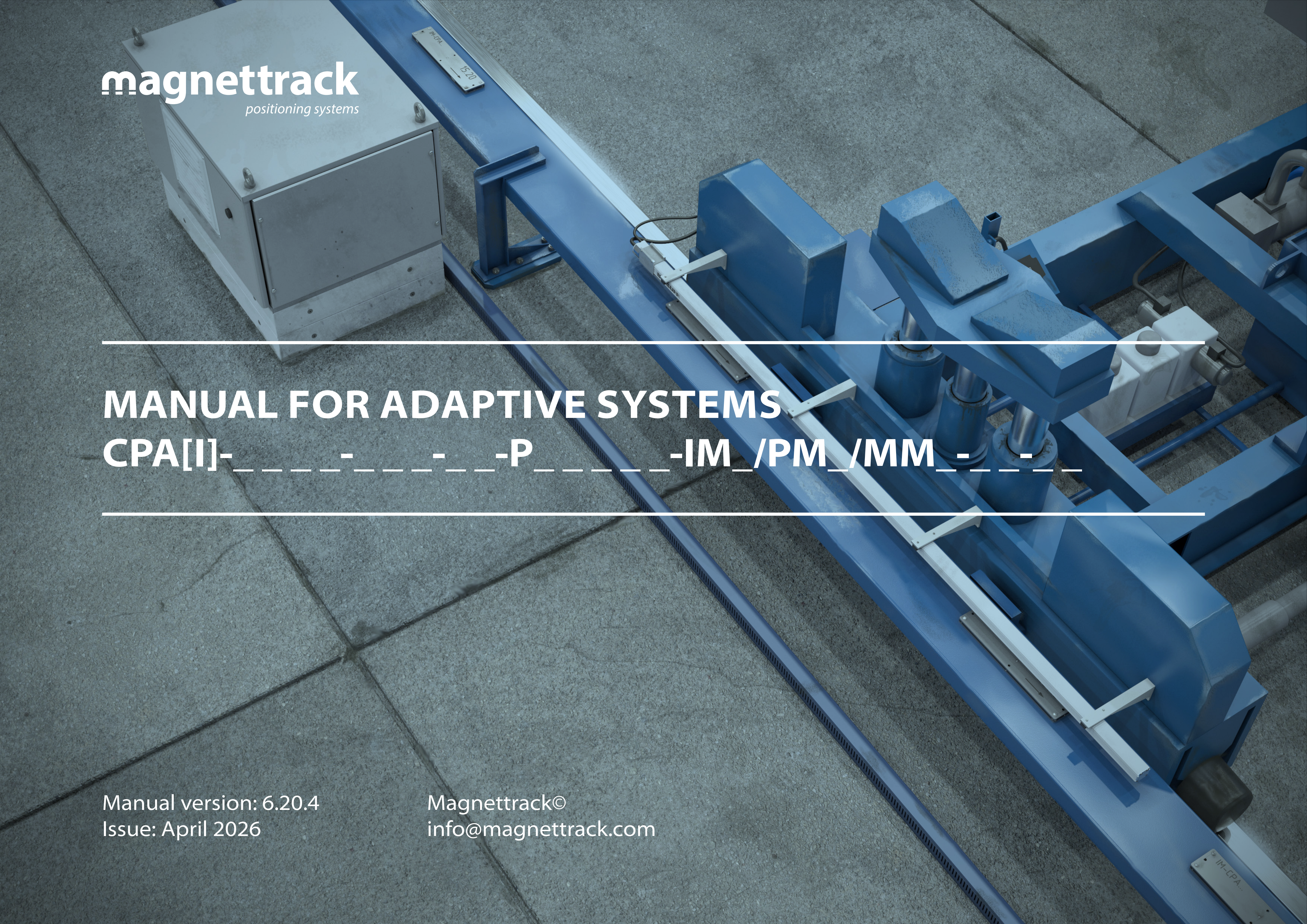

magnettrack
positioning systems

MANUAL FOR ADAPTIVE SYSTEMS
CPA[I]-_ _ _ _-_ _ _ _-_ _-P_ _ _ _ _ _-IM_/PM_/MM_-_ _-_

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magnettrack
positioning systems

1 GENERAL

To avoid any risk, always make sure to follow the warnings and precautions described in this manual. Important information is surrounded by a frame and is marked with i

The binding actions that directly affect proper functioning of the system are marked with i

i

Patent No. EP3193138 "OBJECT TRAVEL MEASUREMENT METHOD" was issued for this product.

Magnettrack system enables measuring absolute travel of objects at distances from several meters to several kilometers. It includes two main components: Magnetostriction micropulse linear-displacement transducer and magnet marker track, along which the transducer moves.

Each marker contains one or several permanent magnets. An electrical pulse generated within the transducer interacts with magnetic field of a marker, thus creating a magnetostriction torsional wave in a wave guide, which spreads with a supersonic speed. The component of torsional wave achieving the end of the wave guide is absorbed in damping zone. The component of torsional wave achieving the start of the wave guide is converted to electrical signal by a coil surrounding the wave guide. Wave spreading time is used to define the position of markers, and, due to to special allocation of markers along the track, the transducer records a unique signature of magnets allocation in any point of the track, which enables getting an absolute value of object position at any point of the positioning distance even after the system power is restarted. This process is performed with high measurement accuracy and reliability, if the provisions of this manual are observed.

Since the measurement distance can be up to several kilometers, the system is ideally suitable for measurement of travel or positioning of cranes, rail vehicles, vacuum or magnetic manipulators, or to be used in automatic warehouse systems. Since Magnettrack uses proximity principle in its operation, such a system requires no maintenance and has a long service life, even under the most severe environmental conditions, including outdoors.

Fig. 1-1. Magnettrack system elements based on position markers

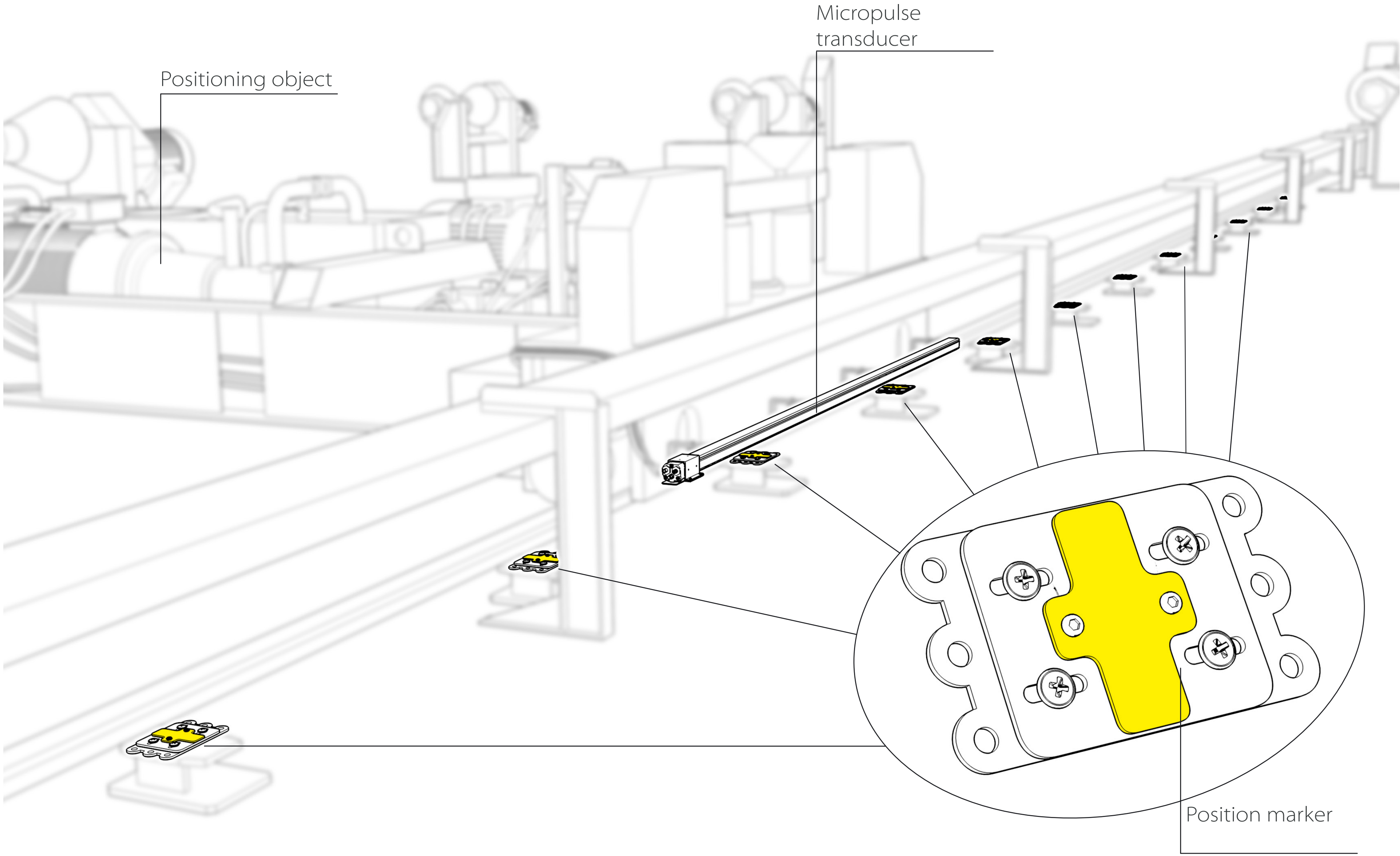


Fig. 1-2. Magnettrack system elements based on interval markers

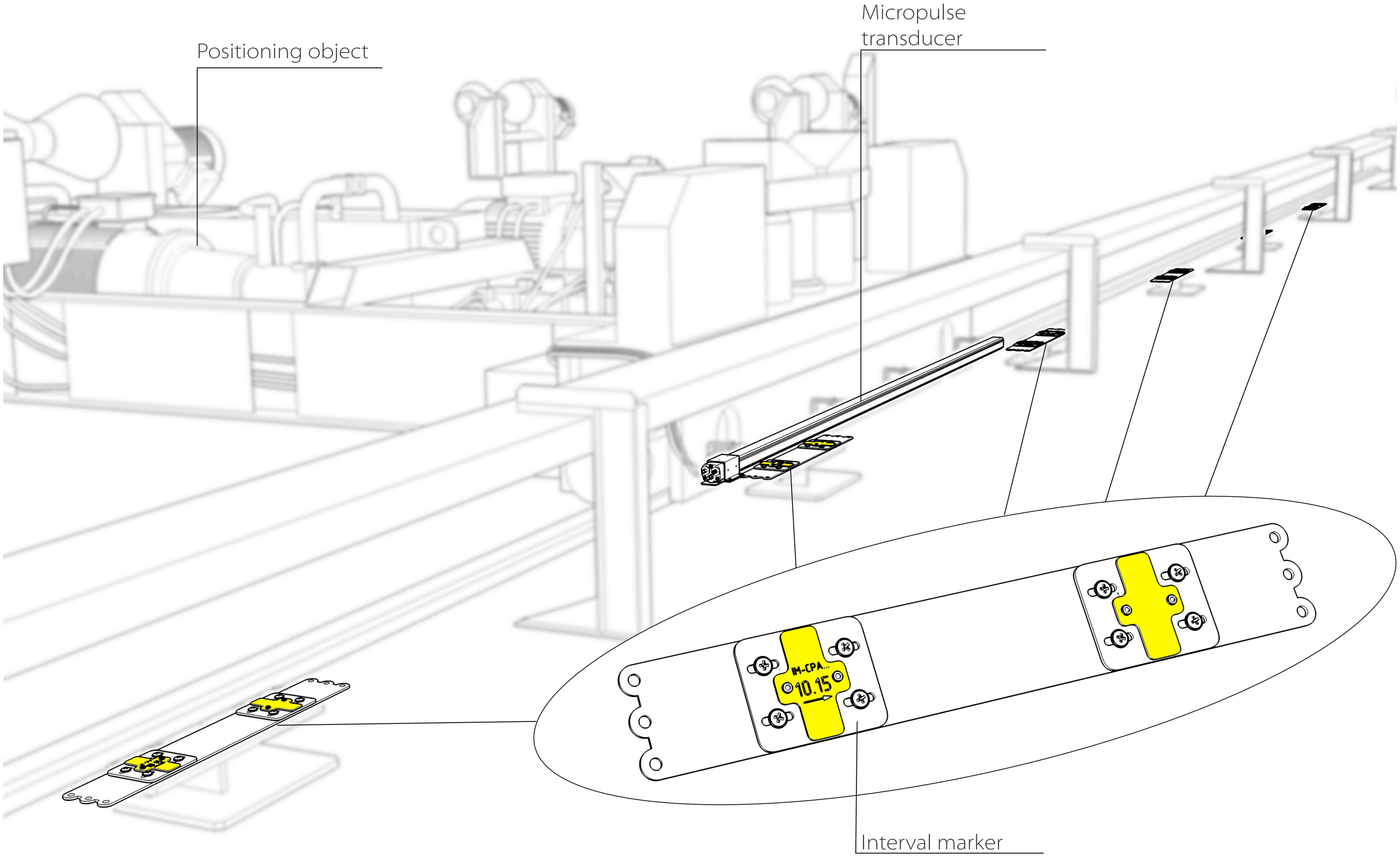
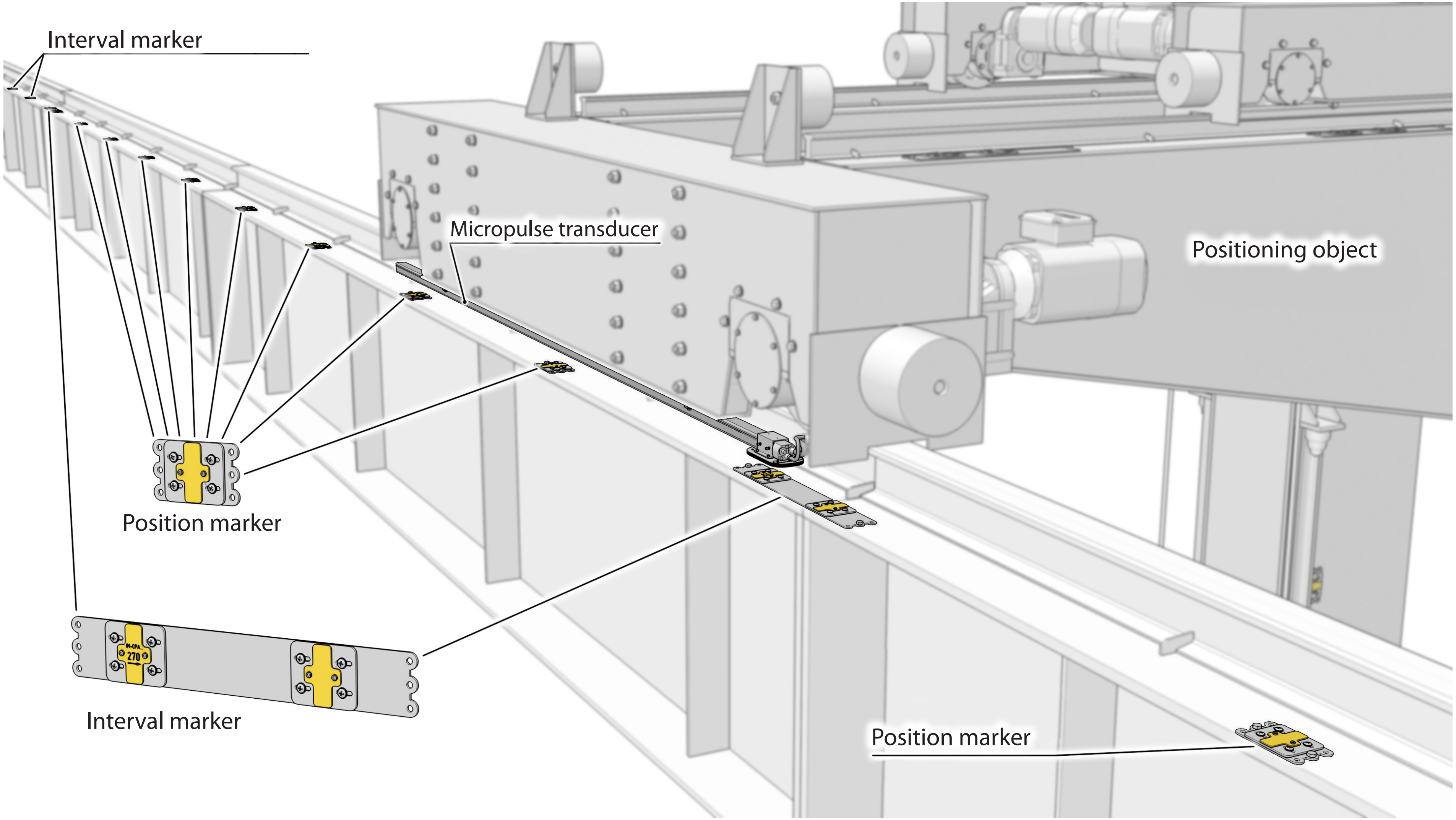


Fig. 1-3. Magnettrack system elements based on mixed type markers



1.1 Designation

CPAI-0120-007-05-P2000P-MM2-30-60

Positioning principle

CPA = Absolute adaptive
CPAI = Absolute adaptive incremental

Positioning distance, m [D]

0005…5,000

Number of unique interval markers

0002...0500

System repeatability, mm [Ac]

01...10

System interface

P = Profinet
T = Profibus
EIP = Ethernet/IP

Nominal length (sensitive surface) of transducer, mm [NL]

0500…4,500

Transducer type

P — profile transducer
R — rod-type transducer

Marker type

PM = position
IM = interval
MM = mixed, position and interval

Number of magnets in interval marker (for IM and MM)
Markers track scheme (for PM)

2 or 3 magnets (for IM and MM)

2 - 2+1 scheme or 3 - 3+1 scheme (for PM)

Logic marker range, mm [S] and amplitude of object vibrations in the sensitive surface plane, mm [Sw]

15–30, 30–60, 45–80

1.2 System specifications

The system may have versions not specified in this user manual.
Such systems and specific documentation for them are available upon request.

	CPA-0050-000-01-P2500P-PM2-15-30	CPAI-0100-011-05-P1500P-MM2-30-60	CPA-0200-000-10-P4500R-IM3-45-80	CPA-0700-030-10-P4500R-MM2-45-80
Maximum positioning distance [D]	50 m	100 m	200 m	700 m
Operating range of the distance from transducer to marker [S]	15 mm	30 mm	45 mm	45 mm
Maximum operating distance to marker [Smax]	34 mm	42 mm	55 mm	55 mm
Minimum operating distance to marker [Smin]	20 mm	13 mm	11 mm	11 mm
Maximum amplitude of lateral object displacement	±15 mm	±30 mm	±40 mm	±40 mm
Nominal length of transducer [NL]	1,500 mm	1,500 mm	4,500 mm	4,500 mm

	CPA-0050-000-01-P2500P-PM2-15-30	CPAI-0100-011-05-P1500P-MM2-30-60	CPA-0200-000-10-P4500R-IM3-45-80	CPA-0700-030-10-P4500R-MM2-45-80
Transducer type	Profile	Profile	Rod	Rod
Static repeatability, mm [Ac]	1	5	10	10
Maximum object velocity	7 m/s			
Number of interval markers (IM) and position markers (PM) in the system	36	11 IM + 70 PM	66	30 IM + 210 PM
Marker type	PM	MM	IM	MM
Operating temperature	– 40...+85 °C / +350 °C			
Storage temperature	– 40...+100 °C / +350 °C			
Impact load, according to IEC 60068-2-27	150 g/6 ms			
Vibration, according to IEC 60068-2-6	20 g, 10...2,000 Hz			
Protection class, according to IEC 60529	IP 67			

	CPA-0050-000-01-P2500P-PM2-15-30	CPAI-0100-011-05-P1500P-MM2-30-60	CPA-0200-000-10-P4500R-IM3-45-80	CPA-0700-030-10-P4500R-MM2-45-80
Transducer material of construction	Anodized aluminum, steel			
Thermal error factor	30 ppm/K			
Type of output signal	Profinet			
Interface version	Profinet I/O			
Transducer output update frequency	1.1 kHz			
Power supply voltage	10 to 30 VDC			
Consumed current	≤ 120 mA			
Protection against reverse polarity	YES			
Overvoltage protection	YES			

1.3 System elements and their functions

Micropulse transducer: generates electrical pulses and picks up readings from magnetostrictive wave to define relative position of the marker.

Nominal transducer length: length of transducer sensitive surface. To ensure optimum conformity, a wide range of standard lengths of sensitive surfaces, from 500 mm to 4,500 mm, is available for each application of Magnettrack system, as defined by required positioning zone and dimensions of the object.

Attachment clamps: required to attach the transducer to positioning object. The clamps contain insulation bushings used for electrical insulation of the transducer from the positioning object. For recommendations on installation and allocation of attachment clamps along the transducer, see section 2.1.

Connectors: electrical connection is performed using the connectors included in the system supply package (for details, see section 2.3)

Interval marker: Magnettrack system element that contains a set of magnets with unique signatures indicating the position of this interval marker along the magnet track, and sends information on relative coordinate to transducer within this range, enabling the latter to define its absolute position relative to the whole track.

Position marker: Magnettrack system element containing one permanent magnet.

Volumetric marker: Magnettrack system marker consisting of two (paired) position or interval markers combined into a single volumetric marker.

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The markers in this manual are depicted schematically and may differ from those supplied complete with the system.

Fig. 1.3-1. System elements

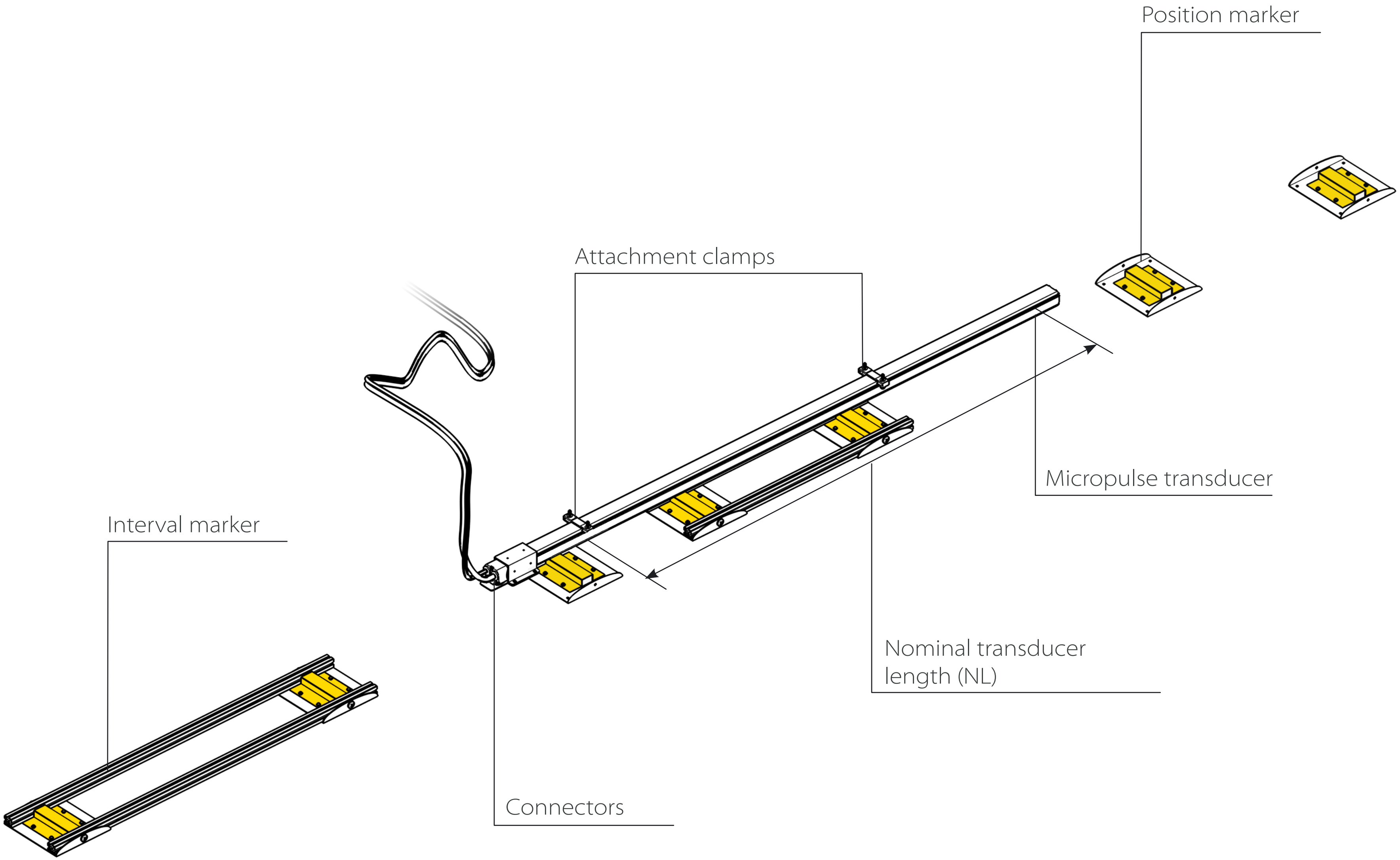
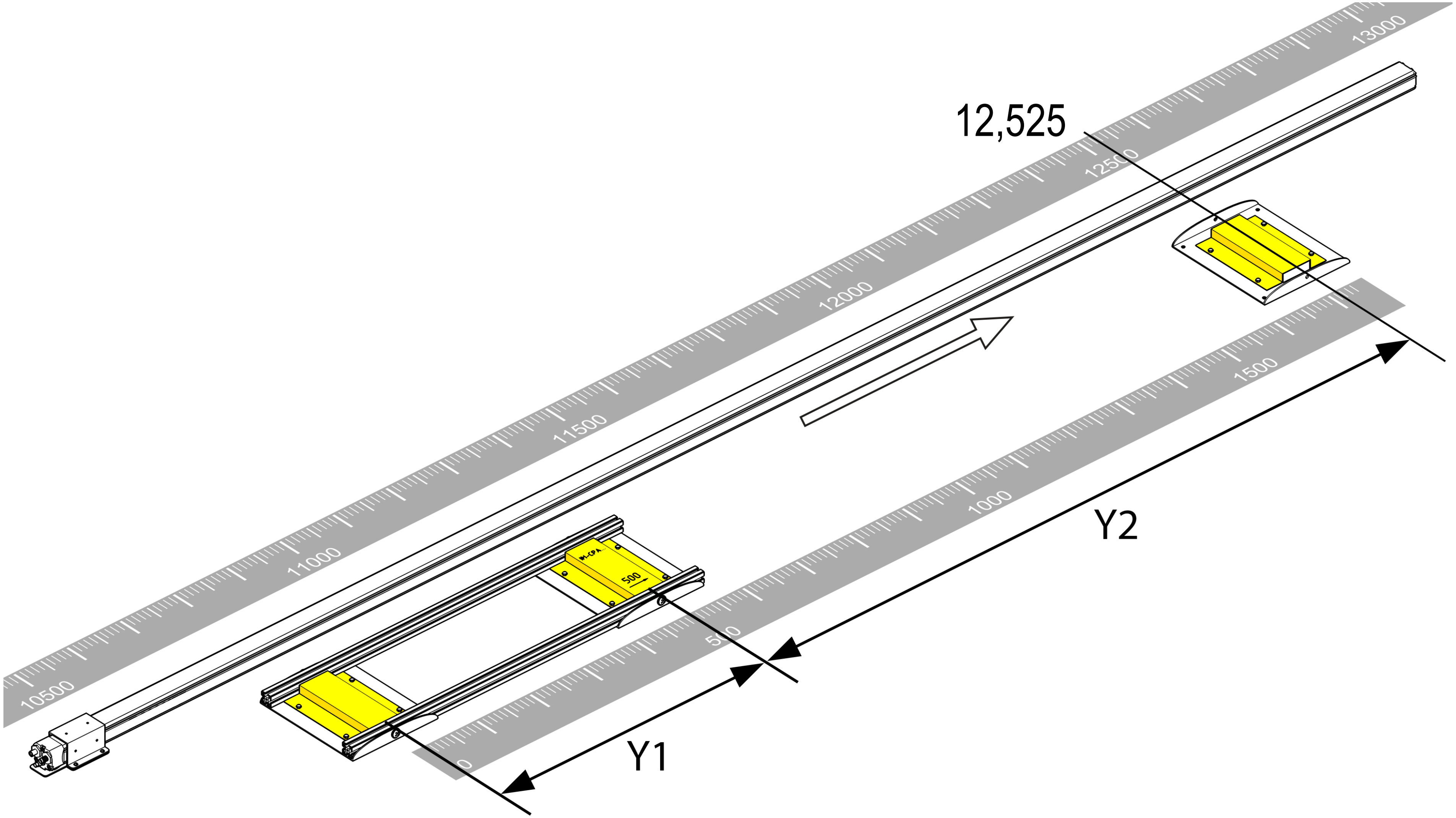


Fig. 1.3-2. Magnetic signature in transducer active zone, where y1 and y2 encode a track section



2 SYSTEM INSTALLATION

Transducer is attached directly to mobile object, the position of which needs to be measured. Markers are installed along the object path on a stationary base. Transducer moves along the marker path together with the object, and its position is constantly updated.

Magnettrack system elements can be installed in reverse order, when the transducer is attached to a stationary base, and markers are located on mobile objects. In such cases, a mobile object may be identified using a unique interval marker, and positioned relative to active length of stationary transducer.

> **i**
>
> Magnettrack system installation requires good knowledge of mechanics, and accuracy and carefulness. Therefore, the system may only be installed by a skilled professional!

Prior to installation of Magnettrack system, turn off the power of all the equipment at the positioning object. If required, provide electrical insulation for the equipment at the positioning object.

Before installing the Magnettrack system, make sure to bleed the pressure from pneumatic/hydraulic parts of the positioning object and around.

If required, post warning signs to prevent false switching of equipment at the positioning object.

Magnettrack positioning system shall not be commissioned in case of any damages at safety components of the positioning objects or electrical components of the system (e.g. damaged connectors, RCDs, etc.). In this cases, the system should be isolated from power source.

Follow professional safety rules to avoid accidents during installation/maintenance.

Keep your hands and fingers safe from getting jammed between the transducer and interval markers upon the system startup.

Make sure that foreign objects along the whole positioning length (structures, cables, hoses, vegetation, etc.) are not within the zone of sensitive surface of the transducer or within the zone of moving marker, in case of reverse installation of Magnettrack system elements.

Install the cable from transducer to controller making sure that:

- Cable is not an obstacle for the system operation and positioning object during the positioning object movement
- The cable is not tensioned, twisted or damaged
- The cable is not located next to power lines.

If welding next to the components of Magnettrack system, make sure to turn the system power off in order to avoid causing its damage by strong inductive currents.

i

High-power motors and permanent magnets generate strong magnetic fields that may adversely affect the system operation. Therefore, make sure to maintain sufficient distance between the transducer and motor / high-power magnet and connected cables.

Do not open micropulse linear transducer or markers! If micropulse transducer or markers are opened, it will compromise functional safety of the system and make the guarantee void.

Use only undamaged/failsafe tools for installation. Do not start the system, if any of its elements is damaged.

After completion of installation/maintenance, perform a trial start of the system and make sure its components function correctly.

i

Magnettrack system does not affect operation of the positioning object and keeps it intact. To maintain such a status, please observe the installation guidelines described in this manual intended for the people having fundamental knowledge in the field of precision mechanics and electrics.

Make sure to use Magnettrack positioning system only for the purposes corresponding to its design and intended use.

2.1 Transducer installation | basic installation of transducer

Transducer and markers must be securely attached to avoid sticking of markers to the transducer body elements as the object moves.

Provide an area free of metal objects of at least 80 mm around the sensitive surface of liner travel transducer.

