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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VII Semester

AU3008 Sensors and Actuators

UNIT – 2 - Variable Resistance and Inductance Sensors

2.1 Resistive Potentiometer

Principle of operation- Construction details- Characteristics and applications of resistive potentiometer

2.1.1 Basic Principle:

- Resistance variation type transducers is one of the important group of transducers that are quite popular, simple and versatile.
- Many system variables like displacement, acceleration vibration, force, pressure, temperature, humidity, sound level, light intensity etc. can be transduced using this category of transducers.
- The basic principle of this kind of transducer is very simple. Resistance of a conducting wire is given by the expression

$$R = \frac{\rho l}{a}$$

Where,' **ρ'** is the specific resistance of the material of the wire, **'l'** is the length of the wire and **'a**' is the area of cross section of the wire.

- Any stimulus or measurand or a variable which changes or affects any one of the quantities like l, a or ρ, the resistance of the wire is changed. This change in resistance can -be suitably converted by a electrical circuitry to a change in voltage. Thus a transducer is obtained.

2.1.2 Potentiometer:

- A resistive potentiometer is a resistive wire wound on a former provided with a sliding contact and excited with a d.c. voltage source or an a.c. voltage source.
- The movement of the slider can be ***translational***, ***rotational*** or a ***combination of these two***, like, helical motion, permitting measurement of linear or rotational motion or a combination of both.
- It may be noted here that this term potentiometer has a slightly different description in Electrical measurement and electronic circuits.
- In electrical measurements, standard potentiometers are used to measure the unknown voltage by comparing it with a standard known voltage.
- In electronic circuits the potentiometer is used to denote a resistance whose value can be changed by a slide wire, i.e. the voltage source is not included.

2.1.2.1 Construction of Potentiometer:

- The potentiometer is three terminals device connected to a sliding electrical contact. If only two terminals are used it acts as a variable resistor or rheostat and if three-terminal are used then a voltage divider.
- In this three-terminal device one end is called an end terminal and the other two ends are main terminals that are internally connected together. The resistance between the main terminal remains constant and the end terminal's resistance can be adjusted with a sliding contact that moves along an axis between the main terminals.

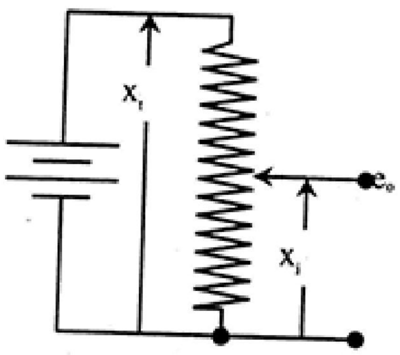


Fig. 2.1 a Linear potentiometer

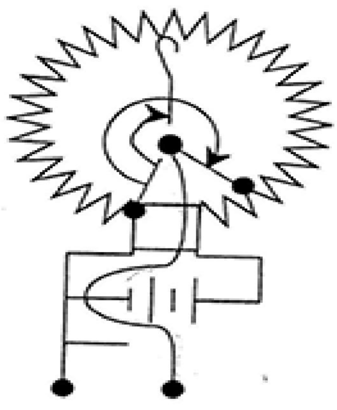


Fig. 2.1 b Rotary potentiometer

- The moving contact may be a conductive element, or, more commonly, a strip of semiconductor. The material and the dimensions determine how much resistance will be presented by the device.

A potentiometer is typically constructed using the following components:

1. **Resistive Element:** This is the core of the potentiometer, providing the electrical resistance. Common materials for the resistive element include:
   - **Carbon:** Offers a wide range of resistance values but may be susceptible to noise and temperature variations.
   - **Metal:** Provides a more stable and precise resistance, but can be more expensive.
   - **Cermet:** A combination of ceramic and metal, offering a balance between stability and cost.
2. **Wiper:** This is a sliding contact that moves along the resistive element, changing the resistance between the wiper and one of the fixed terminals. The wiper is often made of metal or conductive carbon.
3. **Terminals:** These are the fixed points on the resistive element where electrical connections are made. They are typically made of metal.
4. **Enclosure:** The potentiometer may be enclosed in a plastic or metal case to protect it from damage and environmental factors.

