HEIDENHAIN

Technical Information

Exposed linear encoders: permanently stable measured values and detailed accuracy data

Exposed linear encoders are used wherever very high demands are placed on the accuracy of the measured value. This includes production and measuring equipment in the semiconductor industry, PCB assembly machines and measuring machines. In order to ensure permanent accuracy over the entire life cycle of the encoder, HEIDENHAIN has developed the signal processing ASIC HSP 1.0 for application in exposed linear encoders with incremental position value acquisition.

The ASIC almost completely compensates fluctuations in signal amplitude due to interference. The underlying, significantly improved signal stabilization is particularly effective against contamination of the measuring standard or scanning reticle. The result is a permanently stable measuring signal almost entirely without impairment of interpolation accuracy or increased noise component.

HEIDENHAIN is also introducing new accuracy data for exposed linear encoders. They enable the design engineer to refer to detailed information when selecting the appropriate encoder for his application. In addition to accuracy, he can find the following data:

- Accuracy of the graduation over short intervals
- Accuracy of the interpolation
- Position noise

LIDA 400

LIF 400

LIP 6000

Figure 1: Exposed linear encoders with the HSP 1.0 ASIC

April 2016

Greater reliability through stable measured values
Constantly high-quality signal through adaptation of illumination

In principle, HEIDENHAIN encoders provide stable scanning signals that need no additional stabilization. However, contamination in the measuring standard and scanning reticle can negatively affect these scanning signals. Depending on the application, sooner or later it can cause signal quality problems because contamination increases in the course of time.

Reliably high-quality measuring signals
The HEIDENHAIN HSP 1.0 signal processing ASIC permanently monitors the scanning signal. If contamination on the measuring standard or scanning reticle result in signal changes, the HSP 1.0 almost completely compensates them.

In this way, this intelligent ASIC ensures that the scanning signal retains its high quality and stability for the long term. Interpolation error and position noise do not increase in normal operation from contamination.

Permanently stable signal
Position measurement with an exposed linear encoder equipped with the HSP 1.0 signal-processing ASIC therefore results in a **very stable signal** over the entire measuring range—regardless of the traversed contamination. The signal amplitude stays nearly constant at 1 V_{PP} (Fig. 3). Even if the ASIC's control limit were exceeded due to increasing, extremely heavy contamination, it would not result in an abrupt signal failure. Instead, the signal amplitude would only slowly decrease.

