HEIDENHAIN

Technical Information

Exposed and Absolute—

New linear encoder with EnDat 2.2 serial interface for servo control and position measurement on direct drives

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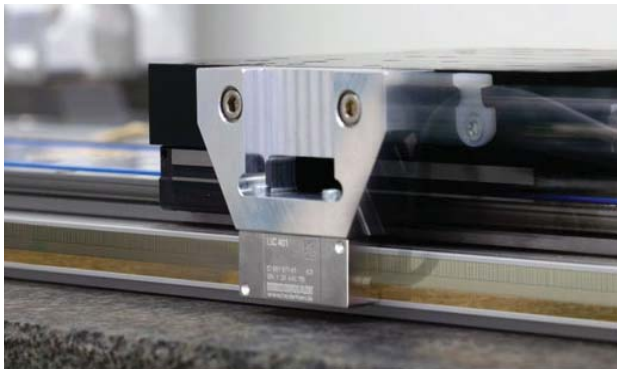
By now, linear motors have made irreversible inroads into highly dynamic applications such as manufacturing and measuring equipment in the semiconductor industry, PCB assembly machines, textile machine and in automation. Direct drives for open and closed-loop control require continuous real-time and exact information on the position of the slide. The accuracy, performance and reliability of the individual axes depend to a great degree on the linear measuring devices on the slides. Primarily, this task is performed by compact, contact-free measuring devices—called exposed linear encoders—which function according to the incremental measuring process. With the new LIC 4000 encoder, HEIDENHAIN now offers an absolute and exposed linear encoder with EnDat 2.2 serial interface. Thanks to its resolution of 1 nanometer and the large measuring length up to 27 m, the servo control and position measurement of linear drives moves into a new dimension and opens the way for new applications.

Position encoders play a special role as feedback in control loops with direct drives. High control-loop gain can only be reached if the encoder provides high-quality position signals. With the high control-loop gain required, even minor disturbances in the encoder output signal can cause serious trouble in drive performance. The higher quality of the position information therefore contributes substantially to significant improvement in speed control and positioning accuracy.



Contact-free linear encoders—known as exposed linear encoders— that generate a high-quality position signal with low interpolation errors are essential for reliable operation of direct drives. This influences servo control and position measurement to a decisive degree.

Encoders that use photoelectric scanning are ideally suited for this task, since very fine graduations can be used as measuring standards by this method. Encoders with optical scanning methods show benefits in the position accuracy, speed stability and thermal behavior of a direct drive, and therefore contribute importantly to the utilization of the potential of direct drives.

Up to now, however, absolute position value formation in exposed linear encoders could not be realized, although absolute encoders offer decisive benefits:

- Availability of the position value immediately upon encoder switch-on, which permits fast position reapproach, especially in concatenated systems or machines with several axes.
- There is no need to move the axes to find the reference position
- Prevention of collisions during initialization of multiple axes

Because **high acceleration capability** and compact designs are required for applications on direct drives, usually only exposed encoders instead of sealed encoders come into question. They operate without friction and, thanks to the lack of an enclosure, are very small and can be designed with little weight. Up to now, only exposed linear encoders

operating according to the incremental measuring method could be used. To realize an optical absolute encoder in exposed design, new technologies and carefully selected manufacturing processes were needed in order to integrate **"absolute technology"** in the mechanical design of the LIDA 400, which was already well proven on the market. The goal was to ensure in the smallest possible space essential criteria such as high accuracy, high traversing speeds, and the reliability for which HEIDENHAIN is so well known.

Step by step to an exposed absolute encoder

Linear encoders that generate a high-quality position signal with low interpolation error place high demands on their optical, mechanical and electronic performance. The external dimensions, which are defined in the technical specifications as the maximum for an exposed absolute encoder, demand innovations and new technologies for the final realization. Not only the high quality of the graduation manufactured for the LIC 4000 with the METALLUR process (Fig. 1), but also the scanning method shares responsibility for low interpolation error.

The graduation carrier—a METALLUR scale tape

HEIDENHAIN has developed a process—known as the METALLUR process—for manufacturing graduations on glass, glass ceramic or steel. The quasi-planar graduation structure is extremely tolerant to contamination and thereby greatly enhances encoder reliability. The manufacturing processes are environmentally friendly and do entirely without chemicals such as those generally needed for etching. A new design using a pulsed laser (Fig. 2) produces the graduation structure. The graduation's high edge definition and homogeneity permit low interpolation error to ensure smooth operation and high controller gain of the linear drive.

