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DEPARTMENT OF BIOMEDICAL ENGINEERING

III Semester- BM3301 SENSORS AND MEASUREMENTS

UNIT - 2

2.6 Active type: Thermocouple - characteristics.

A thermocouple is a temperature sensor (electrical device) used to measure temperature. It comprises two types of metal which are joined together at one end forming a junction. When the junction is cooled or heated it produces a so-called "temperature-dependent voltage" which is used to measure temperature.

The thermal emf developed in a circuit composed of two dissimilar metals with junctions kept at absolute temperatures T1 and *T2* (with$T_1 > T_2$) may be approximately written as

$$E = a(T_1 - T_2) + b(T_1 - T_2)^2$$

where *a* and *b* are constants whose values depend upon the metals used.

Let $\Delta\theta$ = difference of temperatures of hot and cold junctions in °C = $T_1 - T_2$.

$$\therefore \quad E = a(\Delta\theta) + b(\Delta\theta)^2$$

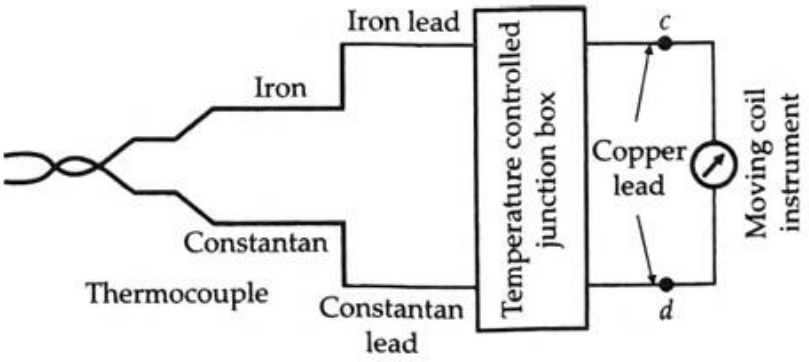
Thus emf of a thermocouple is approximately a parabolic function of the temperature difference between the junctions.

Seebeck Effect:

The Seebeck effect is defined as the generation of an electric potential (or voltage) across two different conductors or semiconductors that are connected in a loop and have a temperature difference between their junctions. The voltage is proportional to the temperature difference and depends on the materials used.

Peltier effect:

When an electric current is passed across a junction between two materials then a temperature difference is created- one junction becomes cooler and one junction becomes hotter. This effect is known as Peltier effect, named after scientist who discovered it.



2.6.1 Measurement of temperature with thermocouple.

Thermocouples are used for measurement of temperature upto 1400°C

2.6.1 Construction of Thermocouples:

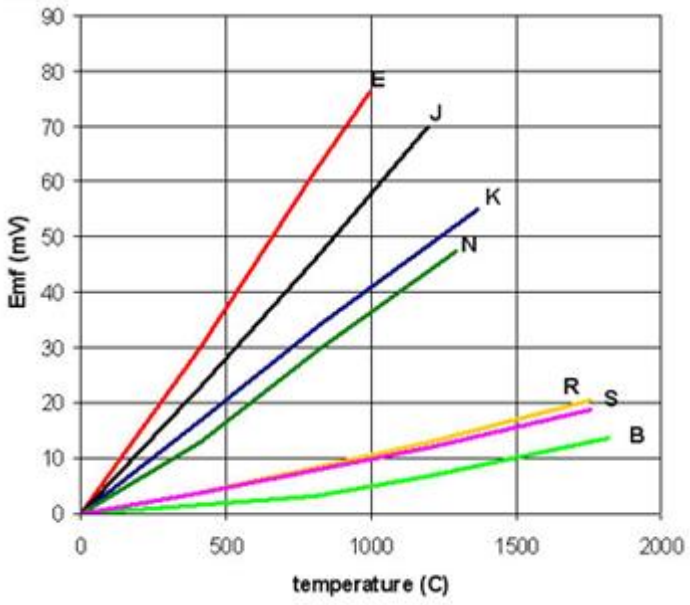
- A pair of two dissimilar metals that are in physical contact with each other form a thermocouple.
- These metals may be twisted, screwed, peened, clamped or welded together.
- The most commonly used method for fabricating is to weld the metals together.
- Industrial thermocouples employ protective sheathing surrounding the junction and a portion of the extension leads.
- The leads and the junction are internally insulated from the sheath.
- Attach the cold junction: The other ends of the thermocouple wires are connected to the measurement or control instrument. This is considered the cold junction.