Construction Process:

1. **Resistive Element:** The resistive element is manufactured using a suitable process, such as sintering for carbon or metal, or deposition for cermet.
2. **Wiper:** The wiper is attached to a mechanical mechanism that allows it to slide or rotate along the resistive element.
3. **Terminals:** The terminals are connected to the resistive element and the wiper.
4. **Enclosure:** The potentiometer is enclosed in a case, if necessary.

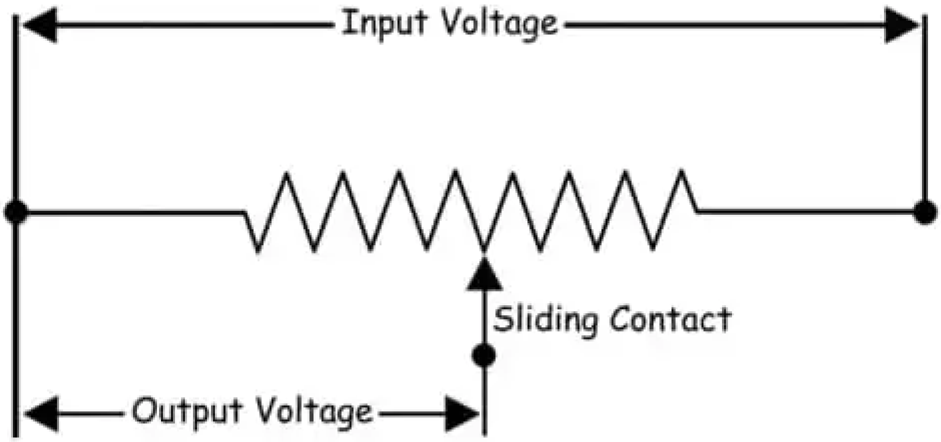
Output voltage $e_0 = \frac{x_i}{x_t} e_i$

- where e_i is the excitation voltage, x_i is the input displacement and x_t is the total length of travel of the sliding contact. The total resistance of the potentiometer is taken as R_p. Therefore, the resistance corresponding to X_i and x_t will be R_{xi} and R_p respectively.
- For the rotary potentiometer

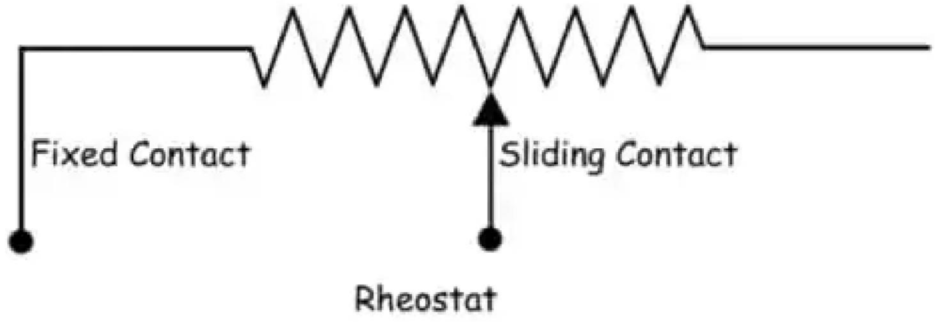
Output voltage $$e_0 = \frac{\theta_i}{\theta_t}\, e_i$$

In many rotary potentiometers θ_t is 350° or 1.95 radian. It can be 360° also.