In the LIC 4000 series with its absolute graduation, the position value is available from the encoder immediately upon equipment switch-on and can be called at any time by the subsequent electronics. There is no need to move the axes individually to find the reference position. The absolute position information is scanned from the scale graduation, which is configured as a pseudo-random-coded (PRC) track with separate incremental track (Figure 4). An innovative scanning method with integrated opto-ASIC contributes to setting new benchmarks for low interpolation error and reliability.

Measuring accuracy and high reliability contribute to machine safety

The newly developed scanning method is based on the high quality of the graduation and provides absolute position values with a specified interpolation error of less than ± 40 nm. Measurements resulted in an actual value significantly lower than the specification (Fig. 5). The value of the position noise, which is critical for servo control, even lies below 20 nm RMS (Fig. 6).

Exposed linear encoders of the LIC 4000 series are optimized for use on fast, precise machines. In spite of its exposed design, thanks to the introduction of a new scanning method with absolute technology and the quasi-planar graduation structure manufactured in the METALLUR process, the LIC 4000 is extremely tolerant of contamination and therefore contributes greatly to reliability in diverse applications over a long period of time. The large scanning field and the single-field scanning additionally reduce sensitivity to contamination.

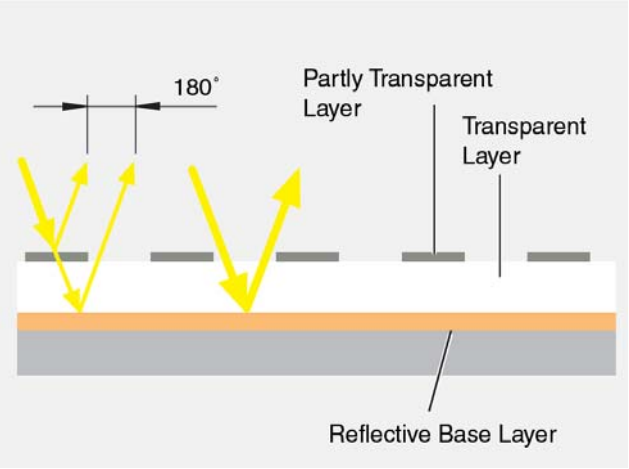


Figure 1: METALLUR design

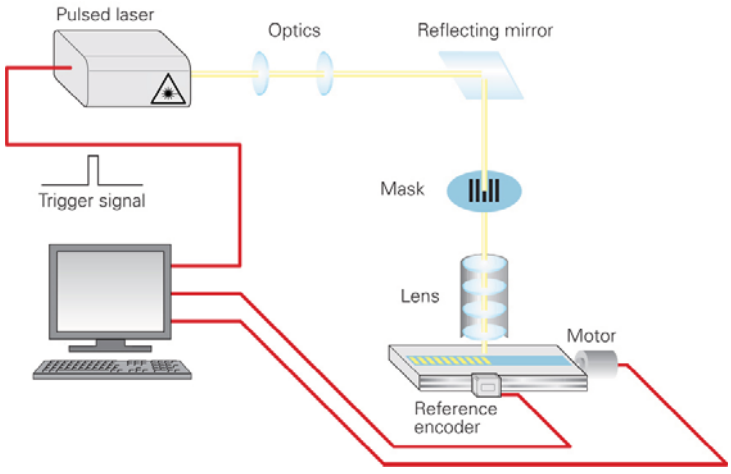


Figure 2: Manufacture of the graduation structure

The contamination applied in a laboratory (such as oil, dust, fingerprints, hair, wires), which can easily hamper the everyday function of an exposed encoder, show only small effects on the functional safety and measuring accuracy of the new LIC 4000 series (Figure 7).

The LIC 4000 can be installed immediately on machine designs already introduced in the market because compatibility with the field-proven incremental encoder of the LIDA 400 series was already ensured during its design phase. Only the cable outlet at the scanning head has a slight change, so that the mechanical characteristics remain unaffected. The advantages of different design types are also available in the LIC 4000 series to machine-tool builders and plant manufacturers for different applications:

- **LIC 4015**
For large measuring lengths up 27 meters
(Steel scale-tape is drawn into aluminum extrusions and tensioned.)