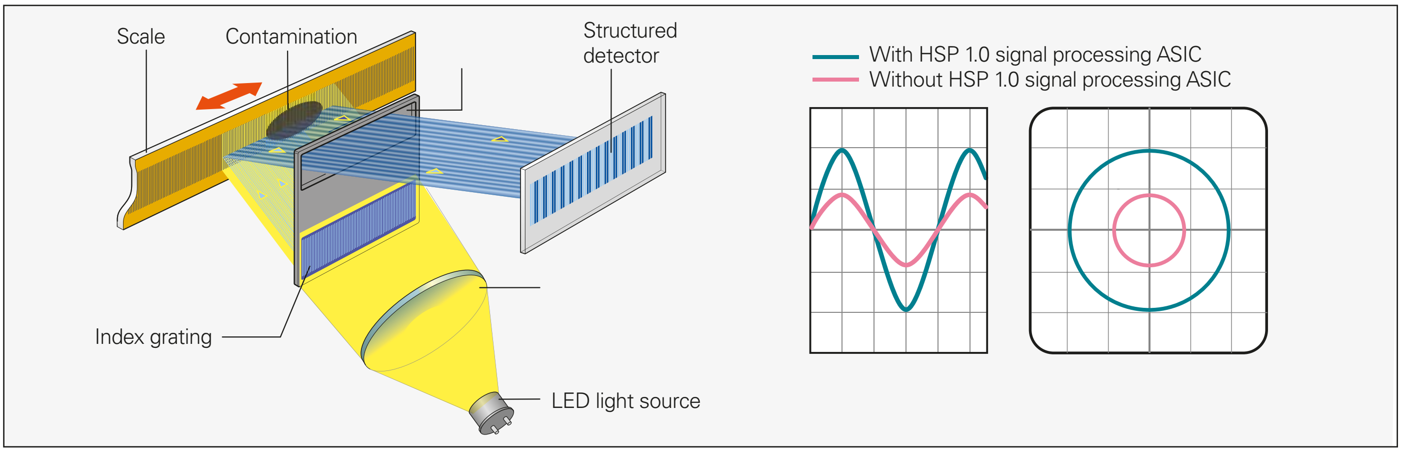


Figure 2: Single-field scanning with large scanning window—in this example the LIDA 400—works in combination with the HEIDENHAIN HSP 1.0 signal processing ASIC to ensure a constantly high-quality scanning signal even with contamination on the measuring standard and scanning reticle.

No influence on the noise component
If the signal amplitude decreases, the HSP 1.0 readjusts it by increasing the LED current. The concomitant increase in light intensity from the LED hardly worsens the noise component in the scanning signals even during heavy signal-stabilizing intervention—quite unlike systems that place the amplification in the signal path, which also increases the noise component.

Contamination does not influence interpolation error in practice
However, the HSP 1.0 signal processing ASIC not only stabilizes the signal amplitude. It also ensures that the signal keeps it original, ideal signal shape under contamination. In this way it keeps interpolation error very small when the measuring standard and scanning reticle are contaminated.

Without contamination, signal stabilization is unnecessary
Among other things, exposed linear encoders from HEIDENHAIN thank their stable scanning signal to the large sensor surface of the structured detector. It ensures that interference has only a small overall influence on signal scanning. The signal stabilization does not have to work quickly or aggressively, which provides optimal conditions for a stable scanning signal. If there is no contamination on the measuring standard or scanning reticle, such as after careful mounting, the signal stabilization does not even start to function.

