HEIDENHAIN

Sealed Linear Encoders

March 2003

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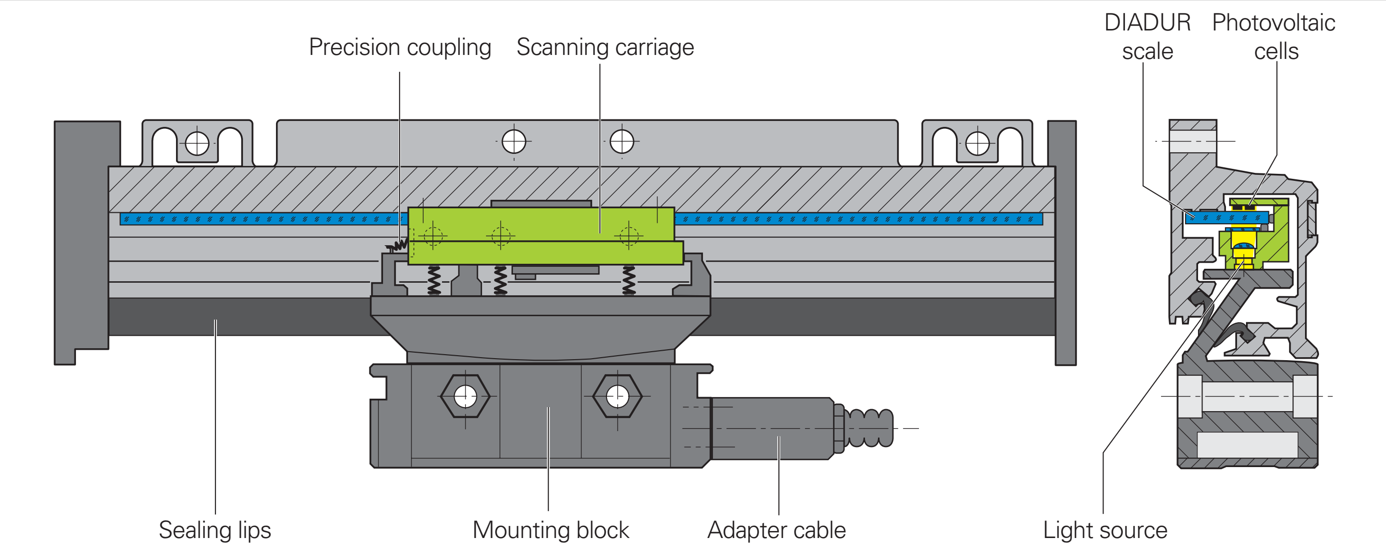
Linear encoders measure the position of linear axes without additional mechanical transfer elements. This eliminates a number of potential error sources:
- Positioning error due to thermal behavior of the recirculating ballscrew
- Backlash
- Kinematic error through lead-screw pitch error

Linear encoders are therefore indispensable for machines that fulfill high requirements for **positioning accuracy** and **machining speed.**

Sealed linear encoders are designed primarily for use on machines and installations that operate in harsh environments, such as
- Milling machines
- Drilling and boring machines
- Machining centers
- Lathes
- Grinding machines
- Electrical discharge machines
- Welding machines
- Bending presses

Mechanical design
The scale, scanning unit and guideway of sealed linear encoders are protected against chips, swarf, dirt and splashwater by an aluminum housing and flexible sealing lips. The scanning carriage travels on a low-friction guide within the scale unit. It is connected with the external mounting block by a coupling that compensates unavoidable misalignment between the scale and the machine guideways.

Maximum permissible vertical and lateral misalignment between scale and mounting block is ±0.2 mm to ±0.3 mm, depending on the model of encoder.



Simplified representation of the **LS 186** Sealed Linear Encoder.

Measuring Principles
Measuring Standard

HEIDENHAIN encoders with optical scanning incorporate measuring standards made of periodic structures known as graduations. These graduations are applied to a carrier substrate of glass or steel. The scale substrate for large measuring lengths is a steel tape.

The precision graduations are manufactured in different photolithographic processes. Graduations are fabricated from:
- extremely hard chrome lines on glass,
- matte-etched lines on gold-plated steel tape, or
- three-dimensional structures on glass or steel substrates.

The photolithographic manufacturing processes developed by HEIDENHAIN produce grating periods of typically 40 µm to 4 µm.