- **LIC 4017**
With defined thermal fixed point
(Steel scale-tape is drawn into aluminum extrusions and fixed at center)

- **LIC 4019**
With adhesive film, for reduced requirements
(Steel scale tape is adhered onto mounting surface)

- **LIC 4013**
Version with thermally adapted graduation carriers
(Glass or glass ceramic scale is cemented to the mounting surface)

Serial position transmission with EnDat 2.2
The EnDat interface from HEIDENHAIN is a digital, bidirectional interface for encoders. It is capable both of transmitting position values as well as transmitting or updating information stored in the encoder, or saving new information. Thanks to the serial transmission method, only four signal lines are required. The data is transmitted in synchronism with the clock signal from the subsequent electronics. The type of transmission (position values, parameters, diagnostics, etc.) is selected through mode commands that the subsequent electronics send to the encoder. The exposed absolute encoders of the LIC 4000 series with EnDat 2.2 interface offer position resolution of 1 nm (nanometer) although, unlike TTL devices, they are not limited in traversing speed. Since the analog scanning signals of the LIC 4000 are digitized and subdivided directly at the place of measurement, the advantages of new absolute scanning methods can be efficiently translated into improved speed stability and positioning behavior of servo motors. Moreover, these very short analog transmission paths provide greater stability in signal quality under the influence of electromagnetic noise. Especially on highly dynamic drives, this permits enhanced accuracy and reduces acoustic noise. The high clock frequency of the EnDat interface also permits very short read-out times for the position data. EnDat 2.2 is now the fastest purely serial interface for position encoders based on the RS 485 transmission characteristics.

More information on EnDat is available at www.endat.de.

Simple installation with diagnostic capabilities including teleservice
The absolute encoders of the LIC 4000 series feature high accuracy and repeatability, and are especially easy to mount. The valuation numbers provided over EnDat 2.2 for the absolute

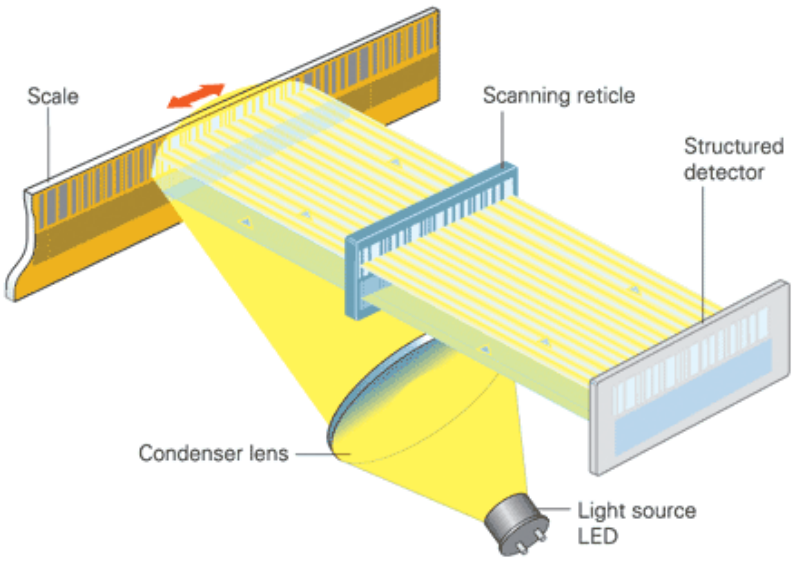


Figure 3: Design and functional principle and design of the optical scanning method of the LIC 4000