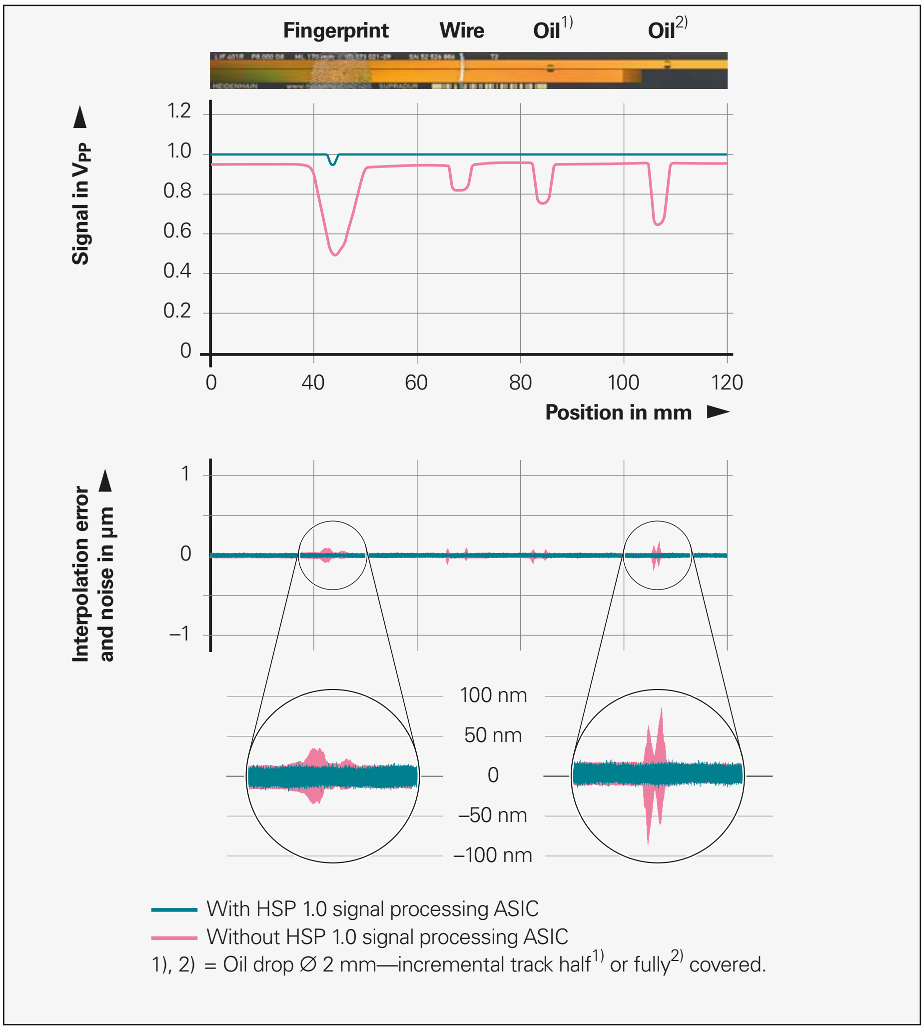


Figure 3: Measuring standard with contamination and the associated signal amplitudes with conventional scanning and scanning with the HSP 1.0 signal processing ASIC

Detailed accuracy data

Exact information for better encoder selection

HEIDENHAIN has expanded its accuracy data for exposed linear encoders. Up to now, the encoder-specific error was specified rather generally as the accuracy grade and the position error within one signal period. In future, users will find the following more detailed information:

- Accuracy of the measuring standard
- Accuracy of the interpolation
- Position noise

The division of data into the accuracy of the measuring standard, the accuracy of the interpolation, and the position noise enables design engineers to make a much more accurate prognosis of attainable accuracy in the respective application. This enables them to better and more easily select the encoder most appropriate for their respective application.

Accuracy of the measuring standard
The accuracy of the measuring standard is mainly determined by

- the homogeneity and period definition of the graduation,
- the alignment of the graduation on its carrier,
- the stability of the graduation carrier.

The accuracy of the measuring standard is indicated by the **uncompensated maximum value of the baseline error**. It is ascertained under ideal conditions by using a series-produced scanning head to measure position error. The measuring points are an integral multiple of the signal period, so that interpolation errors have no influence (Fig. 4).

The accuracy grade a defines the upper limit of the baseline error within any max. one-meter section. For special encoders, a **baseline error for defined intervals** of the measuring standard is additionally stated. In addition to the accuracy grade of e.g. ±1 µm, this now provides the user with the information that in an interval of 5 mm the encoder concerned attains accuracy of ≤ ±0.125 µm (Tab. 1, model LIP 281).

Accuracy of the interpolation
The accuracy of the interpolation is mainly influenced by

- the size of the signal period,
- the homogeneity and period definition of the graduation,
- the quality of scanning filter structures,
- the characteristics of the sensors, and
- the quality of the signal processing.

The accuracy of the interpolation is ascertained with a series-produced measuring standard, and is indicated by a typical maximum value u of the interpolation error (Fig. 5). Encoders with analog interface are tested using HEIDENHAIN electronics (e.g. EIB 741). The maximum values do not include position noise and are indicated in the Specifications.

The interpolation error has an effect with very small traversing speeds and during repeat measurements. In addition, it increases the motor current and with it the temperature of the motor.