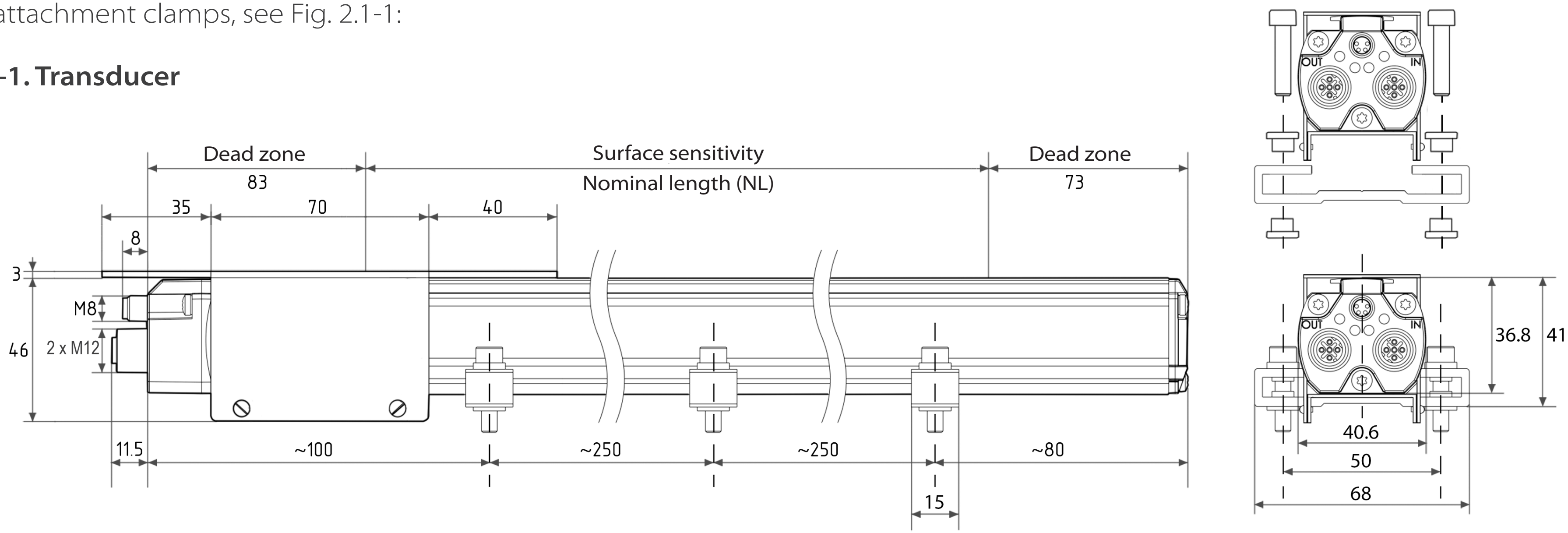
Attachment clamps with insulation bushings and cylindrical bolts compliant with ISO 4762 M5 x 22 with a maximum torque of 2 N/m, included in supply package, enable attaching the transducer on flat surface of the positioning object or any other flat surface rigidly connected to the object. The supply package has a sufficient number of attachment clamps for installation.

For installation diagram and recommended distance for installation of attachment clamps, see Fig. 2.1-1:

To avoid development of resonant frequency caused by vibrational load of > 50 g, it is recommended to secure the clamps with irregular intervals.

> **i** The transducer is shown schematically at the figure. Mounting dimensions of the transducer are available upon request.

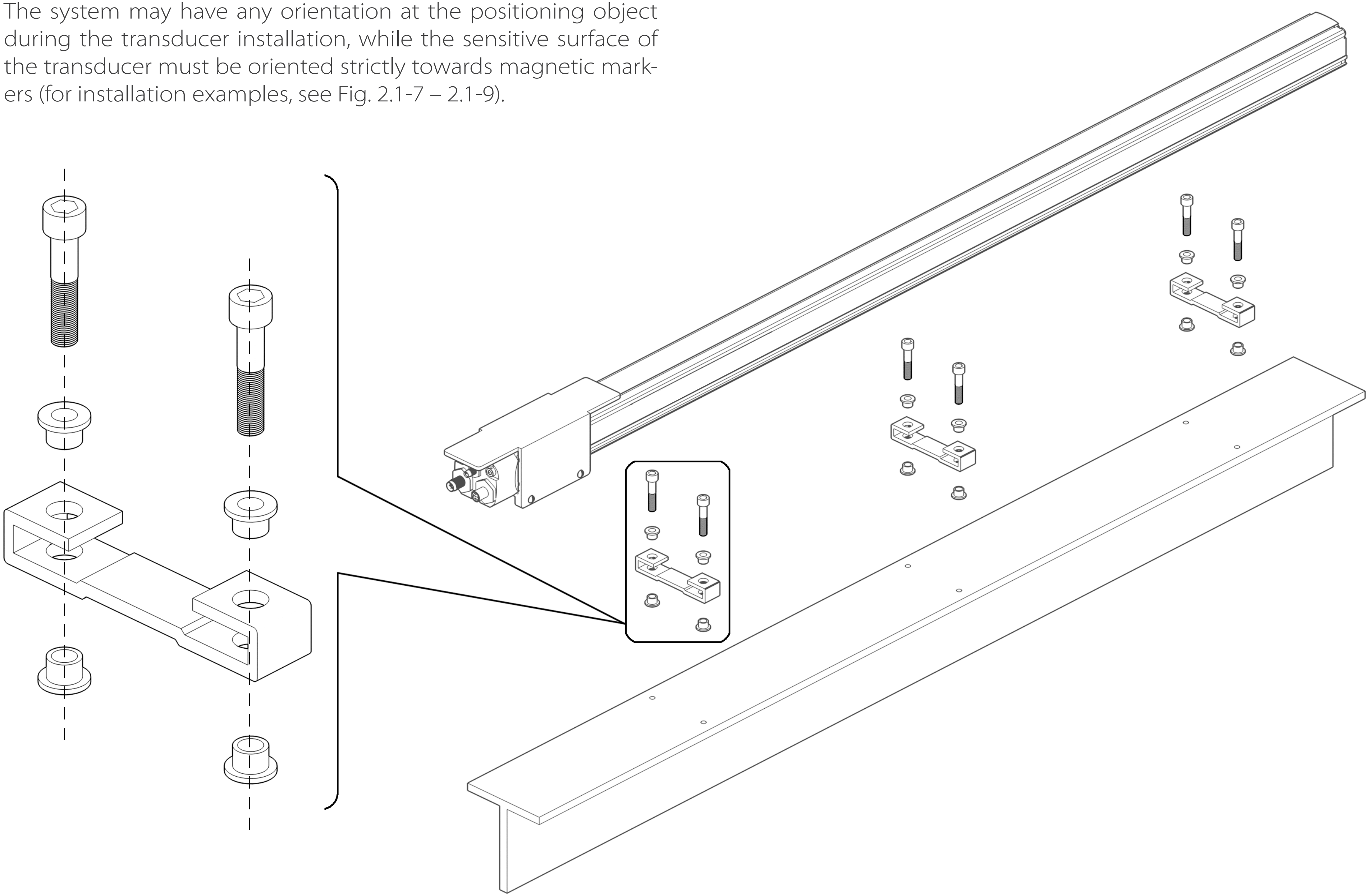
Fig. 2.1-1. Transducer



> **i** Insulation bushings must be used with the transducer's electrical circuit isolated from the positioning object.

Fig. 2.1-2. Attachment clamps with insulation bushings

The system may have any orientation at the positioning object during the transducer installation, while the sensitive surface of the transducer must be oriented strictly towards magnetic markers (for installation examples, see Fig. 2.1-7 – 2.1-9).



Transducer installation using Basic Mounting Kit (BMK)

It is recommended to use transducer complete with BMK. Depending on the type of installation, BMK may have different versions. The BMK is shown in this manual schematically.

Basic Mounting Kit (BMK) is applied for installation of transducer. The use of BMK allows to:

- Adjust the transducer along two transverse axes and in two directions

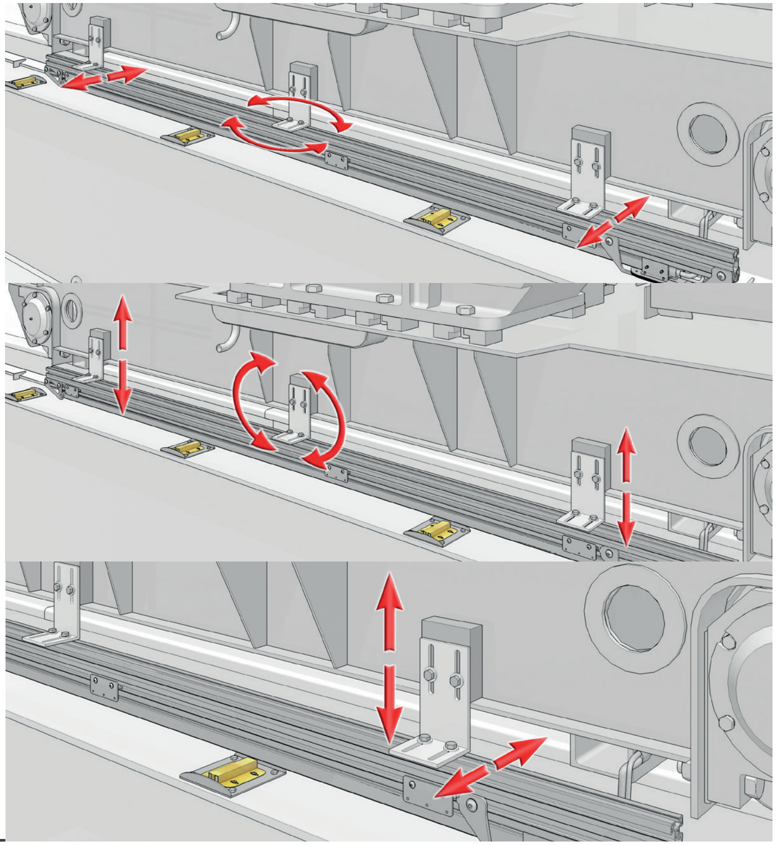


Fig. 2.1-3. Adjustment of transducer

- Protect the body and electrical connectors of the transducer against unforeseen collapses with obstacles along the object path

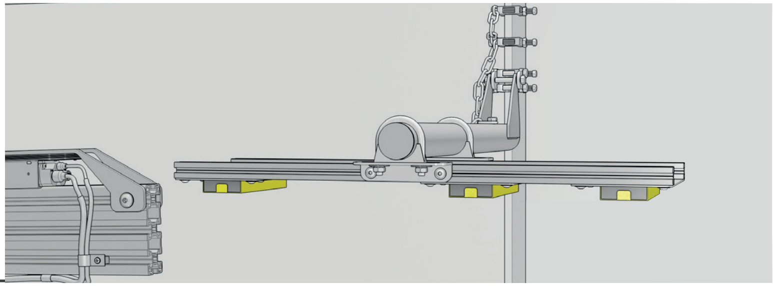


Fig. 2.1-4. Transducer protection using BMK

During movement, especially if the velocity exceeds 3 m/s, a heavy positioning object may start oscillating together with the transducer attached to its body. To avoid significant longitudinal oscillation of the body of a long transducer, please install it using BMK with a rigid aluminum body.

Bumpers serve as reliable protection for connectors of transducer to the system power supply and data transmission network. Slope shape of BMK bumpers prevents severe shocks and, as a consequence, damage of markers and transducer. BMK also enables additional protection of transducer and avoids its damage in some emergency situations.

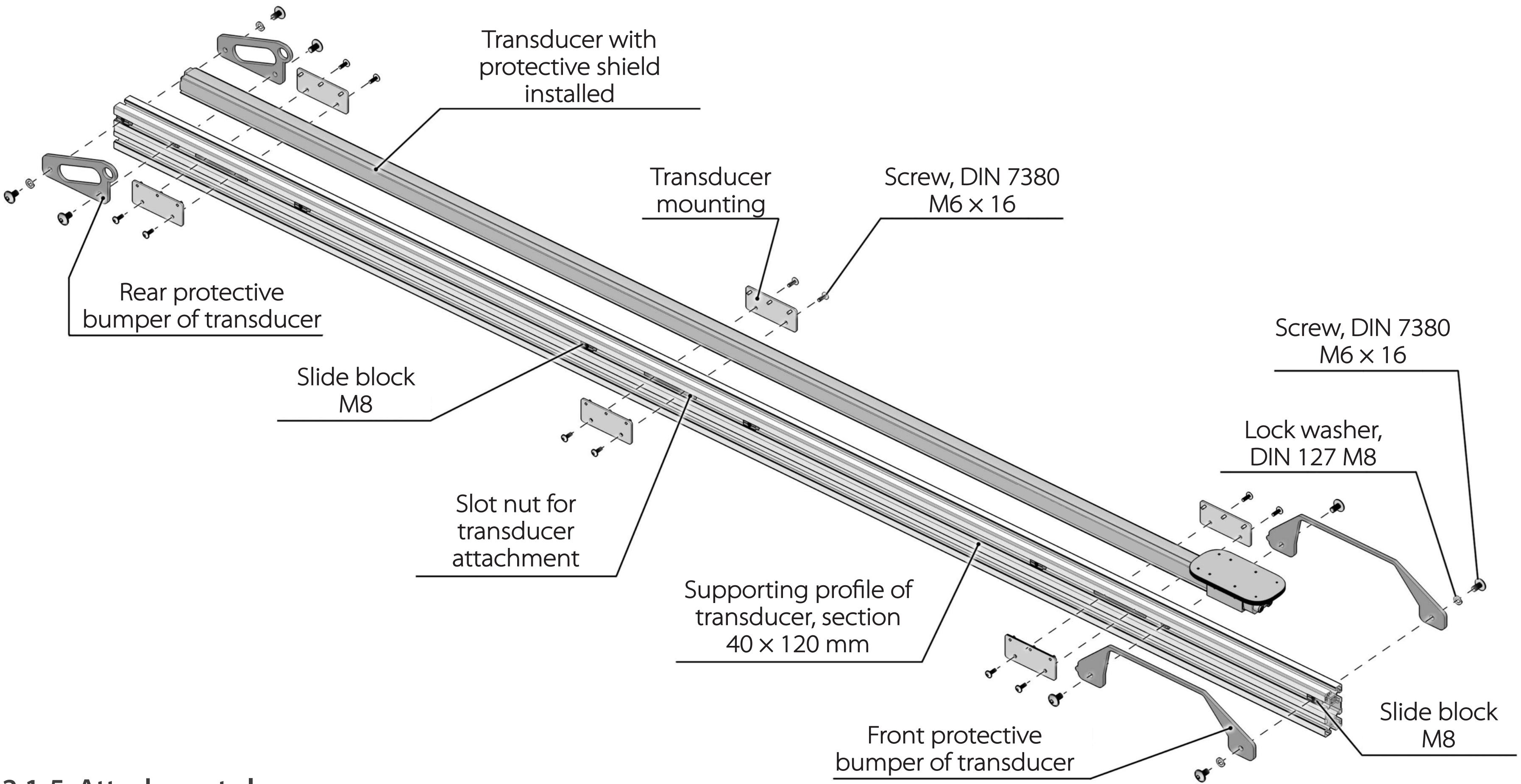


Fig. 2.1-5. Attachment clamps with Insulation bushings

It is recommended to use BMK in all Magnettrack system applications, but in the following cases BMK installation is mandatory:

- When the transducer is 2,000 mm long or longer
- If caliber 2 or higher markers are used.

Aluminum profile is selected based on operating length of transducer:

- 40 x 40 mm for transducers with operating length up to 1,500 mm
- 40 x 80 mm for transducers with operating length from 1,500 mm to 3,500 mm
- 40 x 120 mm for transducers with operating length from 3,500 mm to 4,500 mm.

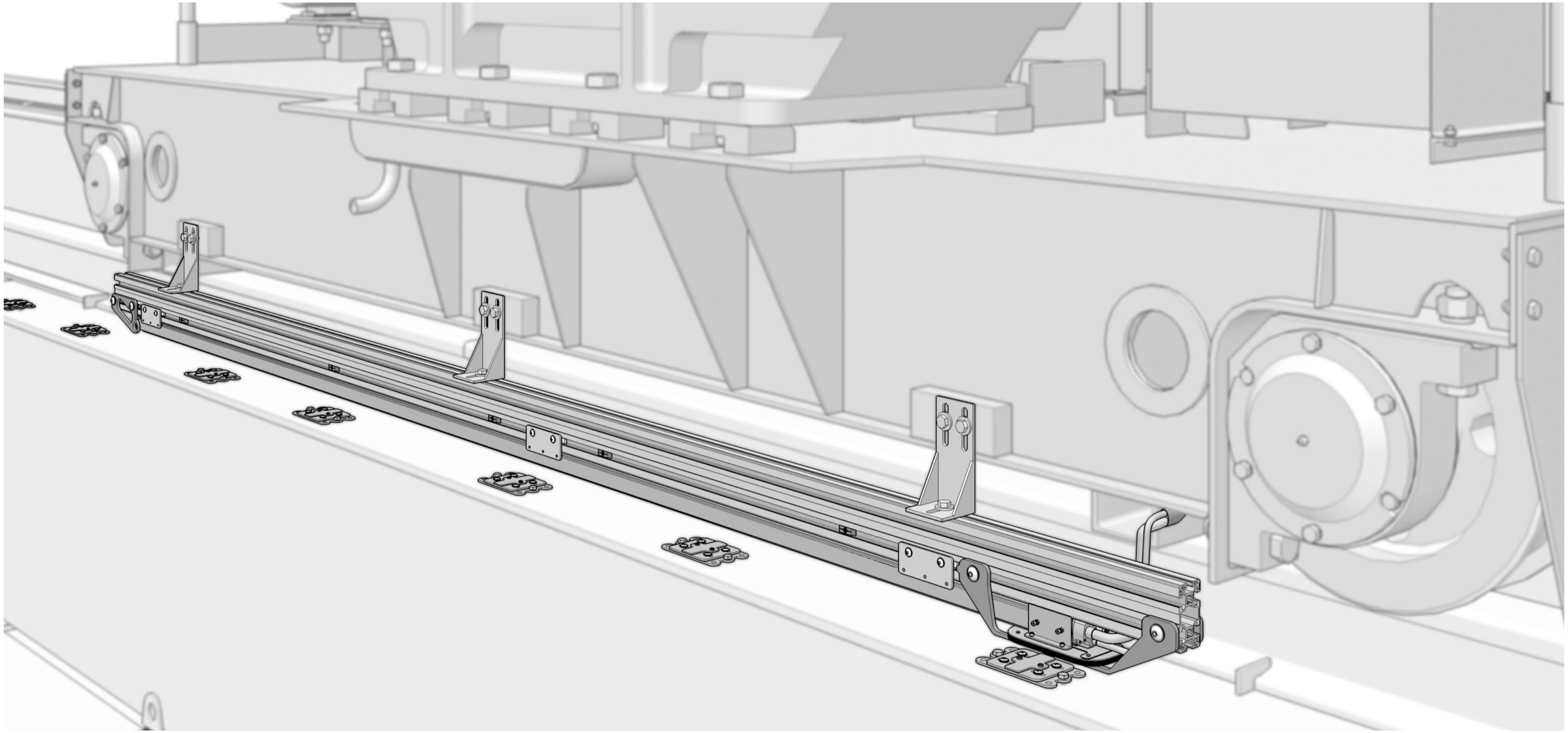


Fig. 2.1-6. Example of installation of BMK-XXXX-40-80

As the object moves along the whole positioning path, there must be no ferromagnetic materials at a distance of up to 80 mm from transducer, except Magnettrack system elements.

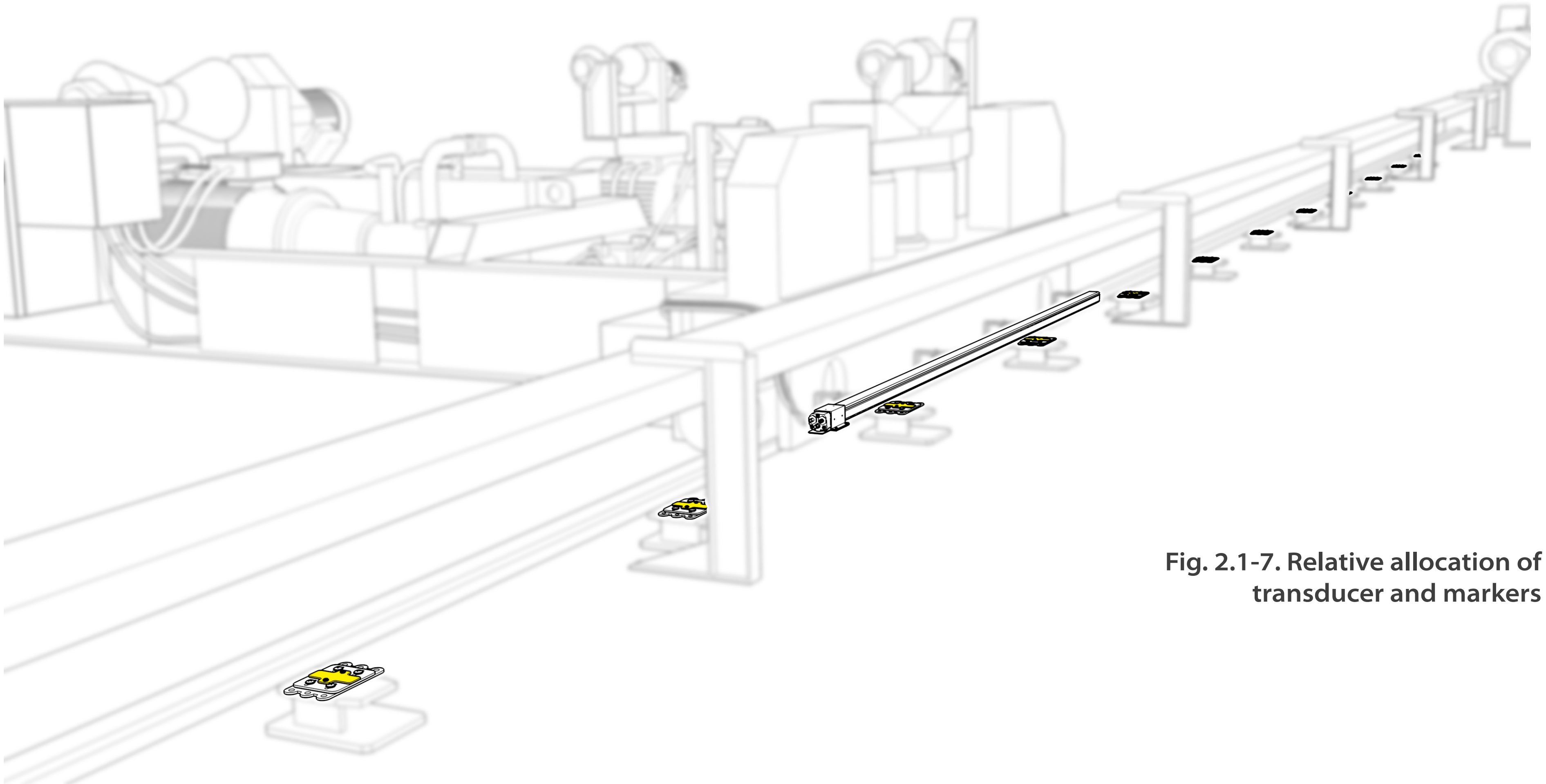


Fig. 2.1-7. Relative allocation of transducer and markers

Fig. 2.1-8. Relative allocation of transducer and markers

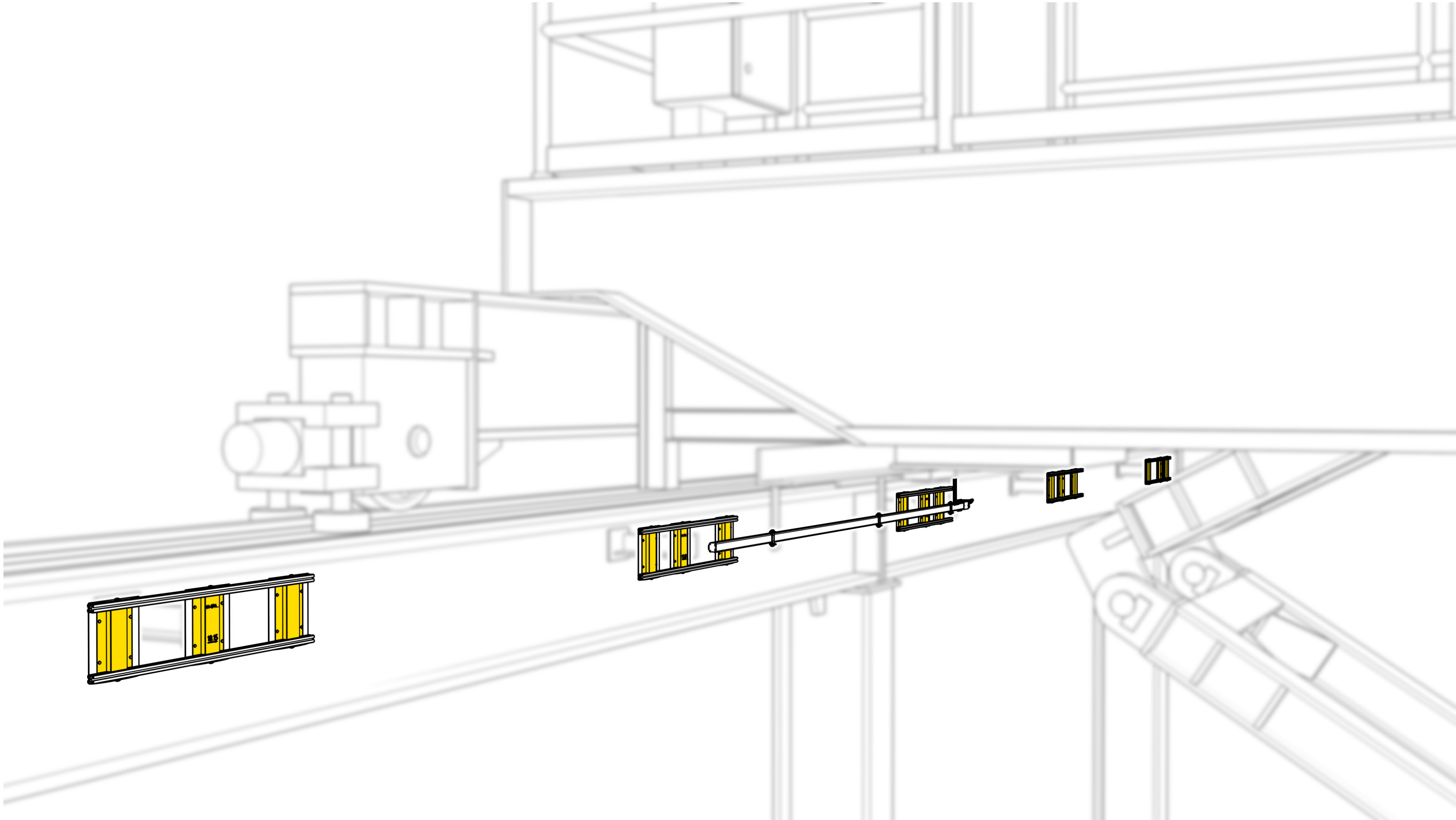
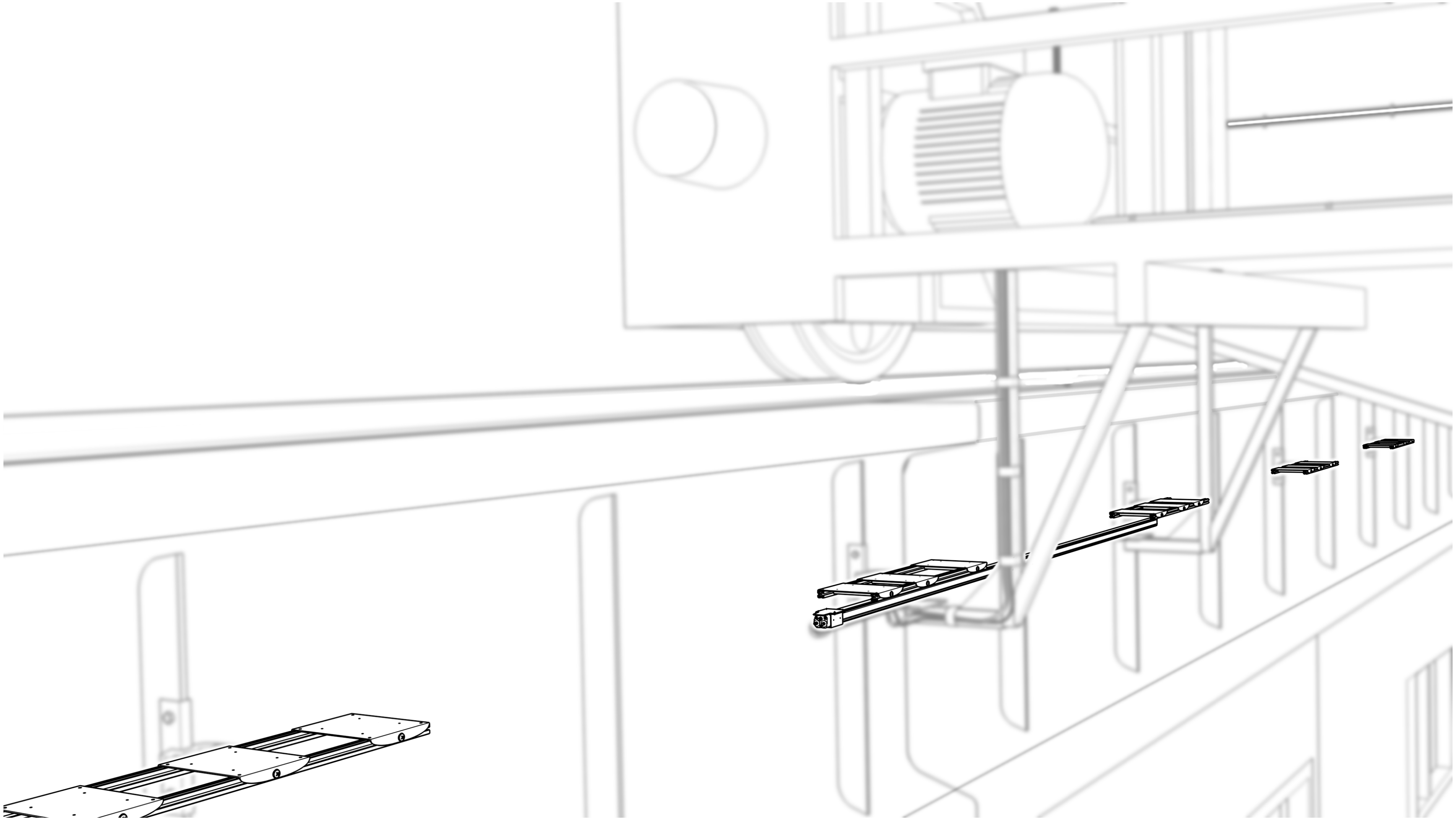


Fig. 2.1-9. Relative allocation of transducer and markers



As the object moves, relative position of transducer and position markers may change, resulting from the error in installation of transducer or markers, or from oscillation of the moving object itself. The following marker deviations relative to the transducer are allowed:

1. Within operating range of the distance from transducer to marker (S).
2. Within the object oscillation amplitude in the plane of transducer sensitive surface (Sw).

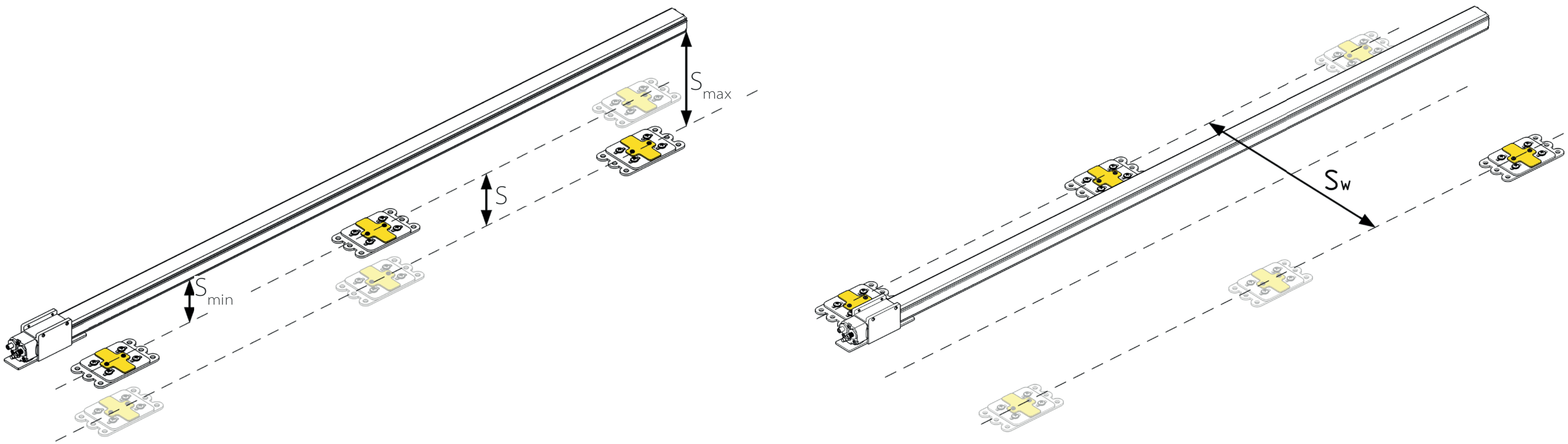


Fig. 2.1-10. Tolerances in deviation of position markers upon their installation

See an example at Page 2.1.10 and 2.1.11

During transducer installation, make sure that its sensitive surface does not extend beyond the limits of operating distance from markers along the track, which is specified in the system datasheet, and is limited by the values of S_{min} and S_{max}, and S_w.

