

A COMPARATIVE STUDY BETWEEN DIFFERENT TYPES OF TEMPERATURE SENSOR

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Abstract- Understanding the characteristics of different types of temperature sensor will enable the user to select the proper temperature sensor for reliable temperature measurement. In this paper, Thermocouple, Thermistor, Resistance temperature detector, Pyrometer and LM35 temperature sensors are evaluated and compared in respect of their advantages and disadvantages based on accuracy, response, range, cost and application areas.

Index Terms- Pyrometer, RTDs, Sensor, Thermocouple, Thermistor.

I. INTRODUCTION

The most basic definition of temperature sensor devices is that they are tools specially designed to measure the hotness or coolness of an object. However, sensors are actually measuring the atomic activity and movement of an object. When temperature sensor devices read an object with zero atomic activity, the temperature point is considered absolute zero. When a substance is heated, it usually moves through several phases: solid to liquid and from liquid to gas until the atomic activity begins increasing. [1]

II. TYPES OF TEMPERATURE SENSOR

THERE ARE TWO BASIC TYPES OF TEMPERATURE SENSORS:

Contact Sensors – This type of sensor requires direct physical contact with the object or media that is being sensed. They supervise the temperature of solids, liquids and gases over a wide range of temperatures.

Non-contact Sensors – This type of sensor does not require any physical contact with the object or media that is being sensed. They supervise non-reflective solids and liquids but are not useful for gases due to natural transparency. These sensors use Plank's Law to measure temperature. This law deals with the heat radiated from the source of heat to measure the temperature [2]

A. Examples of Contact Temperature Sensor

- Thermocouples
- Resistance Temperature Detectors (RTDs)
- Thermistors
- IC Temperature Sensors (LM35)
- Bimetallic etc.

B. Example of Non-contact Temperature sensor

- Optical Pyrometer

III. THERMOCOUPLE

A Thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created. [3]

In 1821 Thomas Johann Seebeck (1770-1831) noticed that, if two wires from different material are connected at their endings performing two different junctions, and these junctions do not have the same temperature, then placing these wires near by a compass, would cause the compass to move. At first he believed that the temperature is the reason to change the magnetic field. Later on, he understood that a current was flowing within the wires that generated a magnetic field and moved the compass. That is called the thermoelectric effect or Seebeck effect. [4]

Figure 1. Shows a Thermocouple circuit

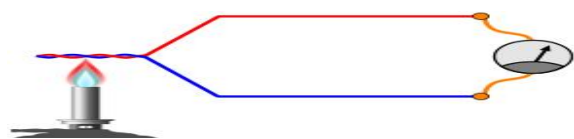


Fig. 1. Thermocouple [4]

C. Advantages

- Self-Powered
- Rugged
- Low cost
- Wide Temperature Range
- High Temperature limits [5]

D. Disadvantages

- Non Linear
- Low Voltage
- Least stable [5]

Thermocouples are made of different types of wire and have very different properties, making one type better for a specific application than another. The descriptions of the types of thermocouples are shown in table 1.

Type	Materials	Min temp	Max temp	Min°C	Max°C
J	Iron Constantan(Cu-Ni)	0°C	750°C	0 mV	42.281 mV
T	Copper Constantan(Cu-Ni)	-250°C	350°C	-6.18 mV	17.819 mV
K	Cromel (Ni-Cr) Alumel (Ni- Al)	-200°C	1250°C	-5.891 mV	50.644 mV
E	Cromel (Ni-Cr) Constantan(Cu-Ni)	-200°C	900°C	-8.825 mV	68.787 mV
N	Nicrosil (Ni-Cr-Si) NiSil (Ni-Si-Mg)	-260°C	1300°C	-4.336 mV	47.513 mV
S	Platinum-13% Rhodium Platinum	-50°C	1768°C	-0.236 mV	18.693 mV
B	Platinum-30% Rhodium Platinum-6% Rhodium	0°C	1820°C	0 mV	13.82 mV
C	Tungsten-5% Rhenium Tungsten-26% Rhenium	0°C	2320°C	0 mV	37.107 mV

Table 1. Description of different types of thermocouple [6]