These processes permit very fine grating periods and are characterized by a high definition and homogeneity of the line edges. Together with the photoelectric scanning method, this high edge definition is a precondition for the high quality of the output signals.

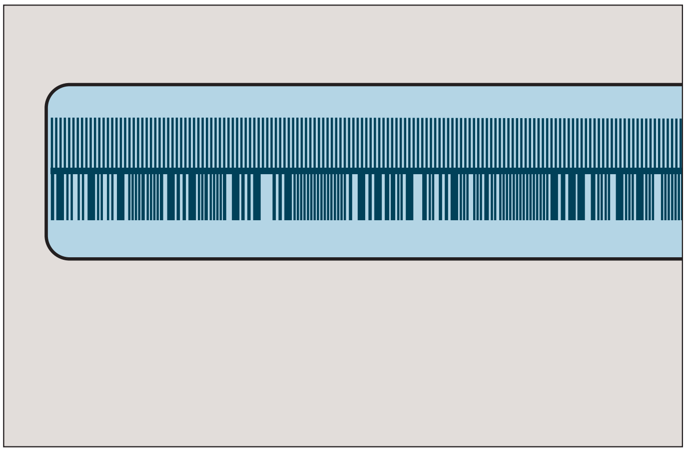
The master graduations are manufactured by HEIDENHAIN on a custom-built high-precision ruling machine.

Magnetic encoders use a magnetizable layer as graduation carrier. In this layer a graduation consisting of north and south poles is formed.

Absolute Measuring Methods

With the **absolute measuring method,** the position value is available from the encoder immediately upon switch-on and can be called at any time by the subsequent electronics. There is no need to move the axes to find the reference position. The absolute position information is read **from the scale graduation,** which is designed as a serial code structure or consists of several parallel graduation tracks with slightly different grating periods. A separate incremental track or the track with the finest grating period is interpolated for the position value and at the same time is used to generate an optional incremental signal.

Graduations of absolute linear encoders



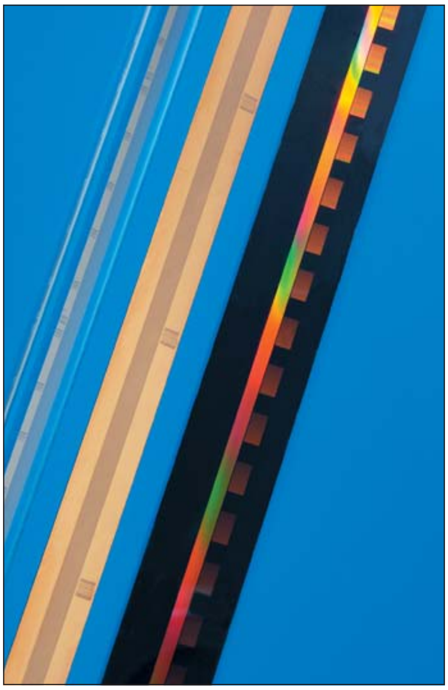
Absolute code structure with complementary incremental track on the scale of an LC 481

Incremental Measuring Methods

With **incremental measuring methods,** the graduation consists of a regular grating structure. The position information is obtained **by counting** the individual increments (measuring steps) from some point of origin. Since an absolute reference is required to ascertain positions, the scales or scale tapes are provided with an additional track that bears a **reference mark.** The absolute position on the scale, established by the reference mark, is gated with exactly one measuring step. The reference mark must therefore be scanned to establish an absolute reference or to find the last selected datum.

In some cases this may necessitate machine movement over large lengths of the measuring range. To speed and simplify such "reference runs," many encoders feature **distance-coded reference marks**—multiple reference marks that are individually spaced according to a mathematical algorithm. The subsequent electronics find the absolute reference after traversing two successive reference marks—only a few millimeters traverse (see table).
Encoders with distance-coded reference marks are identified with a "C" behind the model designation (e.g., LS 486 C).