Fig. 2.1-11. Tolerances in deviation of transducer upon its installation

Example

If Magnettrack system CPA-0200-000-05-P4500R-IM3-45-80 is used, operating range of the distance from transducer to the marker is 45 mm (S = 45). Minimum distance (S_{min}) is 11 mm, maximum (S_{max}) is 55 mm.
The amplitude of oscillations in the sensitive plane (S_w) equals 80 mm. Transducer shall not extend beyond these limits along the whole length of the sensitive surface (NL), equal to 4,500 mm, therefore, the angle of admissible deviation of transducer from longitudinal axis of interval markers equals arcSin(22,5/4,500). In this position, sensitive surface of the transducer will be at a minimum distance from interval marker (S_{min}) on one side, and at a maximum distance (S_{max}) on the other. Similar deviations may occur to transducer in the plane of sensitive surface by arcSin(80/4,500). In this case, the transducer sensitive surface is within limit points of oscillation amplitude S_w.

Example

A positioning object is a crane with diameter of flanged wheels of 750 mm. According to technical regulations, flanged wheels can have a wear of 2 %, i.e. this crane can subside by 7.5 mm. During deployment of Magnettrack system CPA-0200-000-05-P4500R-IM3-45-80 (S = 45 mm) with transducer installed under interval markers (Fig. 2.1-9), make sure to install the transducer at a distance of S_{min} + Sx1/3 mm = 26 mm from markers. If the wheels get worn by 2 % of their diameter, which amounts to 15 mm, the gap between the transducer and the markers will be 26 + 15/2 = 33.5 mm., with maximum operating distance of S_{max} = 45 mm.

In the process of the object measurement, due to normal wear of mechanical parts, e.g. wear of round wheels and/or rails, relative position of transducer and markers gradually changes over time. In these cases, transducer is recommended to be installed so as to keep its position relative to the markers within allowed limits specified above at Fig. 2.1-10 for as long as possible during operation of the measurement object.

If the transducer is above markers (Fig. 2.1-7), it is recommended to install it at a distance of S_{min}+2 x S/3.

If the transducer is located aside from markers (Fig. 2.1-8), it is recommended to install it at a distance of S_{min} + S/2, near the top point of the amplitude of the object oscillation in the plane of transducer sensitive surface, S_w.

If the transducer is under markers (Fig. 2.1-9), it is recommended to install it at a distance of S_{min} + S/3. Thus, nominal wear of mechanical parts will not affect long-term operation of the system.

2.2 Installation of magnetic markers

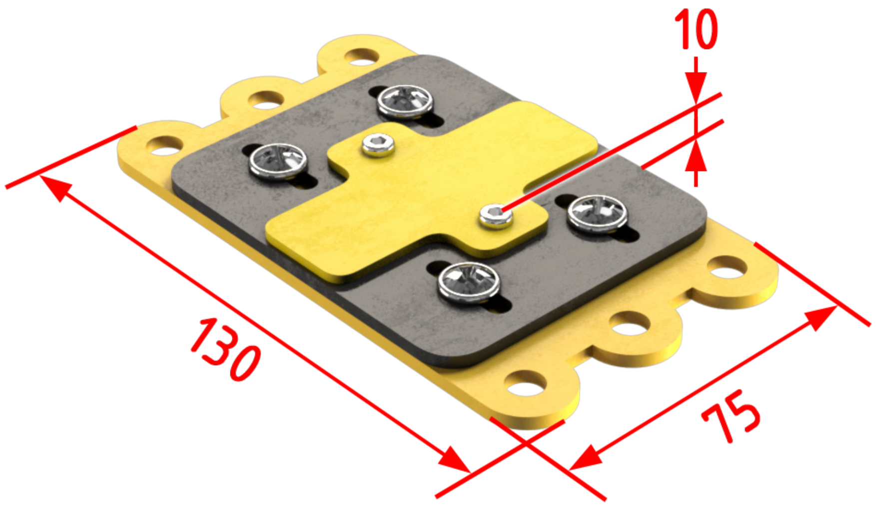


Fig. 2.2-1. Position Marker

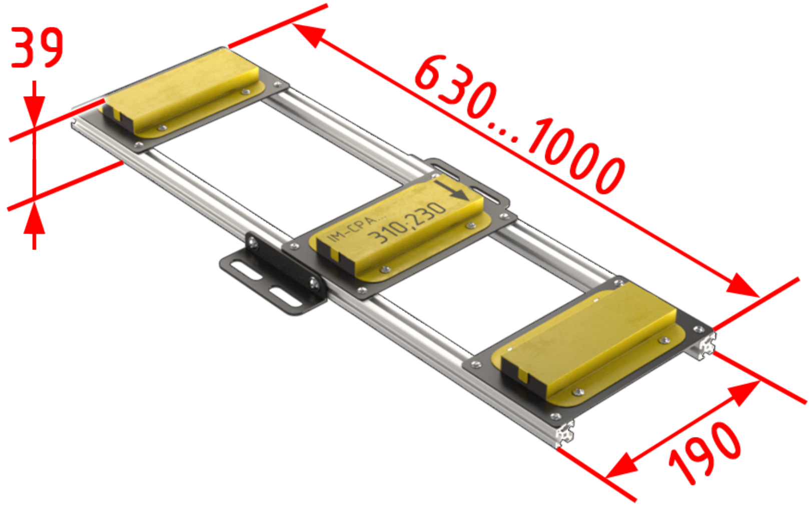


Fig. 2.2-2. Interval Marker

Example of position and interval marker.

> **i** Markers are shown schematically in this manual and may differ from those supplied with the system.

A minimum number of markers is included in the system supply package, sufficient to measure the object position throughout the whole passport distance.

Example

Minimum distance between markers for Magnettrack system CPA-0200-000-05-P4500R-IM3-45-80 is Y_{min} = 260 mm, and the maximum distance is Y_{max} = 4,100 mm. Thus, the supply package will contain 50 interval markers.

If fail-safe markers are installed at a distance from each other less than maximum, Y_{max}, the amount of markers will be insufficient for deployment of the system at the whole positioning distance. Therefore, if the maximum distance between markers must be decreased, and the reliability of Magnettrack system increased for critical positioning objects, custom interval markers can be ordered.

i

To reduce maximum distance between markers even up to minimum, Y_{min}, additional interval markers are available for ordering (see the name in the system datasheet).

Installation of position markers for adaptive systems

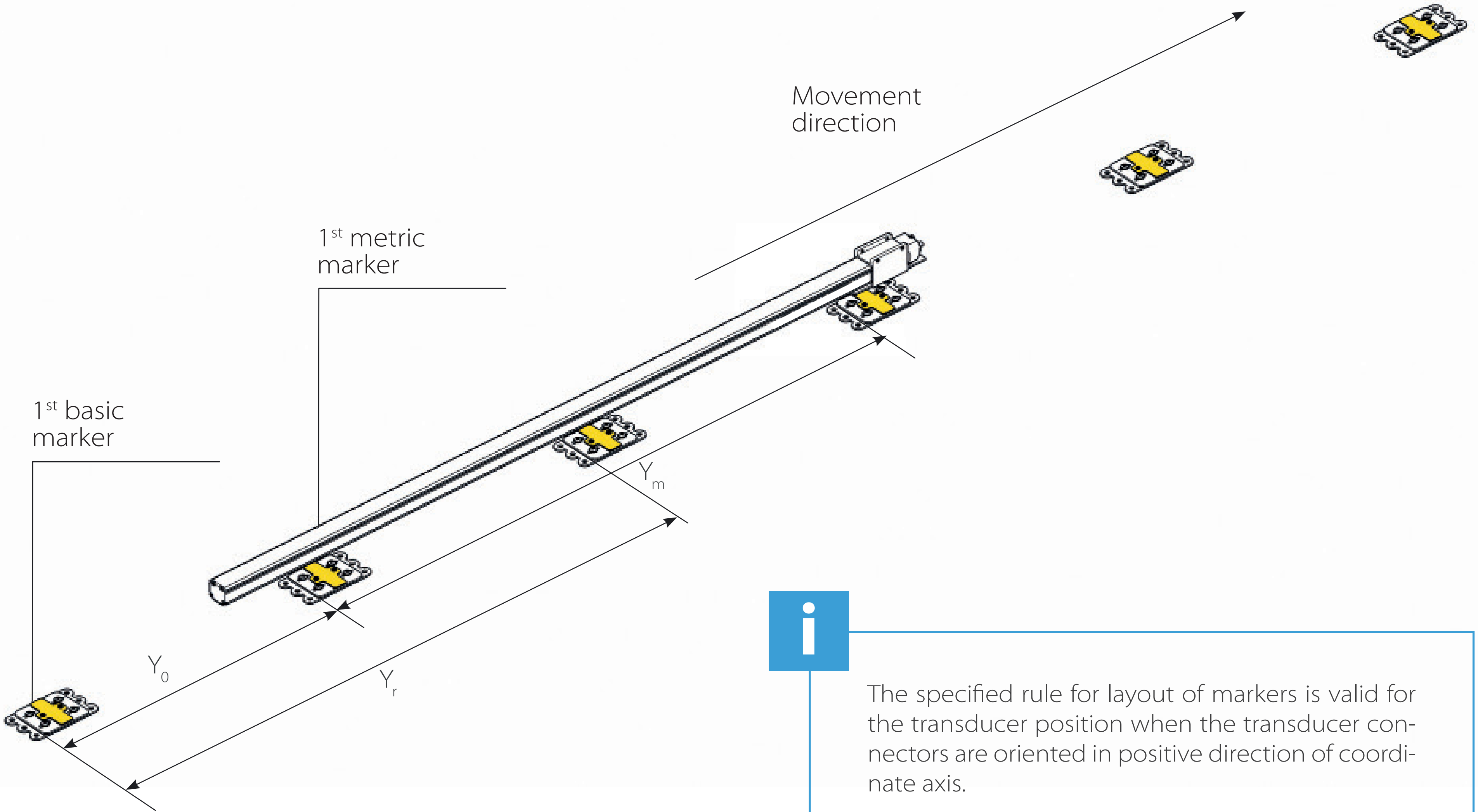
The distances between position markers can not be repeated! To avoid errors in the system operation, use only the distances between position markers specified in the system datasheet!

Position markers installation procedure:

1. Install the first position marker along the track basic in the starting (zero) coordinate position of the object, in the center of transducer operating zone NL_{virt} (NLv_{irt}/2 see data in the system datasheet)).
2. Install the second position marker (metric) at a distance of Y_0 from the first basic marker
3. Install every further basic marker at a distance of Y_r from the previous basic marker
4. Install every further metric marker at a distance of Y_m from the previous metric marker
5. Install the position markers until the final point of the object movement path is achieved. The final absolute coordinate of the object positioning is defined by the last pair of metric and basic markers within the transducer zone in the endposition of the object on the track.

Coordinates table of each marker along the track relative to the previous one indicating its absolute coordinate along the object path is supplied with the system for simplicity and ease of installation of position markers.

Fig. 2.2-3 Installation of position markers



The specified rule for layout of markers is valid for the transducer position when the transducer connectors are oriented in positive direction of coordinate axis.

Magnettrack adaptive system enables installing markers in a certain range of coordinates. Adaptive core of the program will individually calculate and memorize the absolute coordinate of marker installation with required accuracy.

Example of a table of datasheet coordinates for marker installation

PM number	Type	PM installation coordinate, mm			
		Precisely	Minimum	Maximum	Range
1	Basic	0			
2	Metric	1,110	1,102	1,119	17
3	Basic	2,300	2,292	2,309	17
4	Metric	3,370	3,362	3,379	17
5	Basic	4,600	4,592	4,609	17
6	Metric	5,630	5,622	5,639	17
7	Basic	6,900	6,892	6,909	17
8	Metric	7,890	7,882	7,899	17
9	Basic	9,200	9,192	9,209	17
10	Metric	10,150	10,142	10,159	17
11	Basic	11,500	11,492	11,509	17
12	Metric	12,410	12,402	12,419	17
...	...	...	...	...	...

The table is presented for information only and serves as an example.

Installation of interval markers for adaptive systems

For installation of interval markers, the arrows of all markers must be oriented in the same direction. Each interval marker along the track must have a unique signature. The system differentiates a three-magnet interval marker with signature $X_1;X_2$ from a similar interval marker with signature $X_2;X_1$

1. The first interval marker is installed at the object travel zero point in the area of transducer operating zone
2. Each further interval marker is installed along the object path at a distance from the previous marker not less than minimum (Y_{min}) and not more than maximum (Y_{max}) distance between adjacent interval markers, the values of which are specified in the system datasheet.
3. Interval markers are installed along the track according to their direction. Signatures of interval markers along the magnet track must not repeat.
4. Install the interval markers until the final point of the object movement path is achieved.

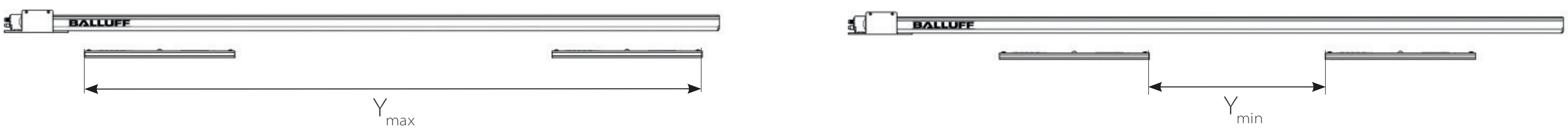


Fig. 2.2-4. Minimum and maximum distance between adjacent interval markers

Installation of markers for incremental systems

Both position and interval markers are usually used for incremental systems within the same track. Magnet marker track may be also created using position markers only.

An object path can be provisionally divided to the following sections:

- Absolute coordinate measurement zones
- Incremental coordinate measurement zones.

Absolute coordinate measurement zone consists of position and/or interval markers that form a unique signature for this zone (see Fig. 2.2-5 – 2.2-6) for the whole object movement path. Meanwhile, only position markers are used for incremental coordinate measurement zones, set at distances close to the maximum possible distance from each other (see the rules for selection of marker installation coordinates below).

Upon restart of Magnettrack power supply, absolute coordinate of the measurement object is available only at the absolute coordinate measurement zones.

If, upon restart of Magnettrack power supply, the object is located at an incremental zone, then its absolute coordinate is unavailable until the object moves to absolute zone of the track.

For examples of absolute and incremental coordinate measurement zones, see the figures below.

Fig. 2.2-5 Example of absolute coordinate measurement zone based on an interval marker

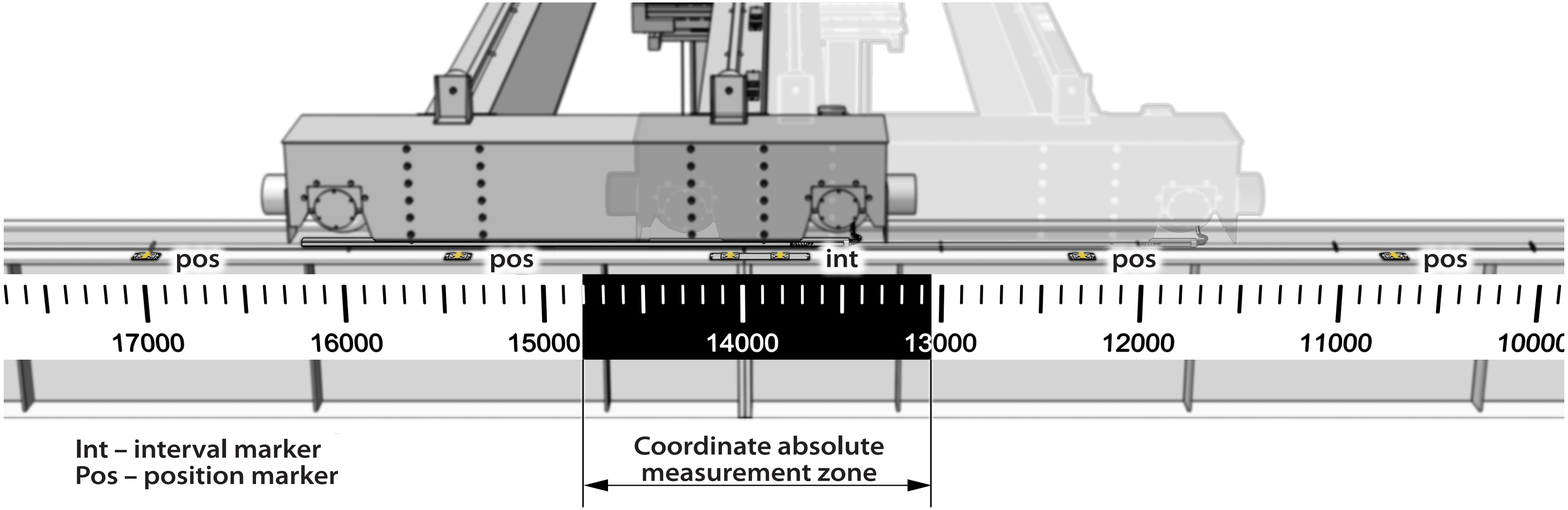
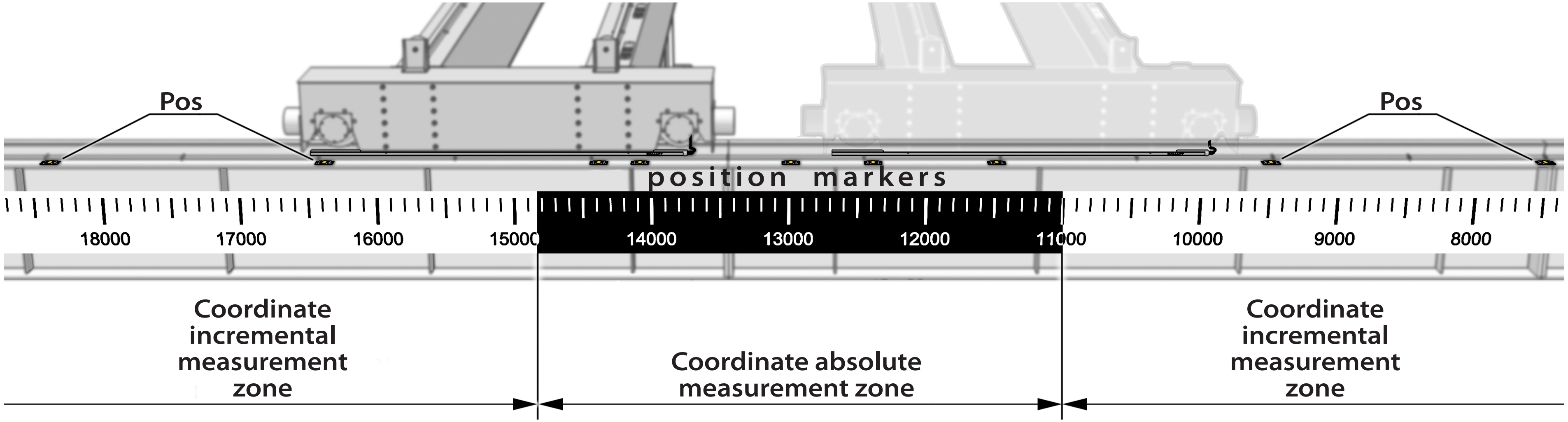
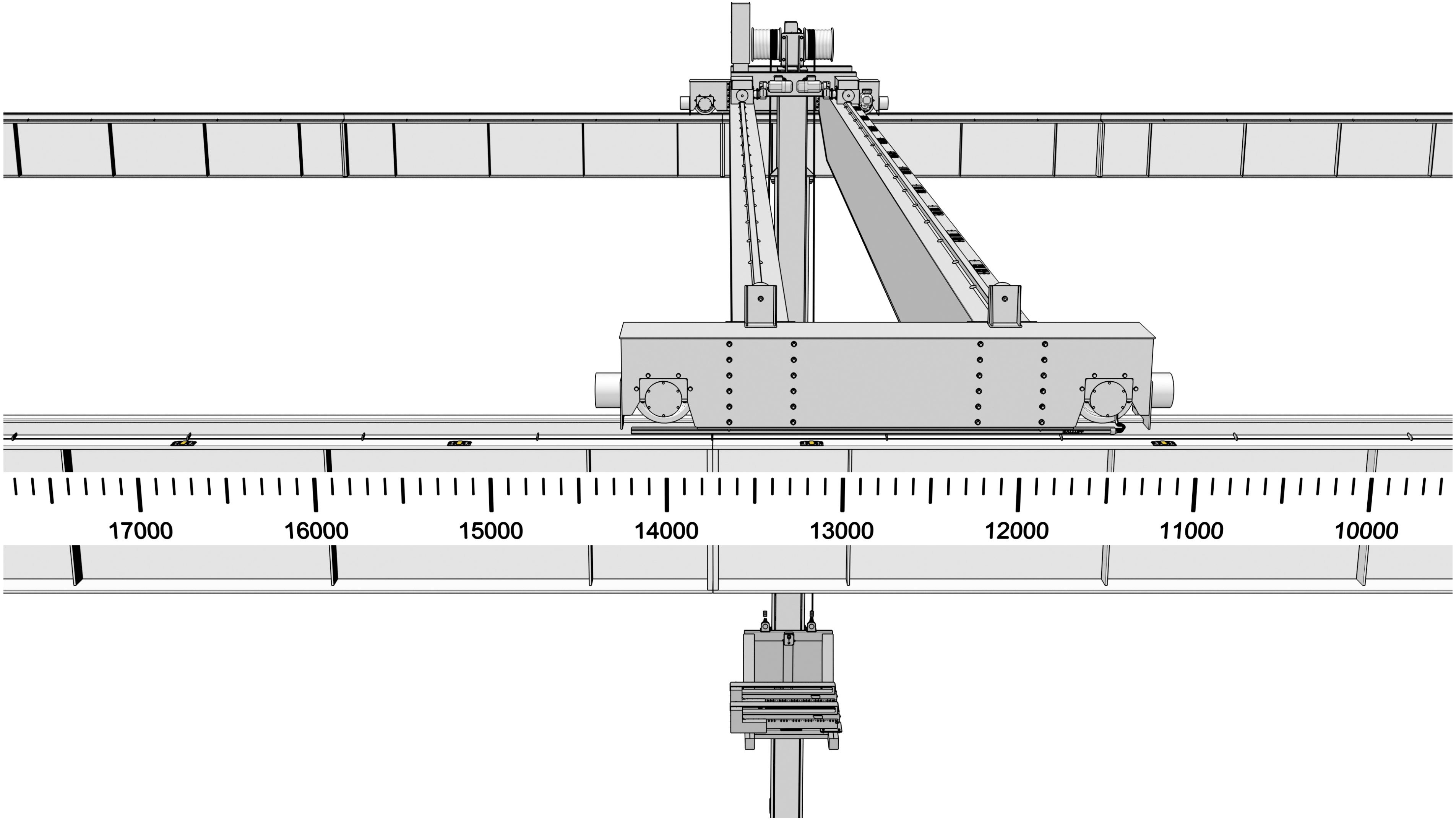


Fig. 2.2-6 Example of absolute coordinate measurement section based on position markers



Pos – position marker

Fig. 2.2-7 Example of incremental coordinate measurement section based on position markers



Markers for incremental systems can be installed rather flexibly. Generally, a track consists of serially alternating zones of absolute and incremental coordinate measurement. User chooses the track zones as absolute or incremental.

The distance from position marker to adjacent interval marker must be within the range from Y_{min} to Y_{max}, see the system datasheet.

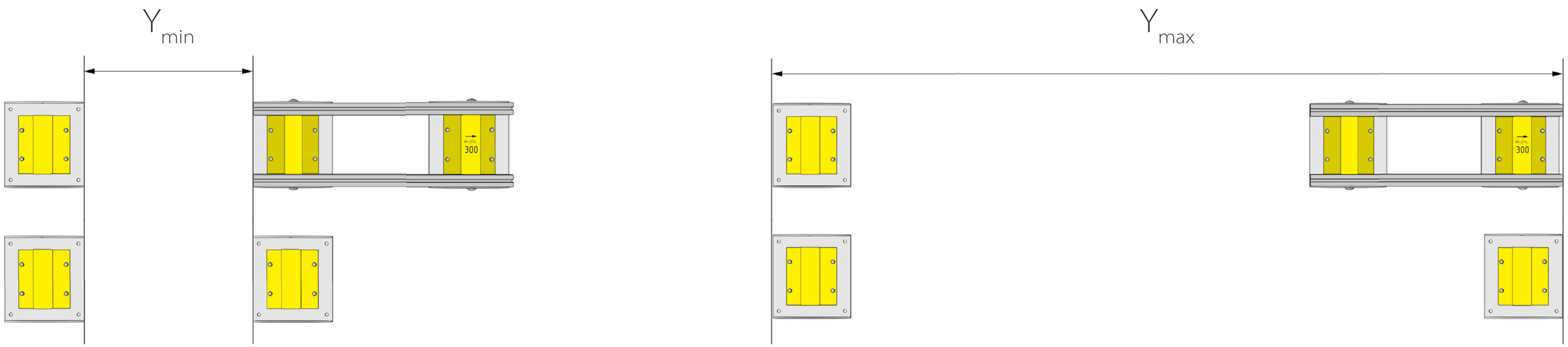
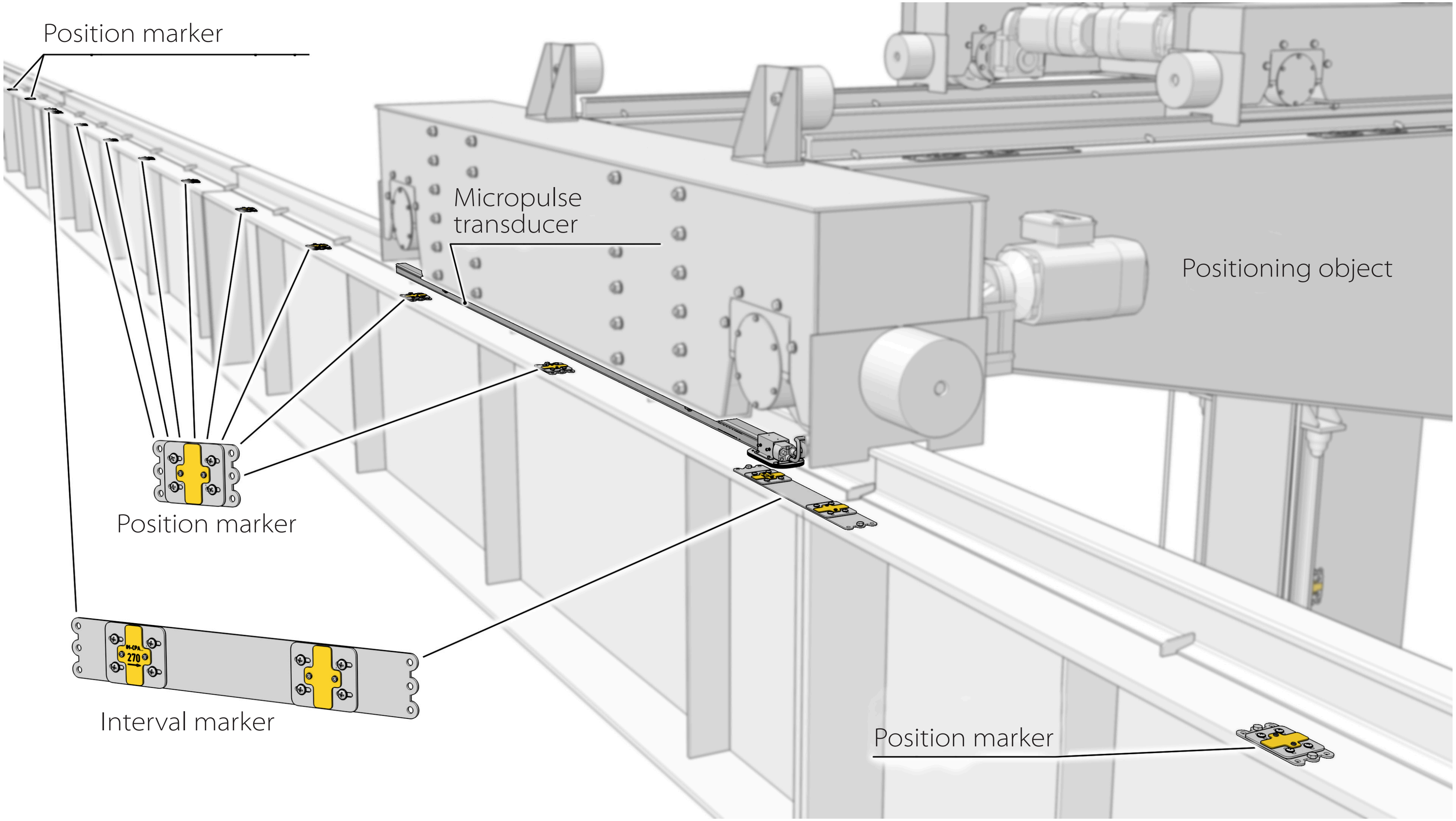


Fig. 2.2-8. Distance between the markers for an incremental system

Fig. 2.2-9 Example of markers allocation for an adaptive incremental system



Example

Adaptive incremental system Magnettrack CPAI-0100-011-05-P1500P-MM2-30-60. Maximum range of object travel measurements is 100 m with transducer 1,500 mm. To measure the travel at a distance of 100 m, a transducer with a length of 2,500 mm minimum would be required for a normal adaptive Magnettrack system, which is not always suitable for small measurement objects, since the transducer with dimensions of 2500 mm or more may extend the object size. In case of an adaptive incremental system, transducer may be used with a significantly shorter length, e.g. 1,500 mm.

Let's assume that the zones of absolute travel are set by unique interval markers every 10 m. A total of 11 such interval markers will be required, equally spaced along the whole track of 100 m. The maximum marker length will be 420 mm.

The distance between interval markers is filled with incremental markers.

The distance between two adjacent incremental markers, and between an incremental and interval marker must not exceed $(NL_{virt} – V_{max} \times T_{plc})$ = 1,370 mm – 3 m/s × 20 msec = 1,310 mm, where:

3 m/sec is the maximum object velocity

20 msec is the time of a single controller cycle

1370 mm is the operating length of transducer. It differs from nominal length of transducer of 1,500 mm by the value of offsets (see system datasheet).

Position markers in amount of (10,000 mm – 420 mm) / 1,310 mm = 7.3 are installed between each pair of interval markers, which, after rounding upwards, will equal 8. A total of 8 × 10 = 80 incremental markers and 11 interval markers will be required for the distance of 100 m.

Magnet track may contain an excessive number of markers to improve fail-safety of Magnettrack system.

Upon restart of Magnettrack adaptive incremental system power supply, absolute coordinate of the object will only be available when the object is positioned at any zone of absolute coordinate measurement initialized earlier or after the object travels to this section.

If the object coordinate is reset to initial coordinate when the system functions in incremental mode, this will not cause a system failure. The system will start the track initialization and will continue functioning in incremental mode.

2.3 Transducer Electrical Connection

When making electrical connections, pay attention to the following: the system and control cabinet must have the same ground potential.

To guarantee electromagnetic compatibility (EMC) the following requirements must be strictly followed:

A. Transducer and processor/controller must be interconnected using shielded cables. Shield: copper braiding covering at least 80 %.

B. The cable shield must be connected to the body of connector.

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

D. Profinet bus line must be installed according to Profinet technical instructions and Profinet-IO assembly guidelines.

In order to prevent noise impact on data transmission, do not install the cable connecting the transducer, controller and power source near high-voltage lines. Inductive interferences coming from AC harmonic oscillations (e.g. from phase angle controls) have an adverse effect, since cable shield provides limited protection against such interferences.

The signal is sent to controller through PROFINET-IO interface. Maximum length of main cable line between active nodes is 100 m.

Data rate achieves 100 MBit/s.

