MULTI-DOF Measurement Technology for Multiple Degrees of Freedom
Dplus encoders for perfect motion systems

Linear encoders measure the position of linear axes without intervening mechanical elements, thereby eliminating multiple potential sources of error:

- Positioning error due to thermal changes in the recirculating ball screw
- Reversal error
- Kinematic error due to the ball-screw pitch error

As a result, linear encoders are essential components on machines requiring high positioning accuracy and machining speed.

Dplus encoders

Dplus encoders measure multiple degrees of freedom on a single machine axis, thereby directly and precisely measuring errors and the machine deviations they cause. Dplus encoders provide exceptional possibilities for optimizing your motion system, particularly when high dynamic performance and accuracy are called for.

Exposed linear encoders are deployed on machines and automated systems requiring high measurement accuracy. Typical applications include the following:

- Production and measurement equipment in the semiconductor industry
- PCB assembly machines
- Ultra-precision equipment such as diamond lathes for optical components, facing lathes for magnetic storage disks and grinding machines for ferrite parts.
- High-accuracy machines, comparators, measuring microscopes, and other precision measuring devices
- Direct drive motors

Mechanical design

Exposed linear encoders consist of a scale or scale tape and a scanning head that operate without mechanical contact. The scales of exposed linear encoders are fastened to a mounting surface. High flatness of the mounting surface is thus an important requirement for the high accuracy of linear encoders.

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Information about the following topics is available upon request or online at www.heidenhain.com:

- Angle encoders with integral bearing
- Modular angle encoders with optical scanning
- Modular angle encoders with magnetic scanning
- Rotary encoders
- Encoders for servo drives
- Linear encoders for numerically controlled machine tools
- Signal converters
- HEIDENHAIN controls

Further information:

This brochure supersedes all previous editions, which thereby become invalid. The basis for ordering from HEIDENHAIN is always the brochure edition valid when the order is placed.

Standards (ISO, EN, etc.) apply only where explicitly stated in the brochure.

For detailed descriptions of all available interfaces, as well as general electrical information, please refer to the Interfaces of HEIDENHAIN Encoders brochure (ID 1079628-xx).

For the required connecting cables, see the Cables and Connectors brochure (ID 1206103-xx).
Multi-dimensional measurement technology

Conventional encoders can measure only one degree of freedom, rendering them blind to unavoidable errors in other directions. In multi-axis systems, an error in one axis carries over into the other axes, thereby affecting the entire motion system. Error in the first axis changes the actual position of the second encoder, and so on. Yet these errors are not normally measured.

The Dplus encoders from HEIDENHAIN, however, can measure multiple degrees of freedom on a single axis, allowing the error in one axis to be measured and compensated for in the next.

The accuracy of a motion system depends on multiple factors:
- Non-linear guideway errors
- Vertical flatness, horizontal straightness
- Pitch, yaw and roll
- Squareness error
- Kinematics error
- Thermal expansion and other thermal effects
- Hysteresis

The challenge of perfecting position measurement in the primary axis is significant. Simply optimizing the scale and scanning head is not sufficient for maximizing a motion system’s precision and dynamic performance. Machine design factors and thermal changes play a greater role as accuracy and dynamic-performance requirements increase. Thanks to multi-dimensional encoders such as the LIP 6000 Dplus, these factors can be directly measured and compensated for.

Higher accuracy and greater dynamic performance

More than ever, productivity and accuracy are key competitive advantages. But faster and more precise production processes are only part of the equation: reproducibility and stable quality are essential as well. Attaining reliably high accuracy greatly expands your manufacturing capabilities, particularly in the high-end spectrum.
Precise measurement for optimal performance

The interferential measuring principle generates signals by utilizing the refraction and interference of light on finely divided gratings. The measuring standard consists of a flat surface with 0.2 μm-high reflecting lines. These lines are read by a scanning reticle featuring a light-permeable phase grating with an identical graduation period.

Interferential encoders use signal periods of 4 μm or less, and these largely harmonics-free scanning signals can be highly interpolated. Consequently, these encoders are ideal when high resolution and accuracy are required.