With distance-coded reference marks, the **absolute reference** is calculated by counting the signal periods between two reference marks and using the following formula:



Graduations of incremental linear encoders

$$P_1 = (abs\ B - sgn\ B - 1) \times \frac{N}{2} + (sgn\ B - sgn\ D) \times \frac{abs\ M_{RR}}{2}$$

where:

$$B = 2 \times M_{RR} - N$$

and:

P_1 = Position of the first traversed reference mark in signal periods

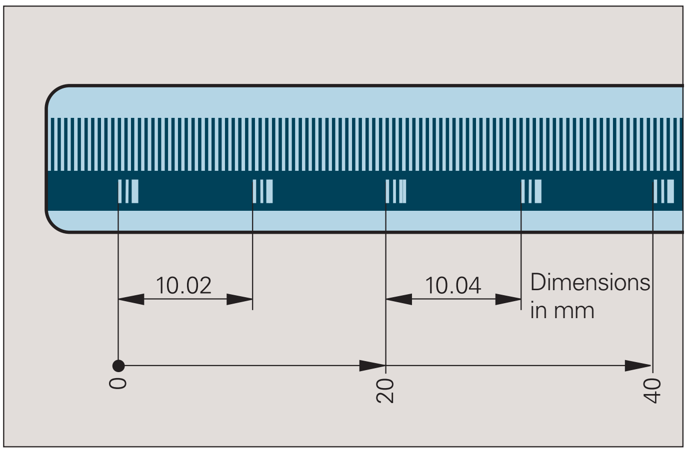
abs = Absolute value

sgn = Sign function (= "+1" or "–1")

M_{RR} = Number of signal periods between the traversed reference marks

N = Nominal increment between two fixed reference marks in signal periods (see table below)

D = Direction of traverse (+1 or –1). Traverse to the right (when installed properly) equals +1.



Incremental graduation with distance-coded reference marks on the scale of an LS encoder

	Signal period	**Nominal increment *N* in signal periods**	**Maximum traverse**
LF	4 µm	5000	20 mm
LS	20 µm	1000	20 mm
LB	40 µm	2000	80 mm

Photoelectric Scanning

Most HEIDENHAIN encoders operate on the principle of photoelectric scanning. The photoelectric scanning of a measuring standard is contact-free, and therefore without wear. It detects even the finest graduation lines just a few micrometers wide, and generates output signals with very small signal periods.

The finer the grating period of a measuring standard is, the greater the effect of diffraction on photoelectric scanning. HEIDENHAIN uses two scanning principles with angle encoders:

- The **imaging scanning principle** for grating periods from 10 µm to 40 µm.
- The **interferential scanning principle** for very fine graduations with grating periods of 4 µm, for example.

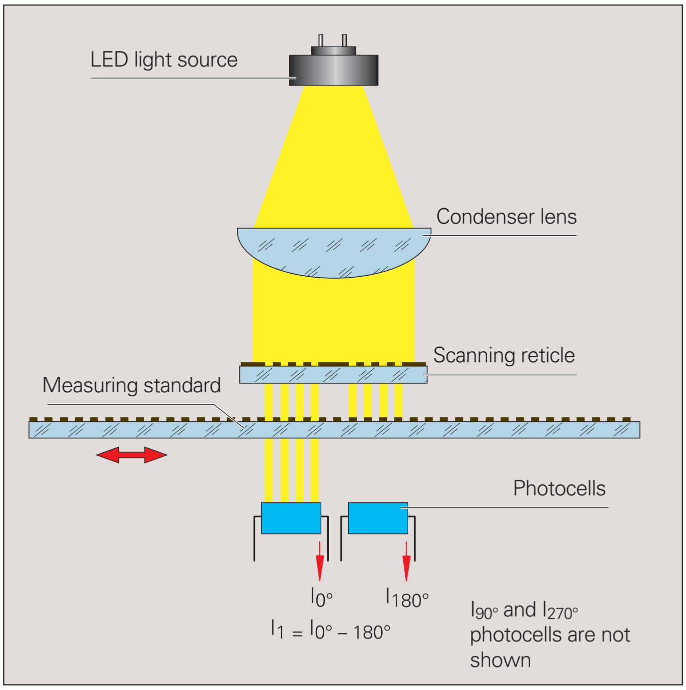
Imaging scanning principle
To put it simply, the imaging scanning principle functions by means of projected-light signal generation: two scale gratings with equal grating periods are moved relative to each other—the scale and the scanning reticle. The carrier material of the scanning reticle is transparent, whereas the graduation on the measuring standard may be applied to a transparent or reflective surface.

