IO-Link Design Guideline

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1 Introduction

1.1 Preface

The aim of this IO-Link Design Guideline is to support engineers in planning automation plants with IO-Link devices. All phases from planning to operation are considered. The guideline describes the necessary activities in a step-by-step manner using a system example.

The IO-Link Design Guideline is based on the IO-Link Interface and System Specification Version 1.1.2 as of July 2013.

For the purpose of improved clarity, symbols are used for structuring the text.

Table 1: Symbols for structuring the text

Symbol	Name	Meaning
	Note	Used to mark a recommendation and/or summary of the currently described facts.
!	Important	Used for information which, if not observed, may result in malfunction during operation.

1.2 What is IO-Link?

IO-Link is a serial digital communication protocol intended to be used in automation technology. It connects sensors or actuators to a programmable logic controller (PLC). In a way, IO-Link provides for digitalization of the “last metre” of the communication link to the sensors and actuators. IO-Link is defined in the international standard IEC 61131-9. Where only binary states (on/off) or analog signals have been transmitted so far, it is now possible to read status information from a sensor or actuator and write parameterization information to the sensor or actuator. IO-Link is not just another bus system, but a point-to-point connection between the IO-Link device and a link device, namely an IO-Link master.

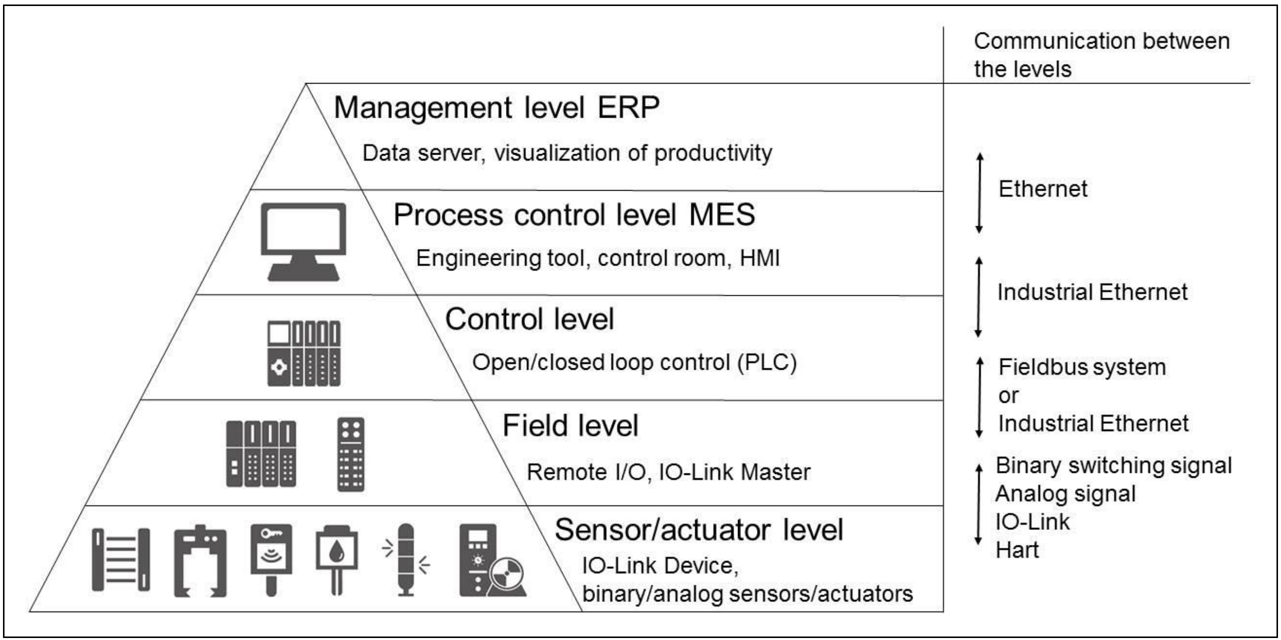

Figure 1: Automation pyramid

The point-to-point connection is set up between an IO-Link master and an IO-Link device (sensor or actuator) using an unshielded three-core cable. One of the three conductors is used for communication, one for power supply to the device electronics and one as the common reference potential. This connection type is called Port Class A in the IO-Link nomenclature and provides a maximum current output of 200 mA. As actuators often require an additional actuator power supply, one more Port Class B is available. With Port Class B, a shielded five-core cable is used for the connection. Besides the three conductors already described above, there another two conductors. One conductor for power supply to the actuators and one more conductor with a separated galvanically isolated reference potential.

The IO-Link master communicates with the IO-Link devices, collects data from them and transmits the data to the higher-level bus system. The IO-Link communication protocol does not include any definitions regarding the higher-level communication protocol.

IO-Link is a communication protocol independent of the bus which cyclically transmits process data and demand-oriented parameterization and diagnostic data from the sensors and actuators via a point-to-point connection.

1.3 Why is it reasonable to use IO-Link devices instead of normal sensors or actuators?

The use of IO-Link sensors and actuators offers many benefits over digitally switching or analog sensors and actuators. The IO-Link technology uses serial communication instead of the linking methods of digital and analog sensors used so far. This communication method allows for the transmission of parameterization and diagnostic data to/from the sensor or actuator. The usage of IO-Link decreases the number of different interfaces or connector plugs in your system. Digital communication can lead to a reduction in system downtimes through predictive maintenance and the parameter definitions of the IO-Link sensors and actuators can be modified while the system is operating.

When using IO-Link devices, in addition to process data, you can also transmit status information and parameter values.

1.4 Target group description

This design guideline is targeted towards experienced readers who are familiar with the planning and engineering of automation plants, but who are not familiar with IO-Link. The document is designed to support the readers in getting to know the IO-Link system. Hence, the most important steps in the planning, engineering and commissioning process of an automation system with IO-Link components are outlined.

1.5 Purpose of the design guideline

The aim of this guideline is to describe the planning process for an IO-Link system on the basis of an example. Different types of IO-Link devices are to be used. Therefore, all required planning steps are explained by means of a notional system.

2 Definition of the system example

In the exemplary planning process, a conveyor system is used as an example. There are different tasks in the conveyor system, which are considered in this document to explain the planning process. It is assumed that it is already clear which sensors and actuators are required, and where they will be located.

The following working hypothesis is valid: It shows the intended location of the selected sensor and actuator.

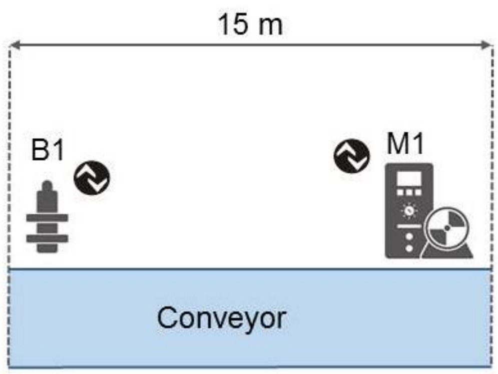

Figure 2: Structure of a conveyor

Figure 2 shows the basic structure of a conveyor. The entire system consists of several conveyors. The IO-Link symbol is used to indicate the IO-Link devices. The conveyor consists of a drive unit *M1* and a speed sensor *B1*. Both components are capable of communicating with IO-Link. As electric motors cannot be controlled directly via IO-Link, the structure of a drive unit is illustrated in Figure 3.