2.6.1.1 Types of Thermocouple:

Type	Positive wire *characteristic*	Negative wire *characteristic*	Plug	Temp. range
T	Copper (blue) *yellow colored*	Constantan (red) *silver colored*	Blue	−300 to 700 °F
J	Iron (white) *magnetic, rusty?*	Constantan (red) *non-magnetic*	Black	32 to 1400 °F
E	Chromel (violet) *shiny finish*	Constantan (red) *dull finish*	Violet	32 to 1600 °F
K	Chromel (yellow) *non-magnetic*	Alumel (red) *magnetic*	Yellow	32 to 2300 °F
N	Nicrosil (orange)	Nisil (red)	Orange	32 to 2300 °F
S	Pt90% - Rh10% (black)	Platinum (red)	Green	32 to 2700 °F
B	Pt70% - Rh30% (grey)	Pt94% - Rh6% (red)	Grey	32 to 3380 °F

https://instrumentationtools.com/what-is-a-thermocouple/

2.6.2 Characteristics of Thermocouple:



Characteristic functions for thermocouples

- Thermocouples are a common passive sensing element that respond to temperature in a measurable way. They are self-powered, requiring no excitation, and can operate over a wide temperature range (up to to 2000°C).
- The graphs depict the voltage response of various thermocouple types over a range of temperatures.
- **Diameter :** By doubling the diameter of the wire, the life increases by 2-3 times.
- When temperatures near ambient are to be measured with a thermocouple and it is inconvenient to use a fixed reference junction and therefore compensating circuits must be employed in the measuring system.
- In many applications it is desirable to place the reference junction at a point far removed from the measurement junction. The connecting wires from the thermocouple head to the meter are, therefore, very long and are usually not at the same temperature throughout their length. This causes errors, which can be avoided by using connecting wires made of the same material as the thermocouple wires. These wires then called ***Compensating Leads***.

2.6.3 Advantages of Thermocouples:

1. Thermocouples are cheaper than the resistance thermometers.
2. Thermocouples follow the temperature changes with a small-time lag and as such are suitable for recording comparatively rapid changes in temperature.
3. Thermocouples are very convenient for measuring the temperature at one particular point in a piece of apparatus.

2.6.4 Disadvantages :

1. They have a lower accuracy and hence they cannot be used for precision work.
2. To ensure long life of thermocouples in their operating environments, they should be protected in an open or closed-end metal protecting tube or well. To prevent contamination of the thermo-couple, when precious metals like platinum or its alloys are being used, the protecting tube has to be made chemically inert and vacuum tight.

3. The thermocouple is placed remote from measuring devices. Connections are thus made by means of wires called extension wires. Maximum accuracy of measurement is assured only when compensating wires are of the same material as the thermocouple wires. The circuitry is, thus, very complex.

2.6.5 Applications of Thermocouple: :

1. Thermocouples have a wide range of applications across various industries, including:

2. **Temperature measurement in industrial processes:** Thermocouples are commonly used for temperature measurement in a wide range of industrial processes, including metallurgy, power generation, chemical processing, and food processing.
3. **Automotive industry:** Thermocouples are used in automotive engines to monitor temperature and ensure that the engine is operating at the correct temperature range.
4. **Aerospace industry:** Thermocouples are used in aircraft engines, rockets, and space vehicles to monitor temperature and ensure that critical components are not overheating.
5. **Medical equipment:** Thermocouples are used in medical equipment to monitor the temperature of patients during surgery, and to measure the temperature of incubators for new-borns.
6. **Household appliances:** Thermocouples are used in gas-powered household appliances, such as ovens, water heaters, and furnaces, to monitor temperature and ensure safe operation.
7. **Environmental monitoring:** Thermocouples are used in weather stations and environmental monitoring equipment to measure temperature in the air, water, and soil.

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