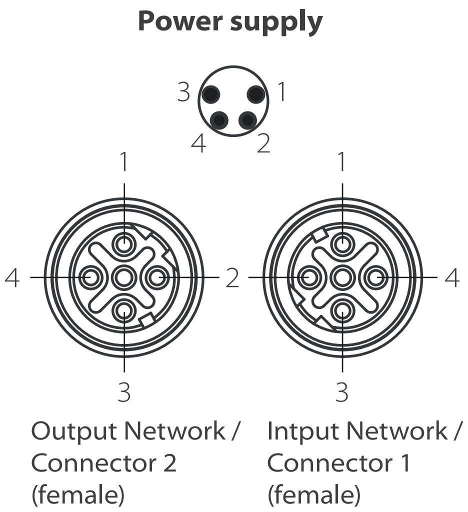


Fig. 2.3-1. Pin assignment (view from transducer side)

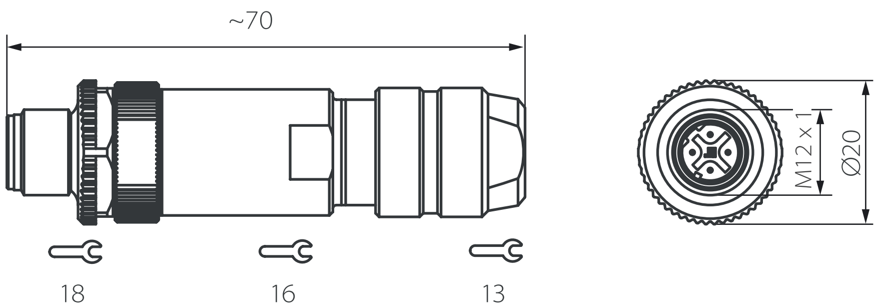


Fig. 2.3-2. Profinet connector (I/O)

Ethernet cable of category Cat 5e minimum, with diameter from 5 to 8 mm is used for connection of transducer to PROFINET network.

Cable contacts are attached to connector using screw terminals. Conductor cross sections is from 0.14 m^2 to 0.75 mm^2.

Maximum torque of the terminal is 0.6 N/m.

i

Automation systems must use PROFINET cables. Standard network cables can only be used in the networks corresponding to conformity class A (CC-A).

Profinet contact wiring

I/O bus (data)		
Pin	**Color**	**Signal**
1	Yellow	TX+
2	White	RX+
3	Orange	TX–
4	Blue	RX–

A 2-wire cable with diameter from 3.5 to 5 mm is used for connection of transducer power supply. A quick cable entry system is applied for connection of contacts.

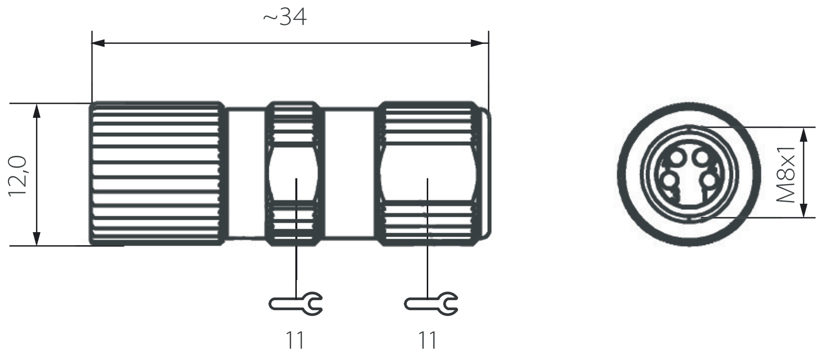


Fig. 2.3-3. Power connector

Conductor cross section is from 0.14 to 0.38 mm^2.

Maximum torque of the terminal is 0.4 N/m.

Power supply wiring

Power supply		
Pin	**Color**	**Signal**
1	Brown	10 to 30 VDC
2	White	Not used
3	Blue	0 V GDN
4	Black	Not used

2.4 System indication

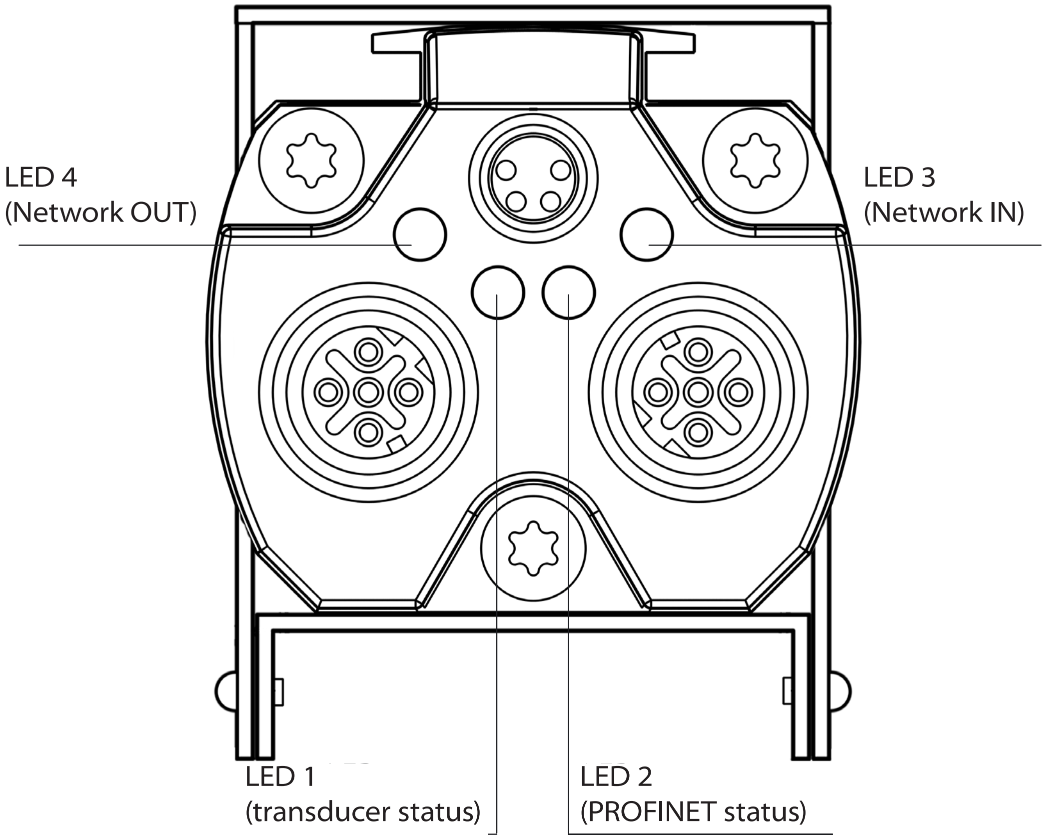


Fig. 2.4-1. Indication at transducer

Tr. Status LED1	Status
Green	Normal functioning. Magnetic marker is the working zone of transducer.
Red	Error. Magnetic marker is faulty or out the working zone of transducer.

Profinet status LED2			
Red (network error)	**Green**	**Value**	**Cause**
Off	Off	No power	
On	On	Transducer not connected to network (no signal)	Profinet cable not connected/power off at the switch/master module not defined
Flashing[1]	On	Transducer connected to network (signal available), but there is no data exchange	Transducer in boot state (time needed until complete activation) Transducer configured incorrectly Wrong/inaccessible IP-address assigned to transducer Controller configuration does not correspond to transducer configuration
Off	On	Transducer connected to network and exchanges data	

[1] *Flashing frequency is 0.5 Hz. The indication lasts for at least 3 sec.*

Network LED3/LED4	Status	Communication
On	Port opened	YES
Flashing	The devise is identified by master module	YES
Off	Port closed	NO

3.1 Equipment configuration

To use transducer in TIA Portal configuration tool, import xml file to the system: "Options" -> 'Manage general station description files xml' (Fig. 3.1-1). After that, choose the xml file path, select required drivers and click on 'Install' (Fig. 3.1-2).

During the update of xml file, make sure it is not currently used by an application, otherwise the system will not be able to update it.

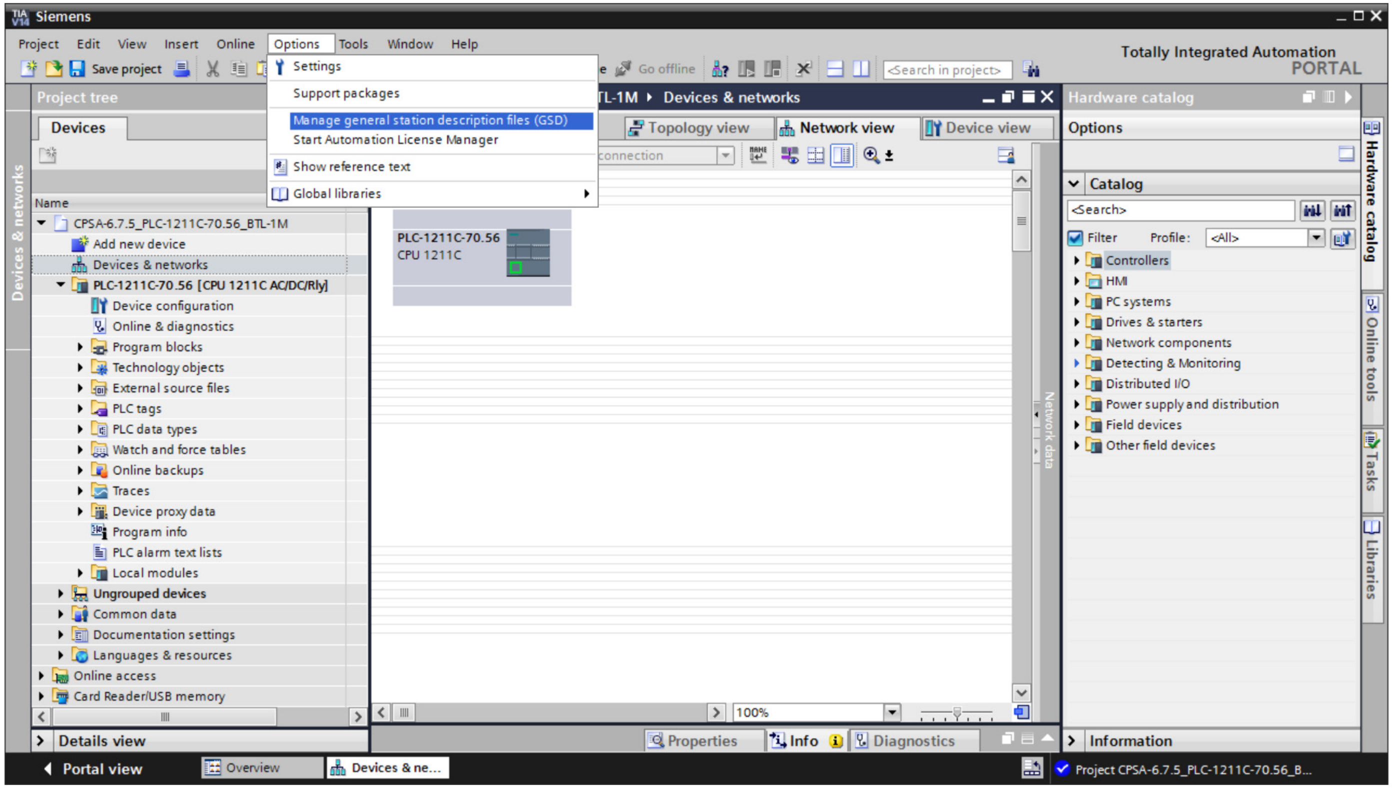


Fig. 3.1-1. Transducer driver import

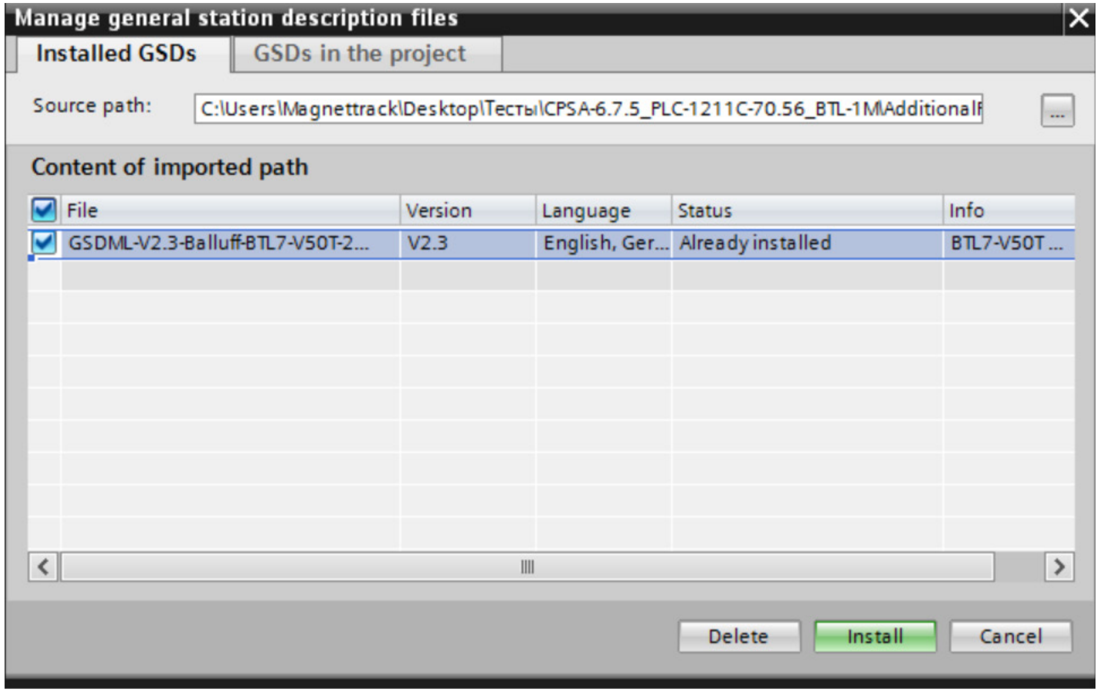


Fig. 3.1-2. Import of a transducer

After the import, transducer will be in Hardware catalog: Other Field Devices\PROFINET IO\Encoders\Balluff GmbH\BTL7-V50T (Fig. 3.1-3).

Select transducer and drag and drop it to the project field Devices & networks.

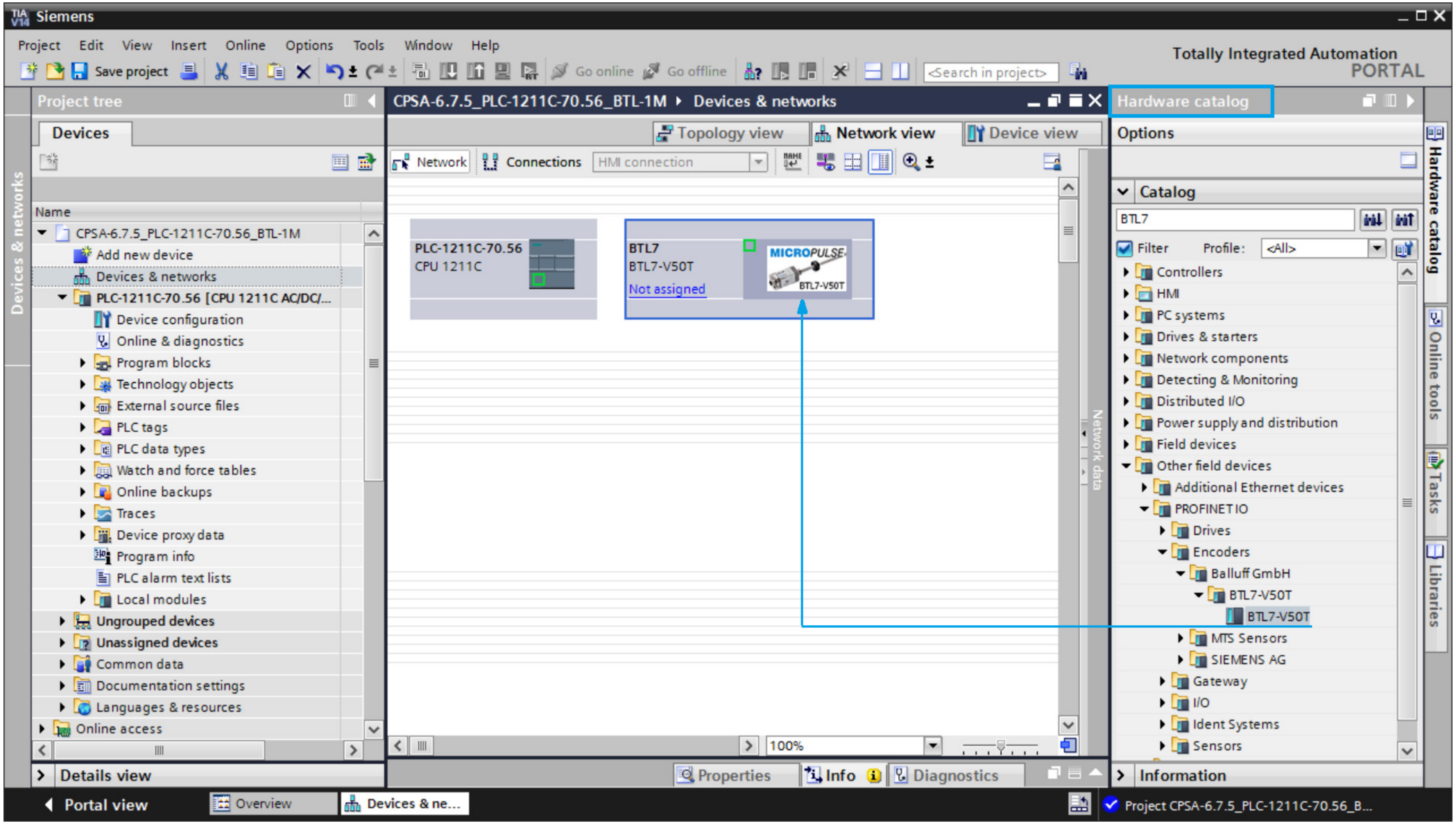


Fig. 3.1-3. Adding a transducer to network

To establish communication between transducer and controller, point the mouse to “Not assigned’ in ‘Device & networks’ window and right click on ‘Assign to new IO controller” (Fig. 3.1-4).

Select required interface of relevant controller in the opened window (Fig. 3.1-5). Click “OK”.

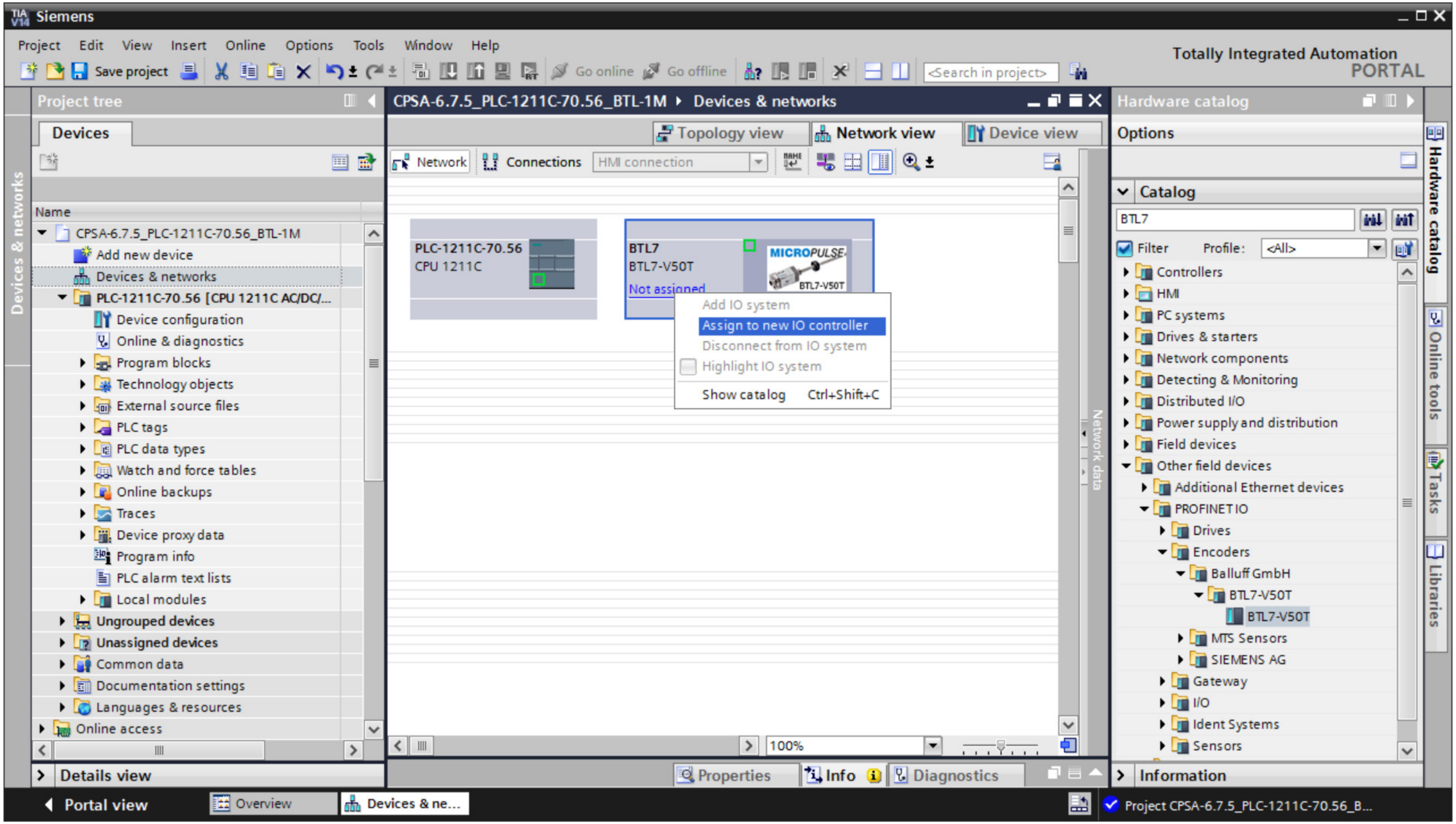


Fig. 3.1-4. Establishing communication between transducer and controller

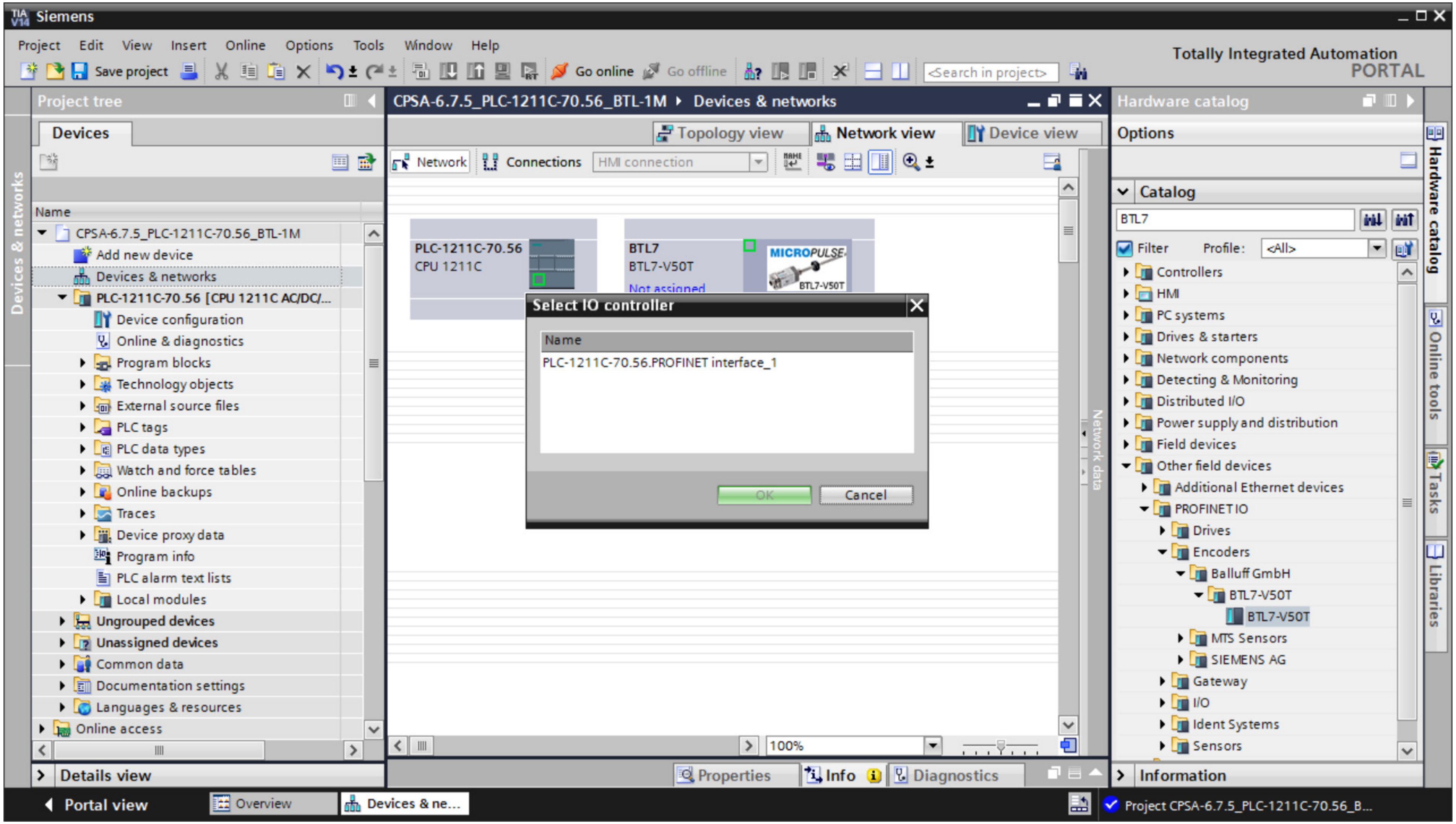


Fig. 3.1-5. Selection of interface

Next, assign functional modules to the device. To do this, select transducer at the graph. Then, open Submodules menu in Hardware catalog window and drag the required module to configuration table (Fig. 3.1-6).

A set of modules with non-fixed number of markers is used for Magnettrack system (FMM position values).

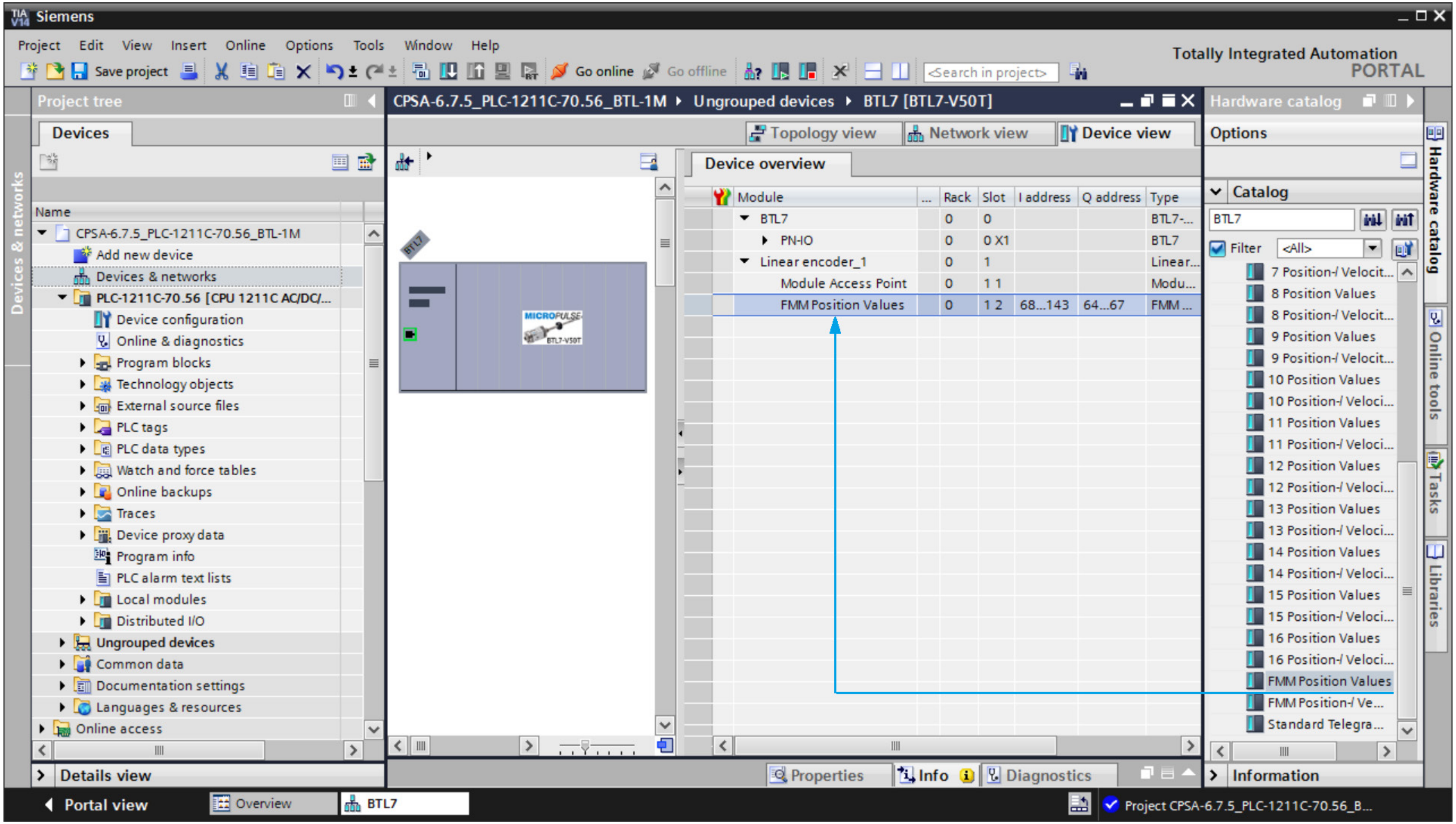


Fig. 3.1-6. Selection of functional module

Click on "FMM Position Values" module in the device configuration table to open parameter dialog (Fig. 3.1-7). Set initial address of input and output message at 'I/O addresses' tab in 'Start address' section or use the default address proposed by the program.

> **i** Please note that initial addresses of input and output messages of the transducer (Input и Output addresses, correspondingly) must match to ensure correct functioning of Magnettrack positioning system. Otherwise, functioning of the positioning system is not guaranteed.

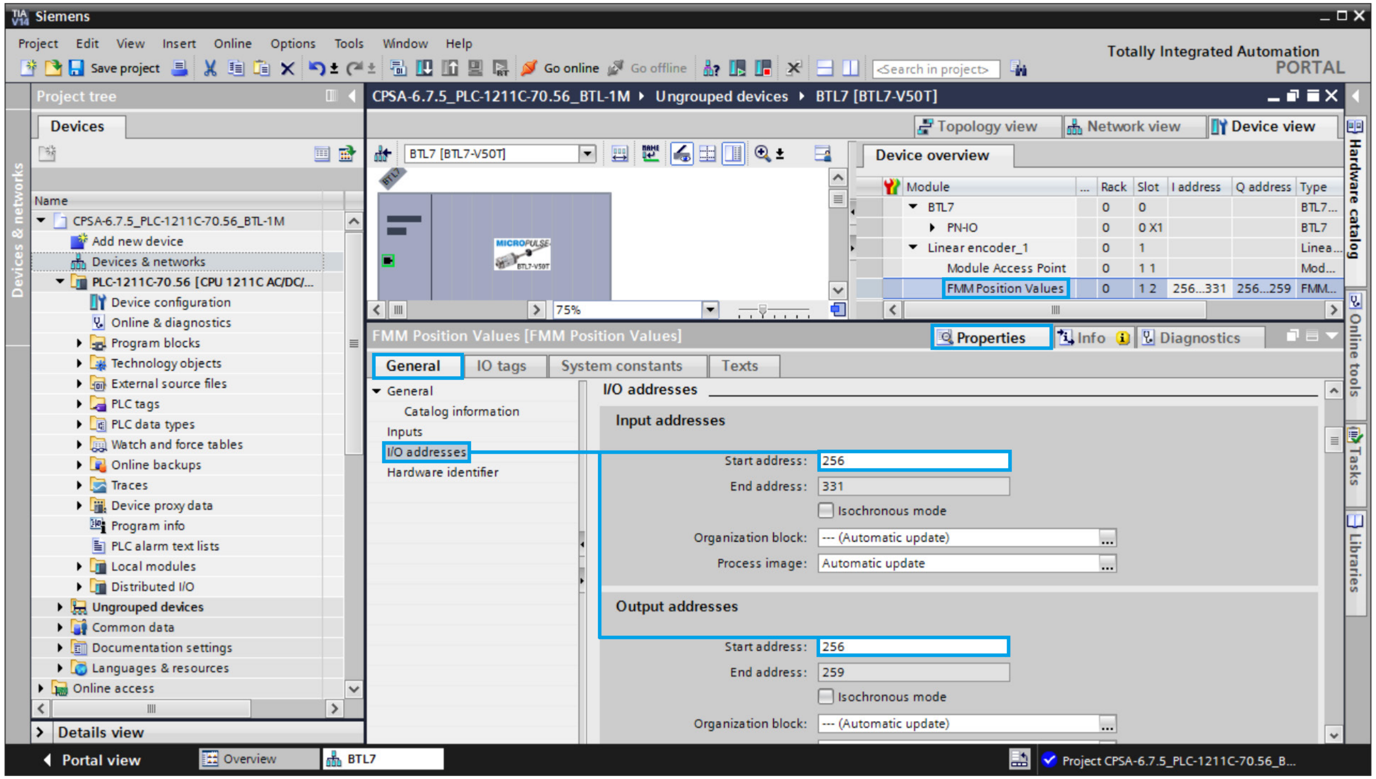


Fig. 3.1-7 Assignment of operating addresses for transducer

Next, assign a name to transducer. To do this, select your network card and update the devices in Online Access of TIA Portal. Enter the transducer name shown in "Online Access" section into 'Device overview' section of your project (Fig. 3.1-8). Next, upload all the changes into controller.