E. Thermocouples are used in many industrial, scientific, and OEM applications. They can be found in nearly all industrial markets: Power Generation, Oil/Gas, Pharmaceutical, Biotech, Cement, Paper & Pulp, etc. Thermocouples are also used in everyday appliances like stoves, furnaces, and toasters. [3]

IV. THERMISTOR

The **Thermistor** is another type of temperature sensor, whose name is a combination of the words THERM-ally sensitive res-ISTOR. A thermistor is a special type of resistor which changes its physical resistance when exposed to changes in temperature. Most types of thermistor's have a Negative Temperature Coefficient of resistance or (NTC), that is their resistance value goes DOWN with an increase in the temperature, and of course there are some which have a Positive Temperature Coefficient, (PTC), in that their resistance value goes UP with an increase in temperature. [7]



Fig. 2. Thermistors [8]

A. Advantages

- High output
- Fast response

B. Disadvantages

- Fragile
- Current source required
- Self-heating
- Limited temperature range
- Non-linear [10]

C. Applications

- ☐ Textile production
- ☐ Plastics processing
- ☐ Petro-chemical processing
- ☐ Air, gas and liquid temperature measurement [11]

V. RESISTANCE TEMPERATURE DETECTORS

Resistance Temperature Detectors (RTDs) are temperature sensors that contain a resistor that changes resistance value as its temperature changes.

They have been used for many years to measure temperature in laboratory and industrial processes [9]

RTDs are used to measure temperatures from -196° to 482° C (-320° to 900° F) [10]



Fig. 3. Resistance temperature device [7]

A. Advantages

- Most stable
- Most accurate
- More linear than thermocouple [10]

B. Disadvantages

- Expensive
- Less-rugged than thermocouple
- Current source required [10]

C. Applications

- Air conditioning and refrigeration servicing
- Food Processing
- Stoves and grills
- Textile production
- Plastics processing
- Petrochemical processing
- Micro electronics
- Air, gas and liquid temperature measurement
- Exhaust gas temperature measurement [11]

VI. PYROMETER

A pyrometer is used to measure the temperature of an object from a distance, without making contact. The method used for making these non-contacting temperature measurements is known as radiation

pyrometer. Non-contact temperature sensors use the concept of infrared radiant energy to measure the temperature of objects from a distance. After determining the wavelength of the energy being emitted by an object, the sensor can use integrated equations that take into account the body's material and surface qualities to determine its temperature. [12]

A. Advantages

- Hand-held and easy to use
- Very accurate and precise
- Quick (1-2 second) response time
- No contact with target object is necessary
- Excellent for high temperature and moving objects
- Non-contact type
- Can monitor movable object
- Portable [13]

B. Disadvantages

- Not useful for measuring temperature of clear gas
- At high temperature, filament erodes frequently
- Expensive
- Optical pyrometers require an operator for use
- Almost impossible to check error of measurement
- Accuracy easily affected by dust, smoke, and background radiation [13]

C. Applications

Pyrometers are most useful for measuring the temperature of objects that are at high temperature, moving, surrounded by an electromagnetic field, or in a controlled environment. They are commonly used for racecar tires, pottery kilns, steel mills, steam traps, and semiconductors. [13]. Figure 4 shows a pyrometer.



Fig. 4. Pyrometer [15]

VII. IC TEMPERATURE SENSORS (LM35)

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in °C), it is with high

precision and wide linear working range, the output voltage is proportional to temperature, when the temperature increase 1Celsius degree, output voltage increase 10mV. It is commonly used as a temperature measurement sensors. Rated operating temperature range: - 55 ~ + 150 °C.

A. Advantages

- Linear output
- Analog or digital output available
- Direct voltage, current
- Low cost

B. Disadvantages

- Narrow Temperature range -55 to 150 °C [14]

C. Applications

- Used for measuring temperature below 150 °C

CONCLUSION

A comprehensive comparison between five different types of temperature sensor is presented. It was shown that each sensor has its own unique features and characteristics. Therefore the decision upon which temperature sensor to use will depend on the range of the temperature to be measured and the application areas of the device.

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