The Dplus encoders, such as the LIP 6000 Dplus, have a carrier with two separate graduation tracks featuring diagonal graduations (±45°), thus permitting direct, high-accuracy measurement of the primary and secondary directions along the entire measuring length.

HEIDENHAIN also offers an incremental two-coordinate encoder for equal measurement in two different directions. Neither direction is primary or secondary. In this case, the carrier is itself a high-accuracy grid graduation.
Measuring multiple degrees of freedom

A body in space can move along six possible axes. These are divided into translational degrees of freedom (X, Y, Z) and rotational degrees of freedom (RX, RY, RZ).

Normally, measuring multiple degrees of freedom requires numerous components. Standard encoders require one scanning head and one measuring standard for each degree of freedom. The Dplus encoders from HEIDENHAIN, however, can significantly reduce the number of components required.

A Dplus scale with two separate graduation tracks and three scanning heads on the same scale, for example, can measure up to three degrees of freedom. This technology makes it possible to implement complex measuring tasks in a simple and compact design.
Diagonal graduations

Position value calculation

\[ x = \frac{1}{\sqrt{2}} (P_{01} + P_{02}) \]
\[ y = \frac{1}{\sqrt{2}} (P_{01} - P_{02}) \]

Harness the advantages of precise error measurement

It would be impossible to home the secondary direction of measurement if the graduations were positioned at right angles (0° and 90°). But with a diagonal configuration, the primary and secondary directions of motion can be homed at the same time.

The resulting absolute position measurement, in turn, lets you achieve greater machine accuracy and identify sources of error.

Dplus-scanning head

The special Dplus scanning head developed by HEIDENHAIN can measure two degrees of freedom at the same time. With the EnDat 3 interface, these two position values are forwarded to the control over a single cable.

The resulting reduction in cabling not only simplifies installation but also optimizes the dynamic behavior of the motion system.
Out-of-plane gap measurement

Conventional encoders can measure only one degree of freedom at a time. Dplus encoders, however, can measure up to three degrees of freedom in the encoder plane, such as X, Y and RZ. Additional measurements in a different plane would require additional encoders and a more complex system design.

The GAP 1081 gap encoder performs vertical measurement, enabling highly convenient and space-saving system expansion for additional directions. Because its components are mounted in the encoder’s main plane, the GAP 1081 delivers rapid measurement directly at the machine.

This encoder can be used for straightforward vertical positioning tasks and continuous vertical measurement along a linear plane. Two scanning heads deployed on a mirror can even measure the pitch or yaw of the given axis, thus greatly simplifying the metrology system design and reducing the required installation work.
Transferable accuracy

Robustness test for the Dplus measuring-standard assemblies

The system accuracy within an application depends not only on how well the encoder was installed but also on the ambient conditions during operation. Thanks to measuring-standard calibrations performed by measuring machines at HEIDENHAIN, the accuracy of the measuring system is increased, and complex on-site, post-installation calibrations are unneeded.

Prior to shipment, the measuring standard is also mounted to a carrier and measured at HEIDENHAIN, thereby decoupling the measuring standard from negative mounting, environmental and transportation factors. As a result, the accuracy measured at HEIDENHAIN is fully transferred from the measuring machine to the application. The calibration table is included.

