Read this manual before installing the position encoder and placing it in operation.

1.1 Proper use
The BML Linear Encoder is installed in a machine or on a piece of equipment. Together with a control system (PLC) it comprises a linear encoder system and may be used only for this purpose.

Unauthorized intervention and unallowed use will result in loss of warranty and liability claims.

1.2 Qualified personnel
This manual is intended for technical personnel who perform the installation and setup.

1.3 Use and testing
Observe the relevant safety regulations for use of the position encoder.

In particular, measures must be taken to ensure that in case of a defect in the position encoder no hazards to persons or equipment can result. These measures include the installation of additional safety limit switches, emergency stop switches and maintaining the permissible ambient conditions. BML Linear Encoders may not be used in lifesaving systems, in aircraft, etc.

1.4 Validity
This manual applies to type BML-S1F position encoders.

An overview of the various versions can be found in Section 12 Versions (refer also to part label).

The CE Marking confirms that our products meet the requirements of the EU Directive 2004/108/EG (EMC Directive) and the EMC Law. In our EMC laboratory, which is accredited by the DATech for Testing Electromagnetic Compatibility, proof has been established that Balluff products meet the EMC requirements of the following generic standards:

EN 61000-6-4 (Emission)

Emission tests:
RF radiation
EN 55016-2-3 Group 1, Class A+B
Noise immunity tests:
Static electricity (ESD)
EN 61000-4-2 Severity Level 3
Electromagnetic Fields (RFI)
EN 61000-4-3 Severity Level 3
Fast transients
(Burst)
EN 61000-4-4 Severity Level 1
Line-carried noise induced by high-frequency fields
EN 61000-4-6 Severity Level 3
Magnetic fields
EN 61000-4-8 Severity Level 4
The BML is a non-contacting, incremental linear position encoder consisting of a sensor head and a magnetic tape. The system is available in several variants: with position signal function only or with additional reference point function. All functions are implemented by means of magnetic sensing. The reference position is integrated in the magnetic tape.

The following table shows the functional variants with their possibilities.

### Variants

<table>
<thead>
<tr>
<th>Output signal</th>
<th>A/B signal</th>
<th>sin/cos signal</th>
<th>Reference signal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Single signal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pole-periodic*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fixed periodic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Distance coded</td>
</tr>
</tbody>
</table>

* Not for versions with analog output

---

**System variant 1: No reference signal**

BML-S1F1...M_0_  BML-S1F2...M_0_  BML-M0...-R0000

Magnetic tape with alternating north and south poles

**System variant 2: 1 Reference signal**

BML-S1F1...M_1_  BML-S1F2...M_1_  BML-M0...-R000x

Magnetic tape with one reference point

**System variant 3: Pole-periodic reference signals**

BML-S1F1...M_2_  BML-S1F2...M_2_  BML-M0...-R0000

Magnetic tape with alternating north and south poles

**System variant 4: Fixed periodic reference signals**

BML-S1F1...M_1_  BML-S1F2...M_1_  BML-M0...-C000

Magnetic tape with multiple reference points at equal distances

**System variant 5: Distance coded reference signals**

BML-S1F1...M_1_  BML-S1F2...M_1_  BML-M0...-A000

Magnetic tape with reference points according to a mathematical algorithm

---

Fig. 2-1: Sensor head configuration

Fig. 2-2: Linear encoder systems
3 Characteristics and Function

3.1 Characteristics
BML linear position encoder systems are characterized by:

- No hysteresis
- High system accuracy of 10 or 20 μm
- High resolution up to 1 μm
- High traverse speeds up to 20 m/s
- Position signal in real time
- Very low linearity deviation (up to max. ±10 μm)
- Insensitive to shock, vibration, contamination such as dust, oil
- Wear- and maintenance-free
- Highly rugged
- Enclosure rating IP 67 per IEC 60529

The digital A/B pulses are interpolated in the sensor head, but the analog signals are processed in the controller.