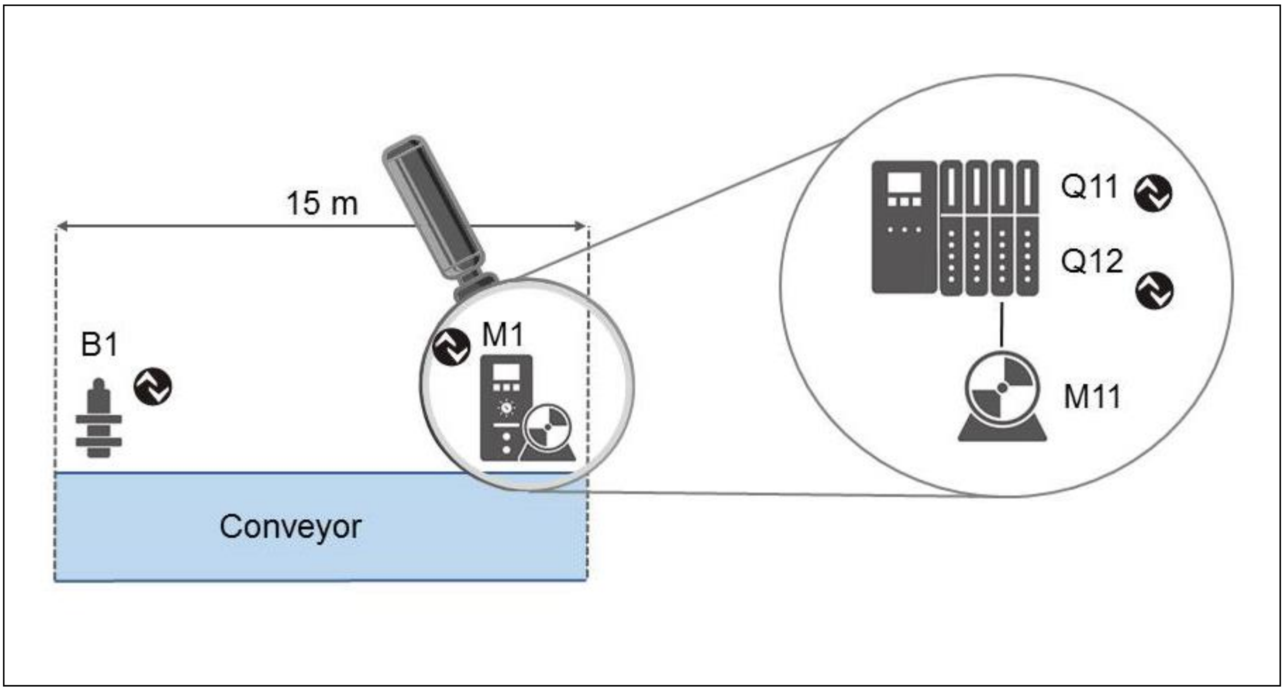

Figure 3: Structure of a drive unit

A drive unit is made up of three components. The first component is a power contactor assembly *Q11* for a star-delta starting circuit with an IO-Link interface. The second component is a motor protection switch *Q12* connected via an IO-Link interface as well. The third required component of the drive unit is the motor *M11*. In order to improve the clarity of the following figures, only the drive unit of the conveyors is shown in the total view.

Figure 4 shows the entire conveyor system. The system has a modular structure and consists of four conveyors. All four conveyors have the same speed sensors *B1* to *B4* and drive units *M1* to *M4*

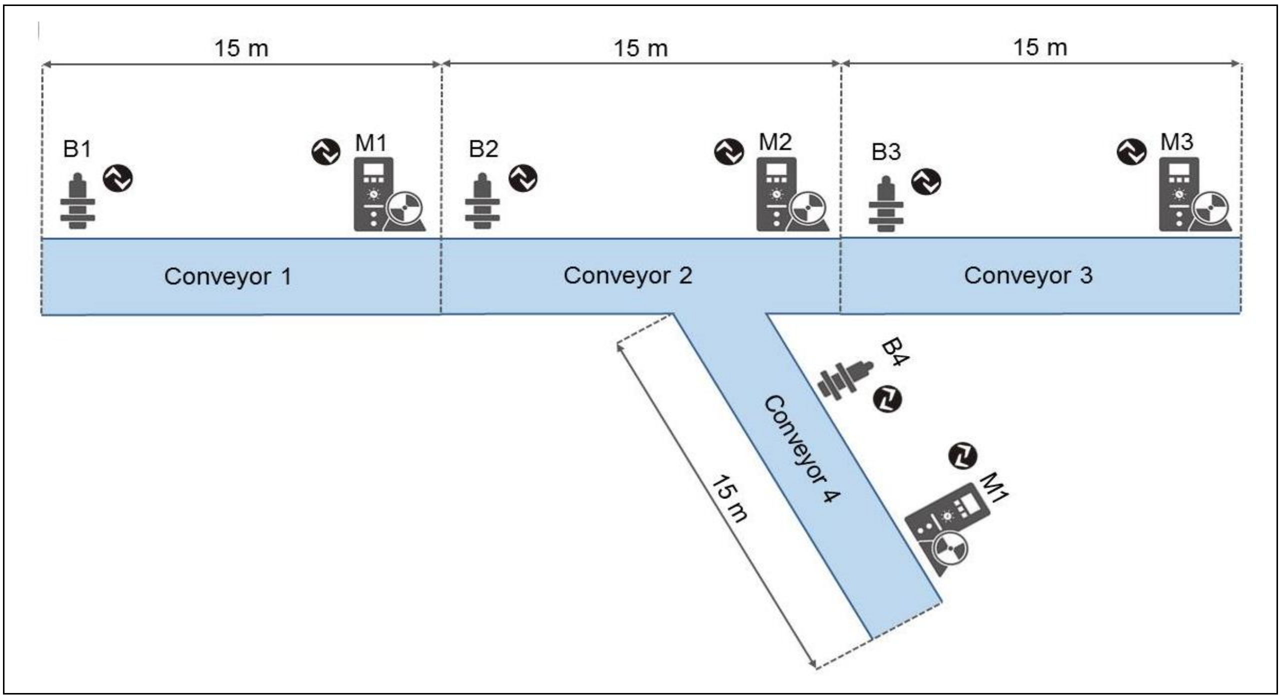

Figure 4: Conveyor system

As shown in Figure 6, more elements have been added to enhance the conveyors' functionality. For example, a control unit is mounted on conveyor 1. The control unit is made up of a push-button switch *S1* for starting and stopping the system and a signal light *P1*, indicating whether the system is operating. In the area of conveyor 2, a temperature measurement unit *B7* intended for monitoring the ambient temperature is installed.

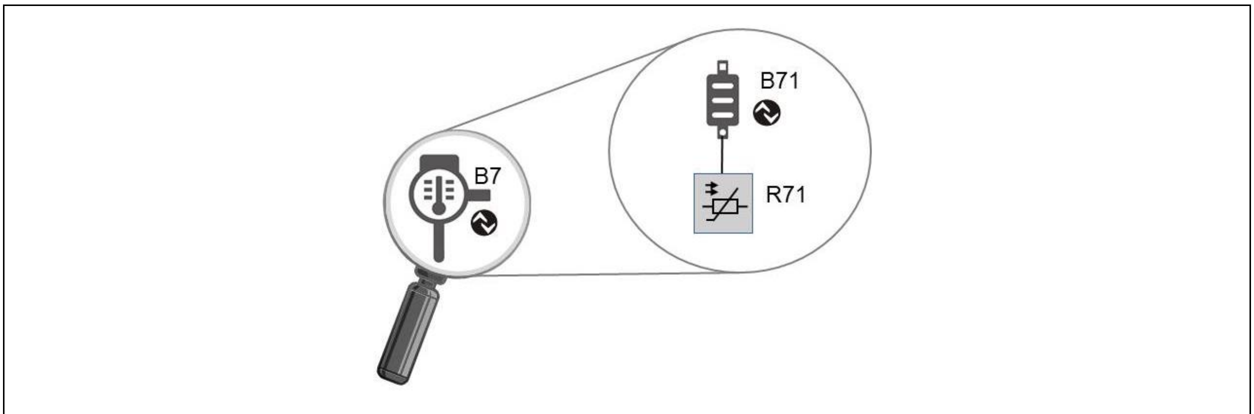

Figure 5: Structure of temperature measurement unit B7

As can be seen in Figure 5, the temperature measurement unit *B7* consists of an IO-Link/analog converter *B71* and a PT100 resistance temperature detector (RTD)*R71*.

Additionally, a signal light *P2* (see Figure 6) with an IO-Link interface is provided in the area of conveyor 2 for signaling critical operational states.