When parallel light passes through a grating, light and dark surfaces are projected at a certain distance. An index grating with the same grating period is located here. When the two gratings move relative to each other, the incident light is modulated: if the gaps are aligned, light passes through. If the lines of one grating coincide with the gaps of the other, no light passes through. Photocells convert these variations in light intensity into nearly sinusoidal electrical signals. The specially structured grating of the scanning reticle filters the light current to generate nearly sinusoidal output signals.

The smaller the grating period of the grating structure is, the closer and more tightly toleranced the gap must be between the scanning reticle and scale. Practical mounting tolerances for encoders with the imaging scanning principle are achieved with grating periods of 10 µm and larger.

The LC, LS and LB linear encoders operate according to the imaging scanning principle.

Imaging scanning principle



Measuring Accuracy

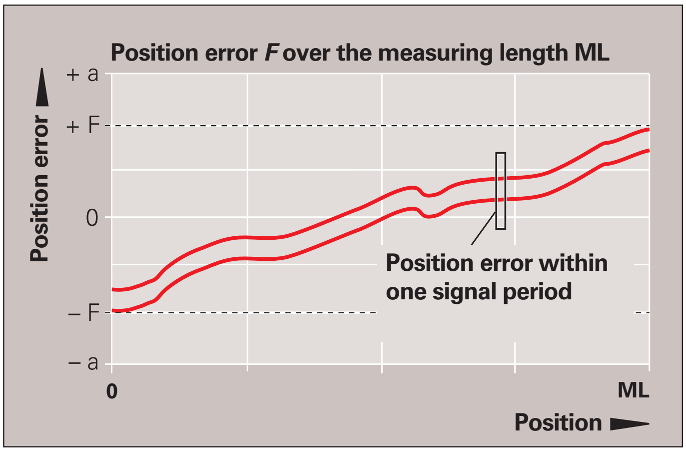
The accuracy of linear measurement is mainly determined by:
- the quality of the graduation
- the quality of scanning
- the quality of the signal processing electronics
- the error from the scale guideway over the scanning unit.

A distinction is made between position error over relatively large paths of traverse—for example the entire measuring range—and that within one signal period.

Position error over the measuring length
The accuracy of sealed linear encoders is specified as accuracy grades, which are defined as follows:

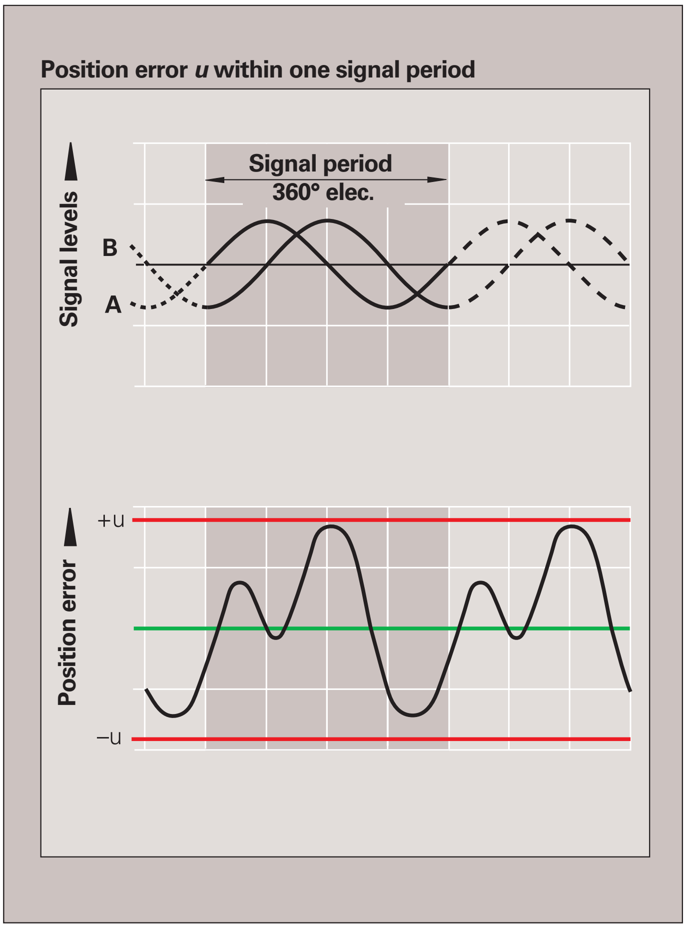
The extreme values of the total error F of a position lie—with reference to their mean value—over any max. one-meter section of the measuring length within the accuracy grade ±a.

