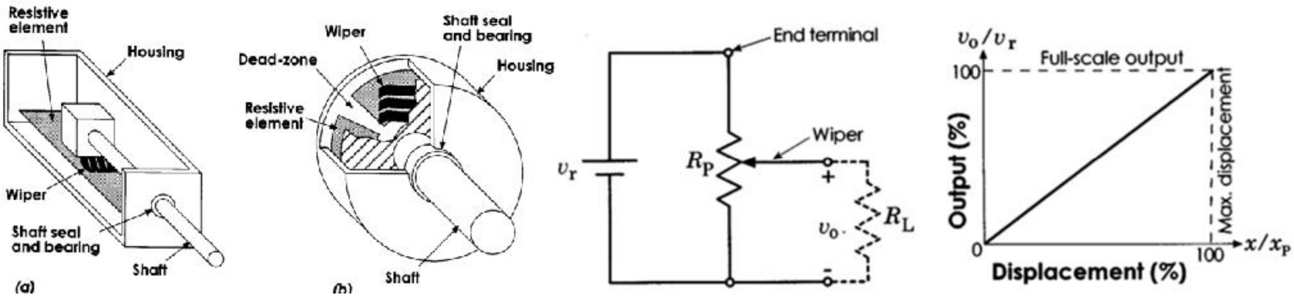
Position means the determination of the object's coordinates (linear or angular) with respect to a selected reference. Displacement means moving from one position to another for a specific distance or angle. In other words, a displacement is measured when an object is referenced to its own prior position rather than to another reference.

A critical distance is measured by proximity sensors. In effect, a proximity sensor is a threshold version of a position detector.

1. Resistive Displacement Sensors

1.1 Potentiometers

Resistive displacement sensors are commonly termed potentiometers or "pots." A pot is an electromechanical device containing an electrically conductive wiper that slides against a fixed according to the position or angle of an external shaft.



To measure displacement, a pot is typically wired in a "voltage divider" configuration. The circuit's output, a function of the wiper's position is an analog voltage available for direct use or digitization. Calibration maps the output voltage to units of displacement

Rotary pots Linear pots String pots



Pots are available in great variety, with specific kinds optimized for specific applications. Position measurement requires a high-quality pot designed for extended operation and these pots are qualified as precision potentiometers. Precision pots are available in rotary, linear-motion and string pot forms.

- String pot: measure the extended length of a spring-loaded cable. String pots are available with maximum extensions exceeding 50 m
- Rotary pots are available with single- or multiturn abilities: commonly 3, 5, or 10 turns.
- Linear-motion pots are available with maximum strokes ranging from roughly 5 mm to over 4 m

A pot's resistive element can be classified as either wirewound or nonwirewound.

Wirewound elements contain tight coils of resistive wire that quantize measurement in step-like increments.

In contrast, nonwirewound elements present a continuous sheet of resistive material capable of essentially unlimited measurement resolution

- Wirewound elements offer excellent temperature stability and high power dissipation abilities. The coils quantize measurement according to wire size and spacing. Providing the resolution limits are acceptable, wirewound elements can be a satisfactory choice for precision measurement; however, conductive plastic or hybrid elements will usually perform better and for considerably more cycles.
- Conductive plastic elements feature a smooth film with unlimited resolution, low friction, low noise,and long operational life. They are sensitive to temperature and other environmental factors and their power dissipation abilities are low; however, they are an excellent choice for precision measurements
- Hybrid elements feature a wirewound core with a conductive plastic coating, combining wirewound and conductive plastic technologies to realize some of the more desirable attributes of both. The plastic limits power dissipation abilities in exchange for low noise, long life, and unlimited resolution. Like wirewounds, hybrids offer excellent temperature stability.