The two digital pulses A and B are electrically phase-shifted by 90°, while the sign of the phase shift depends on which direction the sensor is moving (Fig. 3-1).

For directional counting the two incremental sensors are arranged offset to each other. Thus the sinusoidal output signals from the two incremental sensors are phase-offset to each other by 90° and 270° and can be interpreted as sine and cosine signals.

For the analog sine and cosine signals (sin+, sin−, cos+, cos−) the controller evaluates the difference in the signal amplitudes and uses the 4 signals to interpolate the exact position within one period (Fig. 3-2). For movement over several periods the controller also counts the number of periods.

Note, for proper function the A and B signal must be processed direction-dependent.

3.2 Function principles
The sensor head is attached to the machine component whose position is to be determined, while the magnetic tape is attached along the measurement track. Alternating north and south poles are located along the magnetic tape.

The two incremental sensors in the sensor head measure the magnetic alternating field.

As the magnetic tape is passed over without contact, the entire underside of the sensor head must always lie above the magnetic tape. The two incremental sensors in the sensor head detect the magnetic periods so that the controller can determine the traversed distance.

For directional counting the two incremental sensors are arranged offset to each other. Thus the sinusoidal output signals from the two incremental sensors are phase-offset to each other by 90° and 270° and can be interpreted as sine and cosine signals.

3.3 Interface signals
The sensor head can convert the sine and cosine signals either into digital A/B pulses and send them to the controller (RS422) or directly output the analog sine and cosine signals. The signals are sent as differential signals.

For the analog sine and cosine signals (sin+, sin−, cos+, cos−) the controller evaluates the difference in the signal amplitudes and uses the 4 signals to interpolate the exact position within one period (Fig. 3-2). For movement over several periods the controller also counts the number of periods.

Note, for proper function the A and B signal must be processed direction-dependent.
3.4 Reference point function

For each incremental encoder system the reference position is essential as a starting point for the counting. How the reference point is determined depends on the sensor type, the magnetic tape and the controller itself.

- In the simplest encoder system the sensor head with sine and cosine sensors can only sample the magnetic periods. The magnetic tape has just one track with magnetic north and south poles (Fig. 3-3). In this case the encoder system does not know the absolute position. This is determined by the controller by adding up the counted increments. First however the reference position must be determined by making a homing move.

- A sensor head with an additional reference sensor can output a reference signal as soon as it has reached the magnetically encoded reference point on the second track of the magnetic tape (Fig. 3-4). No external reference switch is necessary.

- In another sensor head version a reference signal is output with each magnetic pole. The signal repeats itself every millimeter (pole-periodic reference pulse). The magnetic tape does not require a second track with a magnetically encoded reference point. In this case an external reference switch must be set to the selected reference position. The controller then precisely evaluates the reference signal when the external reference switch and the reference point signal from the sensor head are active. This means the accuracy requirements for the external reference switch are not so high.

- The sensor head with an additional reference sensor can also be combined with a magnetic tape having fixed periodic reference points (Fig. 3-4). Here the reference points are at integrated over the entire length in the magnetic tape at particular equal distances, e.g. every 10 cm. To determine the exact position, the homing move must be made over the entire length of the magnetic tape up to an external reference switch which selects the correct sensor head reference pulse (AND operation).

- For a magnetic tape with distance coded reference points (Fig. 3-4) the reference points are arranged according to a mathematical algorithm. This makes it possible to know the absolute position as soon as two reference points have been traversed. With this type of tape no external reference switch is required.

Explanations for Fig. 3-4:
To clarify the principle, the reference points are shown in different colors (green and red), although they are physically identical (for details see the User's guide for magnetic tapes at www.balluff.de).
4 Installation of the sensor

Essential for installation:
The permissible distance and angle tolerances shown in Fig. 4-2, 4-3 and 4-4 must be strictly held. The sensor head may not contact the magnetic tape at any time over the measurement track. Contact must be avoided even if the magnetic tape is covered with the optional stainless steel cover strip. The magnetic tape must not be subjected to strong external magnetic fields. Direct contact with a permanent magnet of any kind must be avoided. The encoder system must be installed according to the specified protection type.

