The temperature sensors engineering essay

There are four main temperature-sensing devices available: thermocouples, resistance temperature detectors (RTDs), thermistors, and temperature-transducing ICs. These sensors translate the temperature into a reference voltage, resistance or current, which is then measured and processed and a numerical temperature value is computed.

The Seebeck Effect - if a circuit is made by joining two wires of different metals, any difference in temperature between the joints will produce an EMF which will cause a current to flow in the circuit. Using favourable materials, this EMF will be of the order of 3 to 5 millivolts per 100°C difference between the junctions, and has an approximately linear relationship to temperature.

The choice of thermocouple type will be determined mainly by the range and cost. In cases where replacement sensors are required, the thermocouple type will usually be dictated by the existing instrumentation.

Limitation of use in ambient temperature range

Because the output signal is dependant upon the difference in temperature between the sensing junction and the reference junction (often called the cold-junction, and usually situated inside the measuring instrument), thermocouples are not suitable for measuring or controlling temperatures close to ambient unless the system for measuring the reference junction is exceptionally good. Where low-cost industrial instruments with built-in reference junctions are used, thermocouples are generally not considered to be suitable for use at temperatures within 60°C of that of the instrument.

Accuracy

The accuracy of thermocouples depends upon the quality of the element materials, and three

classes of accuracy are defined by British Standards. Similar classifications apply to other national

standards. For further information about accuracy see inside back cover.

Grounded and isolated junctions

Thermocouple assemblies may be manufactured with the sensing junction grounded to the sheath

or electrically insulated (" isolated") from it. Grounded junctions are usually cheaper to produce and have a faster response, but some control systems will function correctly only with isolated junctions

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Leadwire extension

Whenever a wire in a thermocouple circuit is joined to a wire or terminal made of a different

material another thermocouple will be created at the joint. If such connections between the sensing junction and the measuring instrument are at temperatures different from that of the reference junction, errors will be produced. When thermocouple leads are extended it is therefore essential to use cable made of the same materials as the thermocouple or of materials which have the same thermoelectric characteristic at the temperatures likely to occur at the joints. Cable with conductors of the same materials as the thermocouple element is referred to as extension cable, whereas cable with conductors of cheaper materials with similar characteristics is known as compensating cable. As a general rule compensating cable should not be used if the temperature at the joints

exceeds 100°C. Similarly, if plugs and sockets or terminal blocks are used in thermocouple circuits, the contacts or terminals should be of the same material as the thermocouple element. Plug and socket connectors and terminal blocks of this type are available from Testemp, for further information about extension leads see back cover, and for connectors

Resistance thermometers

Basic principle

Resistance thermometers are a traditional method of precision temperature measurement, and work on the principle of increase of resistance of a metal with increasing temperature. By far the most widely used material for this purpose is platinum, which is usually employed as a fine wire embedded in ceramic or glass, or as a thin film deposited on a ceramic substrate.

Standards

The most usual standard is Pt100 (100 ohms at 0°C), but several other standards are in use (e. g. 130 ohms at 0°C, 1000 ohms at 0°C).

Suitability for use in ambient temperature range

Resistance thermometers are available for measuring temperatures within the range -220°C to+850°C, and unlike thermocouples, they perform well in the ambient and blood temperature ranges.

Accuracy

Resistance thermometers are generally more accurate and stable than thermocouples. The accuracy depends upon the degree of precision in their manufacture, and three classes of accuracy are defined by British Standards.

Connection systems

Resistance thermometer assemblies are manufactured to suit four different connection systems: 2-wire, 3-wire, 4-wire current/voltage, and 4-wire blind loop (see back cover). The 3- and 4-wire systems provide correction for the resistance of the leads. Most ordinary instruments with resistance thermometer input are intended for use with 3-wire sensors, but can be used with 2-wire sensors by shorting out one pair of terminals, although this will result in some loss of accuracy Instruments designed for use with 4-wire sensors should be used with sensors of that type

whenever possible

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Leadwire extension

Resistance thermometer leads can be extended using copper wire with appropriate insulation for the working conditions. Good quality electrical connectors and terminal blocks can be used in resistance thermometer circuits.

