Thermoelectric Transducers

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### Temperature scales

<table>
<thead>
<tr>
<th>Known Temperature</th>
<th>Fahrenheit</th>
<th>Kelvin</th>
<th>Formulae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celsius</td>
<td>°F</td>
<td></td>
<td>°F = (1.8 X °C) + 32</td>
</tr>
<tr>
<td>Celsius</td>
<td>K</td>
<td></td>
<td>K = °C + 273.15</td>
</tr>
<tr>
<td>Fahrenheit</td>
<td>°C</td>
<td></td>
<td>°F = (°C - 32)/1.8</td>
</tr>
<tr>
<td>Fahrenheit</td>
<td>K</td>
<td></td>
<td>K = °F + 459.67/1.8</td>
</tr>
<tr>
<td>Kelvin</td>
<td>°C</td>
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<td>°C = K-273.15</td>
</tr>
<tr>
<td>Kelvin</td>
<td>°F</td>
<td></td>
<td>°F = (1.8 X K) - 459.67</td>
</tr>
</tbody>
</table>

### Temperature Scale Diagrams

- **Celsius**:
  - Boiling point of water: 100 °C
  - Room temperature: 20 °C
  - Freezing point of water: 0 °C
  - Absolute zero: -273.15 °C

- **Fahrenheit**: Boiling point of water: 212 °F

- **Kelvin**:
  - Boiling point of water: 373.15 K
  - Room temperature: 203.15 K
  - Freezing point of water: 273.15 K
  - Absolute zero: 0 K
• Describe working principle of different types of thermoelectric transducers
• Thermo electric effect
  – Seeback effect
  – Pletier effect
  – Thomson effect
Seeback effect

Fig. 128. Thermoelectric effect in a copper–iron circuit
Peltier

- an effect whereby heat is given out or absorbed when an electric current passes across a junction between two materials.
Thomson effect

- Thomson effect is related to the emf that develops between two parts of the single metal when they are at different temperature.
- Thus thomson effect is the absorption or evolution of heat along a conductor when current passes through it when one end of the conductor is hot and another is cold.
3) Thomson Effect

\[ \tau I \nabla T \equiv \text{Power evolved per unit volume} \]
Thermocouples

- Two wires of different metal alloys.
- Converts thermal energy into electrical energy.
- Requires a temperature difference between measuring junction and reference junction.
- Easy to use and obtain.
Thermocouple extension wires

<table>
<thead>
<tr>
<th>Thermocouple Extension Type</th>
<th>ANSI</th>
<th>BS</th>
<th>DIN</th>
<th>NFC</th>
<th>JIS</th>
<th>IEC</th>
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<td>- Constantan ®</td>
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<tr>
<td>KX  + Chromel ®</td>
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<td>- Constantan ®</td>
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<tr>
<td>EX  + Chromel ®</td>
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<tr>
<td>- Copper-E</td>
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</table>
Thermocouple Applications

- Plastic injection molding machinery
- Food processing equipment
- Deicing
- Semiconductor processing
- Heat treating
- Medical equipment
- Industrial heat treating
- Packaging equipment
Thermocouples

**Advantages**
- Simple, Rugged
- High temperature operation
- Low cost
- No resistance lead wire problems
- Point temperature sensing
- Fastest response to temperature changes

**Disadvantages**
- Least stable, least repeatable
- Low sensitivity to small temperature changes
- Extension wire must be of the same thermocouple type
- Wire may pick up radiated electrical noise if not shielded
- Lowest accuracy
Resistance temperature detectors

- The resistance of most metal increases over limited temperature range in reasonably linear way with temperature

\[ R_t = R_0 (1 + \alpha t) \]

- Where \( R_t \) is resistance at a temperature \( t \)
- \( R_0 \) is resistance at \( t=0 \) and \( \alpha \) a constant for metal termed the temperature coefficient of resistance
- RTDs are simple resistive element in the form of coil of wire of such metals as platinium nickel copper alloys
Resistance Temperature Detectors (RTDs)

- Wire wound and thin film devices.
- Nearly linear over a wide range of temperatures.
- Can be made small enough to have response times of a fraction of a second.
- Require an electrical current to produce a voltage drop across the sensor.

![RTD Resistance Vs Temperature (TCR) Curve](image)

Various RTD Element Styles:

- a. Wire-Wound RTD Element
- b. Thin film RTD Element
- c. Kapton Insulated RTD Element
Construction (cont.)

- **Materials:**
  - **Platinum - used for precision applications**
    - Chemically stable at high temperatures
    - Resists oxidation
    - Can be made into thin wires of high chemical purity
    - Resists corrosion
    - Can withstand severe environmental conditions.
    - Useful to about 800 °C and down to below −250°C.
    - Very sensitive to strain
    - Sensitive to chemical contaminants
    - Wire length needed is long (high conductivity)
RTDs

**Advantages**
- Most stable over time
- Most accurate
- Most repeatable temperature measurement
- Very resistant to contamination/
corrosion of the RTD element

**Disadvantages**
- High cost
- Slowest response time
- Low sensitivity to small temperature changes
- Sensitive to vibration (strains the platinum element wire)
- Decalibration if used beyond sensor’s temperature ratings
- Somewhat fragile
Thermistors

- Are small pieces of materials made from a mixture of metal oxides such as chromium cobalt iron manganese, and nickel.
- Thermistors: **Thermal resistor**
- Became available: early 1960’s
- Based on oxides of semiconductors
  - High temperature coefficients
  - NTC
  - High resistances (typically)
Thermistors

- Most are seen in medical equipment markets.
- Thermistors are also used for engine coolant, oil, and air temperature measurement in the transportation industry.

Construction

- Beads
- Chips
- Deposition on substrate
Thermistors

**Advantages**
- High sensitivity to small temperature changes
- Temperature measurements become more stable with use
- Copper or nickel extension wires can be used

**Disadvantages**
- Limited temperature range
- Fragile
- Some initial accuracy “drift”
- Decalibration if used beyond the sensor’s temperature ratings
- Lack of standards for replacement