Sensor

Sensor characteristics:
- correction required to compensate for non-linearity
- range approx. -200°C .. +650°C
- speed: 0.1s in flowing water .. multiple seconds in still air

Some characteristics of the sensor:
- Thermoresistors: sensor
- Physical coupling: Measuring temperature (thermoelements)

<table>
<thead>
<tr>
<th>Material</th>
<th>Tmax</th>
<th>Uth</th>
<th>K</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu-Constantan</td>
<td>760°C</td>
<td>41.310</td>
<td>10</td>
<td>1.310×10⁻⁶</td>
</tr>
<tr>
<td>Fe-Constantan</td>
<td>720°C</td>
<td>39.720</td>
<td>11</td>
<td>5.37×10⁻⁶</td>
</tr>
<tr>
<td>NiCr-Ni</td>
<td>1000°C</td>
<td>41.310</td>
<td>10</td>
<td>1.310×10⁻⁶</td>
</tr>
<tr>
<td>PdRh-Pt</td>
<td>1300°C</td>
<td>13.138</td>
<td>2</td>
<td>1.0×10⁻⁶</td>
</tr>
<tr>
<td>NiCr-Ni</td>
<td>1000°C</td>
<td>41.310</td>
<td>10</td>
<td>1.310×10⁻⁶</td>
</tr>
</tbody>
</table>

Applications of standard thermocouples
- (TYPE K) Chromel-Alumel thermocouples are suitable for continuous use in oxidizing or inert atmospheres up to 1300°C, or for short-term use in vacuum atmospheres at temperatures up to 1705°C.
- (TYPE J) Iron-Constantan thermocouples are suitable for use in vacuum, oxidizing, reducing or inert atmospheres. Must be protected from sulphurous atmospheres. Very accurate at high temperatures. Virtually the same emf (electromotive force) and range as Type K.
- (TYPE E) Chromel-Alumel thermocouples are suitable for continuous use in oxidizing or inert atmospheres up to 1300°C, or for short-term use in vacuum atmospheres at temperatures up to 1705°C.
- (TYPE N) Nicrosil-Nisil thermocouples are suitable for use in oxidizing inert or dry reducing atmospheres. Suitable for measuring temperatures up to 760°C for largest wire size.

Some observable effects of temperature changes:
- Mean square noise voltage changes
- Volume changes (gas, liquids, metals)
- Thermoelectricity
- Changes in conductors and semiconductors
- State changes: into solid, liquid, or gaseous

First step to embed a system into the real world:
Transform all kinds of physical phenomena into analogue voltages
- e.g. speed, pressure, brightness, loudness, colour, force, humidity, distance, salinity, density, radioactivity, spectrometry, reflectivity, acceleration, deformation, …, or: temperature
...there is a short time delay before the transducer is ready to receive a signal (oscillations need to die away first).

To increase the resolution, the outgoing signals are often modulated.

Signals can be formed and volume measurements are possible.

Range measurements: Ultrasound & Infrared

Method: time of flight - phase correlation

- Resolution (optical, acoustic, electromagnetic)
- Phase correlation (optical, acoustic, electromagnetic)
- Intensity (optical, acoustical)
- Doppler methods (acoustical, electromagnetic)
- Interferometry (optical, electromagnetic)

Non-linear, very poor resolution, if system is not balanced.

More ways to measure temperature:

- Spreading resistors
- Piezos and other temperature sensitive quartz elements
- Temperature controlled current sources (e.g. AD950)
- Mercury filled thermometers
- ...
Speed measurements: Doppler current profilers

Physical effect: Doppler shift frequency $f_d = \frac{\nu}{c} f_s$
with source frequency $f_s$, relative velocity $\nu$ and signal speed $c$.

• common current profiler (SonTek):
  - ping signal: 250 kHz-3 MHz
  - range: up to 160 m; velocity: ±10 m/s
  - resolution: 0.15 - 2 mm/s; 1 mm/s
  - accuracy: ±1%
  - blanking zone: 0.2 - 2.0 m

Physical coupling

- Physical phenomena
- Measuring temperature
  - thermocouples, thermistors
- Measuring range and relative speed
  - triangulation
  - Doppler methods
  - interferometry
- Examples: time-of-flight ultrasound & laser, Doppler current profiler