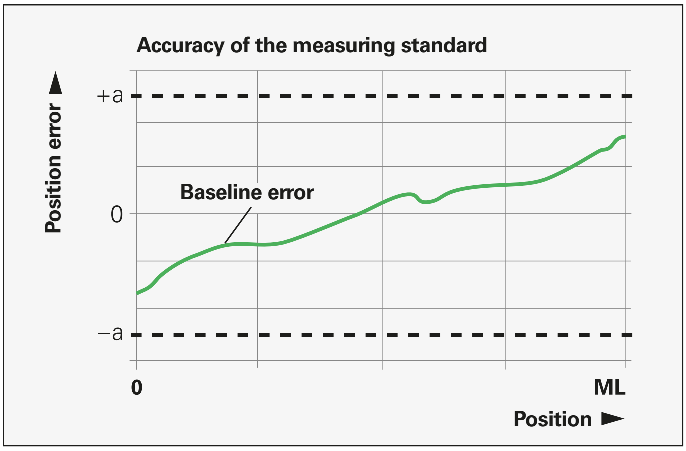


Figure 4

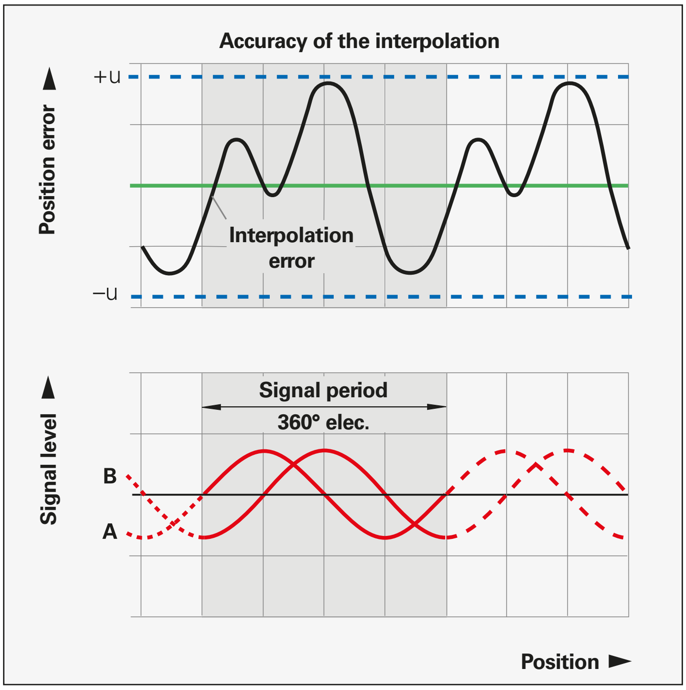


Figure 5

Position noise
Position noise denotes all random processes that result in **unforeseeable position error**. The position values are grouped around an expected value in the form of a frequency distribution.

The position noise depends on the signal processing bandwidths necessary for forming the position values. It is ascertained within a defined time period, and is indicated as a product-specific RMS value.

Position noise is primarily responsible for the reproducibility of measurement results and the repeatability of an encoder. Position noise in the velocity control loop influences running smoothness at low traverse velocities.