4.1 Distances, tolerances
When installing the sensor head and the magnetic tape the following distances and tolerances must be strictly held:
- The distance (air gap) between the sensor head and the magnetic tape as per Figs. 4-2 and 4-3
- The horizontal offset between sensor head and magnetic tape as per Figs. 4-2 and 4-3
- The angle tolerances as per Fig. 4-5. For the tilt along the sensor axis of the sensor head the nominal distance to the magnetic tape at the sensor head position shown in Fig. 4-5 must be held. The two incremental sensors are located there on the underside.

Fig. 4-1: Dimensional drawing

Fig. 4-2: BML-S1F1. Permissible distance between sensor head and magnetic tape, permissible horizontal tolerance

Fig. 4-3: BML-S1F2 Permissible distance between sensor head and magnetic tape, permissible horizontal tolerance

Fig. 4-4: Position of the reference sensor

Fig. 4-5: BML-S1F1 and BML-S1F2 Permissible angle tolerances
4 Installation of the sensor (cont.)

4.2 Determining the installation alignment

The alignments at the front, rear and left are referred to in the installation description and are essential for the correct installation of the sensor head and magnetic tape. The alignments are defined as shown in Fig. 4-6 based on the count direction of the sensor head.

The reference track must be positioned as follows:
- for BML-S1F1: on the right side of the sensor head
- for BML-S1F2: on the cable side of the sensor head

4.3 Attaching the sensor head

The sensor head should be secured with its right or left side against the machine part whose position is to be determined. Two through-holes or threaded holes are drilled on the machine member with a height tolerance of 0.1 mm.

Important!
No force is allowed on the cable in the housing. Provide appropriate strain relief for the cable.

Magnetic tape selection recommendations

Magnetic tape BML-M02-I34-...
The overall system accuracy with this tape is ±10 μm

Magnetic tape BML-M02-I35-...
The overall system accuracy with this tape is ±20 μm

Note:
A detailed technical description and installation guide for the magnetic tape can be found in the user’s guide for the magnetic tape at www.balluff.de
5 Connections

**Important for electrical connections:**

The equipment and the control cabinet must both be at the same GND potential.

To ensure electromagnetic compatibility (EMC), which Balluff confirms with the CE Marking, the following instructions must be followed.

The cable shield must be grounded on the controller side, i.e. connected to the protection ground.

The connection on the sensor side depends on which grounding method is used.

For heightened EMC requirements (e.g. commutation of an electric motor) the sensor head must be installed insulated from the machine, e.g. on plastic.

When routing the cable between the transducer, controller and power supply, avoid close proximity to high voltage lines to prevent coupled noise. Especially critical are electromagnetic fields from AC harmonics (e.g. phase angle controls), against which the cable shield offers only limited protection.

Cable length max. 20 m; wire cross-section min. 0.14 mm², max. 0.5 mm². Longer cables may be used if their construction, shielding and routing make them non-susceptible to interference.

**Important:**

If there is a voltage drop in the supply, it must be ensured that the sensor still sees a nominal operating voltage of 5 V ±5% (see 5.2).

### 5.1 Cable connection

12-conductor cable with sense line (measuring line) for preventing voltage drop in the supply.

<table>
<thead>
<tr>
<th>Cable</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>WH white</td>
<td>A</td>
</tr>
<tr>
<td>BN brown</td>
<td>/A</td>
</tr>
<tr>
<td>GN green</td>
<td>B</td>
</tr>
<tr>
<td>YE yellow</td>
<td>/B</td>
</tr>
<tr>
<td>GY gray</td>
<td>Z</td>
</tr>
<tr>
<td>PK pink</td>
<td>/Z</td>
</tr>
<tr>
<td>BU blue</td>
<td>GND</td>
</tr>
<tr>
<td>RD red</td>
<td>+5 V</td>
</tr>
<tr>
<td>BK black</td>
<td>GND Sense</td>
</tr>
<tr>
<td>VT violet</td>
<td>+5 V Sense</td>
</tr>
<tr>
<td>GYPK gray/pink</td>
<td>NC</td>
</tr>
<tr>
<td>RDBU red/blue</td>
<td>NC</td>
</tr>
</tbody>
</table>