<table>
<thead>
<tr>
<th>Ambient conditions</th>
<th>Transport conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st measurement</td>
<td>2nd measurement</td>
</tr>
<tr>
<td>Cold –10 °C</td>
<td>Heat 50 °C at 50% rF</td>
</tr>
<tr>
<td>Rate of heating/cooling: ±10K/h</td>
<td>Rate of heating/cooling: ±10K/h</td>
</tr>
<tr>
<td>Stabilization time (room temperature)</td>
<td>Stabilization time (room temperature)</td>
</tr>
<tr>
<td>24h</td>
<td>24h</td>
</tr>
<tr>
<td>2nd measurement</td>
<td>3rd measurement</td>
</tr>
<tr>
<td>Heat 50 °C at 50% rF</td>
<td>Humidity 22 °C at 85% rF</td>
</tr>
<tr>
<td>Rate of heating/cooling: ±10K/h</td>
<td>Rate of air humidity change: ±20%</td>
</tr>
<tr>
<td>Stabilization time (room temperature)</td>
<td>Stabilization time (room temperature)</td>
</tr>
<tr>
<td>24h</td>
<td>72h</td>
</tr>
<tr>
<td>3rd measurement</td>
<td>4th measurement</td>
</tr>
<tr>
<td>Humidity 22 °C at 85% rF</td>
<td>Vibrations 6.86 m/s² RMS*</td>
</tr>
<tr>
<td>Rate of air humidity change: ±20%</td>
<td>Packed in cardboard box</td>
</tr>
<tr>
<td>Stabilization time (room temperature)</td>
<td>Stabilization time (room temperature)</td>
</tr>
<tr>
<td>72h</td>
<td></td>
</tr>
<tr>
<td>4th measurement</td>
<td>5th measurement</td>
</tr>
<tr>
<td>Vibrations 6.86 m/s² RMS*</td>
<td>Drop test Drop height: 0.8 m</td>
</tr>
<tr>
<td>Packed in cardboard box</td>
<td></td>
</tr>
<tr>
<td>5th measurement</td>
<td>6th measurement</td>
</tr>
<tr>
<td>Drop test Drop height: 0.8 m</td>
<td></td>
</tr>
<tr>
<td>6th measurement</td>
<td></td>
</tr>
</tbody>
</table>

*40 min: 3.92 m/s² RMS; 15 min: 5.29 m/s² RMS; 5 min: 6.86 m/s² RMS (ASTM D 4169)

Straightness deviation relative to the measuring length
Less cabling and higher dynamic performance

**EnDat 3**

Multi-head processing with EnDat 3

The use of multiple encoders increases overall system cabling, making installation and downstream processing more complex. With the EnDat 3 interface, HEIDENHAIN offers the optimal solution for transmitting a wide range of data on just one cable. Two position values, for example, are calculated in the interface PCB of a Dplus encoder and transmitted over a single cable.

For single-cable transmission, the multi-head processing electronics process the position signals of multiple encoders.

This permits convenient implementation of complex metrology system designs without extensive cabling or separate position value processing.
LIP 6031 Dplus

Incremental exposed linear encoder
- Two diagonal graduations ±45° for measuring the primary and secondary directions
- Glass scale made of glass ceramic; mounting with PRECIMET and fixed-point elements

Scale
- LIP 6001 Dplus

Measuring standard: OPTODUR phase grating on Zerodur glass ceramic; graduation period: 8 µm
- Coefficient of linear expansion: α = 0 ± 0.1 · 10⁻⁶ K⁻¹

Accuracy grade
- X direction: ±3 µm; Y direction: ±20 µm

Baseline error
- X direction: ±0.175 µm/5 mm; Y direction: ±0.350 µm/5 mm

Measuring length (ML) in X direction
- in mm*: 70 120 170 220 270 320 370 420 470 520 570 620 670 720 770 820 870 920 970 1020 1140 1240 1340 1440 1540 1640 1840 2040

Measuring length in Y direction
- ±2 mm

Reference mark
- One at the beginning of the measuring length

Mass
- 0.15 g/mm

Scanning head
- LIP 603 Dplus

Interface
- EnDat 3

Ordering designation
- E30-R4

Measuring step
- 172 pm

Availability of position value
- X direction: < 11 µs at 12.5 Mbit/s; < 8.2 µs at 25 Mbit/s
- Y direction: < 18.7 µs at 12.5 Mbit/s; < 12.1 µs at 25 Mbit/s

Traversing speed
- ≤ 240 m/min

Interpolation error
- ≤ 5 nm

RMS position noise
- 0.5 nm (1 MHz)

Electrical connection
- Cable (0.5 m/1 m/3 m) with interface electronics in the connector (15-pin D-sub (male))

Cable length
- 12.5 Mbit/s: ≤ 100 m; 25 Mbit/s: ≤ 40 m
- During signal adjustment with the PWM 21: ≤ 3 m

Supply voltage
- DC 3.6 V to 14 V (recommended: 12 V)

Power consumption
- 3.6 V: ≤ 1.5 W; 14 V: ≤ 1.8 W
- At 12 V: 110 mA (without load, typical)