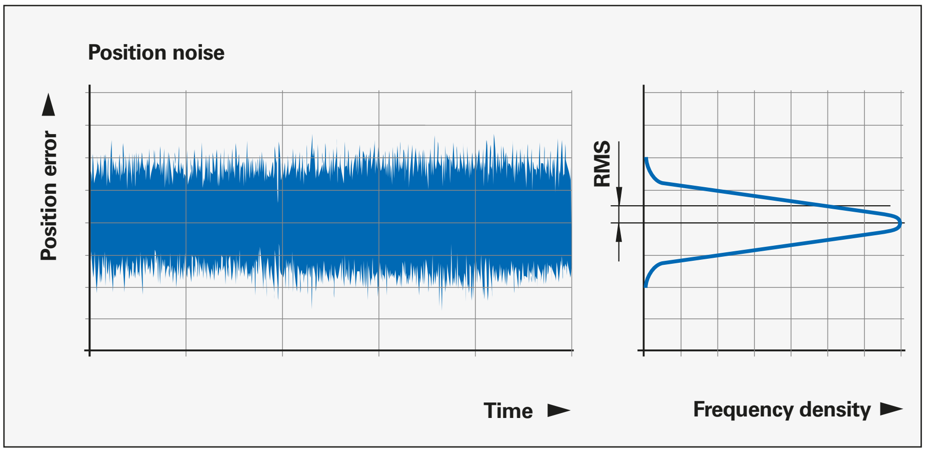


Figure 6

Table 1

	Baseline error		Interpolation error	Signal period	Measuring length	Interface	Model
	Accuracy grade	Interval					
LIP For very high accuracy	± 0.5 µm	≤ ±0.075 µm/ 5 mm	±0.01 nm	0.128 µm	70 mm to 270 mm	TTL	**LIP 372**
						1 V_{PP}	**LIP 382**
	± 1 µm ± 3 µm	≤ ±0.125 µm/ 5 mm	±1 nm	0.512 µm	20 mm to 3040 mm	1 V_{PP}	**LIP 281**
	± 0.5 µm ± 1 µm	≤ ±0.175 µm/ 5 mm	±7 nm	2 µm	70 mm to 420 mm	TTL	**LIP 471**
						1 V_{PP}	**LIP 481**
	± 1 µm	≤ ±0.175 µm/ 5 mm	±12 nm	4 µm	70 mm to 1 440 mm	TTL	**LIP 571**
						1 V_{PP}	**LIP 581**
LIF For high accuracy	± 1 µm ± 3 µm	≤ ±0.225 µm/ 5 mm	±12 nm	4 µm	70 mm to 1020 mm	TTL	**LIF 471**
						1 V_{PP}	**LIF 481**
LIDA For high traversing speeds and large measuring lengths	± 1 µm ± 3 µm ± 5 µm	≤ ±0.275 µm/ 10 mm	±45 nm	20 µm	240 mm to 3040 mm	TTL	**LIDA 473**
						1 V_{PP}	**LIDA 483**

Detailed accuracy data

Acquisition and documentation of data

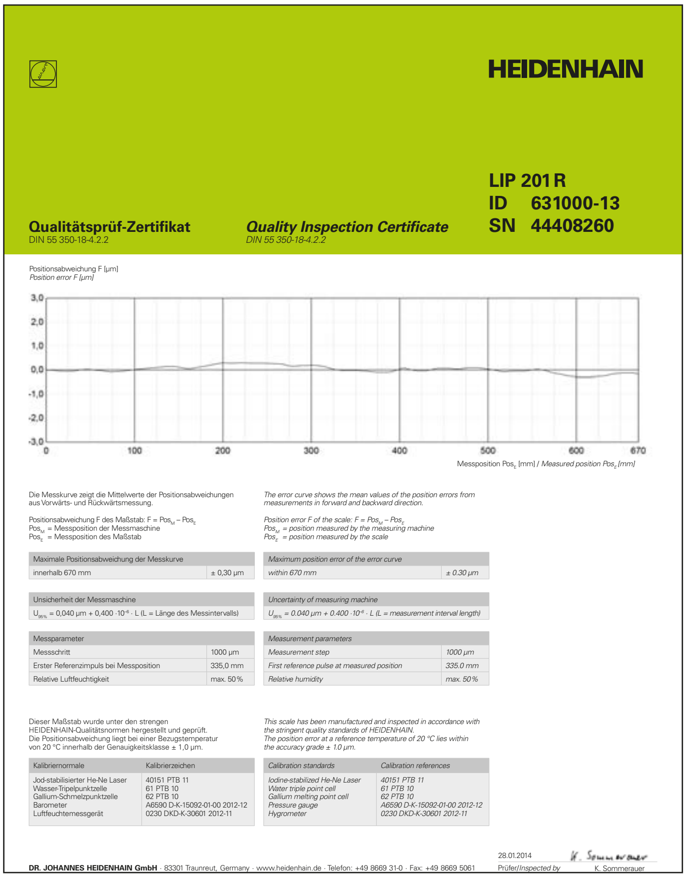
Every exposed linear encoder manufactured by HEIDENHAIN is individually inspected and certified for its quality. For all high-accuracy exposed linear encoders, a **Quality Inspection Certificate with measurement curve and detailed measuring log** (Fig. 7) documents the results of the measurements performed. All other exposed linear encoders are supplied with a Quality Inspection Certificate that certifies the compliance with the limit values specified for the individual encoder.

Measurement of accuracy in one interval
While the accuracy grade is specified for one section of maximally 1 m, or with shorter linear encoders for the entire measuring length and therefore describes the minimum accuracy of the system, the accuracy in one interval permits direct conclusions on the actually attainable accuracy of measured values in small intervals.

To be able to state accuracy in one interval, HEIDENHAIN first defines the interval width for which the accuracy is to be stated. With the LIP 200, for example, the interval width is 5 mm. Then the scale is continually measured over its entire measuring length in defined, very small measuring steps with the chosen interval width. Finally, the uncompensated baseline errors over the interval width measured in this way for each measuring step are evaluated. The worst value, i.e. the greatest measured baseline error over all measured intervals, is then specified as the maximum value $\pm F_I$.

