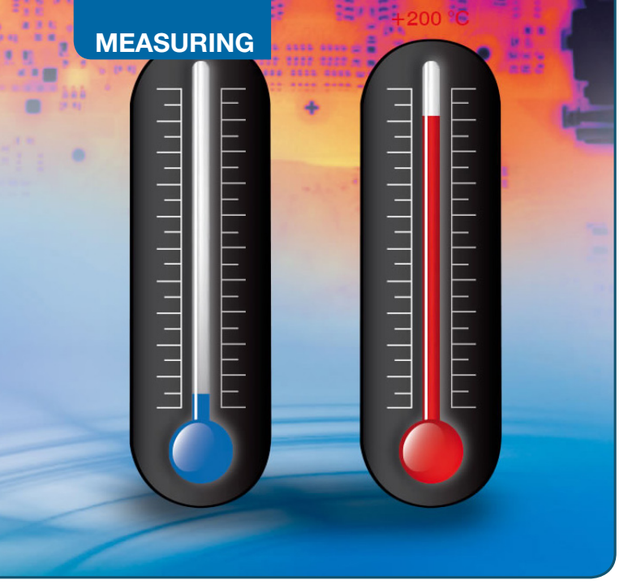


Feeling the heat

Chris Jones, MD of Micro Epsilon, explains how critical thermal stability is when it comes to the accuracy of non-contact displacement sensors

In non-contact displacement measurement applications, engineers often overlook the effects of temperature variations on the measurement accuracy of the sensor.

The temperature stability or thermal stability of a sensor indicates the percentage possible error in the measurement per unit (K or °C). This error is due to a number of factors including the physical expansion of built-in components, or the effect of temperature fluctuations on the performance of electronic components within the sensor itself. These effects result in a slight deviation of measurement results (thermal drift) per °C. However, when the temperature range the sensor is measuring over becomes greater, errors larger than sensor linearity can occur.

Temperature stability is therefore a critical factor in ensuring measurement accuracy, particularly in industrial applications where large temperature variations can occur.

Non-contact displacement sensors can measure many different parameters, including distance, vibration, gaps, surface profiles, runout and position. These sensors come in a wide variety of shapes, sizes and measurement principles. In practice, as well as eddy current and laser triangulation sensors, capacitive and confocal sensors are now commonplace in many production, quality and inspection environments.

Consider all four methods before making a decision

When selecting a suitable non-contact displacement sensor, it is important to check the supplier's technical datasheet carefully before making a purchasing decision. If you do this, you may find that many suppliers do not state the 'temperature error' or 'thermal stability' of their sensors. So how do you know the actual measurement error or how to correct results to account for this?

In order to ensure that the correct buying decision is made, you must first consider the four primary methods of non-contact displacement measurement, i.e. laser triangulation, confocal, capacitive and eddy current and how temperature variations can affect the measurement accuracy in each case.

Laser triangulation principle

In the laser triangulation principle, a laser diode projects a visible point of light onto the surface of the object being measured. The back-scattered light reflected from this point is then projected onto a CCD/CMOS array by a high quality optical lens system. If the target changes position with respect to the sensor, the movement of the reflected light is projected on the CCD array and analysed to output the exact position of the target. The measurements are processed digitally in the integral controller and then converted into a scaled output via analogue and digital interface RS232, RS422 or USB.

The benefits of laser triangulation sensors include a small beam spot, very long measuring ranges are possible, the sensor operates independent of the target material, and a high reference distance between sensor and target. However, the method is limited by a relatively large sensor design (compared to confocal, capacitive and eddy current sensors) and a relatively clean optical path is required for the sensor to operate reliably.

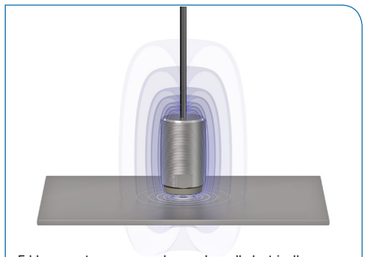
For low cost laser sensors, in terms of measurement errors due to thermal stability, these can be as high as 400ppm/K, which can significantly affect the measurement accuracy. Compared to the other three measuring principles, laser triangulation offers the lowest thermal stability. This is primarily due to the combined temperature errors associated with the sensor itself and the integral electronics.

Laser triangulation offers the lowest thermal stability

However, it should be noted that temperature stability can vary considerably from one laser sensor supplier to another. A supplier of high performance laser sensors is much more likely to state the temperature stability of a sensor on the datasheet. In addition, some suppliers have developed active temperature compensation algorithms for the sensor, which can reduce temperature stability to as low as 100ppm/K.