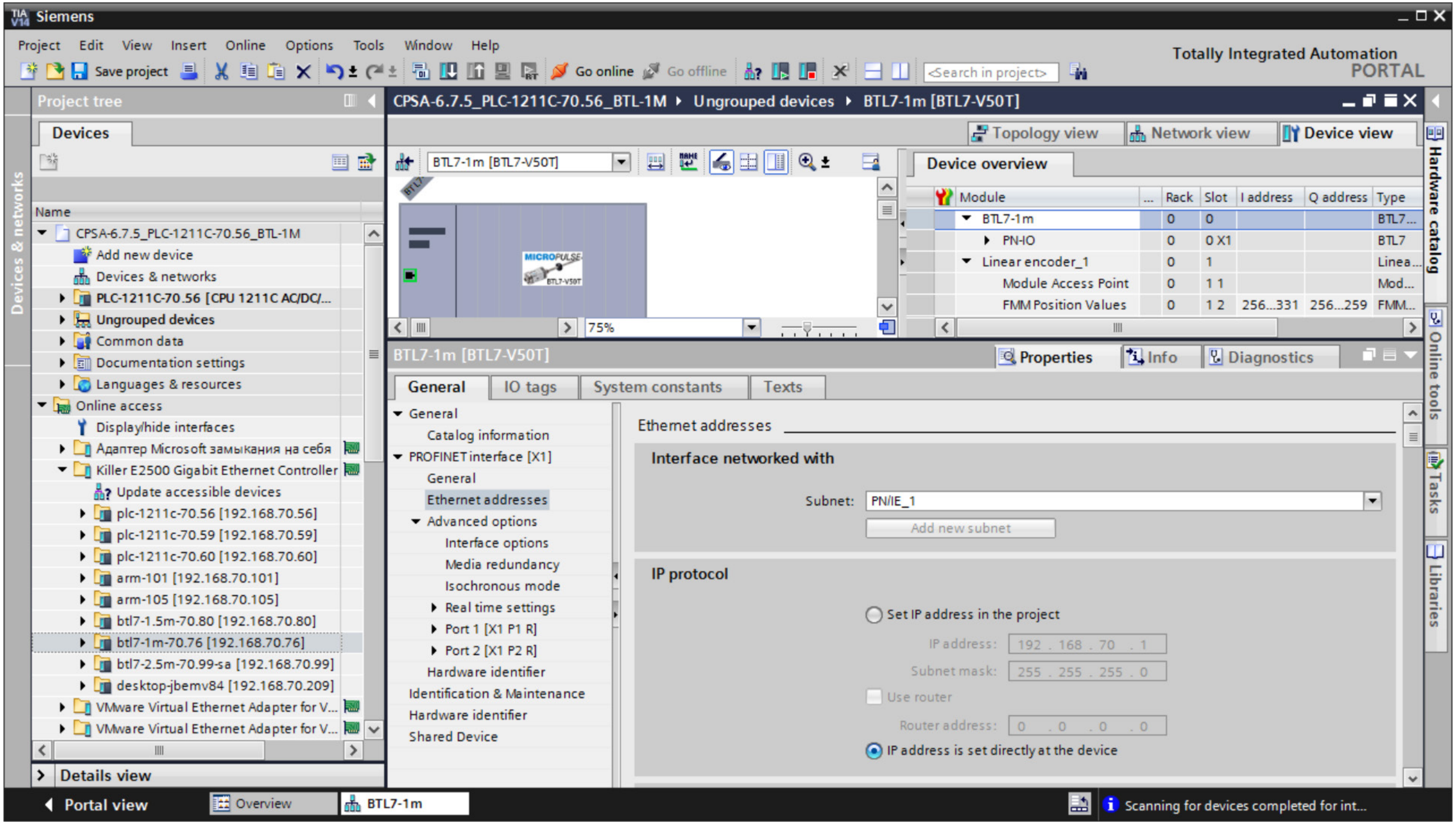


Fig. 3.1-8. Transducer name assignment

If a new name needs to be assigned to transducer, enter the selected device name in the project, in "Device overview" section (see Fig. 3.1-9), and next, right click on transducer icon and select 'Assign Device Name'.

Upload a new name in the new window 'Assign PROFINET device name' (see Fig. 3.1-10). Finally, upload all the changes into controller.

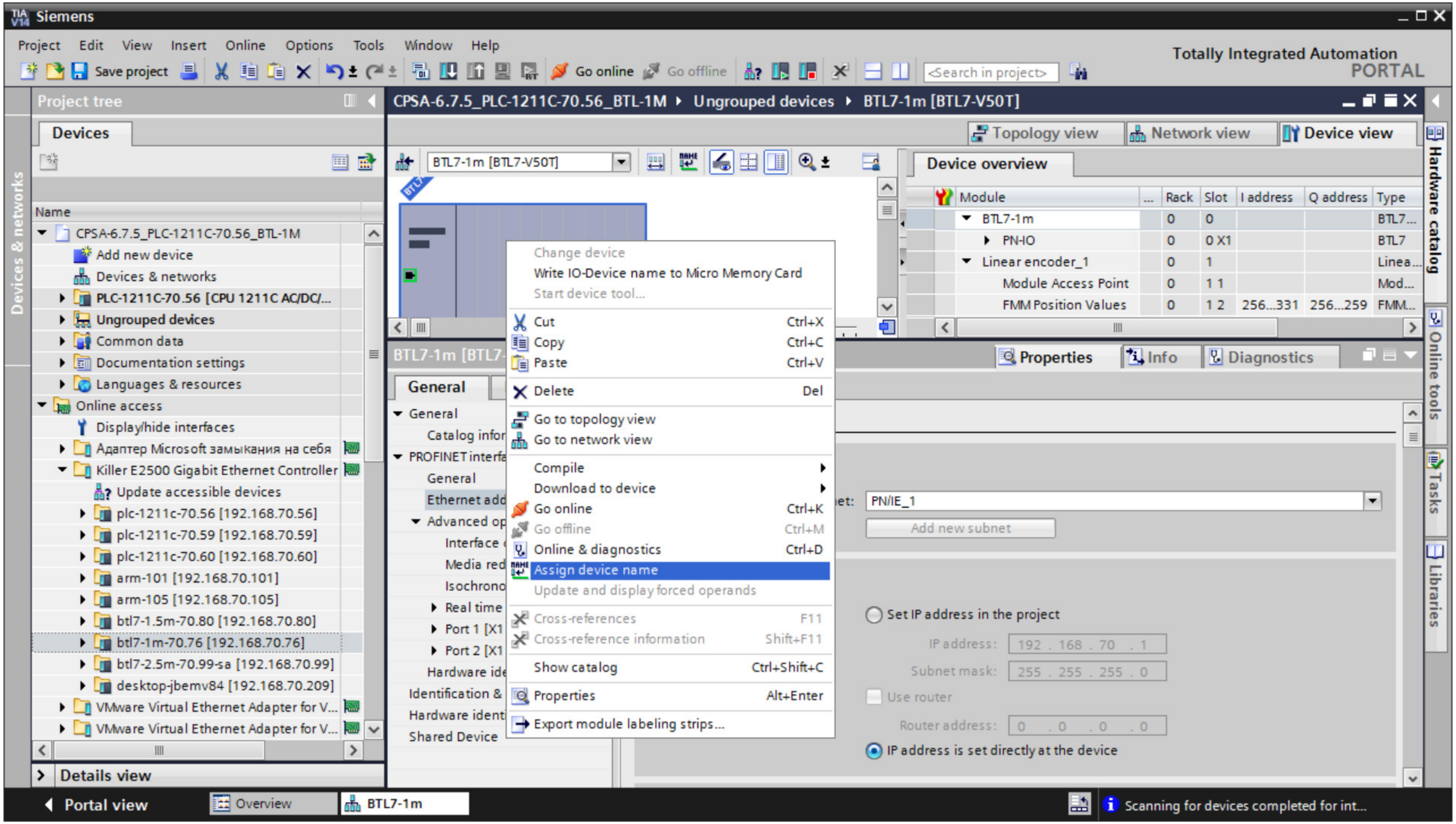


Fig. 3.1-9. Transducer name change

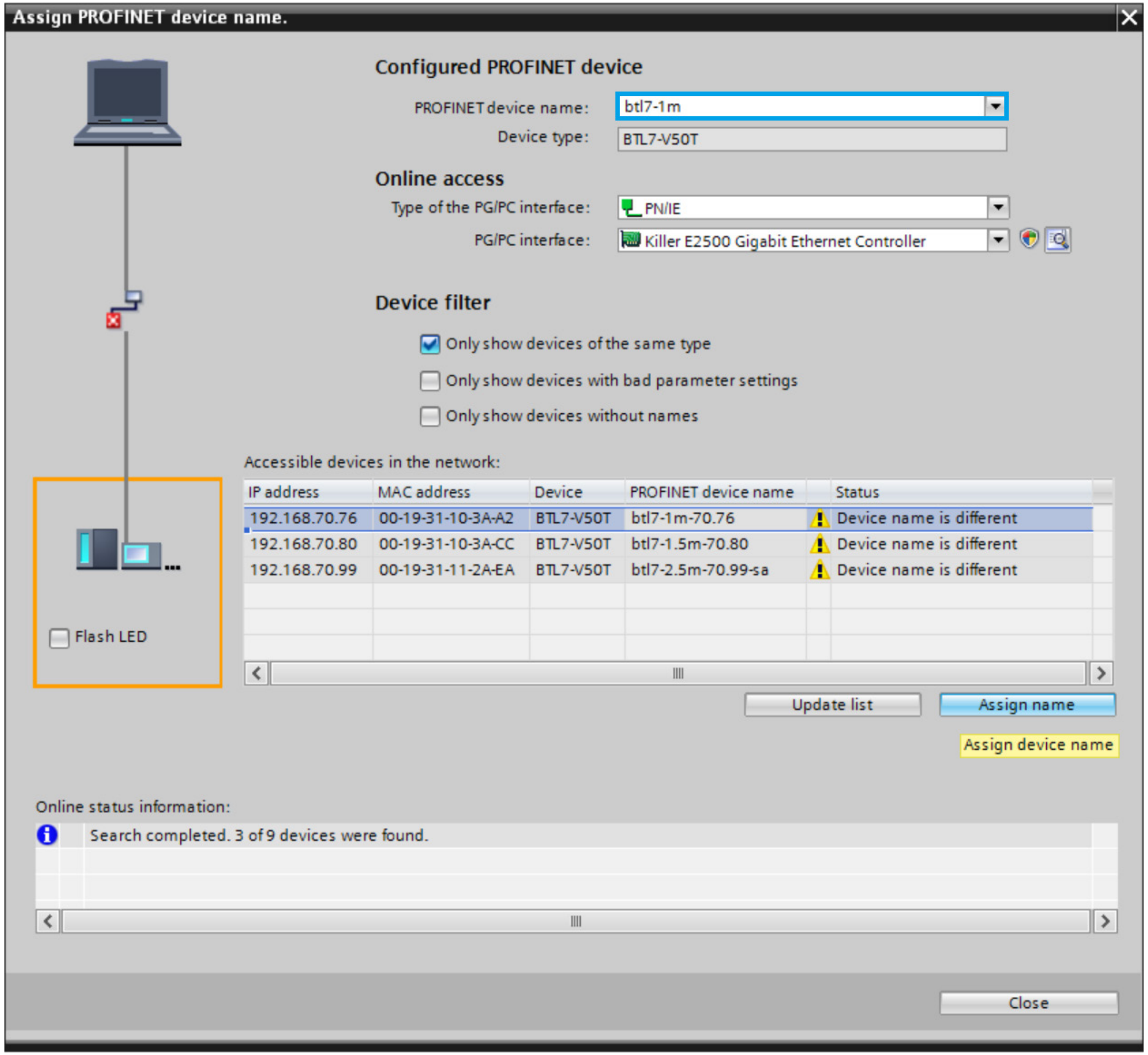


Fig. 3.1-10. Transducer name change

Next, select 'Module Access Point' and 'Module parameters' (Fig. 3.1-11) to change the system scale and the time of diagnostics. To obtain an output of coordinate in millimeters, record the value of 1,000 in 'Scaling: Measuring Steps [nm]' field. In this case, output parameter o_diVelocity will have similar size.

To obtain velocity output in m/s, enter 'Step / 10 ms' in 'Velocity measuring unit' field. Set 0 in the field of diagnostics time for the mode with non-fixed number of markers (Diagnostic time for FMM).

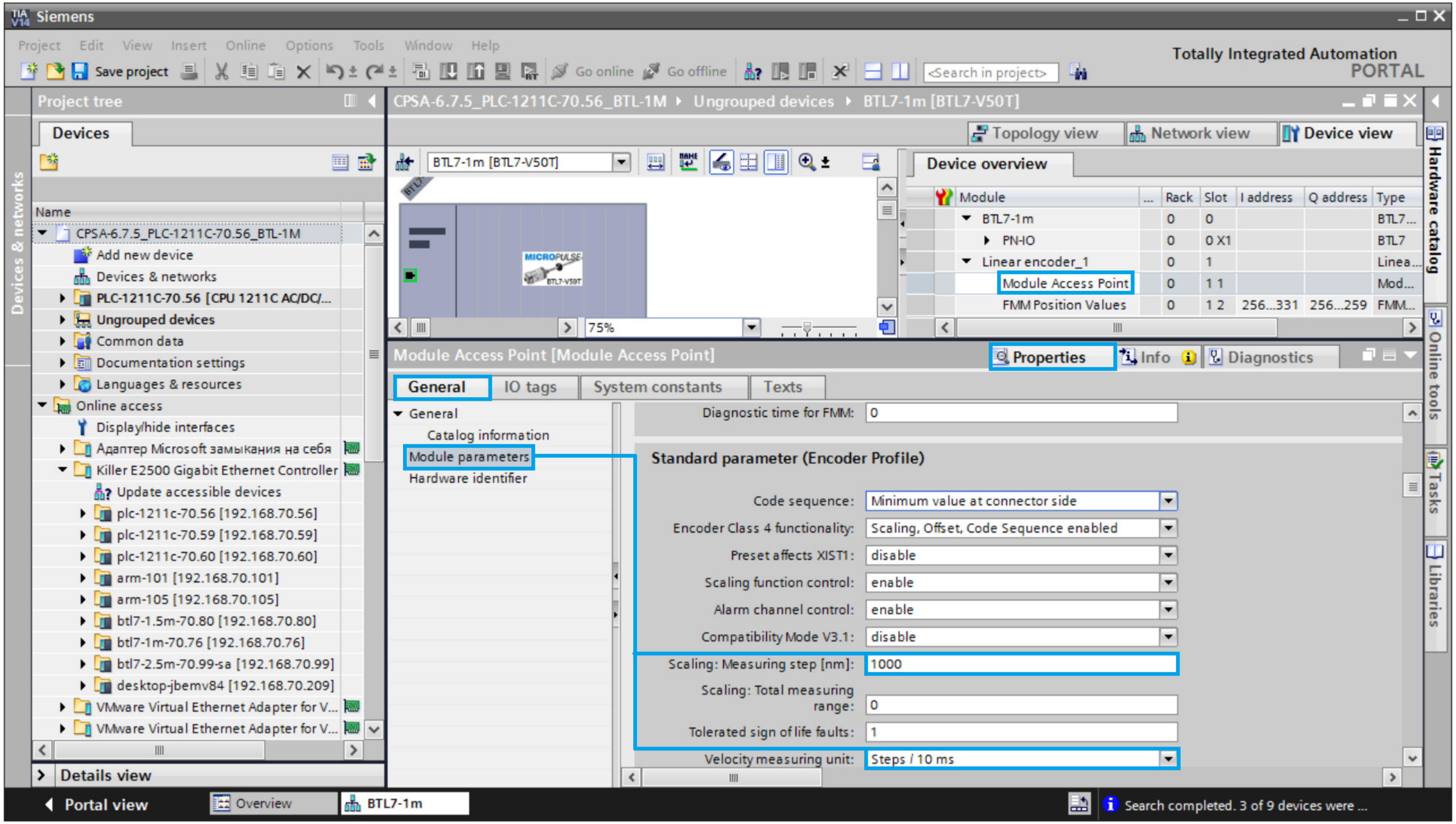


Fig. 3.1-11. Transducer parameterization

Please note that "Alarm channel control" parameter must be set to 'disable', and Compatibility Mode V3.1 – to 'enable' to ensure correct functioning of Magnettrack software.

After the specified values are entered, upload the configuration to controller.

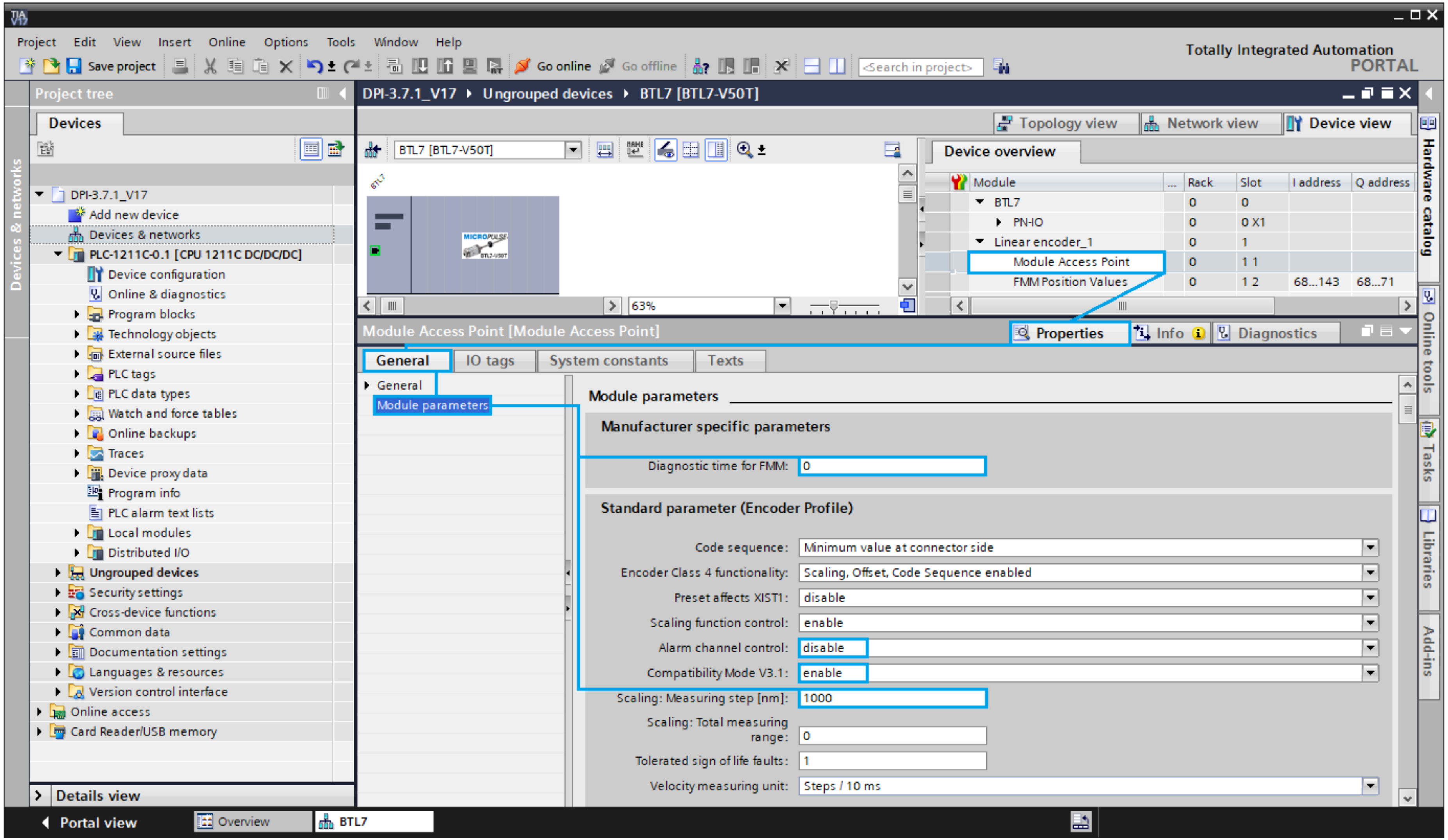


Fig. 3.1-12. Transducer parameterization

3.2 Installation of MT-CPSA[I] software in TIA Portal

To upload Magnettrack program into the project, select Project -> Open... (Fig. 3.2-1) in TIA Portal, specify the path to the project CPSA[I] and click 'Open'.

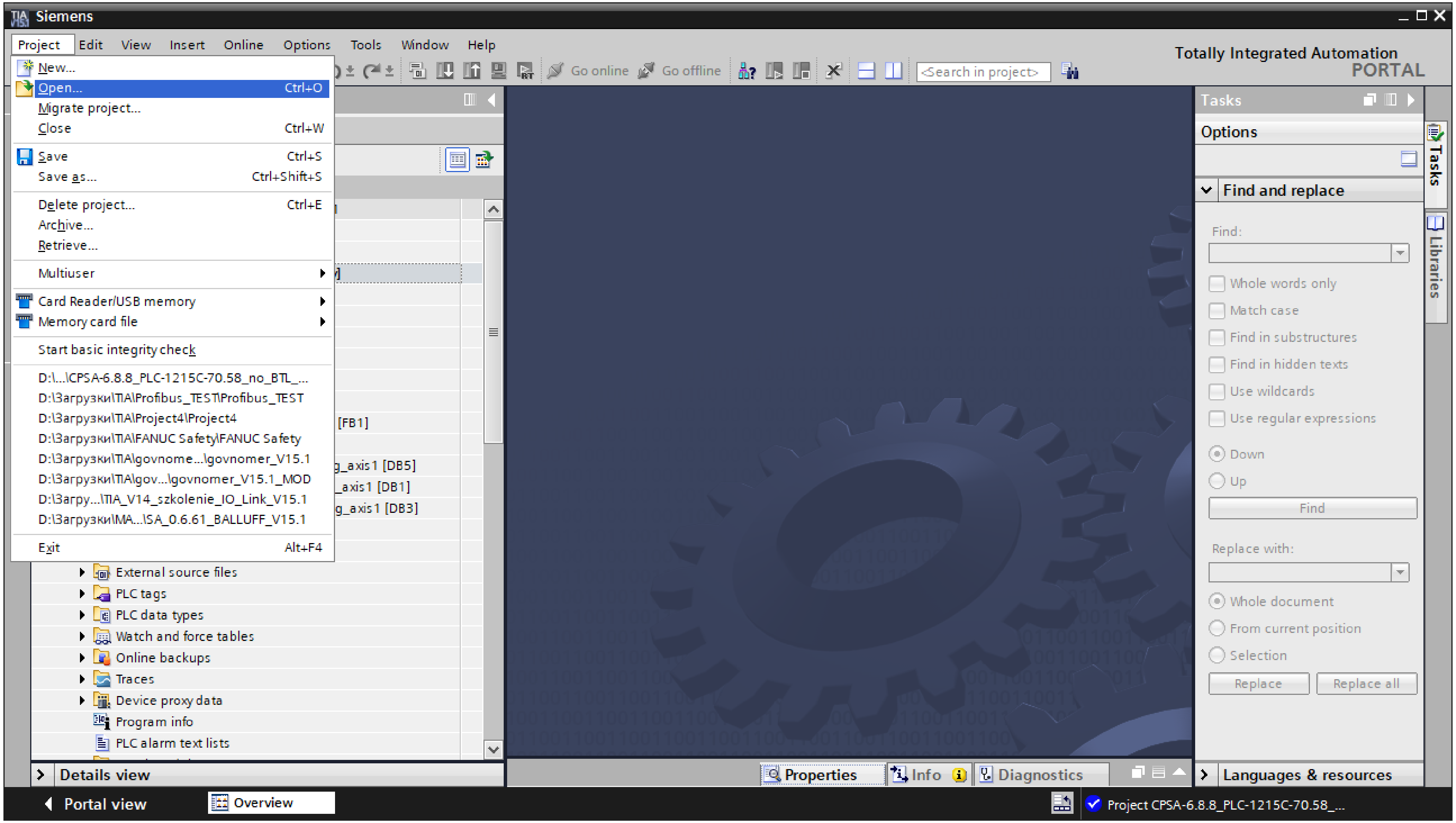


Fig. 3.2-1. Installation of project program MT-CPSA[I]

MT-CPSA[I] program will appear in the right side of the screen, in the projects catalog (Fig. 3.2-2). The project contains functional block **fb-MT-CPSA-X.X.X-Magnettrack** (where X.X.X is the program version) and folder Axis1 that contains three data blocks:

db-MT-CPSA-X.X.X-ErrorsLog_axis1
db-MT-CPSA-X.X.X-Magnets_axis1
db-MT-CPSA-X.X.X-Managing_axis1

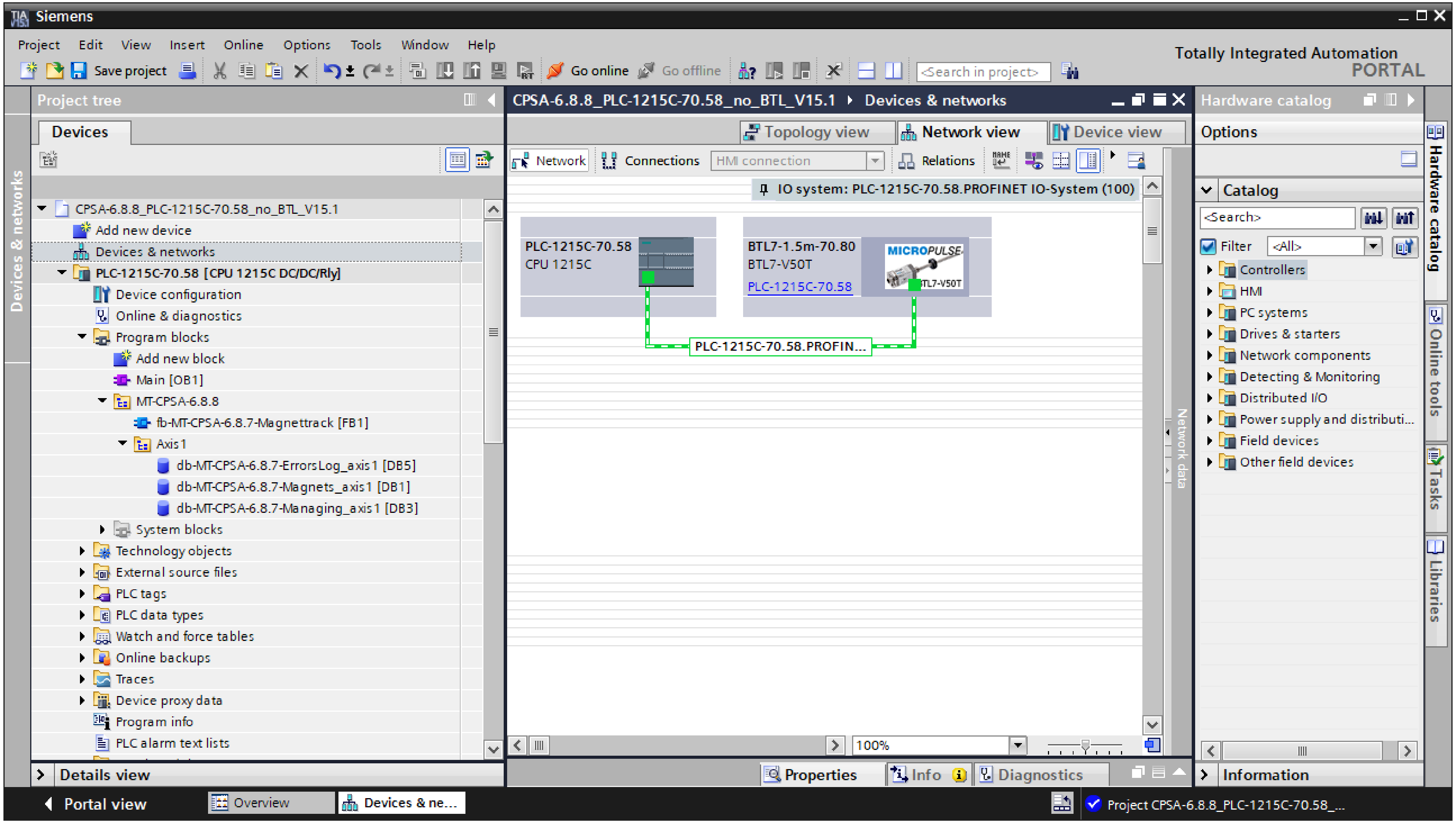


Fig. 3.2-2. Magnettrack functional block in OB1

Add functional block fb-MT-CPSA-X.X.X-Magnettrack from MT-CPSA-X.X.X folder to OB1 organization block (Fig. 3.2-3).

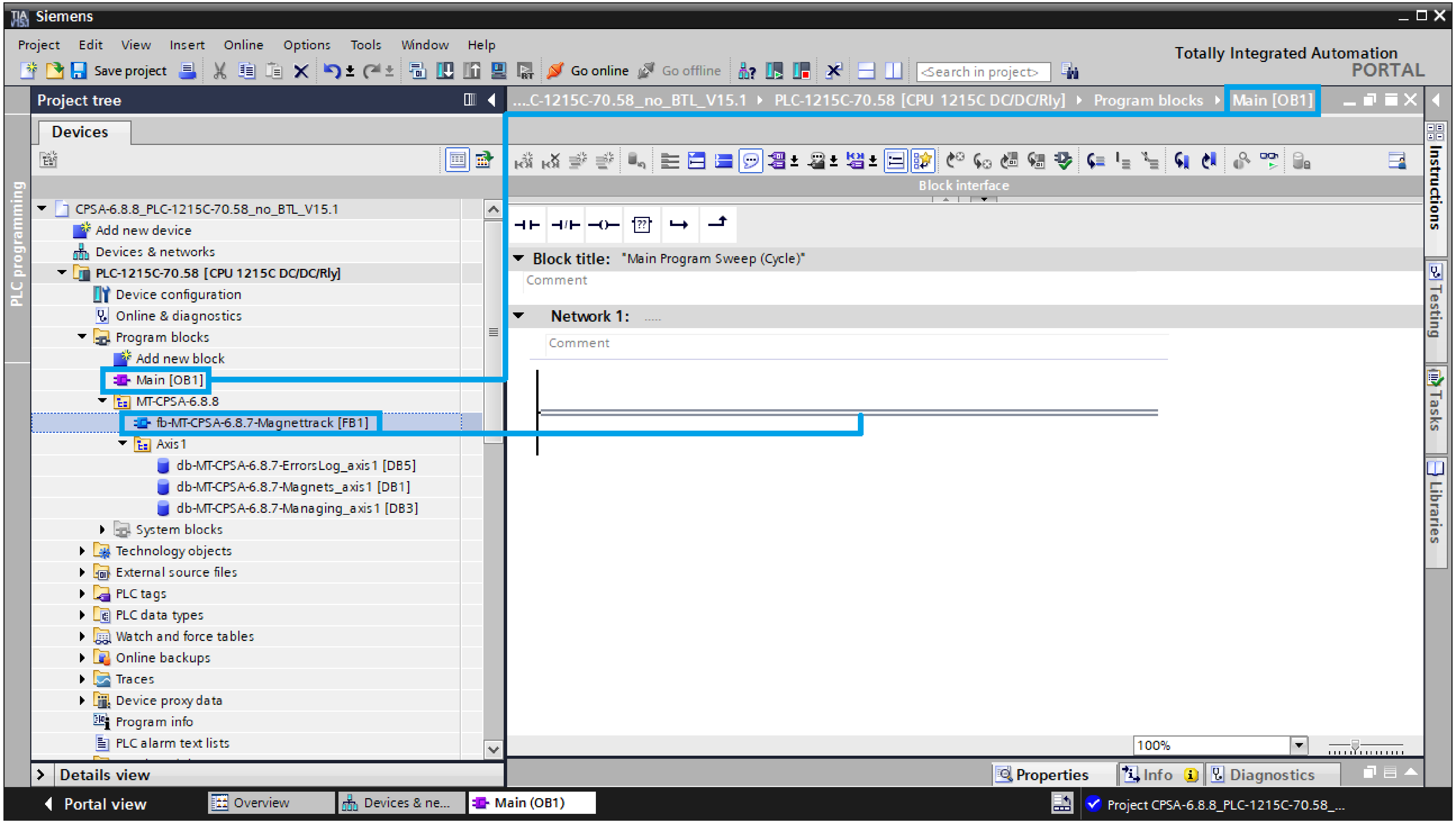


Fig. 3.2-3. Adding Magnettrack functional block to OB1

When Call Options window appears, create a new data block with a random number (Fig. 3.2-4). In the example, it is fb-MT-CPSA-X.X.X-Magnettrack_axis1.