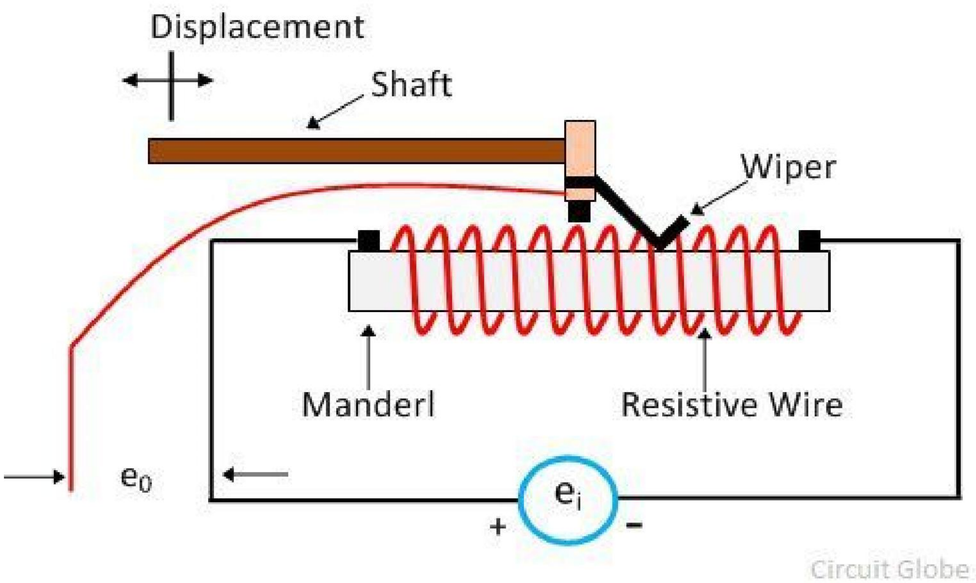
2.1.3 Working of Potentiometer:



- A potentiometer is a passive electronic component. Potentiometers work by varying the position of a sliding contact across a uniform resistance. In a potentiometer, the entire input voltage is applied across the whole length of the resistor, and the output voltage is the voltage drop between the fixed and sliding contact as shown.
- A potentiometer has the two terminals of the input source fixed to the end of the resistor. To adjust the output voltage the sliding contact gets moved along the resistor on the output side. This differs from a rheostat, where one end is fixed, and the sliding terminal is connected to the circuit.



- Here two ends of a straight resistor are connected across the source voltage. A sliding contact can be slide on the resistor through a track attached along with the resistor.
- The terminal connected to the sliding is connected to one end of the output circuit and one of the terminals of the resistor is connected to the other end of the output circuit.



- Secure one end of the resistive element to the ground.
- Affix the other terminal to the power supply source.
- Connect the wiper side with either an input or output in your circuit layout.

By simply following these steps and rotating its knob multiple times, you can adjust resistance levels as needed.

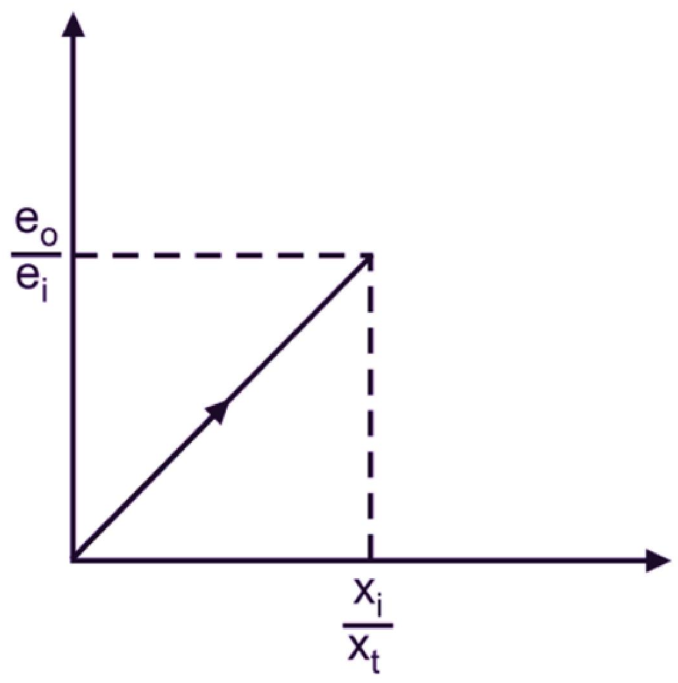
$$e_o = \left(\frac{\text{Resistance of output terminals}}{\text{Resistance of input terminals}}\right) \times \text{Input voltage}$$

$$= \frac{(R/x_t)}{R} \times e_i$$

$$e_o = \frac{x_i}{x_t} \times e_i$$

$$\frac{e_o}{e_i} = \frac{x_i}{x_t}$$

$$x_i = \left(\frac{e_o}{e_i}\right) \times x_t$$



Input – output relationship of Linear Potentiometer

2.1.4 Characteristics of Potentiometer:

a.) Loading effect of potentiometer

The under ideal circumstances, the output voltage varies linearly with displacement as shown in Fig. 2.5(a)