Figure 8 illustrates an example of selected measuring steps. The baseline error within the selected interval width reaches its maximum in the second measuring step. This can then be listed in the documentation as the accuracy of the measuring standard.

Advantages of specifying accuracy in one interval
In many applications it is not the accuracy over the entire measuring range that is decisive, but rather the accuracy in a very narrowly limited section. On PCB assembly machines, for example, the last millimeters of the measuring path decide whether the mounting process can be highly accurate. In such applications, the user can can obtain substantially more precise information from the accuracy in a defined interval than from the accuracy grade.


HEIDENHAIN

LIP 201 R
ID 631000-13
SN 44408260

Qualitätsprüf-Zertifikat
DIN 55 350-18-4.2.2

Quality Inspection Certificate
DIN 55 350-18-4.2.2

Positionsabweichung F [µm] / *Position error F [µm]*

Messposition Pos_E [mm] / *Measured position Pos_E [mm]*

Die Messkurve zeigt die Mittelwerte der Positionsabweichungen aus Vorwärts- und Rückwärtsmessung.

Positionsabweichung F des Maßstab: $F = Pos_M - Pos_E$
Pos_M = Messposition der Messmaschine
Pos_E = Messposition des Maßstab

The error curve shows the mean values of the position errors from measurements in forward and backward direction.

Position error F of the scale: $F = Pos_M - Pos_E$
Pos_M = position measured by the measuring machine
Pos_E = position measured by the scale

Maximale Positionsabweichung der Messkurve	
innerhalb 670 mm	± 0,30 µm

Maximum position error of the error curve	
within 670 mm	*± 0.30 µm*

Unsicherheit der Messmaschine
$U_{95\%}$ = 0,040 µm + 0,400 ·10^{-6} · L (L = Länge des Messintervalls)

Uncertainty of measuring machine
$U_{95\%}$ = 0.040 µm + 0.400 ·10^{-6} · L (L = measurement interval length)

Messparameter	
Messschritt	1000 µm
Erster Referenzimpuls bei Messposition	335,0 mm
Relative Luftfeuchtigkeit	max. 50 %

Measurement parameters	
Measurement step	*1000 µm*
First reference pulse at measured position	*335.0 mm*
Relative humidity	*max. 50 %*

Dieser Maßstab wurde unter den strengen HEIDENHAIN-Qualitätsnormen hergestellt und geprüft. Die Positionsabweichung liegt bei einer Bezugstemperatur von 20 °C innerhalb der Genauigkeitsklasse ± 1,0 µm.

This scale has been manufactured and inspected in accordance with the stringent quality standards of HEIDENHAIN. The position error at a reference temperature of 20 °C lies within the accuracy grade ± 1.0 µm.

Kalibriernormale	Kalibrierzeichen
Jod-stabilisierter He-Ne Laser	40151 PTB 11
Wasser-Tripelpunktzelle	61 PTB 10
Gallium-Schmelzpunktzelle	62 PTB 10
Barometer	A6590 D-K-15092-01-00 2012-12
Luftfeuchtemessgerät	0230 DKD-K-30601 2012-11

Calibration standards	*Calibration references*
Iodine-stabilized He-Ne Laser	*40151 PTB 11*
Water triple point cell	*61 PTB 10*
Gallium melting point cell	*62 PTB 10*
Pressure gauge	*A6590 D-K-15092-01-00 2012-12*
Hygrometer	*0230 DKD-K-30601 2012-11*

28.01.2014
Prüfer/*Inspected by* K. Sommerauer

DR. JOHANNES HEIDENHAIN GmbH · 83301 Traunreut, Germany · www.heidenhain.de · Telefon: +49 8669 31-0 · Fax: +49 8669 5061