Thermistors

Basic principle

Thermistors are solid-state devices that operate on the basis of change of electrical resistance with temperature and are available as negative temperature coefficient (NTC - resistance falls with rising temperature), or positive temperature coefficient (PTC - resistance increases with rising temperature). NTC is the most usual type for temperature measurement, and the rate of change of resistance with temperature is very much higher than that of a resistance thermometer, providing high sensitivity within a small temperature span. This makes thermistors very suitable for measuring temperatures around ambient and for medical applications.

Temperature range

The overall temperature range in which thermistors can be used is approximately -80°C to +400°C. 'The characteristics are determined by the manufacturers, and a wide range of types are available. Unlike thermocouples and resistance thermometers, there are no universally accepted standards but certain values are widely used (e. g. 5K, 10K and 100K ohms at 25°C), and the choice of value will depend upon the operating temperature range. Apart from the over-temperature devices mentioned below, Testemp will only supply thermistor assemblies if the element is supplied free issue or if its exact specification and source of supply are advised by the customer.

Leadwire extension

Thermistor leads can be extended with copper wire, and if the thermistor is appropriate for the temperature range the resistance of the leads will be negligible compared with that of the device itself. Good quality electrical connectors and terminal blocks can be used in thermistor circuits

Over-temperature thermistors

Some PTC thermistors undergo a sudden large increase of resistance (e. g. from 100 ohms to 10K ohms) at a certain temperature. These can be used with very simple circuitry to provide an overtemperature warning or safety trip. Assemblies using such devices are available from Testemp to switch at 80°C, 90°C and 120°C. The switching temperature must be specified at the time of order

and cannot be changed.

Temperature - sensing integrated circuits

These are semiconductor devices which provide a linear millivolt output related to temperature. The type normally used by Testemp is the R. S. Components LM35 CZ (317-960) which operates in the range -40°C to +110°C and has a linear output of 10mV/°C. This high sensitivity makes these elements very suitable for use in the ambient and blood-temperature ranges.

Temperature-transducer ICs

Semiconductor temperature sensors are produced in the form of ICs. Their design results from the fact that semiconductor diodes have temperature-sensitive voltage vs. current characteristics. When two identical transistors are operated at a constant ratio of collector current densities, the difference in base-emitter voltages is directly proportional to the absolute temperature.

The use of IC temperature sensors is limited to applications where the temperature is within a -55° to 150°C range. The measurement range of IC temperature sensors may be small compared to that of thermocouples and RTDs, but they have several advantages: they are small, accurate, and inexpensive.

Temperature sensing ICs are available either in analog form, which output a voltage or current which is proportional to the temperature, or digital, which communicate temperature over a digital communication line, such as one-wire PWM, two-wire I2C, or a multiple wire SPI connection.

Projects That Use Temperature Sensors

The Sonic City project developed a wearable system that creates music based on data from sensors measuring bodily and environmental factors. This includes environmental temperature measurements. A videjo summarising the project is linked to in the media section below, and Viktoria site for the project has a more detailed description.

Sound Kitchen includes temperature sensors and uses voltage changes in liquids to create music. The liquids include wine, soda and other items you might find in a kitchen, and the over all aesthetic connects strongly with cooking.

Comparison of temperature sensor types

The following table offers a comparison of the different characteristics of the various temperature sensor types.