Vibration
- ≤ 500 m/s² (EN 60068-2-6)

Shock
- ≤ 1000 m/s² (EN 60068-2-27)

Operating temperature
- –10 °C to 70 °C

Mass
- APE connector: 30 g
- Connecting cable: 30 g/m

* Please select when ordering

1) This value is stored in the encoder as the parameter XEL.timeHPFout and outputs the time interval between the position-value request (latch) and the availability of the position value in the Master (without cable factors)
2) With transmission in the first LPF
3) Maximum traversing speed when the reference mark is cross (120 m/min)
4) See General electrical information in the Interfaces of HEIDENHAIN Encoders brochure or under www.heidenhain.com.

F = Machine guideway
l = Scale length
r = Reference mark position
s = Beginning of measuring length (ML)
1 = Direction of motion of the scanning unit for increasing position values
2 = Adjustment of the scanning gap
3 = Mark adjustment: alignment pin: Ø 2 mm
4 = Adhesive tape
5 = Adhesive
6 = Center of 1 and 2 of the scanning head
7 = Neutral center of rotation of the scanning head
8 = Signal quality indicator
9 = Bearing surface of encoder
10 = Fixed point for defining the thermal fixed point
11 = Fixed point for defining the thermal fixed point
12 = Direction of motion of the scanning unit for increasing position values
13 = Adjustment of the scanning gap
14 = Mark adjustment: alignment pin: Ø 2 mm
15 = Adhesive tape
16 = Adhesive
17 = Center of 1 and 2 of the scanning head
18 = Neutral center of rotation of the scanning head
19 = Digital connector
20 = Digital connector
LIP 211Dplus/LIP 281Dplus/LIP 291Dplus

Incremental exposed linear encoder
- Two diagonal graduations ±45° for measuring the primary and secondary directions
- Measuring scale made of glass ceramic; mounting with PRECIMET and fixed-point elements

Scale

<table>
<thead>
<tr>
<th>LIP 201 Dplus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring standard</td>
</tr>
<tr>
<td>Coefficient of linear expansion</td>
</tr>
<tr>
<td>Accuracy grade</td>
</tr>
<tr>
<td>Baseline error</td>
</tr>
<tr>
<td>Measuring length in the X direction (ML) in mm*</td>
</tr>
<tr>
<td>Measuring length in Y direction</td>
</tr>
<tr>
<td>Reference mark</td>
</tr>
<tr>
<td>Mass</td>
</tr>
</tbody>
</table>

Scanning head

<table>
<thead>
<tr>
<th>LIP 21</th>
<th>LIP 28F</th>
<th>LIP 29M</th>
<th>LIP 28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface</td>
<td>EnDat 2.2²</td>
<td>Fanuc Serial Interface²</td>
<td>Mitsubishi high speed²</td>
</tr>
<tr>
<td>Ordering designation</td>
<td>EnDat22</td>
<td>Fanuc02</td>
<td>Mit02-4</td>
</tr>
<tr>
<td>Integrated interpolation</td>
<td>16:384-field (14 bit)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Clock frequency</td>
<td>≤ 16 MHz</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Calculation time ( t_{\text{cal}} )</td>
<td>≤ 5 µs</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Measuring step</td>
<td>0.03125 mm (31.25 pm)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Signal period</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cutoff frequency</td>
<td>≤ 3 MHz</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Traversing speed</td>
<td>≤ 120 m/min</td>
<td>–</td>
<td>≤ 90 m/min</td>
</tr>
<tr>
<td>Interpolation error</td>
<td>≤ 0.4 nm³</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>RMS position noise</td>
<td>0.12 nm</td>
<td>0.12 nm (3 MHz⁴)</td>
<td>–</td>
</tr>
<tr>
<td>Electrical connection</td>
<td>Cable (0.5 m) or 1 m (2 m and 3 m at 1 Vpp with interface electronics in the connector (15-pin D-sub male))</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cable length</td>
<td>See Interface description; however ≤ 16 m (≤ 30 m at 1 Vpp with HEIDENHAIN cable During signal adjustment with the PWM 21: ≤ 3 m)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>DC 5 V ± 0.25 V</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Power consumption⁵ (max.)</td>
<td>At 14 V: 2500 mW; at 3.6 V: 2600 mW</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Current consumption</td>
<td>At 5 V: 300 mA (without load, typical)</td>
<td>–</td>
<td>≤ 290 mA</td>
</tr>
<tr>
<td>Laser</td>
<td>Mounted scanning head and scale; Class 1; non-mounted scanning head: Class 3B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibration</td>
<td>65 Hz to 2000 Hz</td>
<td>≤ 200 m/s² (IEC 60068-2-6)</td>
<td>≤ 400 m/s² (IEC 60068-2-27)</td>
</tr>
<tr>
<td>Shock 11 ms</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>0 °C to 50 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>Scanning head: 59 g; connector: 140 g; connecting cable: 22 g/ mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-² Please select when ordering.
-³ Measuring length in Y direction upon traversing of the reference mark: ±0.6 mm
-⁴ Absolute position value after traversing of the reference mark in “position value 2”. With HEIDENHAIN signal converter; ≤ 3 dB cutoff frequency of the downstream electronics; See General electrical information in the Interfaces of HEIDENHAIN Encoders brochure.

