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 circuit boards, 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 cleanness

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 0.000 000 1 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}
Fine	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

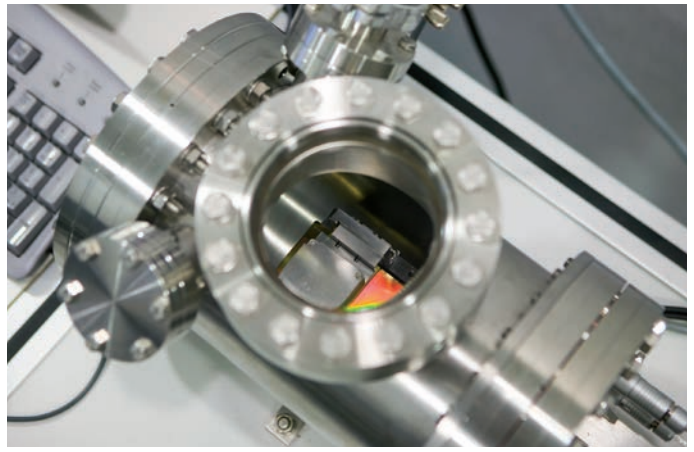
Vacuum applications
Vacuum environments are needed wherever the presence of foreign particles would interfere. Certain types of measurements must be carried out directly within a vacuum, such as the examination of structures at the sub-micron level. Common vacuum applications for linear and angle encoders include electron microscopes, manipulators, multiple actuators, XY tables, wafer inspection in the semiconductor industry, and spectrometer axes for measuring synchrotron radiation.

06/2024

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 circuit boards, adhesives, or coatings but should be completely omitted from devices deployed in ultra-high vacuums. That's why HEIDENHAIN uses vacuum-compatible circuit boards, 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 cleanness
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 24 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 linear encoders of the LIF series require signal converters for signal conversion to $1\ V_{PP}$. These signal converters are housed in the D-sub connector. In high-vacuum applications, the signal converters can be attached directly to the encoder or be installed outside of the vacuum chamber, but in ultra-high vacuum applications, the signal converters must be installed outside of the vacuum chamber. The cable between the scanning head and signal converter can be up to 3 meters in length.

Vacuum-compatible feedthroughs

Vacuum-compatible encoders

The vacuum-compatible encoders from HEIDENHAIN are based on modified standard encoders. The original scanning principle, along with any optoelectronic and optical components, are preserved, but the housing, circuit boards, and adhesives have been modified to meet the requirements of the given vacuum rating.

HEIDENHAIN vacuum-compatible encoders employ the following special measures:
- No magnetizable materials
- Laser inscription instead of labels
- Air vents
- Specialized cleaning and packaging
- Cable with PTFE insulation and tin-plated copper braiding

LIF 481V

	For high vacuum environments of down to 10^{-7} mbar			For ultra-high vacuum environments of down to 10^{-11} mbar
	LIC 4113V/LIC 4193V	**LIF 481V**	**LIF 471V**	**LIF 481 U**
Measuring methods	Absolute	Incremental		
Measuring lengths*	240 mm to 3040 mm[1)]	70 mm to 1640 mm		
Accuracy grade*	±1 µm (Robax); ±3 µm; ±5 µm	±3 µm		
Interpolation error	±20 nm	±12 nm		
Interface	EnDat 2.2; Fanuc α_i; Mitsubishi; Panasonic; Yaskawa	∿ 1 V_{PP}	⊓⊔ TTL	∿ 1 V_{PP}
Signal period	–	4 µm		
Graduation-carrier material*	• Robax glass ceramic $\alpha_{therm} \approx (0 \pm 0.5) \cdot 10^{-6}\ K^{-1}$ • Glass $\alpha_{therm} \approx 8 \cdot 10^{-6}\ K^{-1}$	• Zerodur glass ceramic $\alpha_{therm} \approx 0\ K^{-1}$ $(0 \pm 0.1) \cdot 10^{-6}\ K^{-1}$ • Glass $\alpha_{therm} \approx 8 \cdot 10^{-6}\ K^{-1}$		
Bake-out temperature	100 °C			120 °C
Cables, connectors	• 15-pin D-sub high-vacuum-compatible connector (male)	• 16-pin high-vacuum-compatible round connector (APE in atmosphere) with feedthrough • Signal converter integrated into connector (APE in vacuum)		UHV-compatible plug connector without feedthrough (APE in atmosphere)

* Please select when ordering
1) Robax glass ceramic, available in measuring lengths of up to 1640 mm
Robax is a registered trademark of Schott-Glaswerke, Mainz, Germany

HEIDENHAIN

DR. JOHANNES HEIDENHAIN GmbH
Dr.-Johannes-Heidenhain-Straße 5
83301 Traunreut, Germany
☏ +49 8669 31-0
FAX +49 8669 32-5061
info@heidenhain.de

www.heidenhain.com

More information:
- Brochure: *Exposed Linear Encoders*
- Product Information: *LIF 481V/LIF 471V/LIF 481U*
- Product Information: *LIC 4113V/LIC 4193V*

627568 · 06 · A · 02 · 06/2024 · PDF