This tolerance band is also shown in the calibration chart (see opposite page) and represents the position error within one signal period. With sealed linear encoders, this value applies to the complete encoder system including the scanning unit. It is then referred to as the system accuracy.



Position error within one signal period
The position error within one signal period is determined by the quality of scanning and the signal period of the encoder. At any position over the entire measuring length, it does not exceed approx. ±2% of the signal period. The smaller the signal period, the smaller the position error within one signal period.

	Signal period of scanning signals	Max. position error *u* approx. within one signal period
LF	4 µm	0.08 µm
LC 181	16 µm	0.3 µm
LC 481	20 µm	0.4 µm
LS	20 µm	0.4 µm
LB	40 µm	0.8 µm



LS 629

Incremental linear encoder for measuring steps of 10 µm and 5 µm (0.0005 in. and 0.0002 in.)
- **With integrated guide**
- **Large mounting tolerances and connection over coupling rod**

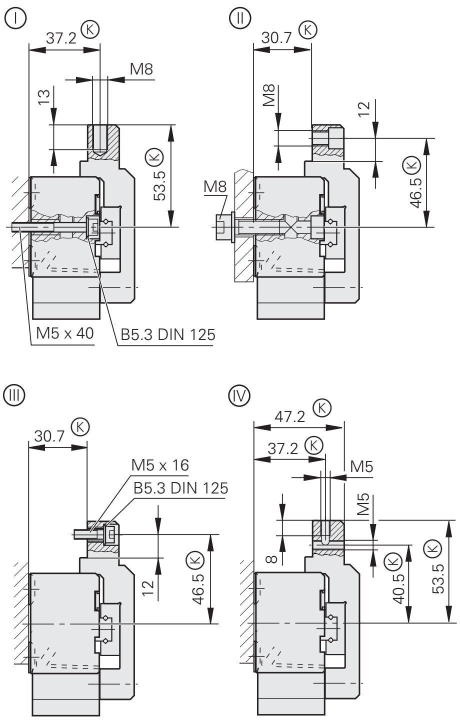
Specifications	**LS 629**
Measuring standard Grating period	Glass scale with DIADUR grating 20 µm
Accuracy grade	± 10 µm (± 0.0004 in.)
Measuring length ML* in mm inches	170, 220, 270, 320, 370, 420, 6.7, 8.6, 10.6, 12.6, 14.5, 16.5, 470, 520, 620, 720, 770, 820, 18.5, 20.5, 24.4, 28, 30, 32, 920 36
Reference marks* **LS 629**	Selectable every 50 mm by magnet Standard setting: 1 reference mark at midpoint
LS 629 C	Distance-coded for ascertaining the absolute position value after max. 20 mm traverse
Max. traversing speed	50 m/min (2362 ipm)
Vibration 55 to 2 000 Hz **Shock** 11 ms	30 m/s² (IEC 60 068-2-6) 200 m/s² (IEC 60 068-2-27)
Required moving force	≤ 10 N
Protection IEC 60 529	IP 53 when installed as per instructions IP 64 with compressed air
Operating temperature	0 to 50 °C (32 to 122 °F)
Weight	0.9 kg + 2.5 kg/m measuring length
Power supply	5 V ± 5 %/< 170 mA (without load)
Incremental signals Signal period Edge separation *a*	⊓⊔ TTL 20 µm ≥ 2,5 µs
Electrical connection Max. cable length	Sep. adapter cable (1 m/3 m/6 m) with and without armor 50 m (164 ft) max.