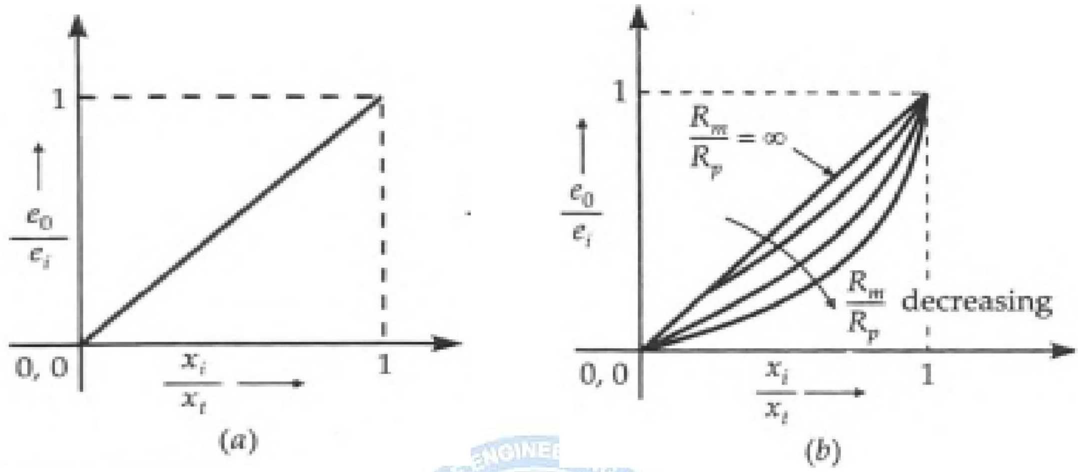


Fig. 2.5 (a) & (b) Loading effect of potentiometer

$$Sensitivity, S = \frac{Output}{input}$$

$$S = \frac{e_0}{x_i} = \frac{e_i}{x_t}$$

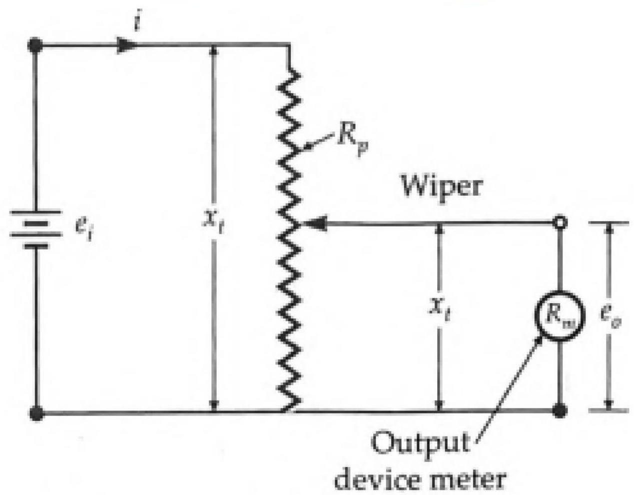


Fig 2.6 Loaded Potentiometer

Thus, under ideal conditions the sensitivity is constant and the output is faithfully reproduced and has a linear relationship with input. The same is true of rotational motion.

For the rotary potentiometer

$$\text{Output voltage } e_0 = \frac{\theta_i}{\theta_t} e_i$$

- However, in practice, the output terminals of the pot are connected to a device whose impedance is finite. Thus, when an electrical instrument, which forms a load for the pot and is connected across the output terminals, the indicated voltage is less than that given by Equation. The error, which is referred to as a ***loading error*** is caused by the input resistance of the output device

- Let us consider the case of a translational potentiometer as shown in Fig. 2.6 Let the resistance of a meter or a recorder monitoring the output be R_m .