*Reference signal*
5.3 Interfaces

**Analog incremental system**

The sensor sends the measured result to the controller as an analog sine-cosine differential signal with an amplitude of approx. 1 Vpp (peak-peak value) in the nominal range. The period is 1 mm. The signals remain low-frequency even at high traverse speeds. To ensure noise-free transmission, the permissible maximum cable length of 20 m should not be exceeded.

**Digital incremental system**

The sensor sends the measured result to the controller as a digital differential voltage signal (RS422). The edge separation A/B corresponds to the resolution of the sensor head.

**Circuit for reference position**

Depending on the model, the sensor sends no reference signal, a pole-periodic reference signal, a single reference signal, a fixed periodic or a distance coded reference signal.

The width of the reference signal for the digital BML-S1F_-Q is always one increment.

For the analog BML-S1F_-A the width of the reference signal is approx. 1/2 period, i.e. 0.5 mm.

For periodic reference points an external reference switch must be attached at the selected reference point position. The controller must link both signals as shown in Fig. 5-7. The accuracy requirements for this switch are not very high.
Table 6-1 shows the relationship between the mechanical resolution, the min. edge separation and the max. traverse speed for BML systems with magnetic tape.

**Important!**
The controller/display must be capable of counting at the minimum edge separation times shown in the tables (take into account the counting frequency of your controller). The minimum edge separation may occur even when the system is at rest due to the internal interpolation procedure.

For the BML the maximum traverse speed depends on the edge separation and the resolution (see Table 6-1). In the table X represents the min. edge separation of the BML type and Y the resolution (see part number).

### Determining the proper BML system for an existing controller

**Example** (see Table 6-1)

**Assumptions:**
- Your controller can detect a min. edge separation of 0.5 μm. If there is no BML with this min. edge separation, select a BML with a greater edge separation.
- The max. traverse speed of the system should be 1 m/s.

**Determining the proper BML:**
- You require a BML with min. edge separation of 1 μm (Type G)
- To be able to travel a max. 1 m/s, select the type with a resolution of 2 μm (Type E)

### Determining the proper controller for an existing BML system

**Example:** At edge separation 1 μm for BML type G the max. frequency of the input signal is 1/4 μs = 250 kHz.

The max. counting frequency for 4x interpolation = 1/edge separation = 1/1 μs = 1 MHz.
7 Startup

7.1 Checking connections

Caution! The connections have no protection against polarity reversal and overvoltage! Before powering up, carefully check your connections to ensure that no components can be damaged by incorrect wiring and overvoltage.

7.2 Turning on the system

Note that the system may perform uncontrolled movements when it is switched on, in particular when it is switched on for the first time and if the BML system is part of a control system for which the parameters have yet to be set. Ensure that no hazards can arise due to such movements.

7.3 Checking system functions

After installing the encoder system or replacing the sensor head, check all the functions as follows:

1. Turn on power to the sensor head.
2. Move the sensor head along the entire measuring range.
3. Check that all signals are output (see Troubleshooting).
4. Check whether the count direction agrees with the direction of travel. If not, reverse connections A and /A.

7.4 Regular checking

The functional capability of the length measurement system and all the associated components should be regularly checked and logged.

7.5 Malfunctions

If there are indications that the linear encoder system is not functioning correctly it should be taken out of service and secured against unauthorized use (see also Troubleshooting).

8 Accessories (order separately)

8.1 Cover strip

To protect the magnetic tape from damage caused by chips or chemicals, you may cover it using a stainless steel cover strip. Note that the permissible air gap between the sensor head and the tape is reduced by the thickness of the cover strip (0.15 mm) (Fig. 4-2).