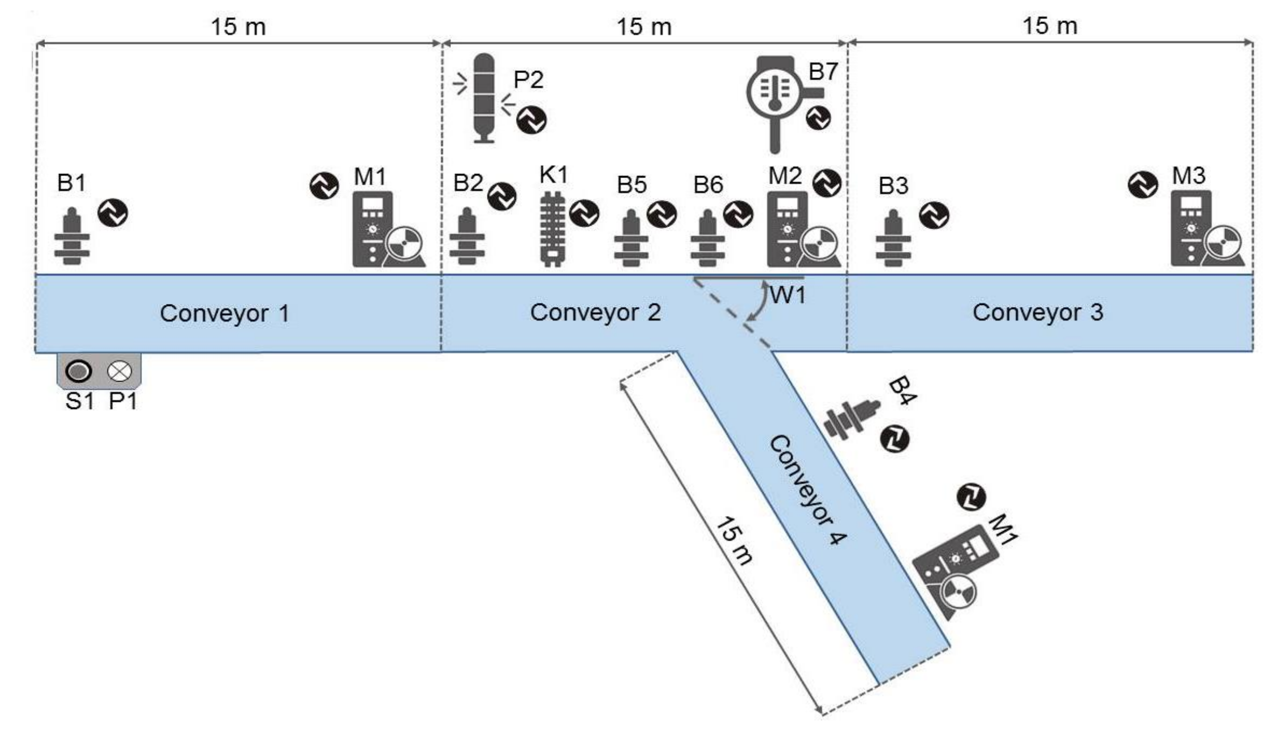

Figure 6: Conveyor system with all sensors and actuators

A deflector *W1* is installed on conveyor 2 to allow for onward transportation of the material on either conveyor 3 or conveyor 4, as required. An RFID (Radio Frequency Identifier) sensor *B5*, an optical distance sensor *B6*, and a solenoid valve *K1* are required for controlling the deflector. All devices that are needed for the deflector are also provided with an IO-Link interface. Figure 6 shows the entire conveyor system with all its sensors and actuators. Table 2 gives an overview of all components installed in the system.

Table 2: Explanation of the individual designations used in Figure 6.

Designation	Type	Task	IO-Link
B1 – B4	Speed sensors	Measure conveyor speed	Yes
M1 – M4	Drive unit	Drive conveyors	Some of them
B5	RFID sensor	Identify conveyed material	Yes
B6	Optical distance sensor	Determine deflector position	Yes
B7	Temperature measurement unit	Monitor ambient temperature	Some of them
K1	Solenoid valve	Pneumatic deflector control	Yes
W1	Deflector	Guide the conveyed material	No
S1	Mech. push-button switch	Start and stop the system	No
P1	Signal light, unicolored	Signals that the system is operating	No
P2	Signal light, multicolored	Signals critical operational states	Yes

2.1 Technical properties of the devices used in the system example

Various IO-Link sensors and actuators are installed in the system example in Figure 6. Figure 7 shows step by step how to proceed with the selection of the IO-Link components.

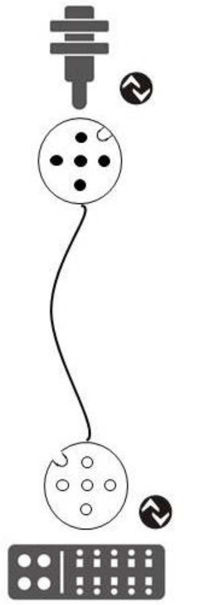

Figure 7: General procedure for the selection of components

In order to be able to make the electro-technical planning, it is important to determine the technical properties of the IO-Link devices. Please note that only the system modules are listed in Table 2 so far. For example, the drive units *M1* to *M4* consist of several components each, as can be seen in Figure 3. The temperature measurement unit *B7* is similarly made up of two components (see Figure 5). In the next step, the technical properties of the IO-Link devices listed below must be determined from the data sheets of the individual manufacturers.

- IO-Link version
  - Which IO-Link version does the device support?
- Port Class
  - With which port class is the device connected?
    - Port class A three-pin with L+, L- (power supply U_S to sensors and electronics) and communication channel (C/Q)
    - Port class B five-pin with L+, L- (U_S), communication channel (C/Q) , 2L+ and 2L- (actuator power supply U_A)
  - Classical (conventional) digital sensors provided with a binary switching output or actuators controlled via 24 V DC voltage can also be operated on an IO-Link port. For this purpose, the IO-Link master is configured as a digital input or output. For example, the mechanical push-button switch *S1* and the unicolored pilot light *P2* can be connected to an IO-Link port.
- Current consumption of the port class

  - Port Class A: The maximum current consumption of the device supplied from voltage U_S is taken from the data sheet.
  - Port Class B: The maximum current consumption of the device supplied from the voltages U_S and U_A is taken from the data sheet.
  - For some devices, the current consumption for U_S is not always specified. In this case, a current consumption ≤ 200 mA can be assumed.
- Connector plug
  - For an IP67 rated device the connector plugs M5, M8 or M12 are allowed under the IO-Link specification. It must be determined which connector type is used on the device. No connector plugs are available for IP20 rating, as usually screw-type or clamp-type connectors are used in this case.
- Size of the process image
  - The size of the process image is not relevant for the electro-technical planning of the system, but will be required later when choosing the IO-Link master.

In the data sheets of the IO-Link devices, you can often find terminal diagrams. In order to enable you to take the required information from these diagrams, the individual connectors and their pin assignments are shown in Table 3 and in Figure 8.

Table 3: Pin assignment of the connectors

Pin	Signal	Description	Core color[1]
1	L+	24 V power supply (U_S+)	brown
2	I/Q	not connected (port class A) DI – digital input (port class A) DO – digital output (port class A)	white
	2L+	extra power supply (U_A+) (port class B)	not defined
3	L-	24 V power supply (U_S-)	blue
4	C/Q	SIO standard input/output or IO-Link communication	black
5	NC	not connected (port class A)	
	2L-	extra power supply (U_A-) (port class B)	not defined

[1] Acc. to IEC 60947-5-2 for four-pin connectors

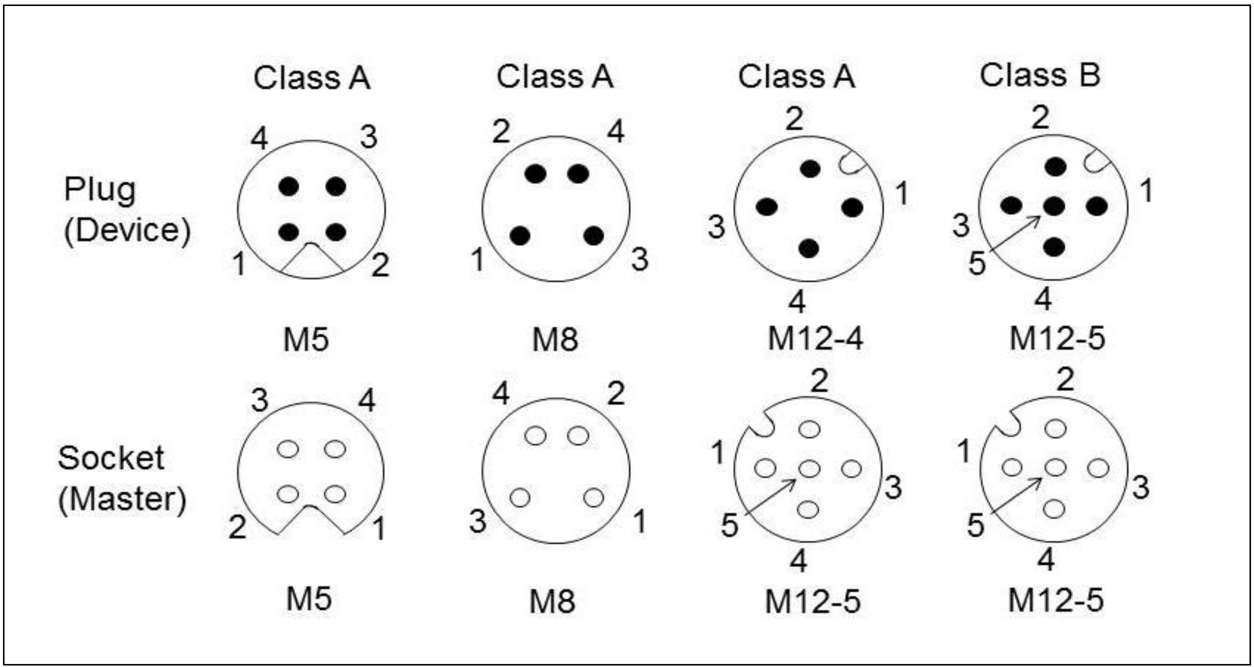

Figure 8: Defined connector

The IO-Link specification defines the port class B only for M12 connectors. It is nevertheless possible to operate IO-Link devices of port class B on IO-Link masters with IP20 rating by freely assigning the terminals. In this case, the additional supply voltage is realized by using a terminal block.