- As explained earlier if the resistance across the output terminals is infinite, we get a linear relationship between the output and the input voltage.

$$e_0 = (x_i / x_t) e_i = K e_i$$

$$K = x_i / x_t$$

- However, under actual conditions the resistance, R_m, is not infinite. This causes a non-linear relationship between the output and input voltages.

$$\frac{(x_i / x_t) R_p R_m}{(x_i / x_t) R_p + R_m} = \frac{K\ R_p R_m}{K\ R_p + R_m}$$

- The ratio of output voltage to input voltage under load conditions is

$$\frac{e_0}{e_i} = \frac{K}{K(1-K)(R_p / R_m) + 1}$$

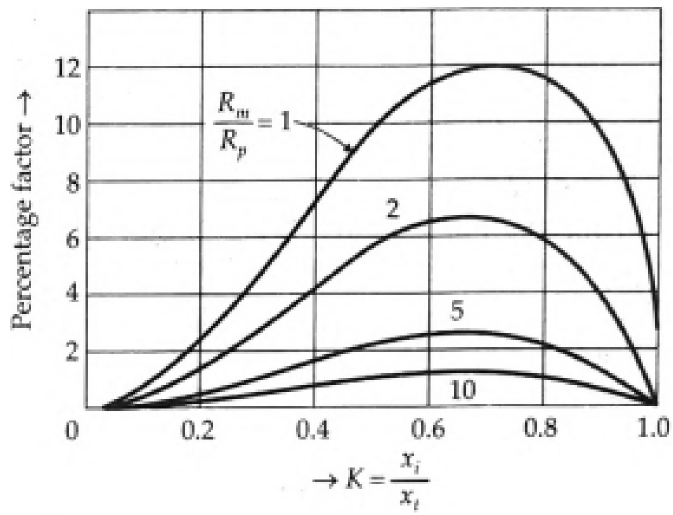


Fig. 2.7 Variation of error due to loading effect of a potentiometer.

If meter resistance were infinite there would be no linearity effects and the output voltage will be a linear function of input displacement x_i.

b.) **Linearity and Sensitivity:**

- It has been explained earlier that in order to achieve a good linearity, the resistance of potentiometer R_p should be as low as possible when using a meter for reading the output voltage which has a fixed value of input resistance R_m.
- In order to get a high sensitivity the output voltage e_0 should be high which in turn requires a high input voltage, e_i.
- Thus linearity and sensitivity are therefore two conflicting requirements. If R_p is made small, the linearity improves, but a low value of R_p , requires a lower input voltage e_i in order to keep down the power dissipation and a low value of e_i results in a lower value of output voltage e_0 resulting in lower sensitivity.
- Thus the choice of potentiometer resistance, R_p, has to be made considering both the linearity and sensitivity and a compromise between the two conflicting requirements has to be struck.

2.1.5 Advantages and Disadvantages of Resistance Potentiometer:

Resistance potentiometers have the following major advantages:

(i) They are inexpensive.

(ii) They are simple to operate and very useful for applications where the requirements are not particularly severe.

(iii) They are very useful for measurement of large amplitudes of displacement.

(iv) Their electrical efficiency is very high and they provide sufficient output to permit control operations without further amplification.

(v) It should be understood that while the frequency response of wire wound potentiometers is limited, the other types of potentiometers are free from this problem.

(vi) In wire wound potentiometers the resolution is limited while in Cermet and metal film potentiometers, the resolution is infinite.

The disadvantages are:

(i) The chief disadvantage of using a linear potentiometer is that they require a large force to move their sliding contacts (wipers).

(ii) The other problems with sliding contacts are that they can be contaminated, can wear out, become misaligned and generate noise. So the life of the transducer is limited. However, recent developments have produced a roller contact wiper which, it is claimed, increases the life of the transducer by 40 times

2.1.6 Applications of Potentiometer:

Common Applications:

- **Volume Control:** In audio systems, potentiometers are used to adjust the volume by varying the resistance in the circuit, thereby controlling the amount of current flowing through the speakers.
- **Light Dimmers:** Potentiometers can be used to dim lights by varying the resistance in the circuit, controlling the amount of current flowing to the light bulb.

- **Position Sensing:** Potentiometers can be used to measure the position of a mechanical component. By attaching the sliding contact to the moving part, the position can be determined based on the resistance measured.
- **Voltage Dividers:** Potentiometers can be used as voltage dividers to create a variable voltage from a fixed voltage source.

❖ **Industrial Controls:**

- ✓ Position sensing
- ✓ Speed control
- ✓ Process control

❖ **Medical Devices:**

- ✓ Patient positioning
- ✓ Therapeutic devices

❖ **Other Applications:**

- ✓ Voltage dividers
- ✓ Rheostats
- ✓ Potentiometric sensors
- ✓ Potentiometers offer versatility and ease of use, making them valuable components in various fields.

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