The eddy current principle

The eddy current measurement principle is an inductive measuring method. A coil is supplied with an alternating current, which causes a magnetic field to form around the coil. If an electrically conducting object is placed in this magnetic field, eddy currents are induced, which form an electromagnetic field according to Faraday's Induction Law. The controller calculates the change in energy transferred from the sensor coil to the target material and converts this into a displacement measurement.



Eddy current sensors can be used on all electrically conductive, ferromagnetic and non-ferromagnetic metals

The advantages here are that this method can be used on all electrically conductive, ferromagnetic and non-ferromagnetic metals. The size of the sensor is relatively small compared to other technologies and the temperature range is high due to the resistance measurement of the sensor and cable. The technology is high accuracy and is immune to dirt, dust, humidity, oil, high pressures and dielectric materials in the measuring gap.

Compared to laser triangulation, eddy current sensors generally provide a higher thermal stability. Temperature-dependent measuring errors can be minimised, for example, by using Micro-Epsilon's electronic (active) compensation method, which ensures thermal stability of less than 150ppm/°C.

In the last few years, Micro-Epsilon has raised the bar in terms of the thermal stability of eddy current sensors. The company has developed a range of next-generation eddy current sensors that use a patented embedded coil technology (ECT), which overcomes the previous limitations of discrete coil windings. The eddyECT sensor coil utilises new inorganic materials to embed the coil, which enables hermetically-sealed, ultra-compact designs. This provides almost unlimited scope in terms of the external design and geometrical shape of the sensors. The sensors also offer extreme mechanical robustness, resulting in longer service intervals and higher temperature stability. The sensors are suitable for harsh operating environments, including high vibration, impact shocks and high operating temperatures (up to 350°C). Sensors have been produced with extremely low thermal drift and with temperature errors of less than 20ppm/K.

The confocal principle

This technology works by focusing polychromatic white light onto the target surface using a multi-lens optical system. The lenses are arranged in such a way that the white light is dispersed into a monochromatic light by controlled chromatic deviation. A certain deviation is assigned to each wavelength by a factory calibration. Only the wavelength that is focussed on the target surface or material is used for the measurement.

Both diffuse and specular surfaces can be measured. With transparent materials like glass, a one-sided thickness measurement can be achieved with the distance measurement. Also, because the emitter and receiver are arranged in one axis, shadowing is avoided.

Confocal sensors are often selected when laser triangulation or other optical sensors are not accurate or stable enough on the surface being measured. Confocal offers nanometre resolution and operates almost independently of the target material. A very small, constant spot size (typically 10-25 micron) is achieved. Miniature radial and axial confocal versions are also available for measuring drilled or bored holes. Restrictions of the technology include the limited distance between the sensor and target. In addition, the beam requires a clean environment.

Confocal sensors offer nanometre resolution

In terms of thermal stability, confocal sensors are more stable than laser triangulation or eddy current. This is due to the design of the sensors, which comprises a cylindrical tube with a series of optical lenses. The sensor is considered 'passive', as the controller and electronics are housed separately in a more controlled temperature environment.

The capacitive principle

With the capacitive principle, sensor and target operate like an ideal parallel plate capacitor. The two plate electrodes are formed by the sensor and the opposing target. If an AC current with constant frequency flows through the sensor capacitor, the amplitude of the AC voltage on the sensor is proportional to the distance between the capacitor electrodes. An adjustable compensating voltage is simultaneously generated in the amplifier electronics. After demodulation of both AC voltages, the difference is amplified and output as an analogue signal.

Because the sensor is constructed like a guard ring capacitor, almost ideal linearity and resolution against metal targets is achieved. Compared to the other measuring methods, the technology offers the highest temperature stability, as changes in the conductivity of the target have no effect on the measurement. The technology is sensitive to changes in the dielectric sensor gap and so operates most effectively in clean, dry applications.

Active guard triaxial cable

Capacitive measurement systems from Micro-Epsilon operate with an active, low noise cable in combination with an active guard ring capacitor. A particularly high quality and precise signal is achieved due to the double shielding of the field. The guard ring electrode provides a protected measuring field for extremely high stability and interference-free, accurate measurements.

Cylindrical, flat capacitive displacement sensors from Micro-Epsilon typically provide very high temperature stabilities down to just 5ppm/K or -60nm/°C across a temperature range of -270°C to +200°C.

www.micro-epsilon.co.uk