It is recommended to use a table similar to Table 4 for collecting this information.

Table 4: Example of device properties

Designation	Type	IO-Link version	Port class	Current consumption form voltage U_S	Current consumption form voltage U_A	Connector type	Size of process image In/Out
B1 – B4	Speed sensor	V1.1	A	50 mA	-	M12	4/0 bytes
Q11, Q21 Q31, Q41	Contactors of drive units	V1.1	B	n.a. (≤200 mA)	250 mA	IP20	2/2 bytes
Q12, Q22 Q32, Q43	Motor protector of drive units	V1.1	A	5 mA	-	IP20	4/2 bytes
B5	RFID sensor	V1.0	A	50 mA	-	M12	8/8 bytes
B6	Light push-button switch	V1.0	A	70 mA	-	M12	2/0 bytes
B71	IO-Link/analog converter	V1.1	A	25 mA	-	M12	2/2 bytes
K1	Solenoid valve	V1.0	B	3 mA	400 mA	M12	4/6 bytes
P2	Signal light multicolored	V1.1	A	410 mA	-	M12	1/8 bytes
S1	Mech. push-button switch	-	DI	-	-	IP20	1/0 bits
P1	Signal light unicolored	-	DO	150 mA through pin 4 (C/Q)		IP20	0/1 bits

2.2 Structuring/arrangement of the IO-Link masters

The IO-Link devices considered so far now have to be connected to an IO-Link master. The master receives the process values from the sensors; these process values are aggregated in the master and transmitted to the higher-level bus system. In the case of an IO-Link actuator, the process value is received from the higher-level bus system and transmitted to the actuator. An IO-Link master can operate only a limited number of IO-Link devices. As a result, several IO-Link masters are normally used. In the following section the number of IO-Link masters is determined and where they will be placed in the system example. Care must be taken to ensure that the maximum line length of 20 m between the IO-Link master and the IO-Link devices defined in the IO-Link specification is not exceeded. Due to these limitations, several IO-Link masters are used in the example. Placing a single master in a central position would result in line lengths of more than 20 m.

If you take a closer look at the conveyor system, you will recognize its modular structure. The control panel on conveyor 1 could be allocated to any of the conveyors. Also, the deflector with its sensors and actuators could be considered as an enhancement of an existing conveyor. The modular structure of this system reduces the production costs as the “same” basic conveyor is reused. In this modular system the individual conveyors can be combined to form a conveyor line and could be enhanced with additional components if required. In order to preserve this modularity, a separate IO-Link master is planned for each conveyor in our system example.

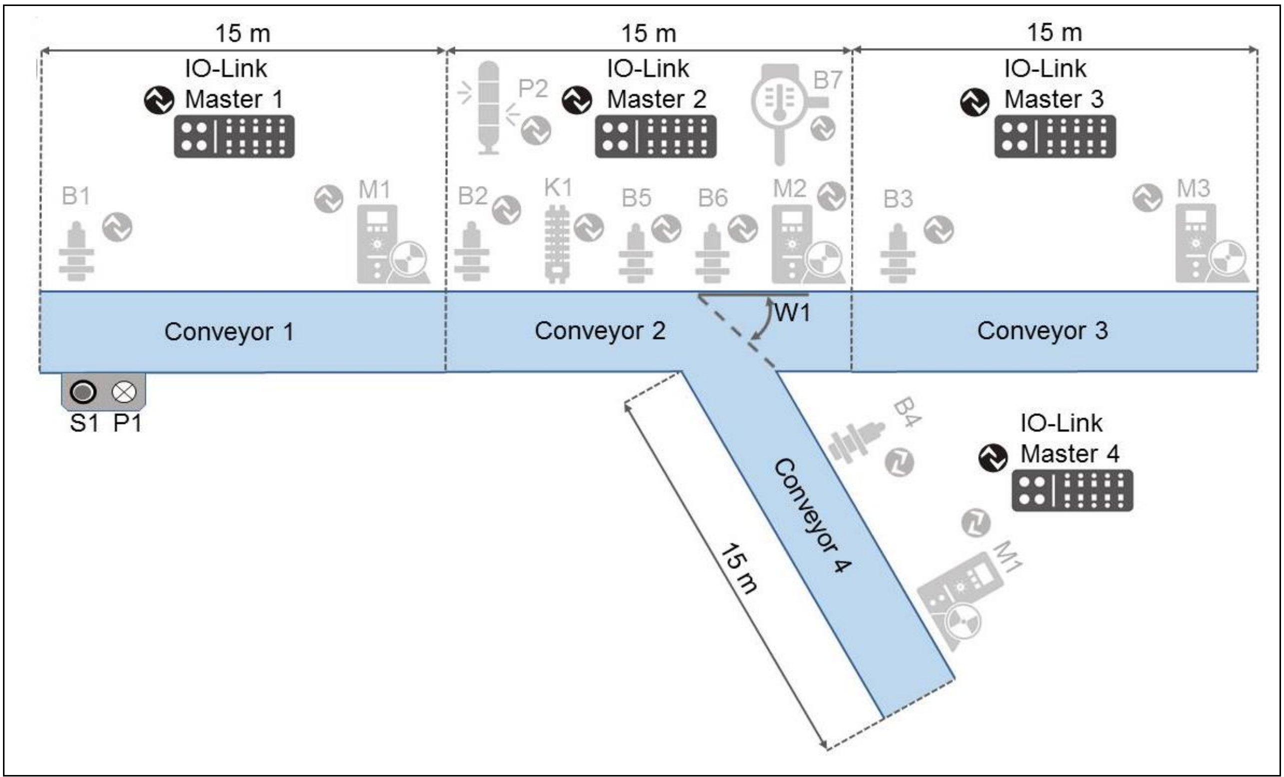

Figure 9: Placement of the IO-Link masters

Figure 9 shows the modular structure described above.

2.3 Selection of the IO-Link masters

The following aspects must be taken into account when choosing the IO-Link master:

- Which higher-level bus system is to be used?
- Which IP rating is required?
- How many ports are needed?
- Which port classes are required by the connected IO-Link devices?
- What are the power requirements for port A?
- What are the power requirements for port B?

! **As a rule, it is recommended to use an IO-Link master with IO-Link version V1.1. It features downward-compatibility to sensors with IO-Link version 1.0.**

Based on the information in Table 4, the necessary properties are defined for selecting the individual IO-Link masters of the system example. First of all, the following is stated for all IO-Link masters:

⇒ All IO-Link masters shall feature an IO-Link version V1.1 and an IP67 rating.

In the next steps, more specifications are made. For this purpose, the properties of the connected devices are collected in the following tables for each of the planned conveyors.

Table 5: Properties of the devices to be connected to conveyor 1

Designation	Type	Port class A	Port class B	Current I_S[2]	Current I_A[3]
B1	Speed sensor	✓		50 mA	
Q11	Contactor of drive unit		✓	≤200mA	250 mA
Q12	Motor protector of drive unit	✓		5 mA	
S1	Mech. push-button switch				
P1	Signal light, unicolored			150 mA through pin 4 (C/Q)	
	IO-Link master on conveyor 1	2	1	≤405 mA	250 mA

The mechanical push-button switch *S1* and the unicolored signal light *P1* in Table 5 can be connected to a port of port class A or B. The corresponding port then has to be configured as a digital input or output. The current for operating an actuator on a digital output is provided via the voltage U_S.