F = Machine guideway
G = Scale length
○ = Reference mark position
● = Beginning of measuring length (ML)
● = Adhesive
● = Mounting element for adhesive bond for defining the thermal fixed point
1 = Neutral center of rotation (0.2 mm under the scale surface)
2 = Depends on the measuring length (ML), additional fix clamp pair
3 = Direction of motion of the scanning unit for ascending position values
4 = Optical centerline
5 = Transversal ML ±0.6 mm
Two-coordinate incremental encoder

For measuring steps of 1 µm to 0.05 µm

Measuring standard

Coefficient of linear expansion

Two-coordinate TITANID phase grating on glass; grating period: 8 µm

Coefficient of linear expansion

\( a_{\text{therm}} = 8 \times 10^{-6} \text{ K}^{-1} \)

Accuracy grade

\( \pm 0.2 \mu m \)

Measuring area

68 mm x 68 mm, other measuring areas upon request

Reference marks

One reference mark in each axis, 3 mm after beginning of measuring length

Interface

1 V peak-to-peak

Signal period

4 µm

Cutoff frequency

\( -3 \) dB

300 kHz

Traversing speed

\( \leq 72 \text{ m/min} \)

Interpolation error

\( \pm 12 \text{ nm} \)

RMS position noise

\( \pm 2 \text{ nm} \) (450 kHz)

Electrical connection

Cable (0.5 m) with 15-pin D-sub connector (male); interface electronics in the connector

Cable length

See the interface description (in accordance with the interface electronics); however, \( \leq 30 \) m (with HEIDENHAIN cable)

Supply voltage

DC 5 V ±0.25 V

Current consumption

\( < 185 \text{ mA per axis} \)

Vibration

85 Hz to 2000 Hz

\( \leq 80 \text{ mV}^{2} \) (EN 60068-2-6)

Shock

11 ms

\( \leq 100 \text{ m/s}^{2} \) (EN 60068-2-27)

Operating temperature

0 °C to 50 °C

Mass

Scanning head: 170 g (without cable)

Grid plate: 75 g

Connector: 140 g

1) The reference mark signal deviates from the interface specification in its zero crossovers K, L (see the mounting instructions)

2) –3 dB cutoff frequency of the downstream electronics

3) With HEIDENHAIN signal converter (e.g., EIB 741)
ISO 4762 M3x (a-t+3) -A2
Md = 0.85 Nm

0.02/100
0.2 F

B-B

4.139
5.7

5
12
37.4
30
112

3.4
6.5

33.3
Md = 40 Ncm

GAP 1081
Incremental exposed linear encoder
- For vertical gap measurement
- Mirror on glass, mounting with PRECIMET

Mirror
GAP 1001
- Glass or glass ceramic with Optodur surface layer
- Coefficient of linear expansion
  \( \alpha_{\text{glass}} = 6 \times 10^{-6} \, \text{K}^{-1} \)
  \( \alpha_{\text{Zerodur}} = 8 \times 10^{-6} \, \text{K}^{-1} \)