Figure 7

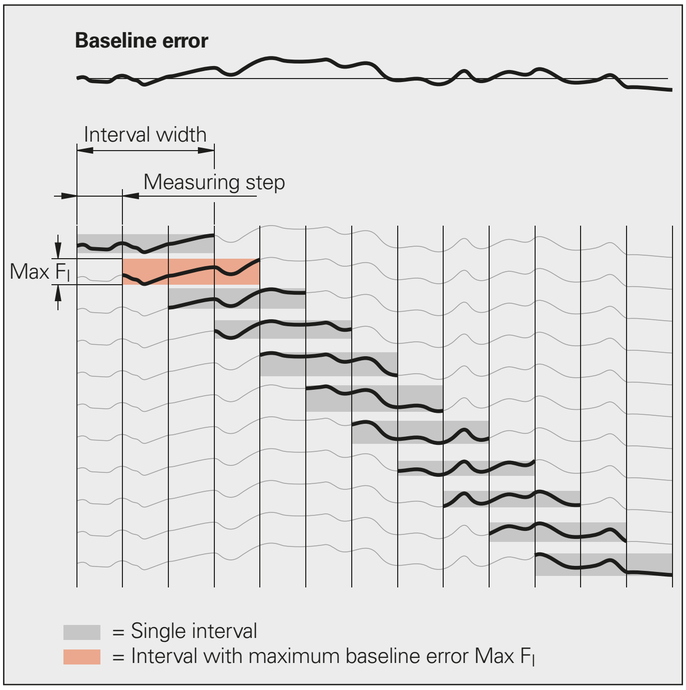


Figure 8: Ascertainment of accuracy in one interval

Figure 9: For each scale of an exposed linear encoder, HEIDENHAIN uses a special measuring machine to ascertain the baseline error in a defined interval.

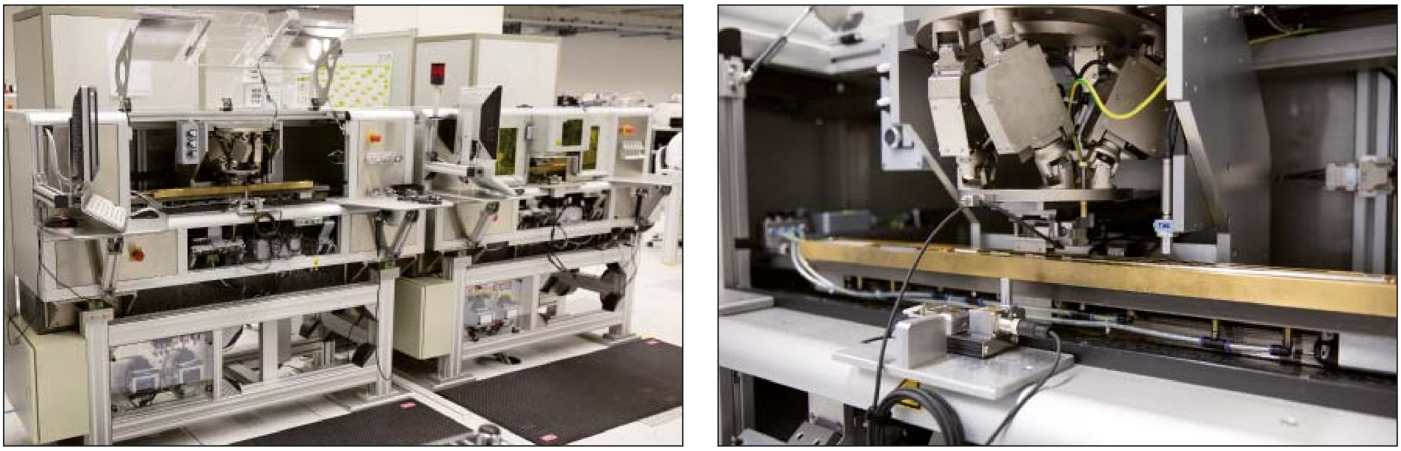


Figure 10: The interpolation deviation of each exposed linear encoder is measured on a special measuring station by measuring the scanning head.

Exposed linear encoders

Exposed linear encoders from HEIDENHAIN are optimized for use on fast, precise machines as sought by the semiconductor industry and automation technology. In spite of the exposed mechanical design, they are highly tolerant to contamination, ensure high long-term stability, and are quickly and easily mounted.

LIF 400

LIP 6000

LIDA 400

HEIDENHAIN

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

www.heidenhain.de

More information:
- Catalog: *Exposed Linear Encoders*

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