[2] Current to be delivered by the master at U_S

[3] Current to be delivered by the master at U_A

Table 6: Properties of the devices to be connected to conveyor 2

Designation	Type	Port class A	Port class B	Current I_S	Current I_A
B2	Speed sensor	✓		50 mA	
Q21	Contactor of drive unit		✓	≤200mA	250 mA
Q22	Motor protector of drive unit	✓		5 mA	
B5	RFID sensor	✓		50 mA	
B6	Optical distance sensor	✓		70 mA	
B71	IO-Link/analog converter	✓		25 mA	
K1	Solenoid valve		✓	3 mA	400 mA
P1	Signal light	✓		410 mA	
	IO-Link master on conveyor 2	6	2	813 mA	650 mA

Table 7: Properties of the devices to be connected to conveyor 3

Designation	Type	Port class A	Port class B	Current I_S	Current I_A
B3	Speed sensor	✓		50 mA	
Q31	Contactor of drive unit		✓	≤200mA	250 mA
Q32	Motor protector of drive unit	✓		5 mA	
	IO-Link master on conveyor 3	2	1	255 mA	250 mA

Table 8: Properties of the devices to be connected to conveyor 4

Designation	Type	Port class A	Port class B	Current I_S	Current I_A
B4	Speed sensor	✓		50 mA	
Q41	Contactor of drive unit		✓	≤200mA	250 mA
Q42	Motor protector of drive unit	✓		5 mA	
	IO-Link master on conveyor 4	2	1	255 mA	250 mA

Based on the requirements on the IO-Link masters in Table 5 to Table 8 it is now possible to select IO-Link masters from different manufacturers. The competence matrix of the IO-Link Community on the home page www.io-link.com provides an overview of the manufacturers. IO-Link masters are available for many higher-level bus systems and with various port configurations. There are IO-Link masters with only port class A or port class B ports or IO-Link masters that support both port class A and port class B. As there is a wide range of IO-Link masters, the present design guideline cannot describe all possible variants.
Prior to choosing a master, you first have to decide which strategy is to be pursued.

1. Strategy 1: use of a single IO-Link master type
   This single IO-Link master type would have to meet the maximum requirements (in this example the IO-Link master on conveyor 2), but would be over-specified for the other applications.

2. Strategy 2: use of a various different IO-Link master types
   In this case, IO-Link masters of different types tailored to the needs of the corresponding (conveyor) application would be used.

Table 9: Advantages and disadvantages of the strategies

	Advantages	Disadvantages
Strategy 1	- Low expenditure of time for planning - Easy procurement and spare parts supply (only one IO-Link master type needed) - No likelihood of confusion (identical masters on all conveyors) - Identical structures of all conveyors	- Higher costs, as some of the masters will be over-specified.
Strategy 2	- More cost-effective procurement, as better suited components are used	- Different structures of the individual conveyors - Higher expenditure of time for planning - More complex procurement and spare parts supply (several IO-Link master types needed) - Danger of confusion (different IO-Link masters on the individual conveyors)

From this point on, strategy 1 will be pursued for the planning process. A notional IO-Link master is used for this purpose. Upon selection of the IO-Link master you have to verify the technical properties. The verification basically consists of comparing the rated currents of the IO-Link masters with the determined currents in Table 5 to Table 8.

Table 10: Exemplary technical specifications of the IO-Link master

<table>
<tr><th colspan="2">Number of ports of port class A</th><th>Number of ports of port class B</th></tr>
<tr><td colspan="2">-</td><td>8 ports</td></tr>
<tr><th>Rated current
Pins 1 and 3</th><th>Rated current
Pin 4 (C/Q)</th><th>Rated current
Pins 2 and 5</th></tr>
<tr><td>200 mA</td><td>150 mA</td><td rowspan="2">Max. total current of 3.5 A across all ports</td></tr>
<tr><td colspan="2">Max. 1.6 A across all 8 C/Q and L+ lines</td></tr>
</table>

! IO-Link devices have a maximum process image of 32 bytes. Not all of the IO-Link masters can transmit 32 bytes per port to the higher-level bus system. Check the manufacturer documentation on this.

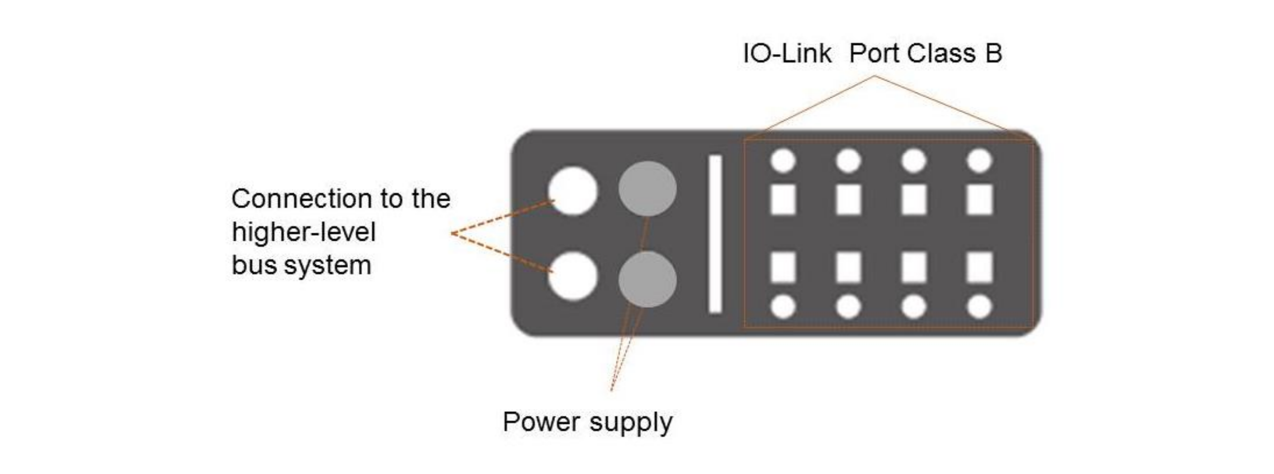

Figure 10: Connection diagram of the IO-Link master

IO-Link masters have a limited current supply per port. According to the IO-Link specification, IO-Link masters should supply 200 mA per port for the port class A, that is for power supply U_S to the sensors and electronics. For the port class B, i.e. for the actuator power supply U_A, no maximum current supply is defined in the IO-Link specification. However, the maximum current supply is limited by the connector. In data sheets of IO-Link masters of port class B often a maximum total current is specified for the actuator supply voltage U_A which must not be exceeded in total across all ports.

If you compare the rated currents in Table 10 with the specifications in Table 5 to Table 8, you will recognize that the selected IO-Link master will deliver a sufficient current in all configurations.

However, there are IO-Link devices on the market which require more than 200 mA from the sensor and actuator power supply. These devices cannot be operated on any IO-Link master. In this case please check the IO-Link master's data sheet to see if it is capable of delivering the correspondingly higher current.

For our system example we assume that the signal light *P1* works properly on the selected IO-Link master despite the fact that the standard is disregarded.

2.4 Planning of the cabling

Once the system structure has been determined and the IO-Link devices and IO-Link masters have been defined, the cabling is planned in the next step.
This primarily involves the connection between the IO-Link master and its IO-Link devices. For port class A a three-core unshielded control line is sufficient for cabling. In practice, however, you will frequently find four-core unshielded control lines instead as they are more available than three-core lines.