Measuring length (ML) in mm*

<table>
<thead>
<tr>
<th>ML</th>
<th>20</th>
<th>30</th>
<th>50</th>
<th>70</th>
<th>120</th>
<th>170</th>
<th>220</th>
<th>270</th>
<th>320</th>
<th>370</th>
<th>420</th>
<th>470</th>
<th>520</th>
<th>570</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>620</td>
<td>670</td>
<td>720</td>
<td>780</td>
<td>820</td>
<td>870</td>
<td>920</td>
<td>1020</td>
<td>1140</td>
<td>1240</td>
<td>1340</td>
<td>1440</td>
<td>1540</td>
<td></td>
</tr>
</tbody>
</table>

Mass
1.1 g + 0.11 g/mm of mirror length

Scanning head
GAP 108
- Measuring gap (nominal) 4.139 mm
- Measuring range ±2 mm
- Reference mark One at midpoint of measuring length
- Interface 1 V

Cutoff frequency -3 dB ≥ 27 kHz
Signal period 2.220 ±0.002 µm

Traversing speed 3.6 m/min
Accuracy grade ±0.2 µm (measurement from a fixed location in the direction of measurement)
±20 µm (motion perpendicular to the direction of measurement)

Baseline error ±39/4 mm (measurement from a fixed location in the direction of measurement)
≤ 0.5 µm/5 mm (with motion perpendicular to the direction of measurement)

Thermal position drift ±36 nm/K
Interpolation error ±2 nm
Non-reproducible position error ±5 nm

Electrical connection
Cable (0.5 m/1 m/3 m) with 15-pin D-sub connector; interface electronics in the connector

Supply voltage DC 5 V ±0.25 V
Current consumption ≤ 200 mA (without load)

Laser
Class 3B

Vibration 55 Hz to 2 kHz
≤ 200 m/s² (IEC 60068-2-6)
≤ 400 m/s² (IEC 60068-2-27)

Shock 11 ms
≤ 200 m/s² (IEC 60068-2-27)

Operating temperature 22 °C ±5 °C

Mass
- Scanning head 50 g
- Connector 80 g
- Cable 27 g

1) During referencing: temperature during adjustment ±2.5 °C during single-side approach

* Please select when ordering

Optical center
Mounting surface for the scale
Beginning of z measurement (with simultaneous x movement)
Reference mark position
Measuring length
Machine guideway
Optical center
Scale
Cable length
Adhesive tape
Position of stop pins; recommendation Ø 3
Direction of motion of the scanning unit for increasing position values
Clamping screw (width A/F: 1.3 mm); M₃ = 30 ±1.8 Nm

Tolerances: ISO 9068
- ISO 2768:1989 M4
- ≤ 6 mm: ±0.2 mm

Visible laser radiation
IEC 60825-1:2008
Class 3B laser product

1) During referencing: temperature during adjustment ±2.5 °C during single-side approach
### Pin layout

**LIP 603**

<table>
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<th>Power supply</th>
<th>Other signals</th>
<th>Serial data transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>UP</td>
<td>Sensor</td>
<td>0 V</td>
</tr>
<tr>
<td>Brown/Green</td>
<td>White/Green</td>
<td>/</td>
</tr>
</tbody>
</table>

**LIP 281 and PP 281R**

<table>
<thead>
<tr>
<th>Power supply</th>
<th>Incremental signals</th>
<th>Other signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>1 Vpp</td>
<td>Uᵢ</td>
<td>Sensor</td>
</tr>
<tr>
<td>Brown/Green</td>
<td>Blue</td>
<td>White/Green</td>
</tr>
</tbody>
</table>

**Cable shield**

- **Color assignment of the connecting cable**
- **Sensor**: The sense line is connected in the encoder with the corresponding power line.
- **Vacant pins or wires must not be used.**

**Further information:**

For detailed descriptions of cables, please refer to the Cables and Connectors brochure.

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1) Only for adjusting, do not use in normal operation
2) Color assignment of the connecting cable
3) PP 281 R