Before gluing on the cover strip, carefully clean the surface of the magnetic tape (acetone, turpentine, mild plastic cleaner, no gasoline).

Options:

1. The cover strip and magnetic tape can be ordered together in appropriate lengths.
2. The cover strip can be ordered separately in 4 defined lengths.

Note:

A detailed technical description and covering strip ordering code can be found in the user's guide for the magnetic tape at www.balluff.de
## Troubleshooting

<table>
<thead>
<tr>
<th>Errors</th>
<th>Possible causes</th>
<th>Remedies/Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The controller sometimes receives no position information.</td>
<td>The necessary supply voltage is not present.</td>
<td>Check whether there is voltage and whether the BML is correctly connected.</td>
</tr>
<tr>
<td></td>
<td>The voltage drop is too great</td>
<td>The encoder system must show an supply voltage of 5 V ±5%.</td>
</tr>
<tr>
<td></td>
<td>The cable is not properly connected.</td>
<td>Check the connections according to the wiring diagrams.</td>
</tr>
<tr>
<td></td>
<td>The orientation of the magnetic tape with reference point is incorrect.</td>
<td>The reference point marking must be on the right side of the BML-S1F1 sensor head or behind on the BML-S1F2 (Fig. 4-6). Replace magnetic tape.</td>
</tr>
<tr>
<td>The controller sees no position information at particular locations.</td>
<td>The distance between the sensor head and the magnetic tape is (in places) incorrect.</td>
<td>Adjust the height of the sensor head. To verify, manually move the head over the entire measurement track.</td>
</tr>
<tr>
<td></td>
<td>The magnetic poles on the tape are damaged in places by strong magnets.</td>
<td>Replace magnetic tape.</td>
</tr>
<tr>
<td>No reference signal is output.</td>
<td>The orientation of the magnetic tape with reference point is incorrect.</td>
<td>The reference point marking must be on the right side of the BML-S1F1 sensor head or behind on the BML-S1F2 (Fig. 4-6). Replace magnetic tape.</td>
</tr>
<tr>
<td>The non-linearity is outside the tolerance.</td>
<td>The sensor head is not moving parallel to the magnetic tape (see tolerance in Fig. 4-5). The distance between the sensor head and magnetic tape is too great.</td>
<td>Correctly position the sensor head (Section 4).</td>
</tr>
</tbody>
</table>
## 10 Technical Data

### Electrical data

<table>
<thead>
<tr>
<th>Model BML-S1F -Q</th>
<th>Model BML-S1F -A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output signal</td>
<td>Digital RS422</td>
</tr>
<tr>
<td>Reference signal</td>
<td>A-signal, B-signal, reference signal</td>
</tr>
<tr>
<td>Resolution</td>
<td>Depending on model 1 µm, 2 µm, 5 µm, 10 µm</td>
</tr>
<tr>
<td>Output voltage</td>
<td>Differential RS422 signal</td>
</tr>
<tr>
<td>System resolution</td>
<td>Depending on tape model ±10 µm, ±20 µm</td>
</tr>
<tr>
<td>Distance dependent hysteresis</td>
<td>0 µm</td>
</tr>
<tr>
<td>max. non-linearity of processing electronics</td>
<td>±2 µm</td>
</tr>
<tr>
<td>max. non-linearity of the overall system (sensor head + magnetic tape)</td>
<td>up to ±10 µm with BML-M02-I34...</td>
</tr>
<tr>
<td>Temperature coefficient of overall system like steel</td>
<td>10.5 x 10⁻⁶/K⁻¹</td>
</tr>
<tr>
<td>Max. traverse speed</td>
<td>up to 20 m/s (see Tab. 6-1)</td>
</tr>
<tr>
<td>Reverse polarity protected</td>
<td>no</td>
</tr>
<tr>
<td>Overvoltage protection</td>
<td>no</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>5 V ±5%</td>
</tr>
<tr>
<td>Current draw at 5 V supply voltage</td>
<td>&lt;50 mA + current draw of controller (depending on internal resistance)</td>
</tr>
<tr>
<td>Shock load per EN 60068-2-27</td>
<td>100 g/6 ms</td>
</tr>
<tr>
<td>Continuous shock per EN 60068-2-29</td>
<td>100 g/2 ms</td>
</tr>
<tr>
<td>Vibration load per EN 60068-2-6</td>
<td>12 g, 10...2000 Hz</td>
</tr>
</tbody>
</table>