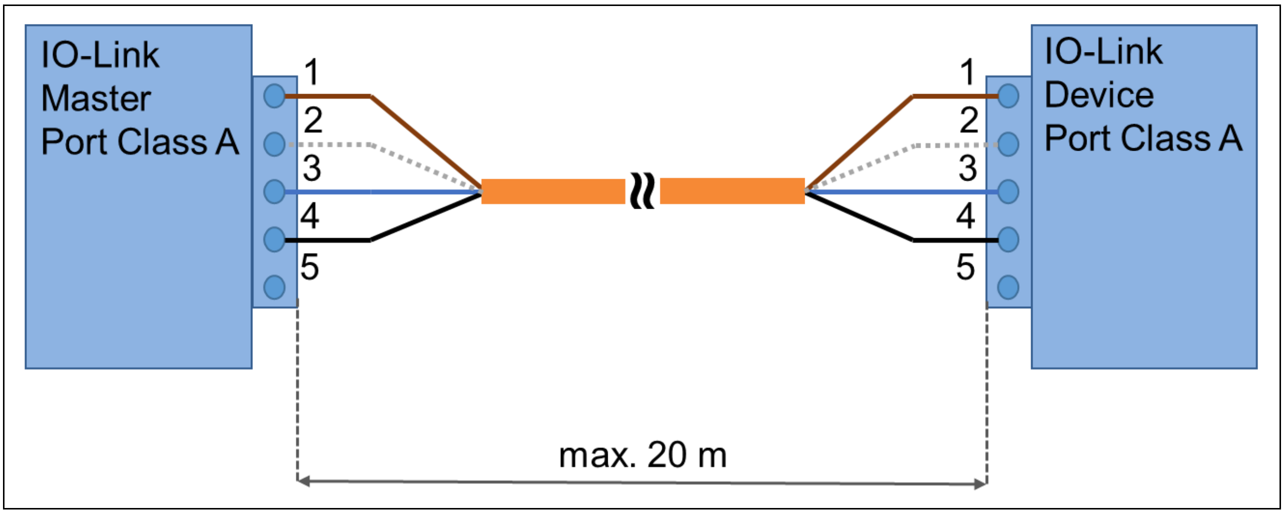

Figure 11: Connection between IO-Link master and IO-Link device of port class A

Figure 11 shows the connection between an IO-Link master of port class A and an IO-Link device of port class A. When using a three-core cable, the pins 1, 3 and 4 are interconnected. With this, proper functioning of the device is already given. If a four-core cable is used, the pin 2 connections at each end should be interconnected to each other as shown. Although this is permissible, you should make sure that pin 2 of an IO-Link master of port class A is not being used or configured as a digital input.

To connect an IO-Link device of port class A with an IO-link master of port class B a three-core cable is recommended. If a four-core or five-core cable is used, at pins 2 and 5 of the device an additional voltage applies. You must ensure that pins 2 and 5 are left unconnected at one end or you have to check that the additional

voltage does not result in malfunctions of the IO-Link device.

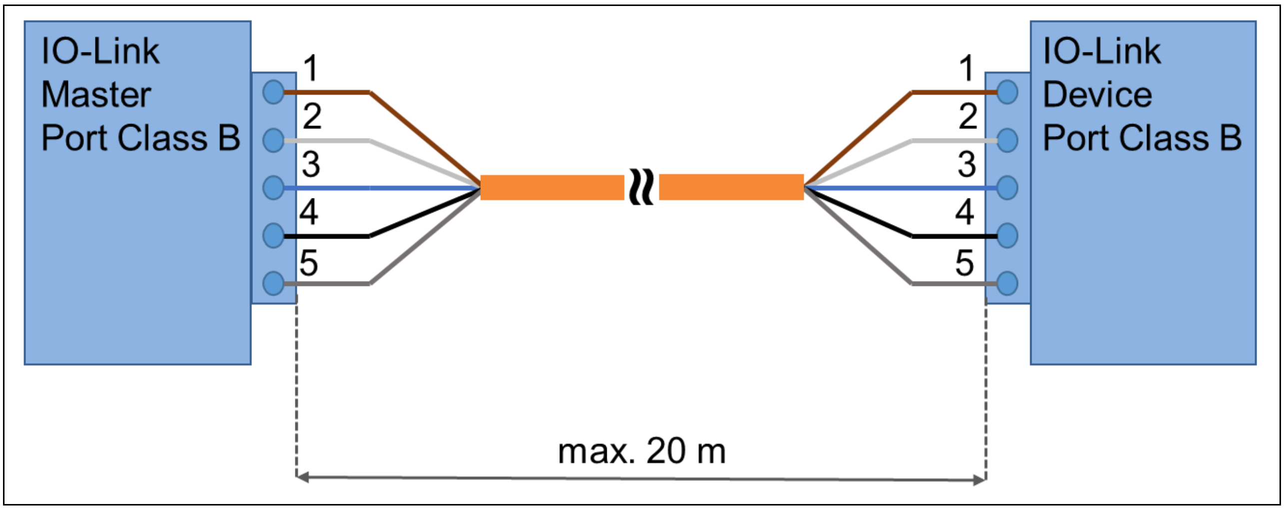

Figure 12: Connection between IO-Link master and IO-Link device of port class B

Figure 12 shows the connection between an IO-Link master of port class B and an IO-Link device of port class B.

In case of an IP20 rated device or master, the cores are individually connected to the corresponding single terminals. For devices with IP67 rating the connectors shown in Figure 8 are defined. The pin assignment of the connectors can be found in Table 3.

Table 11: Overview of possible cabling

Port class IO-Link master	Port class IO-Link device	Line	Note
A	A	3-/4-/5-core	Make sure that pin 2 of the master is neither connected nor used as a digital input
A	B	3-/4-/5-core	The actuator power must be supplied externally to the device.
B	A	3-/4-/5-core	Make sure that pin 2 of at least one connector is not connected.
B	B	5-core	-

When using a safety-related emergency stop function through the master of port class B, the simultaneous operation of devices of port class A and port class B must be considered separately.

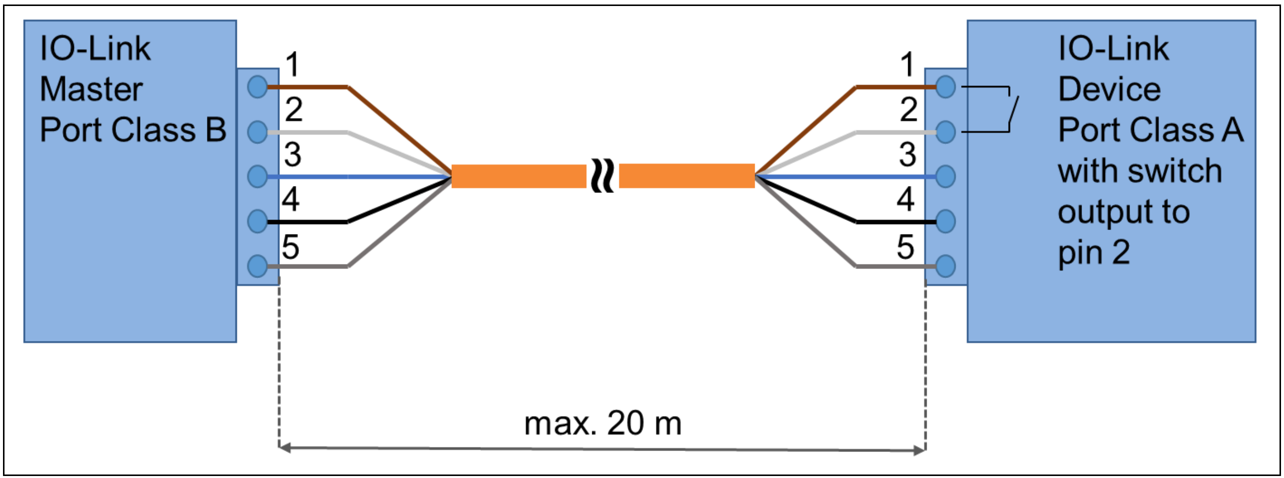

Figure 13: Connection between IO-Link master (port class B) and IO-Link device (port class A)

It is prohibited to connect an IO-Link master of port class B to an IO-Link device of port class B through a **five-core cable**, as shown in Figure 13, as this would disable a potentially configured emergency stop function. Normally, actuating the emergency stop button will cut off the actuator supply voltage (pin 2) at the IO-Link master of port class B and de-energize the load circuits of the IO-Link actuators of port class B connected to the master (emergency stop function). If an IO-Link master of port class B and an IO-Link device of port class A are connected via a five-core cable, it may happen under special circumstances that a switch contact occurs in the circuit between pin 1 and pin 2, as shown in Figure 13. When this contact is closed, the sensor supply voltage across pin 1 is bridged to the actuator supply voltage across pin 2, hence causing inadvertent power supply to the actuator load circuits. In this configuration, the emergency stop function will not work.

2.5 Consideration of the line length, the currents and the voltage drop

! **When planning the cabling, make sure that the maximum cable length between the IO-Link master and an IO-Link device does not exceed 20 m.**

Regarding the power supply, you also have to make sure that a sufficient supply voltage is available at the device. As a voltage drop occurs along every supply cable, the entire cable route from the power supply unit to the IO-Link device must be taken into account. Figure 14 and Figure 15 illustrate this topic. In the following, the voltage drops along a supply cable, from the power supply unit through the IO-Link master to the IO-Link device, are determined in an exemplary manner. For an IO-Link master of port class B, the voltage drop must be calculated separately for each of the two supply voltages (U_S and U_A).