After a data block is created, it is automatically moved to root folder Program blocks. Move it to folder Axis1 (Fig. 3.2-4.1)

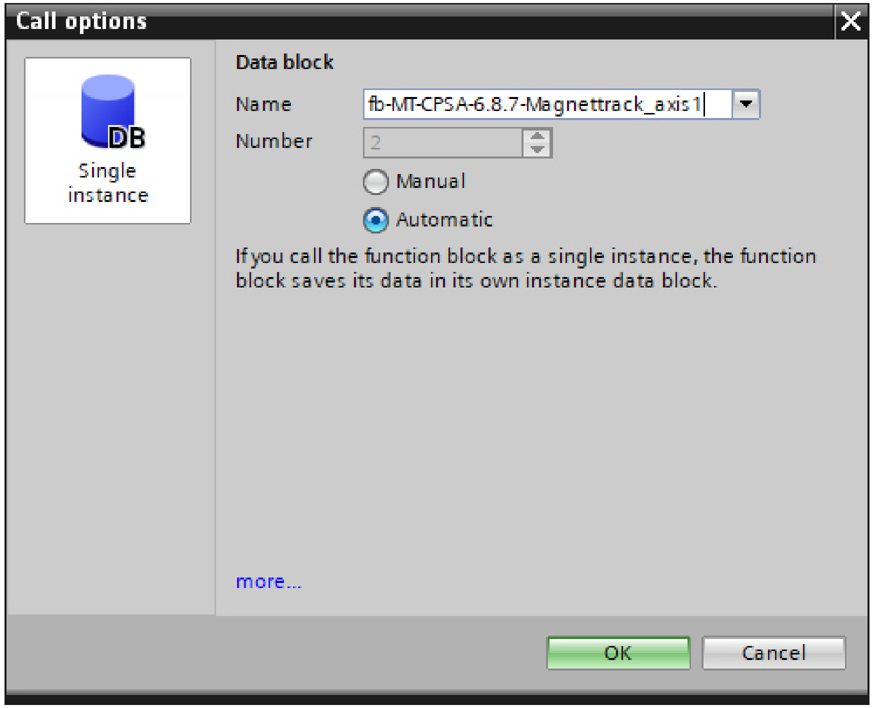


Fig. 3.2-4. "Call Options" window for creation of data block

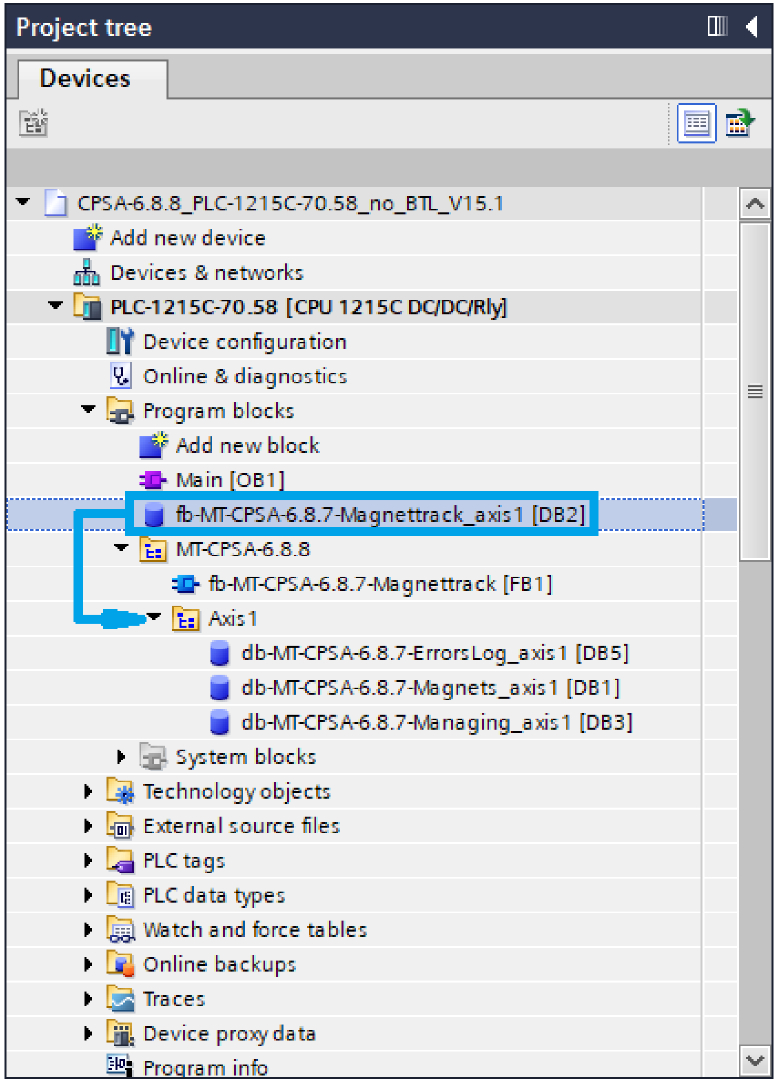


Fig. 3.2-4.1. Movement of data block to Axis1 folder

A functional block has two main data inputs and one output highlighted in the block with a brighter font color. It will suffice to identify only these I/O's for system functioning.

Five additional outputs highlighted with pale font are optional, but may provide more information about the object and system status.

Input data:

i_Parameters: select Parameters area from database db-MT-CPSA-X.X.X-Managing_axis1

io_Managing: select Managing area from database db-MTCPSA-X.X.X-Managing_axis1.

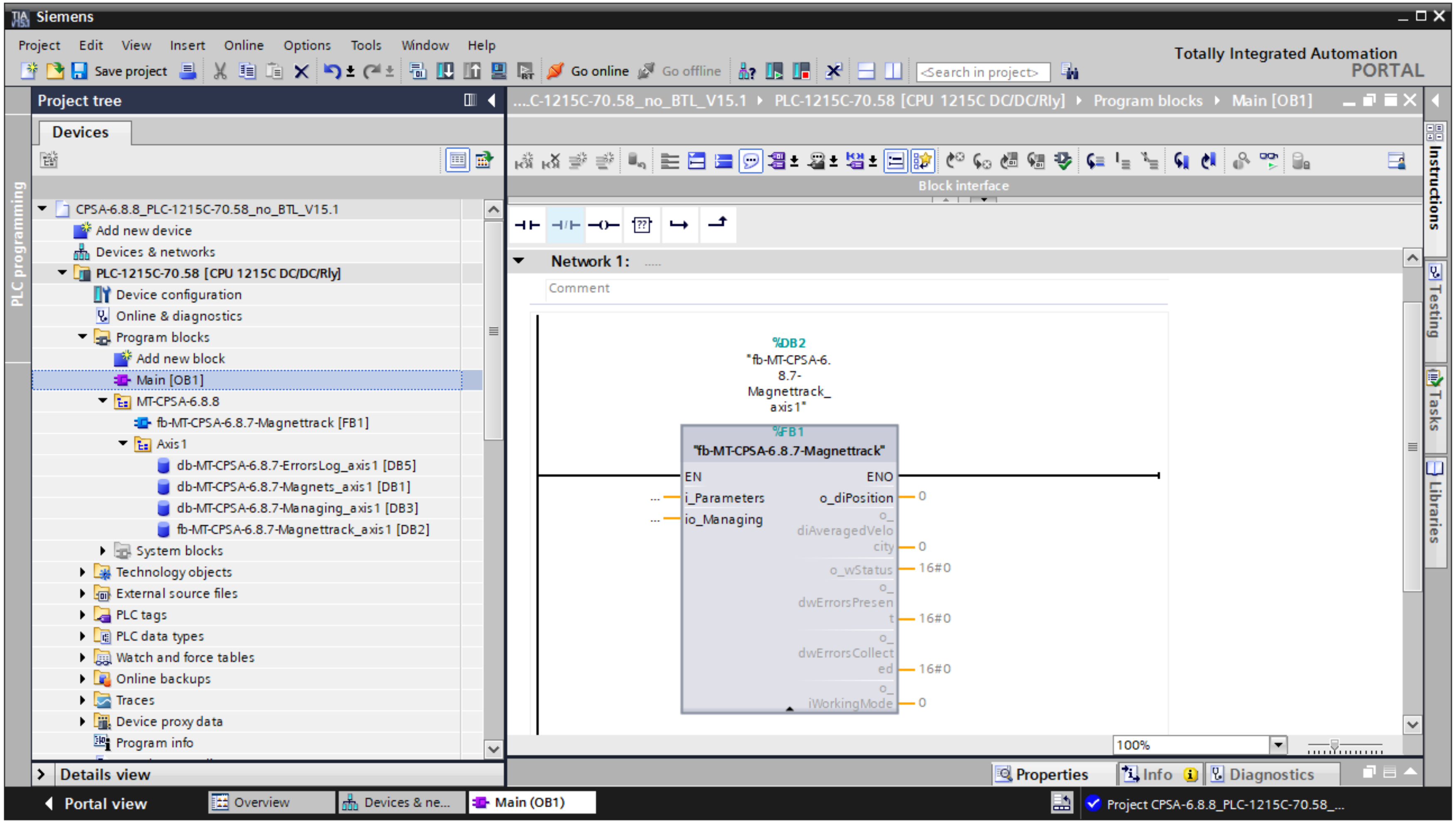


Fig. 3.2-5. Magnettrack functional block in OB1

Output data:

o_diPosition: select Output.Position from database db-MT-CPSA-X.X.X-Managing_axis1
o_diAveragedVelocity: select Output.AveragedVelocity from database db-MT-CPSA-X.X.X-Managing_axis1
o_wStatus: select Output.Status from database db-MT-CPSAX-.X.X-Managing_axis1
o_dwErrorsPresent: select Output.ErrorsPresent from database db-MT-CPSA-X.X.X-Managing_axis1
o_dwErrorsCollected: select Output.ErrorsCollected from database db-MT-CPSA-X.X.X-Managing_axis1
o_iWorkingMode: select Output.WorkingMode from database db-MT-CPSA-X.X.X-Managing_axis1.

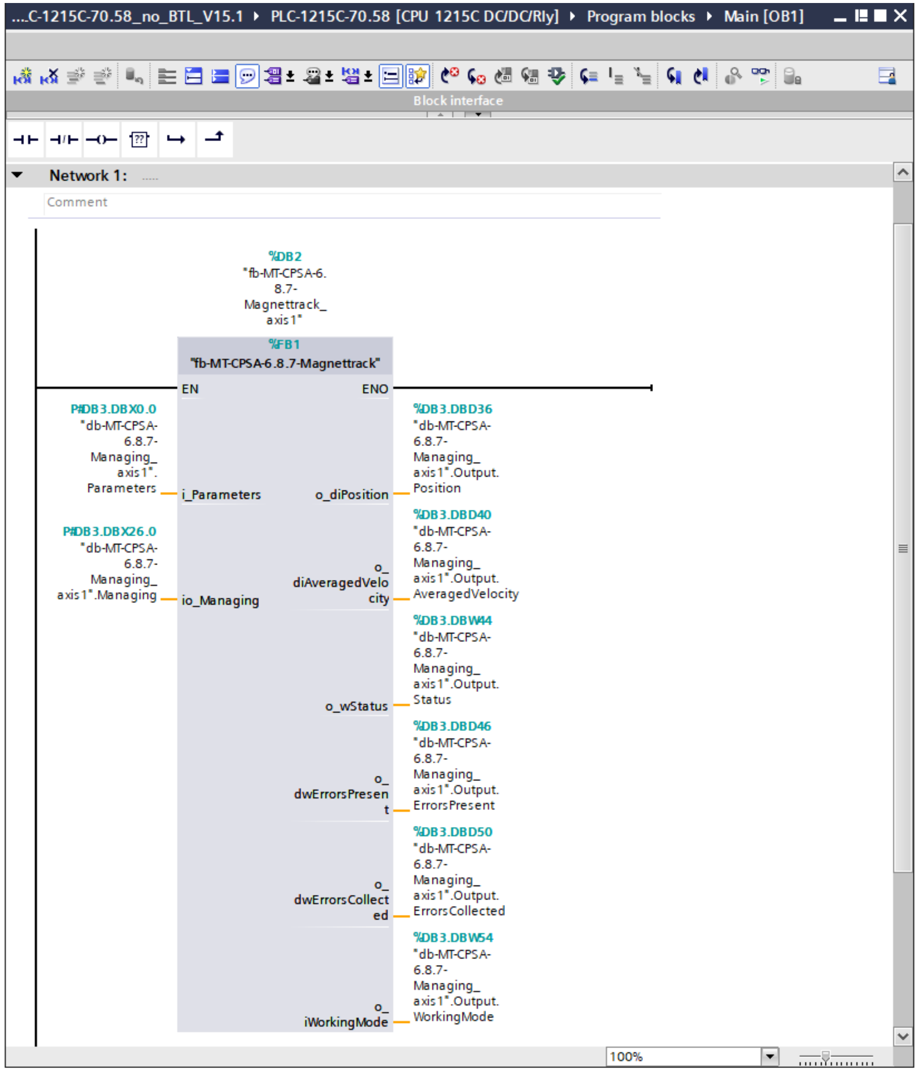


Fig. 3.2-6. Definition of input and output data of Magnettrack function

After input and output values of functional block are defined, Main organizational block (OB1) may be uploaded to controller.

If the positioning object moves along more than two axes, or if one controller processes movement of several objects, add required number of axes to the project. To do this, create a required number of copies of Axis1 folder in MT-CPSA-X.X.X folder (Fig. 3.2-7):

After that, rename the copied data blocks and axis folder correspondingly to the axis/object number (Fig. 3.2-8).

The numbers of new data blocks will get updated upon the next upload to controller.

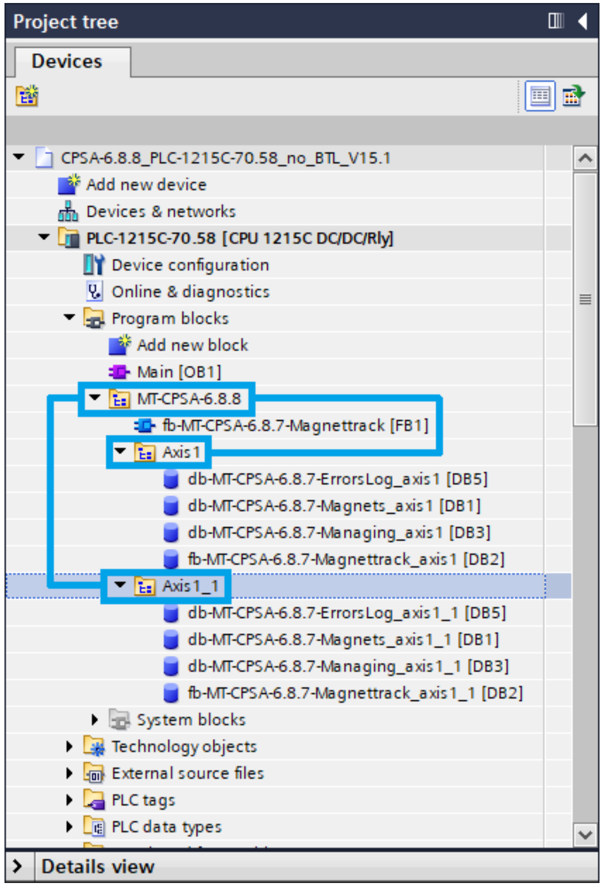


Fig. 3.2-7. Adding new data blocks for additional positioning axes

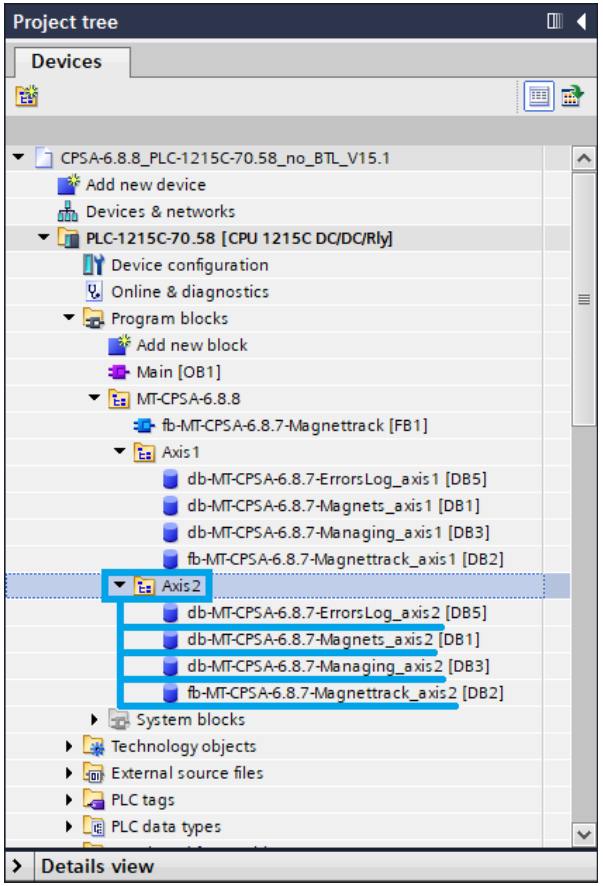


Fig. 3.2-8. Renaming data blocks

Create a new branch (Network 2) in organization block OB1 and add functional block fb-MT-CPSA-X.X.XMagnettrack to it from folder MT-CPSA-X.X.X (Fig. 3.2-9).

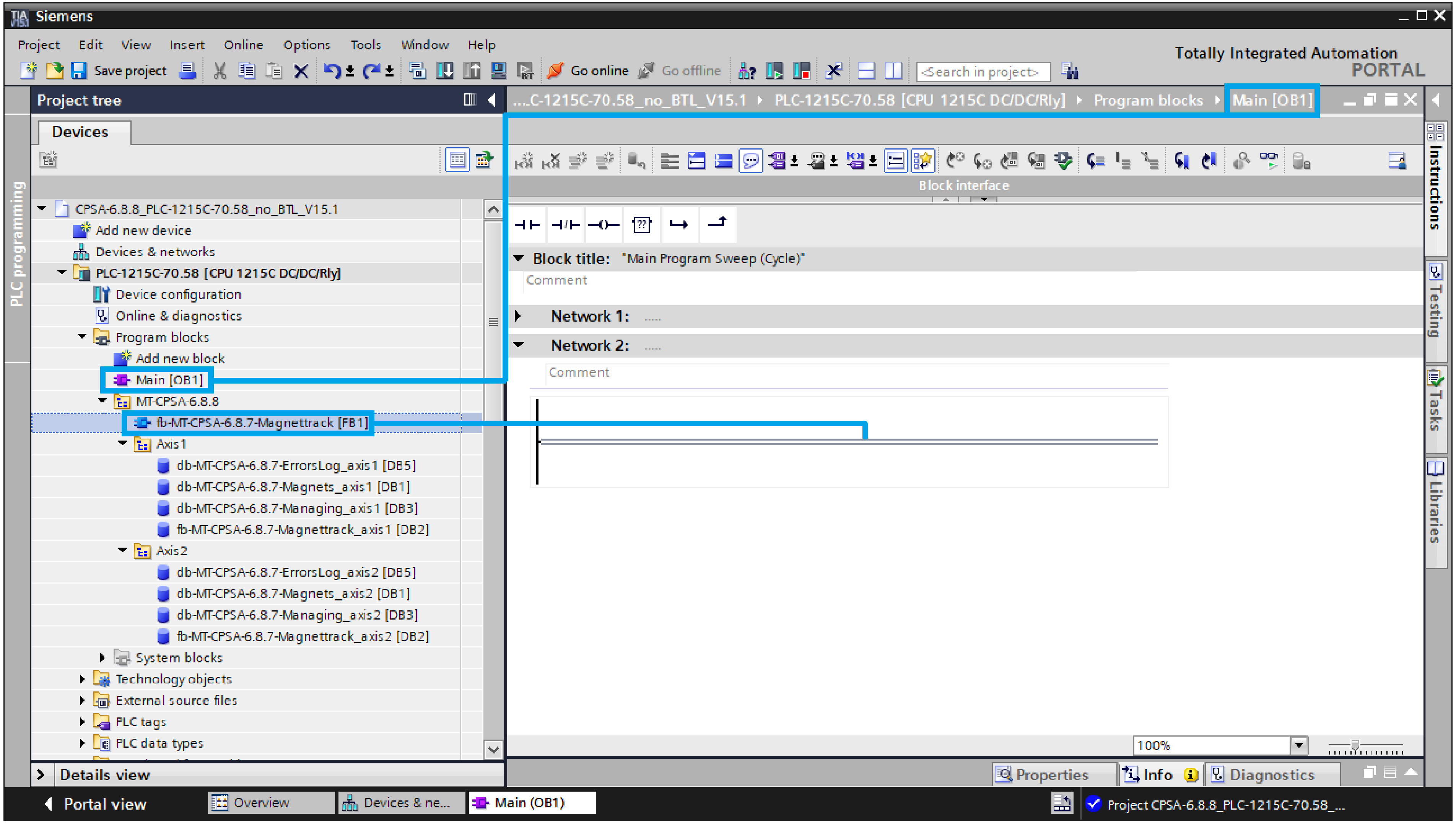


Fig. 3.2-9. Adding Magnettrack functional block for an additional axis in OB1

When “Call Options” window appears, create a new data block or select a corresponding copied block (Fig. 3.2-10). In the example, it is fb-MT-CPSA-X.X.X-Magnettrack_axis2.

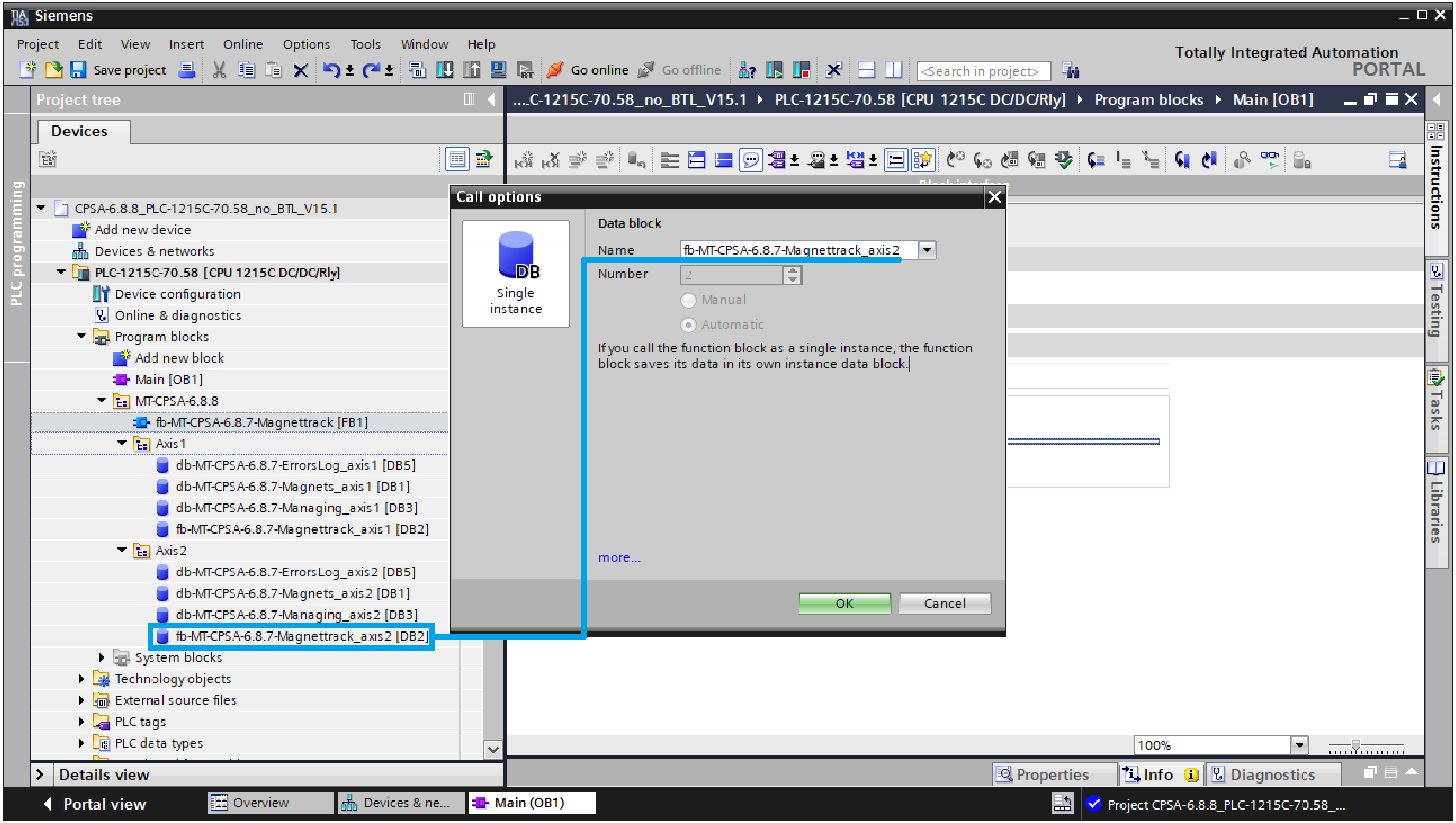


Fig. 3.2-10. “Call Options” window of Magnettrack functional block for an additional axis

Enter input data and assign outputs
similar to the procedure written above, using db-MT-CPSA-X.X.X-Managing_axis2 as data block.

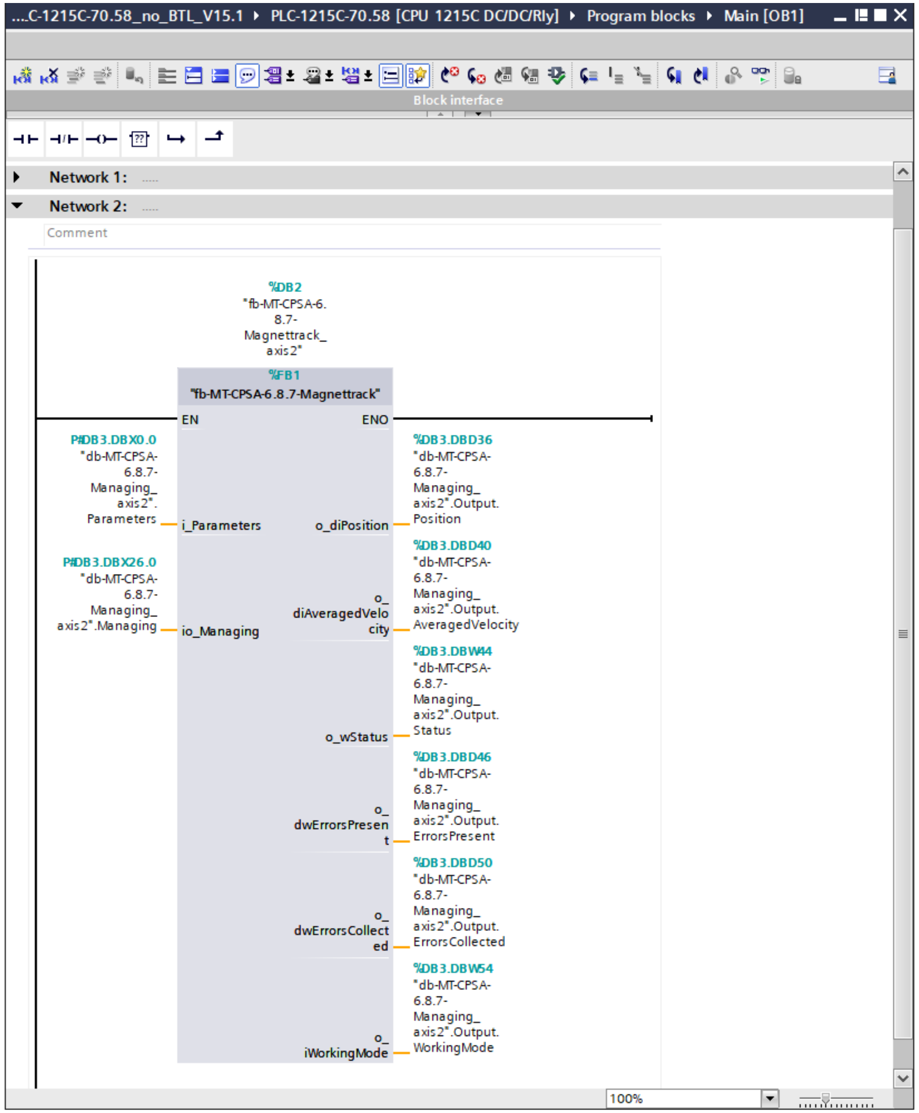


Fig. 3.2-11. Definition of input and output data of Magnettrack function for an additional axis

Before further setting, it is recommended to compile a program. Duplicate data block numbers within the program will be automatically replaced with unique ones; a renumbering confirmation dialog box will be displayed in this case. (Fig. 3.2-12).

If required, data block numbers can be changed manually. To do this, select manual mode for number definition (Manual) for each data block and select the desired number (Fig. 3.2-12.1). If the number is not unique, a corresponding warning will appear.

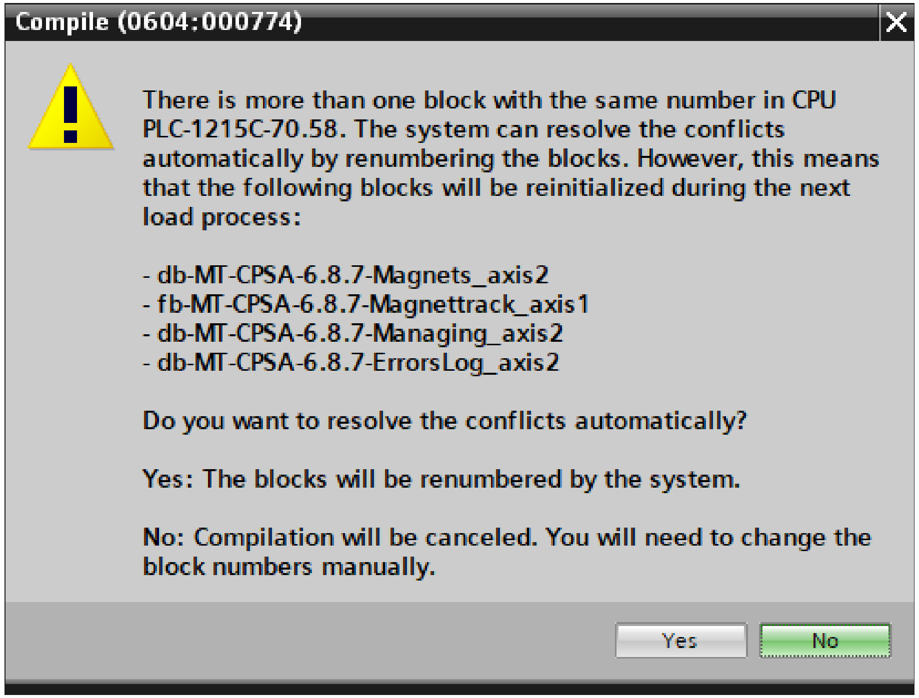


Fig. 3.2-12. Window for confirmation of db numbers change

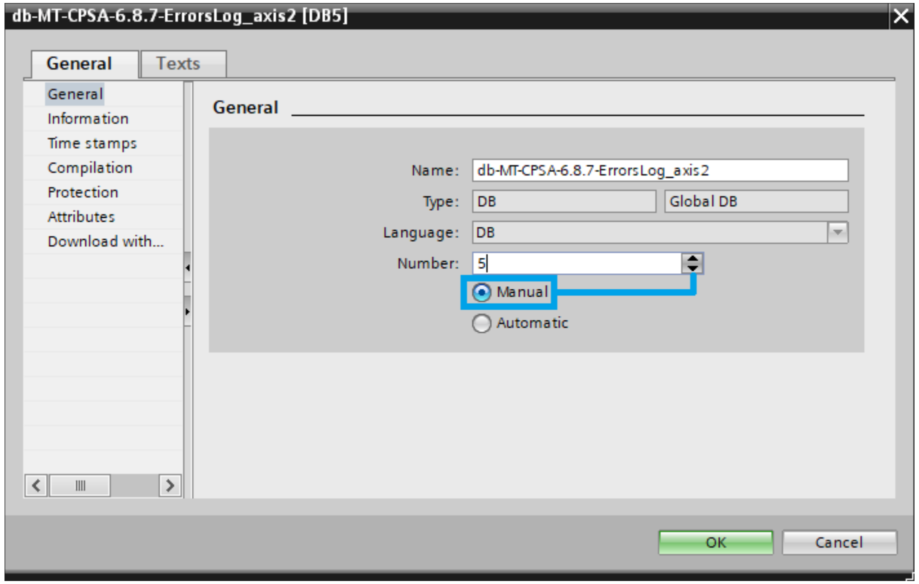


Fig. 3.2-12.1. Manual definition of data block number

Database db-MT-CPSA-X.X.X-Magnets and db-MT-CPSA-X.X.X-Managing must be in Retain memory.