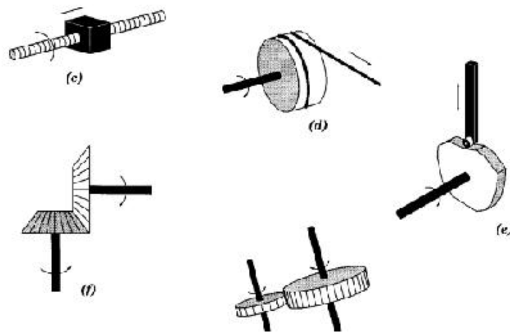
Electrical loading:

Use a regulated voltage source whose output is stable with load variations

Use high input-impedance signal conditioning or data acquisition circuitry
Use only a portion of the pot's full travel
Wirewound pots possess the lowest temperature coefficients. Temperature-compensating signal-conditioning circuitry can also be used.
Pots can operate using either a dc or an ac voltage source. However, wirewound pots are susceptible to capacitive and inductive effects that can be substantial at moderate to high frequencies
To measure displacement, a pot must attach to mechanical fixtures and components. The housing typically mounts to a stationary reference frame, while the shaft couples to a moving element. The input motion (i.e., the motion of interest) can couple directly or indirectly to the pot's shaft.
<u>Direct Coupling</u>

- The input motion maps 1:1 to the shaft motion
- The input motion cannot exceed the pot's mechanical travel limits
- Angle measurement requires a rotary pot; position measurement requires a linear-motion pot
- The pot must mount close to the motion source
- The input motion must be near-perfectly collinear or coaxial with the shaft axis

Mechanisms with a mechanical advantage scale motion and adjust travel limits. Mechanisms that convert between linear and rotary motion enable any type of pot to measure any kind of motion. Transmission mechanisms distance a pot from the measured motion. Compliant mechanisms compensate for misalignment.



Gears scale the mapping between input and pot shaft motions according to gear ratio. They also displace rotation axes to a parallel or perpendicular plane according to type of gear (e.g., spur vs. bevel). Gears introduce backlash. Friction rollers are a variation on the gear theme, immune to backlash but prone to slippage. The ratio of roller diameters scales the mapping between input and pot shaft motions.
Rack-and-pinion mechanisms convert between linear and rotary motion. Mapping is determined by the rack's linear pitch (i.e., tooth-to-tooth spacing) compared to the number of teeth on the pinion. Backlash is inevitable.
Lead-screws convert rotary motion to linear motion via the screw principle. Certain low-friction types (e.g., ball-screws) are also capable of the reverse transformation (i.e., linear to rotary). Either way, mapping is controlled by the screw's lead the distance the nut travels in one revolution. Lead-screws are subject to backlash
Cabled drums convert between linear and rotary motion according to the drum circumference, since one turn of diameter D wraps or unwraps a length πD of cable. An external force (e.g., supplied by a spring or a weight) might be necessary to maintain cable tension.
Pulleys and belts transmit rotary motion scaled according to relative pulley diameters. The belt converts between linear and rotary motion. (See Figure 6.6(a)) The empty area between pulleys provides a convenient passageway for other components. Sprocket wheels and chain have similar characteristics. Matched pulley-belt systems are available that operate with negligible slip, backlash, and stretch.
Cams map rotary motion into linear motion according to the function "programmed" into the cam profile.
Linkages can be designed to convert, scale, and transmit motion. Design and analysis can be quite complex and mapping characteristics tend to be highly nonlinear.
Conduit, like a bicycle brake cable or Bowden cable, can route a cable over an arbitrary path to connect a pot to a remote motion source. The conduit should be incompressible and fixed at both ends. Mapping is 1:1 with some mechanical slop. Lubrication helps mitigate friction.
A mechanism's mapping characteristics impact measurement resolution and accuracy.
The pot's shaft type and bearings must be taken into consideration and protected against excessive loading.
A good design will:

- Give the pot mount the ability to accommodate minor misalignment

- Protect the shaft from thrust, side, and bending loads (i.e., not use the pot as a bearing)
- Provide hard limit stops within the pot’s travel range (i.e., not use the pot’s limit stops)
- Protect the pot from contaminants
- Strain-relieve the pot’s electrical connections