	If the currents of the IO-Link devices are lower than 200 mA, a cable with a core cross-sectional area of 0.35 mm² and a length of up to 20 m can be used to connect the IO-Link master and IO-Link device. No special calculation is required in this case. **Nevertheless, the supply cables between the power supply unit and the IO-Link master should be checked for voltage drops.**

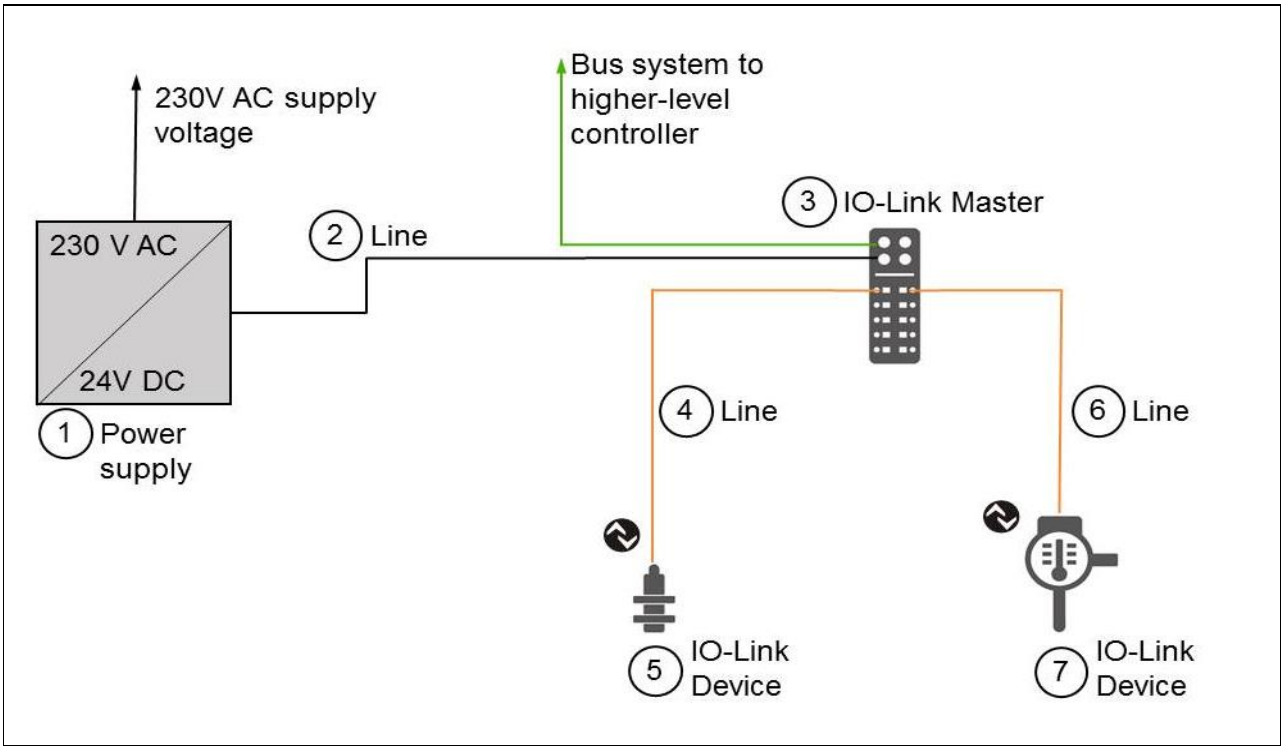

Figure 14: Setup for the calculation example

Figure 14 shows an exemplary setup to be used as a basis for calculating the voltage drop along the supply cables. The power supply unit ① provides a voltage of 24 V across its output. The power is supplied via a cable ② to the IO-Link master ③ and from there to the IO-Link device ⑤ and the IO-Link device ⑦. It is to be expected that voltage drops in relation to the initial supply voltage will occur along the cables ②, ④ and ⑥. For further calculations we assume the cable and device properties described in Table 12.

Table 12: Exemplary properties for the calculation of the voltage drop

	Description	Properties
1	Power supply unit	Rated voltage 24 V DC ±1% tolerance
2	Control line Power supply → IO-Link master	Length: 10 m Core cross-sectional area: 0.75 mm²
3	IO-Link master	Voltage drop: 0.5 V Rated current: 100 mA
4	Control line IO-Link master → IO-Link device 1	Length: 15 m Core cross-sectional area: 0.35 mm²
5	IO-Link device 1	Rated current: 200 mA Rated voltage: 19 to 30 V
6	Control line IO-Link master → IO-Link device 2	Length: 15 m Core cross-sectional area: 0.35 mm²
7	IO-Link device 2	Rated current: 100 mA Rated voltage: 19 to 30 V

Based on this assumption, the calculation of the voltage drop from the power supply unit to the IO-Link device according to Figure 15 is explained in the following section.

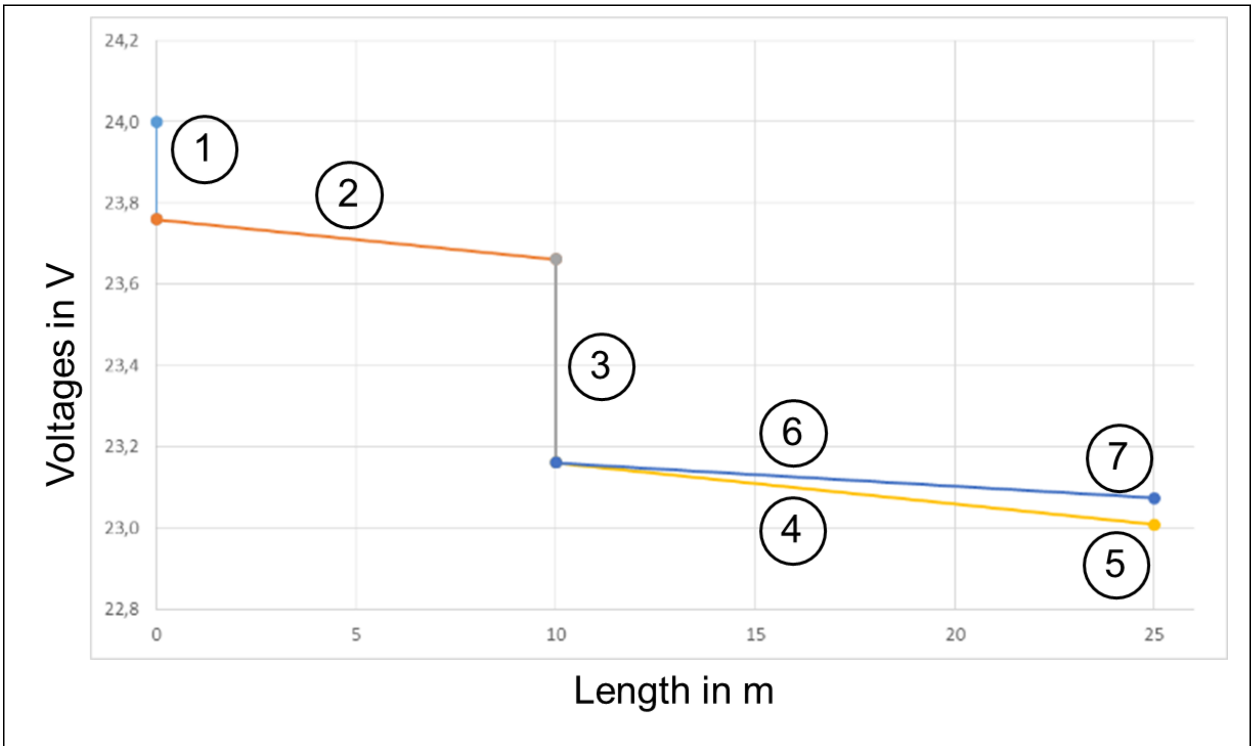

Figure 15: Voltage drops

Item 1 in Figure 15 is the “starting point” of the calculation. For the consideration of the voltage drop, a “worst-case” calculation should be performed. As a result, the low (min.) limit value of the supply voltage ($24\,V \cdot (100\% - 1\%) = 23.76\,V$) at the power supply unit is assumed in the first step.