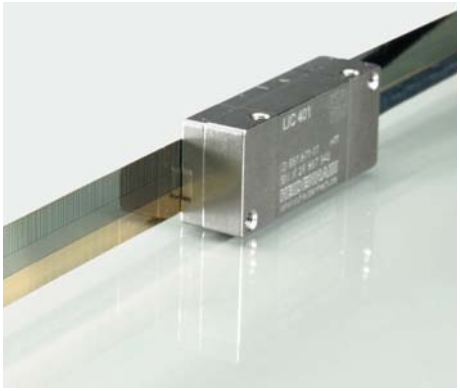


Figure 4: Scale tape of the LIC

track, incremental track and position value calculation provide a real-time status report on the condition of the encoder—both at rest and in motion. Mounting tolerances in conjunction with valuation numbers make reliable mounting possible without having to do without a safety margin in the field. The valuation numbers are also used for online diagnosis over the EnDat 2.2 interface. The diagnostic system generates error messages and warnings, and is an essential prerequisite for a high level of availability of the overall system. It enables machine-tool builders and plant manufacturers to communicate directly with the control of a problem machine or system whether it be in Munich, Chicago, Tokyo or Singapore and gain unambiguous information on the condition of the machine in order to initiate appropriate measures on site. Of course it can also collect statistical information and use it for preventive maintenance.

Summary

The LIC 4000 compact exposed linear encoder is an absolute measuring device with a high resolution of 1 nanometer that sets a new standard for control behavior and positioning accuracy. It is based on the well proven EnDat 2.2 serial interface for fast data transfer. The EnDat protocol makes it possible to transfer various data besides position information.

In addition to the familiar linear encoder using the incremental measuring principle, for demanding positioning and control tasks in various applications such as in the semiconductor industry, metrology, medical technology, automation and textile machines, machine tool builders and plant manufacturers can now make use of an exposed absolute encoder that contributes to a decisive degree to the accuracy, performance and reliability of individual axes both for today's and for future generations.

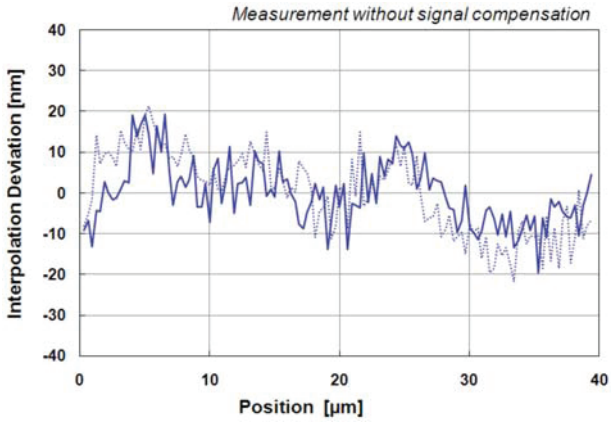


Figure 5: Measured interpolation error

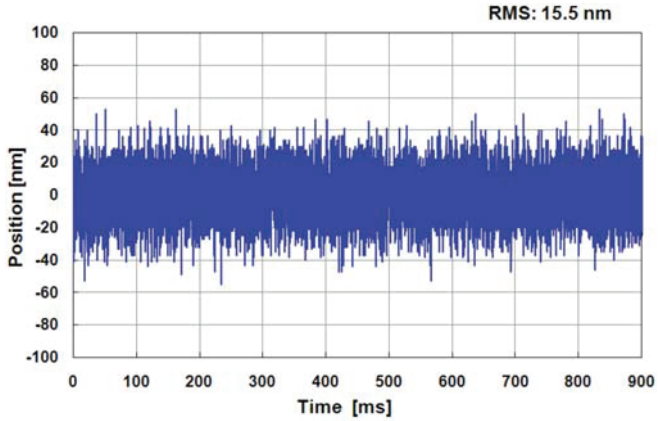


Figure 6: Measured position noise

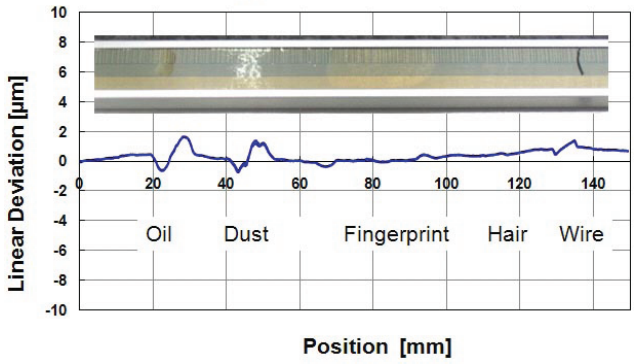


Figure 7: Contamination behavior of the LIC 4000 series

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For more information:

- Brochure: *LIC 4000 Series Exposed Absolute Linear Encoder*