



Technical Information

Linear Encoders for Vacuum Environments

A vacuum is an empty space devoid of air or any other gas. Depending on their quality, vacuums are classified as rough, fine, high, or ultra-high.

Vacuum technology plays a critical role in numerous production processes and research applications. Procedures that use vacuum technology have become indispensable in fields such as electronics, thin-film technology, new materials research, biotechnology, medical technology, and analysis technology.

The components used in vacuum environments, including the encoders needed for positioning tasks, must meet high standards. HEIDENHAIN linear encoders for high and ultra-high vacuum environments meet these requirements thanks to special design features:

- Vacuum-compatible PCBs, adhesives, and coatings for reduced outgassing
- Vented hollow spaces for shorter pumping time
- Temperature resilience for high bake-out temperatures
- Use of non-ferromagnetic materials for high process reliability
- Clean-area production
- Pre-packaging bake-out for exceptional cleanliness

Vacuum classes

When air is pumped out of a space, the pressure drops and a vacuum is created. The less air that remains, the higher the vacuum class. There are four classes of vacuum. Pressures of down to 1 mbar constitute a **rough vacuum**, and lower pressures, a **fine vacuum**. Under 0.001 mbar, a **high vacuum** is attained, and below 0.0000001 mbar, an **ultra-high vacuum**.

Vacuum	Pressure in mbar	Height in km above sea level	Mean free path in m without collision of two gas molecules	Time in s for covering a surface with particles
Rough	10^{+3} to 1	< 50	$< 10^{-5}$	$< 10^{-5}$
Medium	1 to 10^{-3}	50 to 100	10^{-5} to 10^{-1}	10^{-5} to 10^{-2}
High	10^{-3} to 10^{-7}	100 to 500	10^{-1} to 10^{+3}	10^{-2} to 10^{+2}
Ultra-high	$< 10^{-7}$	> 500	$> 10^{+3}$	> 100

Vacuum applications

Vacuum environments are needed wherever the presence of foreign particles would interfere. Certain types of measurements must be carried out directly within a vacuum, such as the examination of structures at the sub-micron level. Common vacuum

applications for linear and angle encoders include electron microscopes, manipulators, multiple actuators, XY tables, wafer inspection in the semiconductor industry, and spectrometer axes for measuring synchrotron radiation.

Requirements for vacuum-compatible encoders

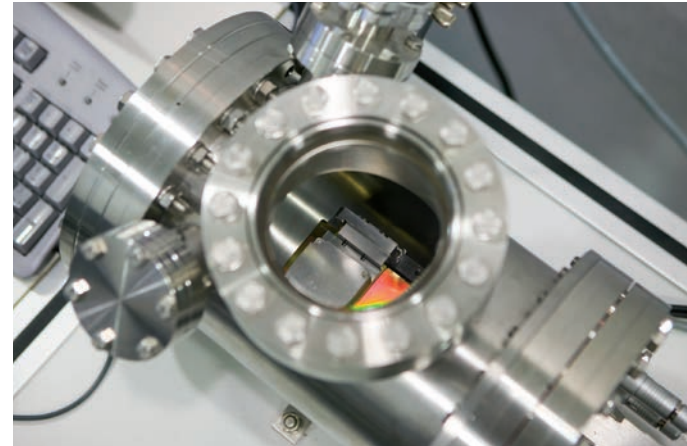
Standard encoders from HEIDENHAIN suffice for applications in rough and fine vacuum environments with a limited temperature range. But encoders for high and ultra-high vacuums must meet special requirements.

Low outgassing

In order to prevent a dramatic pressure increase within the vacuum chamber, vacuum-compatible encoders must not release gases in large quantities. In an ultra-high vacuum, every component is critical. Some plastics, for example, outgas solvents. Plastics like these are commonly contained in printed circuit boards, adhesives, or coatings but should be completely omitted from devices deployed in ultra-high vacuums. That's why HEIDENHAIN uses vacuum-compatible PCBs, adhesives, and coatings. In an ultra-high vacuum environment, the number of components must be reduced to a minimum. Signal converters, for example, should be kept outside of the vacuum chamber, which is why HEIDENHAIN offers vacuum-compatible encoders featuring external signal converters. These devices can also be placed within the vacuum chamber in applications requiring merely a high vacuum.

Ventilation of hollow spaces

Generating a vacuum requires pumping the air out of a space. The time required for attaining the desired pressure, known as the pumping time, should be kept to a minimum for fast deployment of the vacuum system. Pumping times can be shortened when air is able to escape quickly from all hollow spaces. For this reason, HEIDENHAIN encoder housings are equipped with additional air vents, second openings for threaded holes, and holes drilled into empty cavities.



Avoidance of ferromagnetic materials

Depending on the processes within the vacuum chamber, certain materials cannot be used. Ferromagnetic materials, for example, cannot be used in electron microscopes for inspecting microelectronic circuits. The measuring standards and scanning heads of vacuum-compatible encoders from HEIDENHAIN are made of non-magnetizable materials. Because its signal converters contain ferromagnetic materials, HEIDENHAIN offers encoders that permit external installation of the signal converter.

High temperature resilience

Achieving a high vacuum class requires heating the chamber to 100 °C or 120 °C, thus vaporizing any water molecules still clinging to the encoder's housing. This enables faster pumping. As a consequence, vacuum-compatible encoders must be designed for temperatures of up to 100 °C or 120 °C.

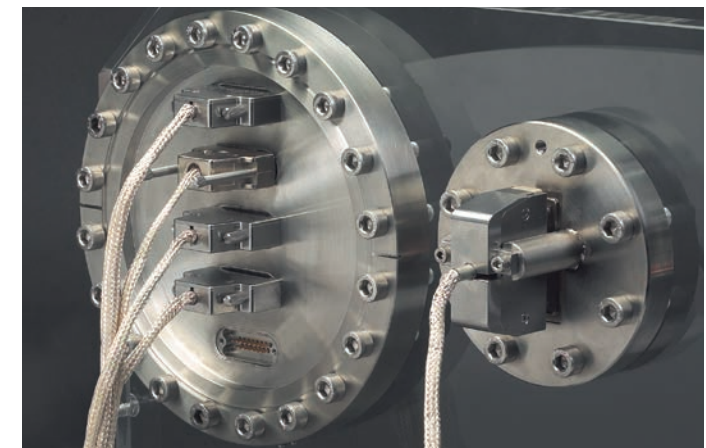
High cleanliness

Encoders used in a vacuum chamber require special cleaning for minimal contamination. Most greases, oils, and fingerprints will outgas within a vacuum environment and are therefore prohibited. If fine particles or dust are released within the vacuum chamber, they could destroy the microelectronic circuits under inspection or falsify experimental results. Production, cleaning, and packaging are therefore subject to special requirements.

Prior to packaging (double packaging), the devices are baked out at 100 °C for 48 hours, thereby releasing residual atmospheric contamination from the surface and pumping it away.

Electrical connection

HEIDENHAIN encoders are equipped with connectors that can be used with vacuum-compatible feedthroughs. The LIP and LIF series linear encoders require a signal converter for changing their signals to 1 V_{PP}. This signal converter is housed in the D-sub connector. In high-vacuum applications, the signal-converter can be attached directly to the encoder but in ultra-high vacuum applications, the signal converter must be installed outside of the vacuum chamber. That's why the LIP and LIF encoders for high vacuums are available in two cable versions. The maximum permissible cable length between the scanning head and the signal converter is three meters.



Vacuum-compatible feedthroughs