Database storage requirements

Database	Storage	Comments
db-MT-CPSA-X.XX.XX-**Magnets**_axisY db-MT-CPSA-X.XX.XX-**Managing**_axisY	NVMe	Must be STRICTLY located in the NON-VOLATILE memory area of the controller.
db-MT-CPSA-X.XX.XX-**ErrorsLog**_axisY	RAM NVMe	The system can be located either in non-volatile memory or in the PLC's regular memory, depending on the user's choice, depending on the need to save the system error log between PLC restarts. By default, it is located in regular memory.
db-MT-CPSA-X.XX.XX-**Magnettrack**_axisY	RAM	1. Must be located in the PLC's regular memory. Placing this database in NON-VOLATILE PLC memory is STRICTLY PROHIBITED. 2. **Changing the initial values of variables is prohibited.** Otherwise, the system may not function correctly after a PLC reboot.

The system is configured in data block **db-MT-CPSA-X.X.X-Managing_axisY,** where Y is the number of positioning axis. To start the system, assignment of the following parameters are required and sufficient:

SensorAddress: transducer address (68 in the example) – page 3.2.13

SensorDiagAddress: transducer diagnostic address (277 in the example) — page 3.2.13

DbMagnetsNum: number of database for storage of information on magnetic marking must match the number of corresponding base in the axis folder (in the example 700).

The position value is displayed in output parameter **Position.**

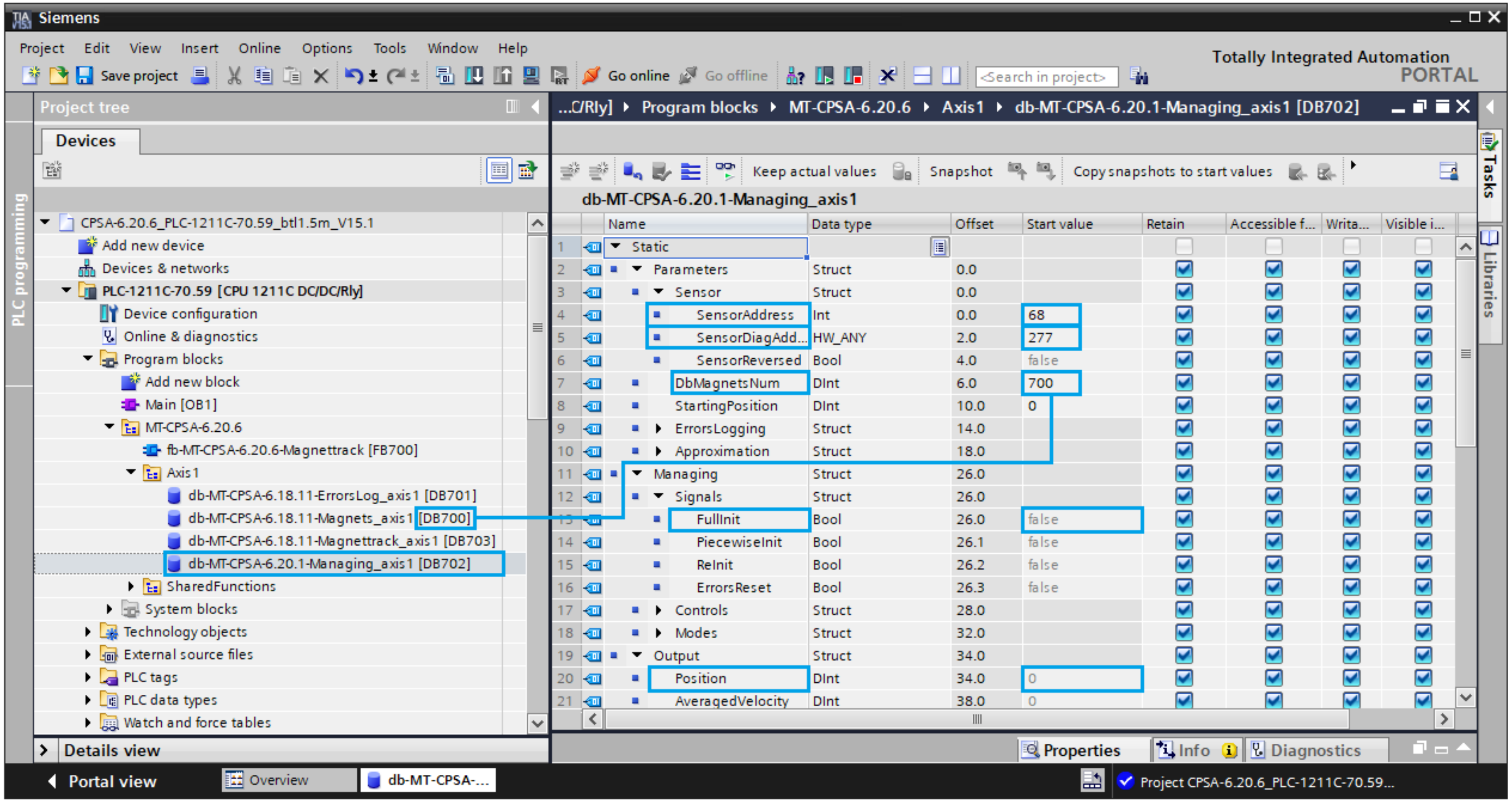


Fig. 3.2-13. Defining the parameters of data block db-MT-CPSA-X.X.X-Managing_axisY

Transducer address values can be found through the following path: SensorAddress: Devices & Networks -> select transducer in the device list -> Device View -> FMM Position Values -> first address in the range.

After configuring is completed, upload the program to controller.

SensorDiagAddress: Devices & Networks -> select transducer in the device list -> Device View -> Module Access Point -> Properties -> System Constants -> Hardware identifier.

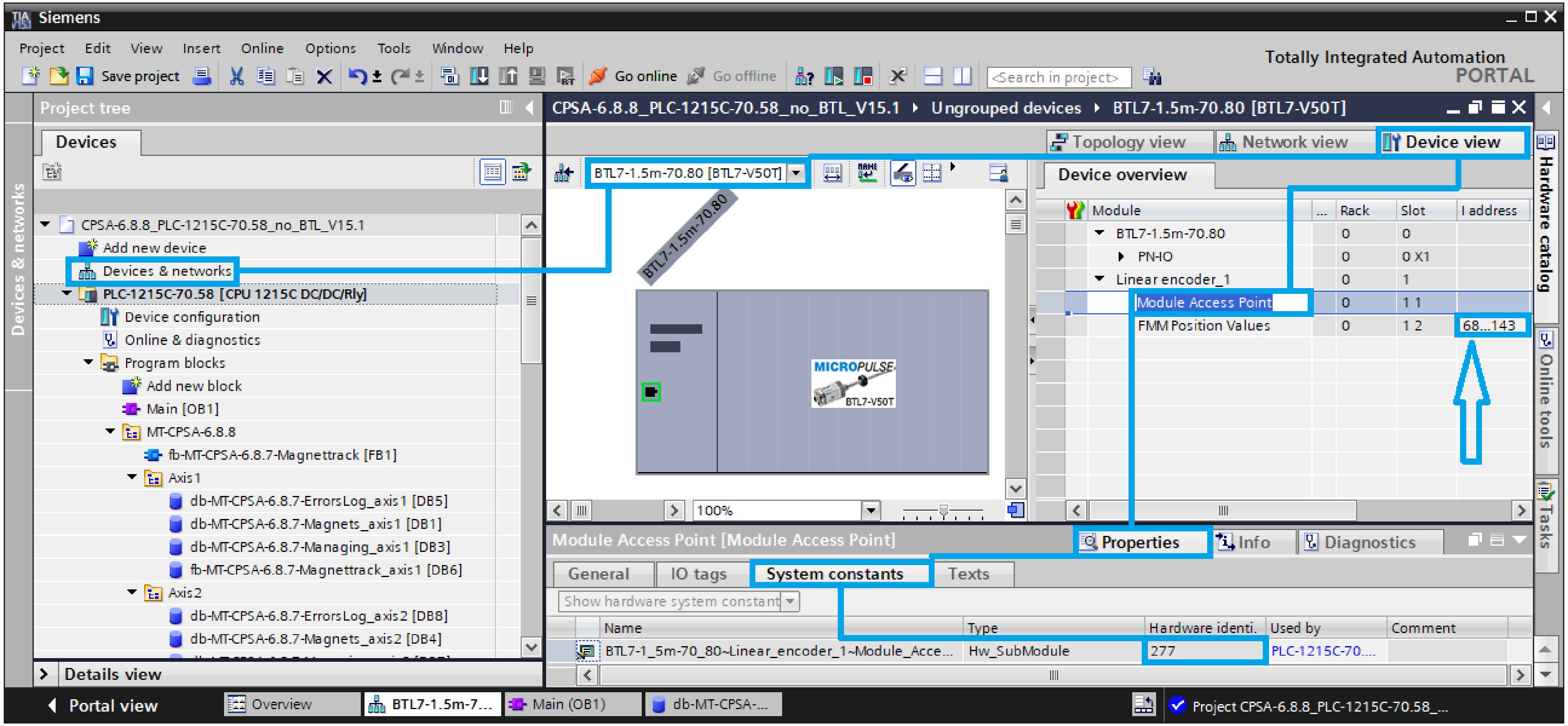


Fig. 3.2-14. Transducer addresses for definition of Managing_axisy data block parameters

Data block db-MT-CPSA-X.X.X-Managing_axisy parameter table, where Y is the axis number

Structure	Name of parameter	Type	Example of value	Description
Sensor	SensorAddress	Int	68	Transducer address (mandatory parameter)
Sensor	SensorDiagAddress	HW_ANY	277	Transducer diagnostic address (mandatory parameter)
Sensor	SensorReversed	Bool	FALSE	Trigger of virtual reverse of a transducer to 180°
Parameters	DBMagnetsNum	DInt	6	Number of the database for storage of information on magnetic marking (mandatory parameter)
Parameters	StartingPosition	DInt	0	Object coordinate upon system initialization, µm

Modulus of initial coordinate of the object is limited by the value of $(2^{31} - 1)$ = (2,147,483,647).

This factor must be considered during selection of starting coordinate (StartingPosition).

If the measured coordinate (Position) exceeds the specified boundary, then the controller will enter STOP MODE or the object coordinate will change the sign and the system behavior will become unpredictable.

Structure	Name of parameter	Type	Example of value	Description
ErrorsLogging	ErrorsLogOn	Bool	FALSE	Enable/disable error recording
ErrorsLogging	ErrorsLogOnlyCritical	Bool	FALSE	Enable/disable recording of critical errors only causing loss of coordinate
ErrorsLogging	ErrorsLogDbNum	Int	5	Number of the data base for storage of errors
Approximation	ApproximationOn	Bool	FALSE	Enable/disable approximation
Approximation	ApproximationTime	Time	T#2S	Approximation time
Approximation	ApproximationOrder	Int	2	Approximation method

Table of Initialization Signals and Error Reset

Structure	Name of parameter	Type	Example of value	Description
Signals	FullInit	Bool	FALSE	System reset to manufacturer's defaults, including restoration of starting coordinate StartingPosition
Signals	PiecewiseInit	Bool	FALSE	Signal on start of initialization of the next independent section of the magnet track and reset of errors, and setting of the current object coordinate to StartingPosition (see section 4.1)
Signals	ReInit	Bool	FALSE	Clearing of an array of marker coordinates and reset of errors, saving the current object coordinate
Signals	ErrorsReset	Bool	FALSE	Reset of error flags and delete information in error log

Table of control signals for data block db-MT-CPSA-X.X.X-Managing_axisY, where Y is axis number

Structure	Name of parameter	Type	Example of value	Description
Controls	BlockDbMagnets	Bool	FALSE	Blocking of data base with information on magnetic marking
Controls	AutoMotionControl	Bool	FALSE	When set to TRUE, the position of magnetic marking can be flexibly changed in operating zone of the transducer during the system operation
Controls/ SignatureAnalyzer	AnalyzeDbMagnets	Bool	true	TRUE – the program analyzes errors of magnetic marking No. 7 (signature not found in database), No. 8 (signature duplicate) and No. 9 (abrupt change of coordinate) in each controller cycle FALSE – the program analyzes errors of magnetic marking No. 7 (signature not found in database), No. 8 (signature duplicate) and No. 9 (abrupt change of coordinate) only during the initiating cycle of controller
Controls/ SignatureAnalyzer	LastDeltaEngine	Bool	false	Defines absolute position of the object based on signatures of two extreme magnets in the transducer operating zone. Enables working in closed-loop magnetic marking
Controls/ SignatureAnalyzer	DeltasFiltration	Bool	false	TRUE – improve the measured distances between two adjacent magnets. Rounds the measured distance to the nearest value, multiple of system step
Controls/Interval-Markers	StartRefMarkersExist	Bool	TRUE	TRUE – the first calculation of absolute coordinate is performed if at least one unique interval marker is available in the transducer operating zone. Other markers may be additionally present
Controls/Interval-Markers	StartRefOnlyMarker	Bool	FALSE	TRUE – the first calculation of absolute coordinate is only performed if only one unique interval marker is available in the transducer operating zone

Table of operation modes for data block db-MT-CPSA-X.X.X-Managing_axisY, where Y is axis number

Structure	Name of parameter	Type	Example of value	Description
Modes	FixedMode	Bool	FALSE	Enable/disable Fixed mode
Modes	HighAccuracy AdaptiveMode	Bool	FALSE	Enable/disable high accuracy adaptive mode

Data block Db-MT-CPSA-X.X.X-Managing_axisY output table, Where Y is the axis number

Structure	Name of parameter	Type	Example of value	Description
Output	Position	DInt	1305762	Absolute coordinate of the object relative to user zero, µm
Output	AveragedVelocity	DInt	-4	Average object velocity calculated over the last 20 cycles of controller, µm/s
Output	Status	Word	16#0	System functioning status
Output	ErrorsPresent	DWord	16#0000_0000	Current errors of system functioning
Output	ErrorsCollected	DWord	16#0000_0000	System functioning errors logged in the system after the last error reset
Output	WorkingMode	Int	1	System functioning mode

Functioning with several positioning axes

Magnettrack adaptive system program enables simultaneous working with several objects or positioning axes at the same controller independently from each other.

To do this, set up the system for each axis according to section 3.2 of this manual.

When working with several positioning axes and/or objects, the load on controller increases proportionally, which increases the required volume of read-only memory for storage of an array of marker coordinates and increases the time for processing of a single cycle, which affects maximum possible velocity of the positioning object movement along each of the axes, since, positioning object can not be moved with a velocity exceeding one half of minimum allowed distance between markers over the time of one controller cycle, when Magnettrack adaptive system is used.

$$V^{max} = \frac{D_0}{2T_{plc}^{max}}$$

Example 1

Magnettrack adaptive positioning system is installed at an overhead crane to monitor 3 readings:

1. Current absolute coordinate of the right side of the crane bridge. Let's call this axis $X_{1.}$

2. Current absolute coordinate of the left side of the crane bridge (to monitor the crane sidesway). Let's call this axis $X_{2.}$

3. Absolute position of overhead crane trolley. Axis Y.

Two Magnettrack adaptive positioning systems are installed along the crane movement path, X_1 and X_2, using interval markers with transducer length of 4,500 mm for positioning distance of 600 meters, CPA-0600-000-05-P4500R-IM3-45-80, and Magnettrack adaptive positioning system is installed along the path of trolley using position markers with a 2,500 mm transducer at a distance of 30 meters, CPA-0030-000-02-P2500P-PM1-30-60 (Fig. 3.2-15).

Maximum possible crane velocity is 2 m/s, and maximum trolley velocity is 1 m/s. Minimum admissible distance between interval markers at axes X_1 and X_2 is 260 mm, and minimum distance between position markers of axis Y is 220 mm.

Thus, we obtain that maximum admissible time of one controller cycle for the crane travel at maximum velocity along axes X_1 and X_2 will be not more than $T_x = D_0/2V_{max} = 260/4000 = 0.065$ sec or 65 ms, and along axis Y – not more than $T_y = 220 / 2{,}000 = 0.11$ sec or 110 ms.

Ultimately, maximum admissible time of one controller cycle for operation of the whole system of three positioning axes (organizational block OB1 inquiry cycle) shall not exceed 65 ms. Meanwhile, the volume of controller non-volatile memory must be not less than 2 bytes per magnet. The total required number of 3-magnet interval markers for axes X_1 and X_2 at a distance of 600 meters will be 2 x 190 = 380 or 1,140 magnets, and the number of position markers for axis Y, with position markers installed with an average distance of 1 meter from each other will be 30, or 30 magnets. Thus, considering the service data in amount of 1 kB for each axis, minimum volume of non-volatile controller memory must be at least (1,140x2 + 30) + 1,024x3 = 5,382 bytes.

Example 2

Input positioning data similar to Example 1. Let's calculate the maximum admissible velocity of the object with known time of one cycle of controller inquiry.

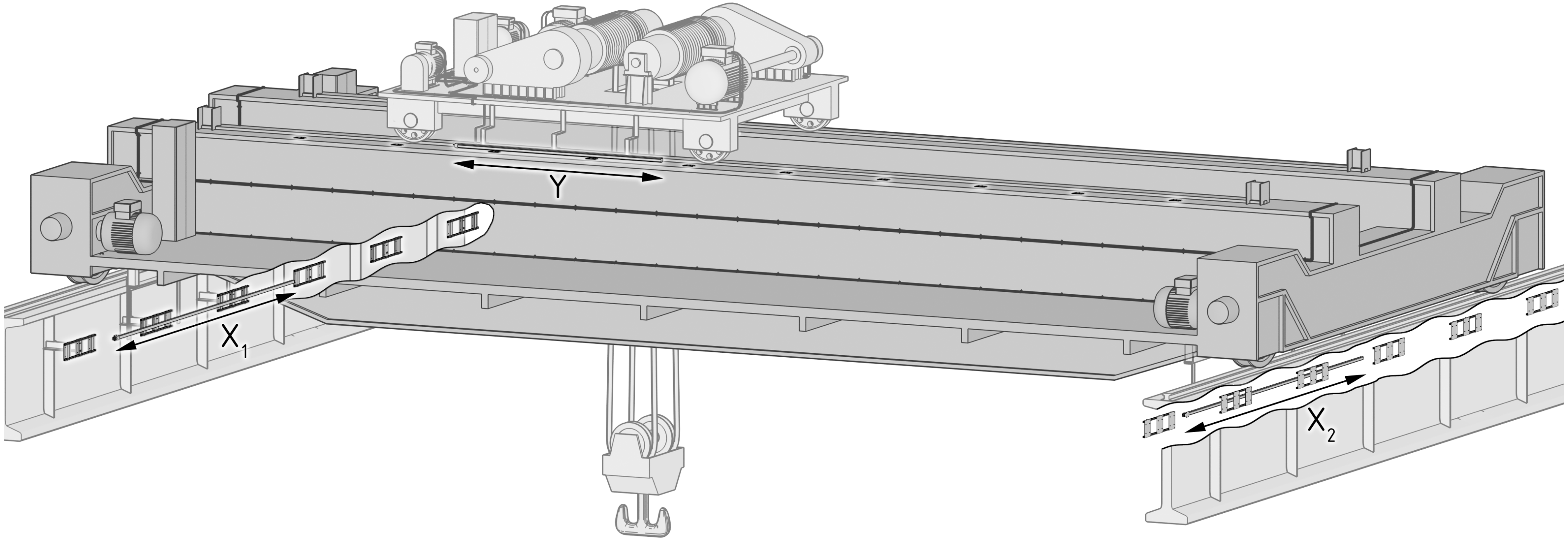
Two Magnettrack adaptive positioning systems are installed along the crane movement path, X_1 and X_2, using interval markers with a linear transducer length of 4,500 mm for positioning distance of 600 meters, CPA-0600-000-05-P4500R-IM3-45-80, and Magnettrack adaptive positioning system is installed along the path of trolley Y using position markers with a 2,500 mm long linear travel transducer for a distance of 30 meters, CPA-0030-000-02-P2500P-PM2-30-60 (Fig. 4.2-1).

After installation of Magnettrack program and uploading of 3 positioning axes to controller, maximum controller time cycle was $T_{plc} = 20$ ms.

Minimum admissible distance between interval markers is 260 mm, and minimum distance between position markers is 220 mm.

Thus, maximum admissible crane velocity along axes X_1 and X_2 will be $V_x = D_0 / 2T_{plc} = 130 / 20 = 6.5$ m/s, and along axis Y – $V_y = 110 / 20 = 5.5$ m/s.

Fig. 3.2-15. Example of positioning object with three Magnettrack axes



3.3 Control signals

Magnettrack program provides a number of control signals (see table) that a user can apply to adjust operation of the system for specific operating conditions.

Structure	Name of parameter	Type	Typical default value	Description
Controls	BlockDbMagnets	Bool	FALSE	Blocking of data base with information on magnetic marking
Controls	AutoMotionControl	Bool	FALSE	When set to TRUE, the position of magnetic marking can be flexibly changed in operating zone of the transducer during Installation system operation.
Controls/ SignatureAnalyzer	AnalyzeDbMagnets	Bool	true	TRUE – the program analyzes errors of magnetic marking No. 7 (signature not found in database), No. 8 (signature duplicate) and No. 9 (abrupt change of coordinate) in each controller cycle. FALSE – the program analyzes errors of magnetic marking No. 7 (signature not found in database), No. 8 (signature duplicate) and No. 9 (abrupt change of coordinate) only during the initiating cycle of controller.
Controls/ SignatureAnalyzer	LastDeltaEngine	Bool	false	Defines absolute position of the object based on signatures of two extreme magnets in the transducer operating zone. Enables working in closed-loop magnetic marking.

Structure	Name of parameter	Type	Typical default value	Description
Controls/ SignatureAnalyzer	DeltasFiltration	Bool	false	TRUE – improve the measured the distances between two adjacent magnets. Rounds the measured distance to the nearest value, multiple of system step
Controls/ Interval-Markers	StartRefMarkersExist	Bool	FALSE	TRUE – the first calculation of absolute coordinate is performed if at least one unique interval marker is available in the transducer operating zone. Other markers may be additionally present.
Controls/ Interval-Markers	StartRefOnlyMarker	Bool	FALSE	TRUE – calculation of absolute coordinate is performed upon initiating cycle if only one unique interval marker is available in the transducer operating zone.

Depending on specific use, individual control signals can be enabled/disabled by default.

Description of BlockDbMagnets signal

When BlockDbMagnets flag is set to TRUE, the system blocks recording of any information into db-MT-CPSA-X.X.X-Magnets database. Adding of new markers, deletion or change of the position of current markers will not be reflected in db-MT-CPSA-X.X.X-Magnets database.

It is recommended to set BlockDbMagnets to TRUE after complete initialization of the system in cases, when no change of magnet marking is expected. Setting of BlockDbMagnets = TRUE will enable preventing accidental changes of magnet database.

The figure below shows an example when an interval marker was moved by 500 mm. Upon activation above a displaced marker, Magnettrack system with a blocked database of magnets will issue an object coordinate 500 mm lower in the second case, which will not correspond to reality.

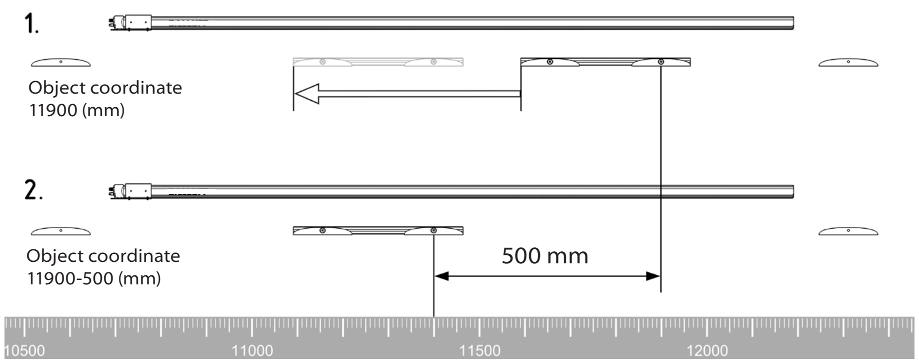


Fig. 3.3-1. Displacement of coordinate from displacement of marker BlockDbMagnets = TRUE

If AnalyzeDbMagnets = TRUE flag is additionally raised (see below), then the system will analyze the changed magnetic signature of this section and define whether errors 7, 8 and 9 are present. Considering that the magnet database is blocked, availability of any of the above errors in magnetic marking may cause incorrect calculation of coordinate in an initiating cycle of the program.

> **Initiating program cycle is** a program cycle where an absolute object coordinate unavailable earlier is calculated. For example, initiating program cycle appears upon system activation, or upon an object entry into the zone with magnetic marking. Program initiating cycle is run always when AnalyzeDbMagnets = TRUE flag is raised (see below).

> When magnet database is unlocked **BlockDbMagnets = FALSE,** errors 7 and 9 are not logged in the system due to adaptation of Magnettrack system to the change in the track magnetic marking.

Description of AutoMotionControl signal

In some cases, magnetic marking must be changed, e.g. the distance between markers must be corrected to eliminate error 8. In particular, such a need arises during installation of magnetic markers prior to the first startup of Magnettrack system, and after repair and restoration of magnetic marking.

Regardless of the value of AutoMotionControl, the following conditions must be observed when magnets are moved in the transducer operating zone:

- Measurement object must stay immobile
- Never move all magnets simultaneously
- The object coordinate must be available at all times. Errors when a coordinate is lost (e.g. errors 1, 2 and 3) must be avoided
- It is prohibited to change the gap between the marker and the transducer

For a more precise setting of markers position, it is recommended to use free version of SCADA Magnettrack software.

AutoMotionControl = FALSE

If AutoMotionControl = FALSE, make sure to follow the additional conditions described below during travel of magnets in the transducer operating zone

- Never move a leading magnet (see the section with AnalyzeDbMagnets signal description)
- Accuracy of absolute coordinate definition may be compromised
- It is recommended to completely extract the magnet from the transducer operating zone and install it to a new place in order to change the magnet position
- An extreme magnet opposite to the leading magnet in the transducer operating zone can only be moved from the center.

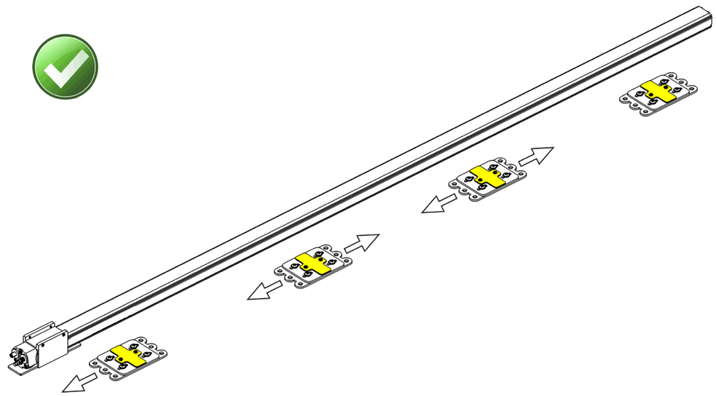


Fig. 3.3-4. Conditions for movement of magnets in the transducer work zone with AutoMotionControl = FALSE

AutoMotionControl = TRUE

If AutoMotionControl = TRUE, the system automatically defines that the object has stopped and prepares the program for change of magnetic marking in the transducer operating zone. To guarantee that the object is stopped, the system uses a filter that takes 100 cycles of controller operation. When the system completes the setting, s_xIsReadyForMotionControl flag will automatically change to TRUE.

In order to be able to move markers in the transducer work zone, any marker must be moved first, except the leading one, making sure that s_xMotionControlIsOn flag changes to TRUE.

AutoMotionControl signals are available in db-MT-CSPA-X.X.X-Magnettrack database in MotionControl structure (see Fig. 3.3-5).

Only change the marking in transducer operating zone, if extremely required, and after consultation with manufacturer's support service!

The system automatically resets the settings that enable changing the position of markers in transducer operating zone after the object starts moving. Meanwhile, AutoMotionControl preserves its TRUE value.

To change marking in another section, repeat the above actions. If no further marking change is planned, it is recommended to reset AutoMotionControl = FALSE flag.

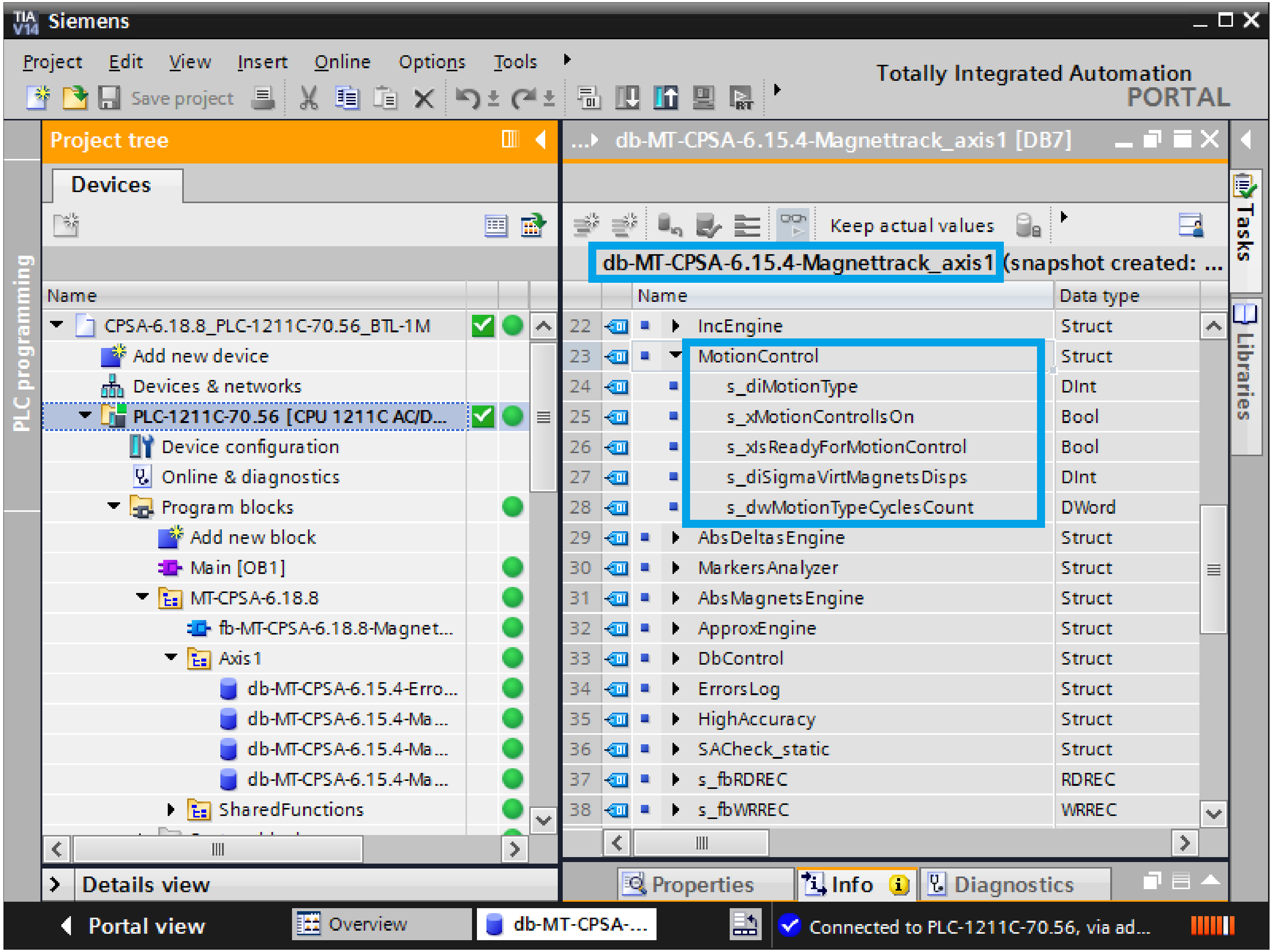


Fig. 3.3-5. AutoMotionControl control signals

Description of AnalyzeDbMagnets signal

AnalyzeDbMagnets flag is responsible for analysis of errors in magnet marking. When AnalyzeDbMagnets = TRUE flag is raised, the program analyzes availability of errors 7, 8 and 9 in each controller cycle.