### Ambient conditions

| Operating temperature | −20 °C...80 °C |
| Storage temperature   | −30 °C...85 °C |

### Degree of protection per IEC 60529

| IP67 |

### Mechanical data

<table>
<thead>
<tr>
<th>Distance sensor head-magnetic tape</th>
<th>0.01...0.35 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing material</td>
<td>Aluminum, black anodized</td>
</tr>
<tr>
<td>Connection type</td>
<td>12-conductor cable</td>
</tr>
<tr>
<td>Weight</td>
<td>14 g</td>
</tr>
</tbody>
</table>

### Cable data

<table>
<thead>
<tr>
<th>Type</th>
<th>12-conductor cable, drag chain compatible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature</td>
<td></td>
</tr>
<tr>
<td>Flexed</td>
<td>−20...80 °C</td>
</tr>
<tr>
<td>Fixed</td>
<td>−40...90 °C</td>
</tr>
<tr>
<td>Cable diameter</td>
<td>5.3 ±0.3 mm</td>
</tr>
<tr>
<td>Cable bending radius</td>
<td></td>
</tr>
<tr>
<td>Flexed</td>
<td>81 mm</td>
</tr>
<tr>
<td>Fixed</td>
<td>41 mm</td>
</tr>
<tr>
<td>Cable length</td>
<td>max. 20 m</td>
</tr>
</tbody>
</table>

### 11 Scope of Delivery

<table>
<thead>
<tr>
<th>Sensor head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensed Guide</td>
</tr>
</tbody>
</table>
## Magnetic Linear Encoder System

### 12 Versions

Part number for sensor head with digital RS422 square wave signal (see part label)

**Type:**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BML-S1F-1-Q61D-M310-G0-KA05</td>
<td>(type example)</td>
</tr>
</tbody>
</table>

- **Connection type:**
  - KA05 = PUR cable 5 m, available cable lengths 2, 5, 10, 15, 20 m
  - min. edge separation
  - D = 0.12 μs
  - E = 0.29 μs
  - F = 0.48 μs
  - G = 1 μs
  - H = 2 μs
  - K = 4 μs
  - L = 8 μs
  - N = 16 μs
  - P = 24 μs

- **Reference signal**
  - 0 = none
  - 1 = single, fixed periodic or distance coded
  - 2 = pole-periodic

- **Pole width**
  - 3 = 1 mm

- **Resolution (edge separation A/B)**
  - D = 1 μm
  - E = 2 μm
  - F = 5 μm
  - G = 10 μm

- **Output voltage**
  - 1 = digital RS422 square wave

- **Supply voltage**
  - 6 = 5 V

- **Orientation**
  - 1 = longitudinal
  - 2 = lateral

**Ordering code:** BML _ _ _
Part number for sensor head with sinusoidal analog signal sin/cos 1 Vpp (refer to part label)

Type:

- Connection type: KA05 = PUR cable 5 m, available cable lengths 2, 5, 10, 15, 20 m
- max. traverse speed: 9 = >10 m/s
- Reference signal
  - 0 = none
  - 1 = single, fixed periodic or distance coded
- Pole width
  - 3 = 1 mm
- Resolution
  - Z = not relevant
- Output voltage
  - 2 = analog 1 Vpp
- Supply voltage
  - 6 = 5 V
- Output signal
  - A = analog sin/cos
- Orientation
  - 1 = longitudinal
  - 2 = lateral

Ordering code: BML - _ _ _