Characteristic

Platinum RTD

Thermistor

Thermocouple

TemperatureIC

Active Material

Platinum Wire

Metal Oxide Ceramic

Two Dissimilar Metals

Silicon Transistors

Changing Parameter

Resistance

Resistance

Voltage

Voltage or Current

TemperatureRange

-200°C to 500°C

-40°C to 260°C

-270°C to 1750°C

-55°C to 150°C

Sensitivity

2 mv/°C

40 mV/°C

0. 05 mV/°C

~1 mv/°C or ~1 uA/°C

Accuracy

-45 to 100°C: ±0. 5°C; 100 to 500°C: ±1. 5°C; 500 to 1200°C: ±3°C

-45 to 100°C: ±0. 5°C; degrades rapidly over 100°C

0 to 275°C: ±1. 5 °C to ±4°C; 275 to 1260°C: ±0. 5 to ±0. 75%

±2 °C

Linearity

Excellent

Logarithmic, Poor

Moderate

Excellent

Response Time

2-5 s

1-2 s

2-5 s

Stability

Excellent

Moderate

Poor

Excellent

Base Value

100 Î© to 2 kÎ©

1 kÎ© to 1 MÎ©

< 10 mV

Various

Noise Susceptibility

Low

Low

High

High

Drift

+/- 0. 01% for 5 years

+/- 0. 2 to 0. 5°F per year

1 to 2°F per year

0. 1°C per month

Special Requirements

Lead Compensation

Linearization

Reference Junction

None

Device Cost

$60 - $215

$10 - $350

$20 - $235

$5 - $50

Relative System Cost

Moderate

Low to Moderate

Moderate

Low

Application of temperature sensors:-

Temperature sensors attach to and embed within solid material in a variety of applications and by a variety of means. In many of these applications, there is a fear the sensor can come loose or detach from the solid material, resulting in temperature measurement errors and long response times. Fortunately, the LCSR method works to help determine whether or not a sensor is in good contact with a solid material. The method is useful for RTDs, thermocouples, and strain gauges. The figure below shows LCSR transients from laboratory testing of a thin-film RTD with varying degrees of bonding. It is clear the LCSR signal is sensitive to the degree of bonding between each sensor and the solid material.

The TS-540 is a LM335A IC temperature sensor from National Semiconductor and operates over a temperature range of -40C to +100C. It is a linear temperature-to-voltage sensor with an output directly proportional to absolute temperature at 10mV/K and can be calibrated for ILX Lightwave Temperature Controllers except the LDC-3916 Laser Diode Controllers. The TS-540 is a metal case TO-46 transistor three leaded package. At 25°C, calibration accuracy is 1°C (0. 5C typical).

The AD590 is a small temperature sensor that converts a temperature input into a proportional current output. The advanced technology in the AD590 is especially suited for special temperature measurement and control applications between -55 and 150°C when solid state reliability, linearity and accuracy are required. The AD590 temperature sensor can be used to determine minimum, average, and differential temperatures, in addition to being used for thermocouple cold junction compensation and temperature control applications. The size and responsiveness of the AD590 make it perfect for uses where size is a consideration, such as on PC boards or heat sinks. Just power up and measure absolute temperature (Kelvin). No linearization, amplification or cold junction compensation is required.

temperature sensors deviation:-

If the sensor is not ideal, several types of deviations can be observed:

The sensitivity may in practice differ from the value specified. This is called a sensitivity error, but the temperature sensor is still linear.

Since the range of the output signal is always limited, the output signal will eventually reach a minimum or maximum when the measured property exceeds the limits. The full scale range defines the maximum and minimum values of the measured property.

If the output signal is not zero when the measured property is zero, the temperature sensor has an offset or bias. This is defined as the output of the sensor at zero input.

If the sensitivity is not constant over the range of the temperature sensor, this is called nonlinearity. Usually this is defined by the amount the output differs from ideal behavior over the full range of the sensor, often noted as a percentage of the full range.

If the deviation is caused by a rapid change of the measured property over time, there is a dynamic error. Often, this behaviour is described with a bode plot showing sensitivity error and phase shift as function of the frequency of a periodic input signal.

If the output signal slowly changes independent of the measured property, this is defined as drift (telecommunication).

Long term drift usually indicates a slow degradation of temperature sensor properties over a long period of time.

Noise is a random deviation of the signal that varies in time.

Hysteresis is an error caused by when the measured property reverses direction, but there is some finite lag in time for the sensor to respond, creating a different offset error in one direction than in the other.