Meanwhile, error 8 (signature duplicate) is continuously analyzed, and errors 7 (signature not found in database) and 9 (abrupt change of coordinate) are analyzed if BlockDbMagnets = TRUE.

If flag AnalyzeDbMagnets = FALSE is off, errors 7 and 8 are only logged during initiating cycle of the program, upon coordinate calculation, after its loss or in the first controller cycle. Error 9 is not analyzed, even during initiating cycle. Next, during further program cycles, the coordinate is calculated based on leading magnet in transducer operating zone.

Errors 7, 8 and 9 may appear, for example, if markers are installed incorrectly, or if changes are made in magnet marking. System activation above changed magnet marking may lead to calculation of a wrong coordinate or error during initiating program cycle, especially when magnet database is blocked BlockDbMagnets = TRUE.

It is recommended to set AnalyzeDbMagnets flag to off (FALSE) for the system where magnet marking does not change during long-term operation of the object, and for highly dynamic objects. This will enable reducing the load on controller, without damage to accuracy of coordinate calculation. If an unscheduled change of marking is possible, it is recommended to set AnalyzeDbMagnets flag to TRUE.

Fig. 3.3-2. Definition of coordinate based on leading magnet

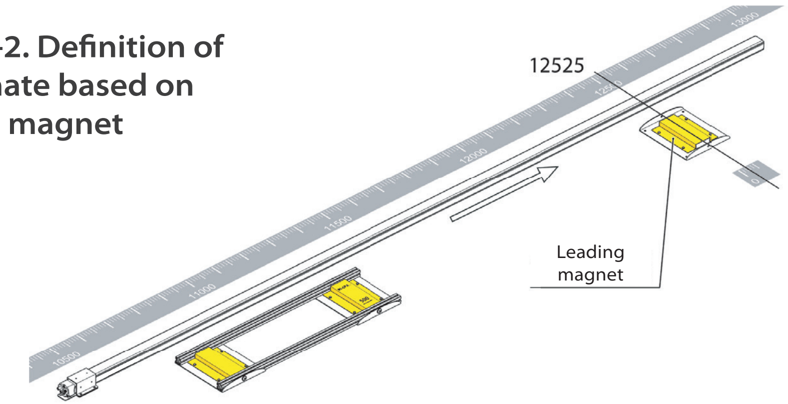
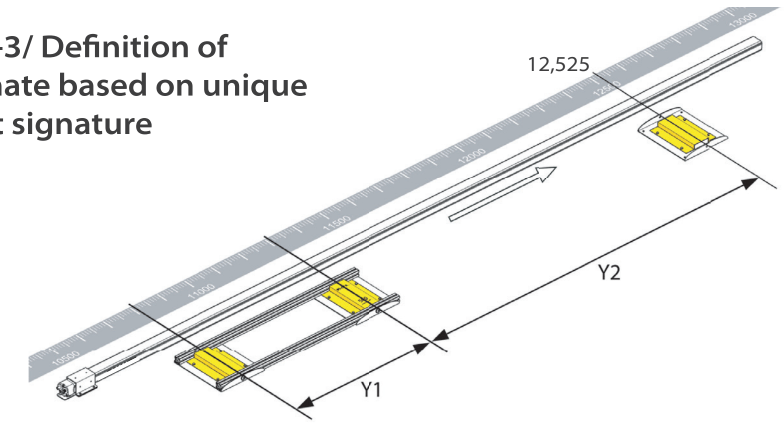


Fig. 3.3-3/ Definition of coordinate based on unique magnet signature



Leading magnet is the magnet nearest to the transducer end in transducer operating zone, when the transducer is not virtually reversed by 180° (SensorReversed = FALSE). If the transducer is reversed by 180° (SensorReversed = TRUE), then the magnet closest to transducer zero is the leading magnet.

Description of LastDeltaEngine signal

Defines absolute position of the object based on signatures of two last magnets in the transducer operating zone. It allows to work on closed marker contours (for example, a circle) based on position markers in combination with the enabled Fixed mode FixedMode = TRUE.

For example, set LastDeltaEngine to TRUE in order to define the position of the bridge of a polar crane applied for maintenance at NPP.

Description of DeltasFiltration signal

If DeltasFiltration = TRUE, the program processes the obtained magnet coordinates to improve accuracy of the definition of magnetic signature in transducer operating zone. After the processing, magnetic signature data is compared versus db-MT-CP-SA-X.X.X-Magnets database to define absolute object coordinate.

For example, if an object can deviate from linear path while moving, then the angle of transducer deviation from the magnet marking axis will affect calculation of magnet signature coordinates. DeltasFiltration enables more reliable identification of magnetic signature in transducer operating zone in such situation. DeltasFiltration = TRUE improves reliability of Magnettrack system operation.

Description of StartRefMarkersExist signal

StartRefMarkersExist = TRUE enables calculation of absolute coordinate in the program initiating cycle in the magnet track sections, where at least one unique interval marker is present. As opposed to StartRefOnlyMarker (see below), raised StartRefMarkersExist flag enables the initiating cycle to obtain an absolute coordinate, if a unique interval marker and other magnets/markers are present in the transducer operating zone.

This function allows creating more fail-safe systems using additional position markers.

Activated StartRefMarkersExist function implies that markers and transducer were installed according to all the coaxiality and orthogonality requirements.

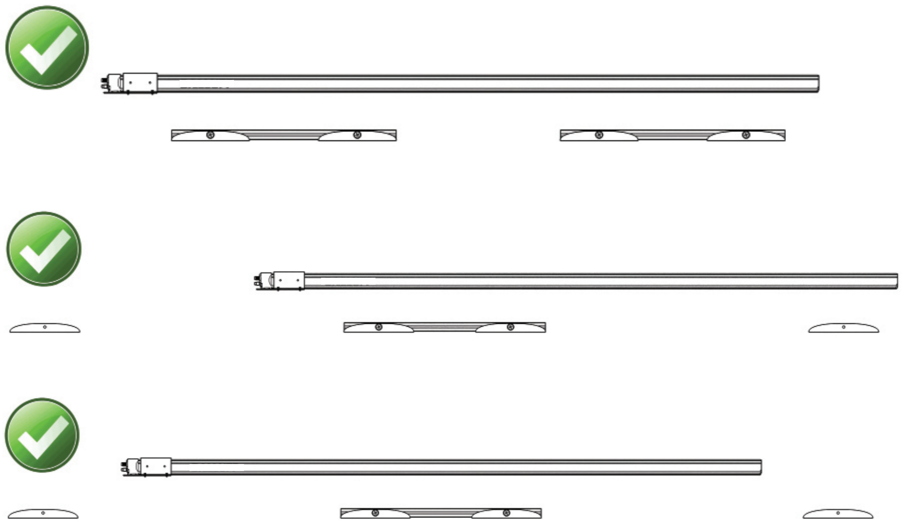


Fig. 3.3-6 Condition to obtain correct initial coordinate

Description of StartRefOnlyMarker signal

StartRefOnlyMarker = TRUE enables calculation of absolute coordinate in the program initiating cycle in the magnet track sections, where only one unique interval marker is present with no other magnets/markers.

As opposed to StartRefMarkersExist (see above), raised StartRefOnlyMarker flag does not enable the initiating cycle to obtain an absolute coordinate, if some other magnets/markers are present in the transducer operating zone additionally to the only unique interval marker (see Fig. 3.3-7).

StartRefOnlyMarker = TRUE enables reliably obtaining an initial coordinate, e.g. after system startup or upon entering into magnet marking.

It is recommended to set this flag to TRUE for adaptive incremental systems only, based on position and interval markers.

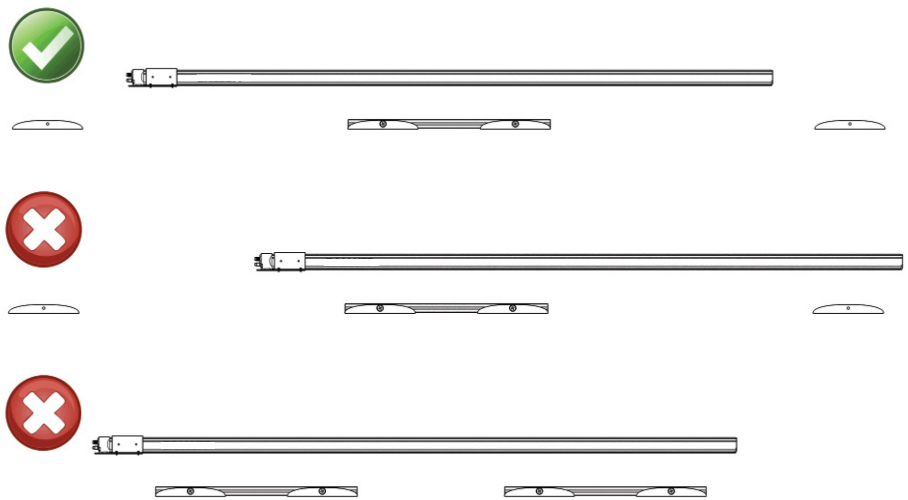


Fig. 3.3-7. A coordinate may be calculated if the only one interval marker is available in transducer zone

To enable free movement of the object coordinate, position markers must be allocated at a sufficient distance from interval marker, so as to ensure that the only one interval marker is present in the transducer operating zone, with no other magnets/markers present at all (see Fig. 3.3-8).

If StartRefOnlyMarker = FALSE and StartRefMarkersExist = FALSE, then the initiating cycle calculates the first coordinate based on unique magnetic signature in transducer operating zone.

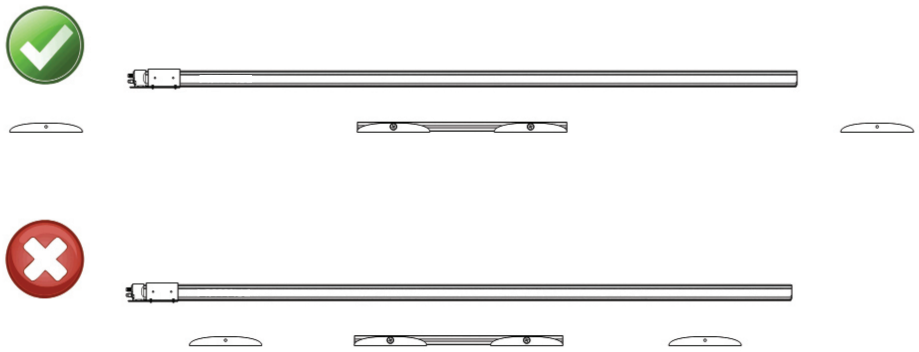


Fig. 3.3-8. Installation of position markers near interval markers prevents calculation of coordinate

If StartRefOnlyMarker = TRUE, then StartRefMarkersExist signal automatically turns to FALSE.

It is recommended to set flags StartRefOnlyMarker = TRUE or StartRefMarkersExist = TRUE, if the system marking contains interval markers. And the installation rules are followed.

> **i**
>
> In the systems based on position markers only, StartRefOnlyMarker and StartRefMarkersExist must be set to FALSE.

3.4. Operation Modes

Apart from the main Adaptive operation mode of Magnettrack system, two additional operation modes are available for users:

Structure	Name of parameter	Type	Example of value	Description
Modes	FixedMode	Bool	FALSE	Enable/disable Fixed mode
Modes	HighAccuracyAdaptiveMode	Bool	FALSE	Enable/disable high accuracy adaptive mode

Fixed Mode

Fixed mode is enabled by FixedMode = TRUE flag. Development mode for application at worn equipment, when vibration and oscillations of an object create conditions for some magnets/markers to come out of sensitive zone of the transducer. This mode allows saving a coordinate at a maximum possible area of magnet marking. Including that when sensitive zone of transducer comes out from magnet marking (violation of relative distances of transducer and marker marking).

When flag FixedMode = TRUE is raised, the following functions and modes are overridden to enabled/disabled state:

1. BlockDbMagnets = TRUE.
2. AnalyzeDbMagnets = TRUE .
3. AutoMotionControl = FALSE.
4. BlockDbMagnetsAtStop = FALSE.
5. HighAccuracyAdaptiveMode = FALSE.

The system uses all capacities of Magnettrack software to provide absolute and accurate coordinate to the user. Three main operation modes are applied depending on errors in magnetic signature:

In this mode, the system forcedly blocks the magnet database trusting the information on magnet marking saved in the memory (magnet database). Any changes of magnet track will be ignored. Meanwhile, error 9 is not diagnosed by the system.

i

The system stops adapting to changes of magnet marking.

In Fixed mode, absolute coordinate is calculated in each cycle of Magnettrack program similarly to initiating cycle. Absolute coordinate is calculated every time when possible, according to raised flags StartRefOnlyMarker and StartRefMarkersExist. There are three options:

1. StartRefOnlyMarker = FALSE and StartRefMarkersExist = FALSE to calculate absolute coordinate based on unique magnetic signature in transducer operating zone.
2. StartRefOnlyMarker = TRUE and StartRefMarkersExist = FALSE to calculate absolute coordinate in the magnet track sections, where only one unique interval marker is present with no other magnets/markers.
3. StartRefOnlyMarker = FALSE and StartRefMarkersExist = TRUE to calculate absolute coordinate in the magnet track sections, where at least one unique interval marker is present.

In the areas of magnet marking, where it is impossible to calculate an absolute coordinate using the set flags, the system will calculate absolute coordinate relative to leading magnet or in incremental mode.

Thus, Fixed mode gives priority to the information on magnet marking saved in memory. Therefore, it is prohibited to change magnet marking.

If magnet marking is changed, there may be cases when an incorrect absolute coordinate is calculated when working in Fixed mode.

For example, if an interval marker was shifted by 500 m during object operation in FixedMode = TRUE mode, then, as this interval marker moved to a new position, Magnettrack program will show an abrupt change of coordinate by the value of interval marker displacement, i.e. by 500 mm. Such a behavior is explained by the fact that in Fixed mode the system trusts the magnet database with higher priority, rather than the system capacities to adapt magnet marking.

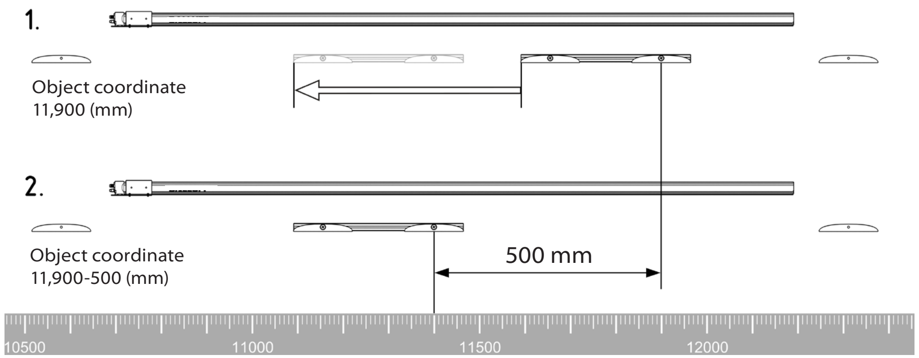


Fig. 3.4-1. Incorrect coordinate due to changes of magnet marking in FixedMode = TRUE mode

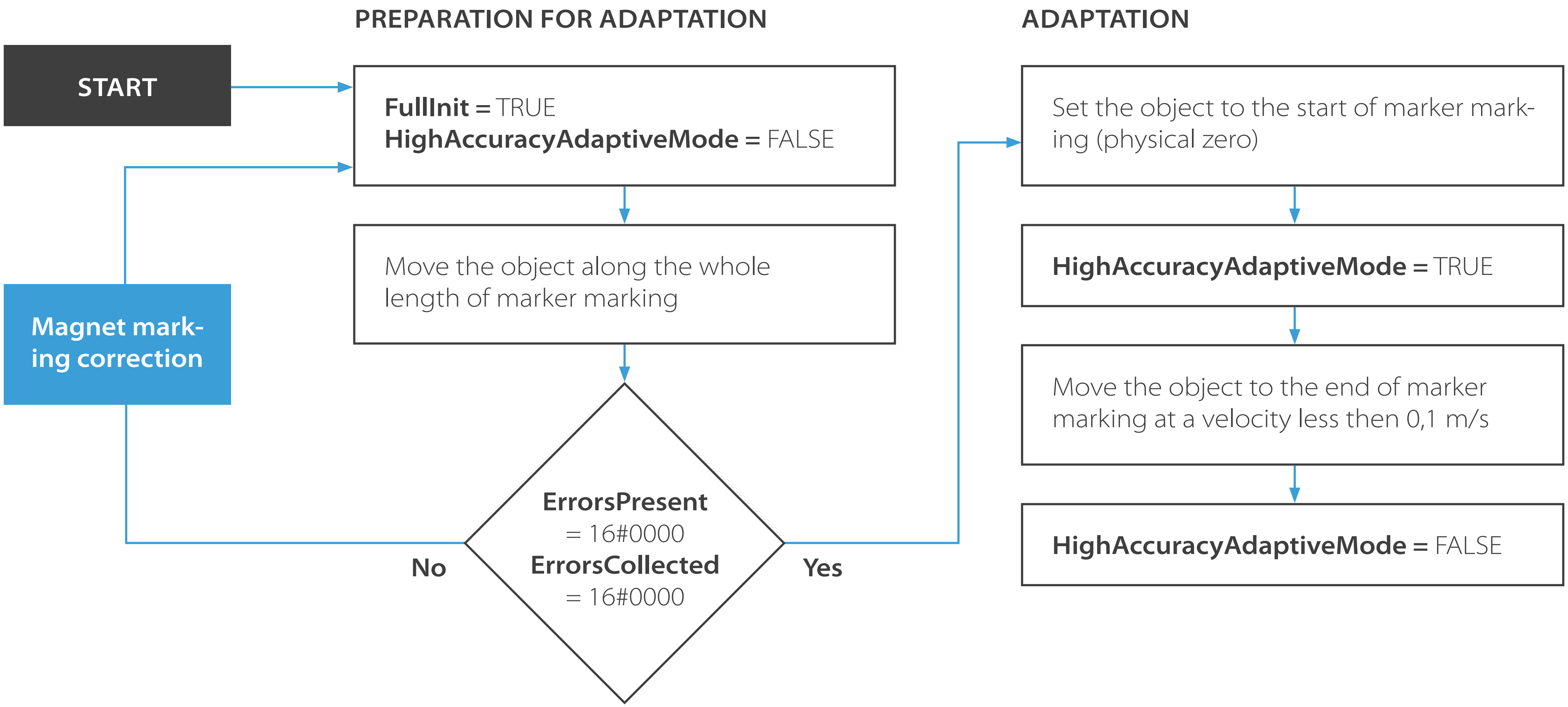
High accuracy adaptive mode

High accuracy adaptive mode is enabled by HighAccuracyAdaptiveMode = TRUE flag and allows achieving absolute system accuracy of up to 1 mm at a distance of 50 meters.

To improve the accuracy, make sure to conduct the process of highly accurate adaptation of Magnettrack system. During adaptation, the system updates the coordinates of magnet marking.

For the systems with intermittent magnet track (see item 4.2), the coordinates are only updated within the limits of current section of continuous magnet track marking. Coordinates of the other sections' magnet marking are not updated.

Recommended sequence of system training



The process of high-accuracy adaptation can be started any time during operation of Magnettrack system. The required accuracy may only be achieved after adaptation of the whole magnet marking. The High Accuracy Adaptive mode automatically removes flags AutoMotionControl = FALSE.

The process of highly accurate adaptation can be started if only one magnet is present in the transducer working zone. When magnet marking is changed, highly accurate adaptation must be repeated.

Please note that magnet marking coordinates update process requires additional controller capacity and may adversely affect the operation in dynamic systems. High-accuracy adaptive mode requires extended computational resources of controller, therefore, it is recommended to follow the above diagram and to disable high-accuracy adaptive mode after training. Meanwhile, the system continues functioning using updated magnet coordinates and issues highly accurate position coordinates.

4 SYSTEM STARTUP. TROUBLESHOOTING

When the system is started, it is assumed that it was installed according to requirements and recommendations of this user manual, that the cables have been correctly laid and connected and checked, that configuration of the elements and functional block system are set up, and that system inputs and outputs have been configured. Otherwise, functioning of Magnettrack system is not guaranteed.

Despite that the connections are protected against reverse polarity, system components may be damaged due to wrong connection or overvoltage. Before supplying power, carefully check all connections.

Please note that, upon a first startup or if Magnettrack is operating as part of a closed-loop control system the parameters of which have not been set yet, the system can make uncontrolled movements. Make sure to take measures to ensure safety of personnel and equipment.

4.1 System initialization

Initialization of Magnettrack adaptive positioning system is a process of detection of markers on the track, calculation of their coordinates and saving of these coordinates into an array in non-volatile controller memory. BlockDbMagnets signal is used to enable or disable initialization mode. BlockDbMagnets = FALSE corresponds to enabled initialization mode.

Upon the first startup, StartingPosition coordinate is assigned to the object, which can be easily adjusted by the system administrator. Upon startup, a coordinate is assigned to each magnet in transducer operating zone according to initial object coordinate (StartingPosition).

Coordinates of further markers are calculated based on calculated coordinates of previous markers.

i

It is recommended to manually block magnet databases BlockDbMagnets = TRUE after the system is started and functions normally. Continuously enabled initialization mode is only effective when magnet marking is regularly changed.

Three types of actions are possible when working in the mode of unblocked array (BlockDb Magnets = FALSE):

1. **Adding a marker –** is performed when the system identifies a marker not logged earlier in magnet database, db-MT-CPSA-X.X.X-Magnets.
2. **Deleting a marker –** is performed when the system identifies a missing marker logged earlier in magnet database, db-MT-CPSA-X.X.X-Magnets.
3. **Marker update –** is performed when the system finds a displaced marker.

During the system initialization, make absolutely sure that there are no errors in the system operation. If any errors occurred during initialization, then remove the error source first (see section 4.2), and move the object to the position where the first error occurred, reset the error flag, and continue operation in initialization mode only after the above actions are performed.

i

When operating Magnettrack adaptive system, never move the positioning object at a velocity exceeding the nameplate value.

1. Full initialization (FullInit parameter) –

system reset to manufacturer's defaults, including restoration of starting coordinate StartingPosition. This action is performed upon a first startup or in case of large-scale changes of the track marking.

2. Repeated initialization (ReInit parameter) –

clear of an array of marker coordinates and reset errors, saving the current object position. The coordinates of interval or position markers are recorded relative to current position of the positioning object.

3. Initialization of an additional autonomous magnet track section (PiecewiseInit parameter) —

system transfer to the mode for initialization of an additional autonomous section of magnet track.

4. Error reset (ErrorsReset parameter) —

apart from two initialization types, the system can apply a control signal to independently reset errors and registration log (ErrorsReset parameter) without changing an absolute coordinate and an array of marker coordinates.

For the structure of control signals with the actions they result in, see Table 4.1-1.

Table 4.1-1. Structure of Control Signals

Control signal	Reset of absolute system coordinate	Reset to zero of all markers coordinates array	Error log reset
Full initialization FullInit	√	√	√
Repeated initialization ReInit	—	√	√
Initialization of an additional autonomous section of the magnet track PiecewiseInit	—	—	√
Error reset ErrorsReset	—	—	√

System operating mode

System initialization

After the system is initialized, it must be switched to the global Fixed mode

Fixed mode is the standard operating mode of the industrial positioning system

Modes	Struct	34.0			☑
FixedMode	Bool	34.0	false	TRUE	☑
HighAccuracyAdaptiveMode	Bool	34.1	false	FALSE	☑

4.2 System initialization with autonomous sections of magnet marking

Magnettrack adaptive system with an intermittent magnet track is a system, the track of which contains individual sections where the distance between adjacent position or interval markers exceeds the length of operating active zone of transducer, $NL_{virt.}$

An autonomous section is a section of magnet marking, where the distances between adjacent markers do not extend beyond datasheet values (see section 2.2).

An algorithm for initialization of autonomous sections of magnet marking is as follows:

1. After initialization of the first autonomous section of magnet marking, the object moves to the start of the next autonomous section in any point, where only one! outer magnet is present for the section of this magnet marking.

ATTENTION: When an object moves to additional section of magnet marking with activated Magnettrack system, magnets will be temporarily absent in transducer operating zone. The system transfers to operation mode 5 (absence of coordinate), errors 1, 2 and 3 are logged. This system behavior is adequate; object movement must be continued and any appearing errors and absence of coordinate must be ignored.

2. Enter the value of current absolute coordinate of the object in the field StartingPosition.

Minimum admissible distance between adjacent sections of magnet track must be observed equal to $NL_{virt} + V_{max} \times T_{plc.}$ Recommended minimum distance between two autonomous sections of magnet marking is at least $2 \times NL_{virt.}$

3. Send an impulse to input PiecewiseInit.

ATTENTION: When an impulse is sent to PiecewiseInit input, the system erases the error history and transfers to operation mode 3 (incremental mode).

4. As an object continues moving along the track and achieves the next magnet of this autonomous section, the system will add both magnets into database. Relative coordinate + Starting Position value is assigned to coordinate of the first magnet of autonomous section.

Initialization of an additional autonomous section of magnet marking can be performed with any initial number of magnets within operating zone of transducer, if there are no duplicates of magnet signatures within all autonomous sections of magnet markings.

All limitations and rules for initialization of a standard system with continuous magnet marking also apply for initialization of systems with autonomous marking sections.

4.3 Troubleshooting

Apart from absolute coordinate of positioning object and average velocity of the object travel, the system has 3 service outputs with diagnostic data for integration into control and data gathering system.

System status (Status output)

Number	Description of positioning status
1	The system functions normally. No errors were logged.
2	The system functions normally. Errors were logged during system operation.
3	The system logs an error in current position of the object, the coordinate continues being calculated.
4	The system logs critical error in current position of the object, the coordinate is lost.

System working mode (WorkingMode output)

Number	Description of positioning mode
1	The system functions normally. The object position is calculated based on the object coordinate measurement relative to the coordinate of leading magnet calculated by the program in the previous controller cycle.
2	The system functions normally. The coordinate is calculated based on complete correspondence of current magnet signature in the transducer operating zone to the data in magnet database.
3	The system functions normally. The coordinate is calculated in incremental mode.
4	The system calculates the coordinate in approximation mode.
5	Critical error detected, further positioning is impossible.

Error processing data structure (ErrorsPresented and ErrorsCollected outputs):

Byte 0							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Error 8	Error 7	Error 6	Error 5	Error 4	Error 3	Error 2	Error 1
Byte 1							
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Not used	Not used	Not used	Not used	Not used	Not used	Error 10	Error 9

For description of errors and actions aimed at their elimination, see Table:

No.	Error description	Error occurrence situation	System behavior upon an error	Error elimination actions
1	No magnet was detected in transducer sensitive zone.	When the system is powered on or during the system operation.	The system transfers to status 4 No positioning or initialization is performed.	Check the magnet marking for integrity and correct allocation and availability of markers within the transducer operating zone.
2	No magnet was detected in transducer operating zone.	When the system is powered on or during the system operation.	The system transfers to status 4 No positioning or initialization is performed.	Check the magnet marking for integrity and correct allocation and availability of markers within the transducer operating zone.
3	The distance between adjacent markers is less than allowed datasheet value.	When the system is powered on or during the system operation.	The system transfers to status 4 No positioning or initialization is performed.	Check the magnet marking for integrity correct allocation and availability of markers within the transducer operating zone Make sure there are no extra magnets on the magnet track.

No.	Error description	Error occurrence situation	System behavior upon an error	Error elimination actions
4	Only one magnet is found within the transducer work surface (for non-incremental adaptive systems only, CPA-xxx).	Upon system power on.	The system transfers to status 4 No positioning or initialization is performed.	To obtain an absolute coordinate, move the object to the zone with unique magnet signature.
5	There are no magnets logged earlier in the transducer operating zone.	During the system operation .	The system transfers to mode 3 Positioning continues.	Check magnet marking of the track for integrity and correct allocation.
6	Positioning error at incremental mode.	In system operation mode 1 or 2.	The error is for information, the operation status and mode do not change. Positioning and initialization continue.	
		In system operation mode 3.	The system transfers to status 4 No positioning or initialization is performed.	Make sure that the object movement velocity does not exceed half of the minimum distance between markers over the time of a single cycle of controller inquiry . Make sure that markers are allocated correctly.

No.	Error description	Error occurrence situation	System behavior upon an error	Error elimination actions
7	No correspondence found between current magnet signature in operating zone of transducer and magnet database.	In system operation mode 1. Error 5 is present.	The system transfers to operation mode 3, status 3. Positioning continues in incremental mode. After the transducer moves to the absolute section magnet marking logged earlier, the system transfers to operation mode 1, status 2.	Move the object to the absolute section of magnetic marking logged earlier . Make sure that markers are allocated correctly in the error section (status 3). Make sure that marker was not displaced or replaced in the transducer zone. Check the distances between markers and their integrity. Re-check the section initialization or run full initialization of the track.
		In system operation mode 1 or 2. Error 5 is absent.	Positioning continues in current mode, status 3	
		Upon system power on.	The system transfers to status 4 No positioning or initialization is performed. After the transducer moves to the absolute section of magnet marking logged earlier, the system transfers to operation mode 1 or 2 depending on the value of AnalyzeDbMagnets flag, status 2.	

No.	Error description	Error occurrence situation	System behavior upon an error	Error elimination actions
8	Magnet signature in transducer working zone is encountered in magnet database more than once.	In the process of system operation in mode 2.	The system transfers to operation mode 1, status 3. Positioning and initialization continue.	Eliminate marker duplicates in track marking. Re-initialize the section. Check the transducer and markers for correct installation – it should not extend beyond vertical or lateral oscillation limits.
		Upon system power on.	The system transfers to status 4. No positioning or initialization is performed.	
9	Detected a nonconformity of absolute coordinate of magnetic signature in the transducer operating zone to its coordinates in the magnet database .	During the system operation Error 5 is present.	The system transfers to operation mode 3, status 3. Positioning continues in incremental mode.	Make sure that the object movement velocity does not exceed half of the minimum distance between markers over the time of a single cycle of controller inquiry. Make sure that markers are allocated correctly. Return to correct marking.
		During the system operation Error 5 is absent.	The system operates in mode 1 . After the transducer moves to the absolute section of magnet marking logged earlier, the system transfers to status 2, and operation mode 1 or 2 depending on the value of AnalyzeDbMagnets flag.	
		Upon system power on (error 9 was earlier logged in the system).	The object coordinate is compromised/does not correspond to actual coordinate.	

No.	Error description	Error occurrence situation	System behavior upon an error	Error elimination actions
10	Maximum admissible number of magnets in the system is exceeded.	During the system operation.	An error is for information only, positioning continues in current status, new markers will not be entered into the base.	Remove extra markers from the track. Set flag BlockDbMagnets AtStop = TRUE, if moving the magnets in the transducer operating zone. Completely initialize the track.

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When magnet database is unlocked BlockDbMagnets = FALSE, errors 7 and 9 are not logged in the system due to adaptation of Magnettrack system to the change in the magnetic marking.

When flag AnalyzeDbMagnets = FALSE is off, system diagnoses errors 7 and 8 only at the time of initiating cycle.

When flag AnalyzeDbMagnets = TRUE is set, the system diagnoses error 8. If magnet database flag BlockDbMagnets = TRUE is set, then errors 7 and 9 are additionally diagnosed.

In Fixed mode, FixedMode = TRUE, the system diagnoses appearance of errors 7 and 8; error 9 is not diagnosed.

THANK YOU
FOR YOUR ATTENTION!

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