***** Please indicate when ordering

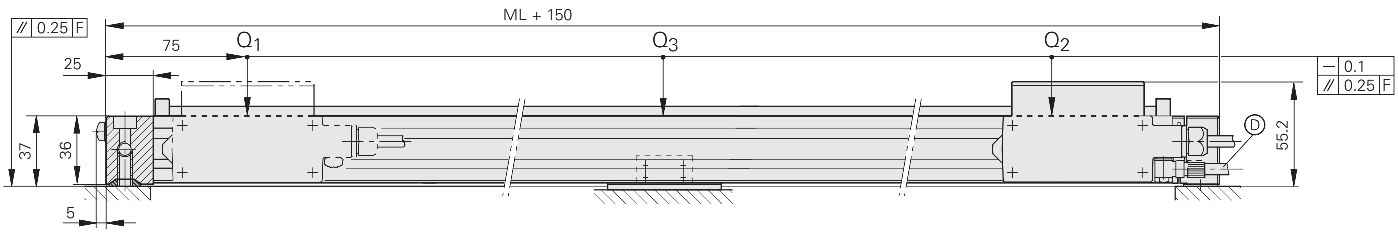
Dimensions

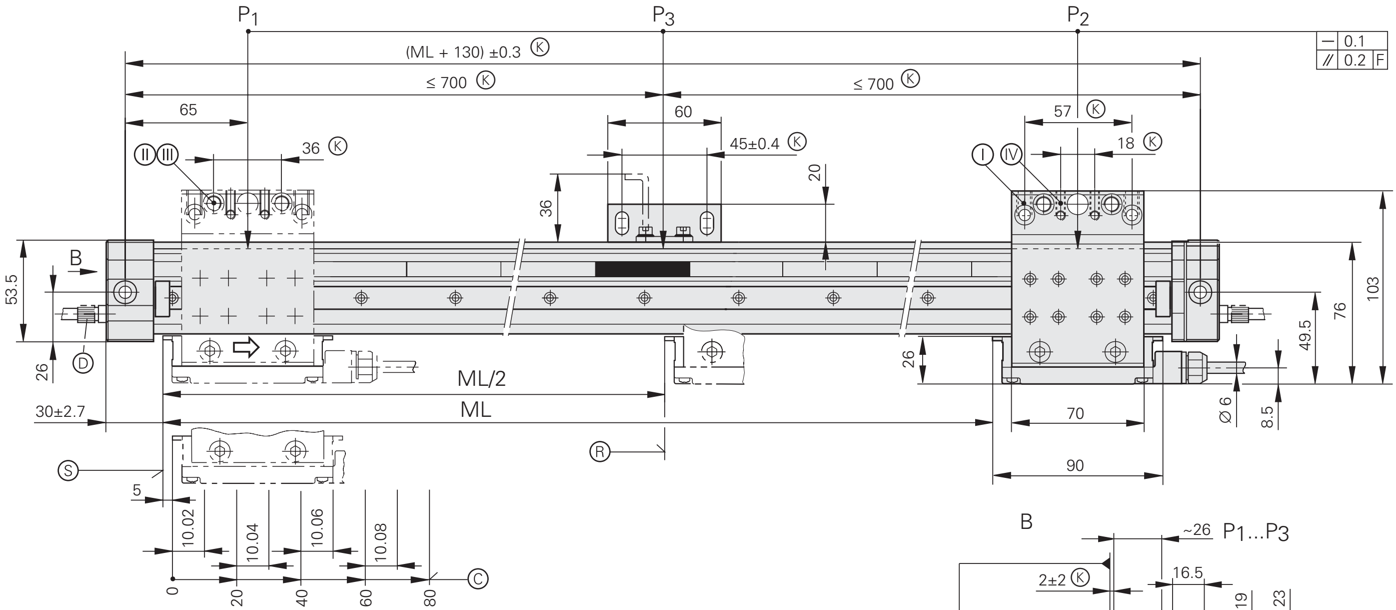
in mm

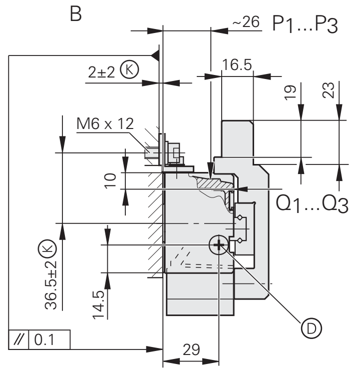
DIN ISO 8015
ISO 2768 - m H



Ⓘ, Ⓘ Ⓘ,
Ⓘ Ⓘ Ⓘ, Ⓘ Ⓥ = Mounting options
F = Machine guideway
P, Q = Gauging points for alignment
Ⓚ = Required mating dimensions
Ⓓ = Compressed air inlet
Ⓡ = Reference mark position LS 629
Ⓒ = Reference mark position LS 629 C
Ⓢ = Beginning of measuring length (ML)
⇨ = Direction of scanning unit motion for output signals in accordance with interface description







Mounting with coupling rod