For determining the voltage drop across the line ② between the power supply unit and the IO-Link master (see Figure 15), first of all the total line current I_{L1} is needed. The total line current ② results from the sum of all rated currents of the connected devices ⑤ and ⑦ and the rated current of the IO-Link master ③ (see equation 1).

$$I_{L1} = I_M + I_{D1} + I_{D2} = 100\,mA + 200\,mA + 100\,mA = 400\,mA = 0.4\,A \qquad 1$$

Based on the result of equation 1, the voltage drop can be determined by means of equations 2 to 4.

$$U = R_L \cdot I \qquad 2$$

$$U = R_B \cdot 2 \cdot l \cdot I \qquad 3$$

$$U = \rho \cdot \frac{2 \cdot l}{A} \cdot I \qquad 4$$

U: $Voltage\ drop\ along\ lin\ in\ V$

R_L: $Line\ resistance\ in\ \Omega$

R_B: $Resistance\ coefficient\ of\ line\ \Omega/m$

ρ: $Specific\ resistance\ of\ line\ material$

$$Line\ copper\ \rho = 1.69 \ldots 1.75 \cdot 10^{-2} \Omega \frac{mm^2}{m}$$

l: $Line\ length\ in\ m$

A: $Core\ cross\text{–}sectional\ area\ in\ mm^2$

I: $Line\ current\ A$

From equation 4 and the technical cable specifications results a voltage drop of 100 mV along line ②. Hence, a voltage of $23.77\,V - 0.1\,V = 23.66\,V$ is applied to the IO-Link master.

At item ③ in Figure 15 you can see the voltage drop in the IO-Link master. The voltage drop occurs between the supply point and the ports of the IO-Link master. If this value is not specified in the IO-Link master's data sheet, an internal voltage drop of 0.5 V can be assumed. Across the ports for connecting the IO-Link devices a voltage of $23.66\,V - 0.5\,V = 23.16\,V$ is now available.

Equation 4 is used again to calculate the voltage drops along the lines ④ and ⑥. The current I in the lines is equal to the rated current of the connected IO-Link devices ⑤ and ⑦.

From this results a voltage drop of 150 mV along the line ④. Hence, a voltage of $23{,}16\,V - 0{,}15\,V = 23{,}01\,V$ is applied to the IO-Link device ⑤. This voltage is sufficient for the IO-Link device (see rated voltage range specified in Table 12).

The voltage drop along the line ⑥ is 90 mV. Hence, a voltage of $23{,}16\,V - 0{,}09\,V = 23{,}07\,V$ is applied to the IO-Link device ⑦. This voltage is also sufficient for the IO-Link device (see rated voltage range specified in Table 12).

The voltages U_S and U_A must be considered separately when calculating the voltage drop.

Besides this, only the usual provisions for cable laying, for example regarding cable segregation, the protection against damage and the adherence to the minimum bending radii, must be observed.

2.6 Documentation of the results

When all relevant issues of the hardware-related planning process have been completed, the results must be documented accordingly. The documentation should comprise the following elements:

- Table 4: Example of device properties
- Table 10: Exemplary technical specifications of the IO-Link master
- Table 13: Documentation of the IO-Link master assignment
- Figure 16: Topology of conveyor 1
- Figure 17: Topology of conveyor 2
- Figure 18: Topology of conveyors 3 and 4
- Data sheets of the IO-Link devices and the IO-Link master.

Table 13 indicates the IO-Link device allocation to the ports of the IO-Link masters.

Table 13: Documentation of the IO-Link master assignment

IO-Link master	Port number	Port class	Device	Parameter setting
IO-Link master 1 Conveyor 1	1	B	B1 – Speed sensor	IO-Link
	2	B	Q12 – Motor protection switch	IO-Link
	3	B	S1 – Mech. push-button switch	Digital input
	4	B	Q11 – Power contactor -	IO-Link
	5	B	P1 – Signal light -	Digital output
	6	B	-	deactivated
	7	B	-	deactivated
	8	B	-	deactivated
IO-Link master 2 Conveyor 2	1	B	B3 – Speed sensor	IO-Link
	2	B	Q32 – Motor protection switch	IO-Link
	3	B	B5 – RFID sensor	IO-Link
	4	B	B6 – Optical distance sensor	IO-Link
	5	B	P2 – Signal light	IO-Link
	6	B	Q32 – Power contactor	IO-Link
	7	B	K1 – Solenoid valve	IO-Link
	8	B	B71 – IO-Link/analog converter	IO-Link
IO-Link master 3 Conveyor 3	1	B	B3 – Speed sensor	IO-Link
	2	B	Q32 – Motor protection switch	IO-Link
	3	B	Q32 – Power contactor	IO-Link
	4	B	-	deactivated
	5	B	-	deactivated
	6	B	-	deactivated

	7	B	-	deactivated
	8	B	-	deactivated
IO-Link master 4 Conveyor 4	1	B	B4 – Speed sensor	IO-Link
	2	B	Q42 – Motor protection switch	IO-Link
	3	B	Q42 – Power contactor	IO-Link
	4	B	-	deactivated
	5	B	-	deactivated
	6	B	-	deactivated
	7	B	-	deactivated
	8	B	-	deactivated

In the following section, Figure 16 to Figure 18 illustrate the cabling of the individual conveyor segments.

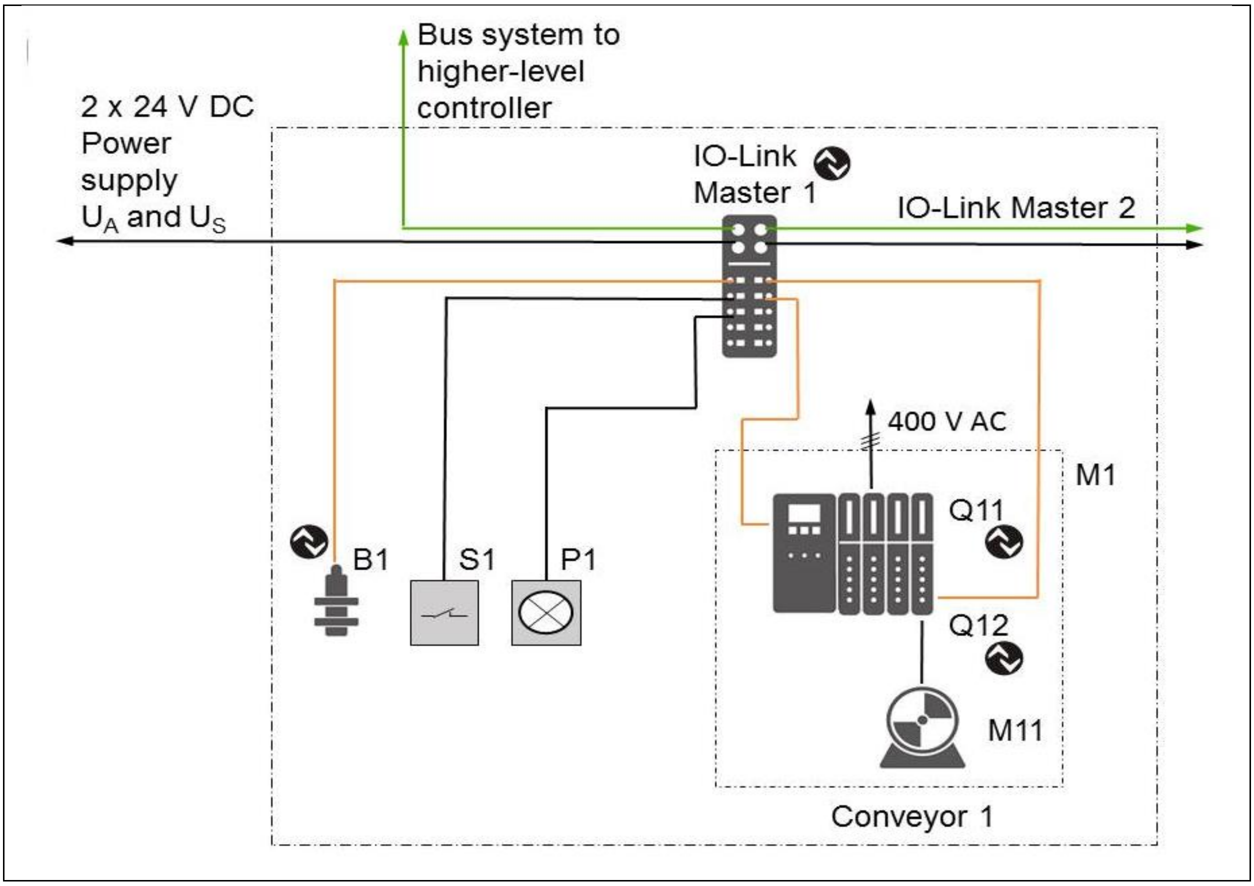

Figure 16: Topology of conveyor 1

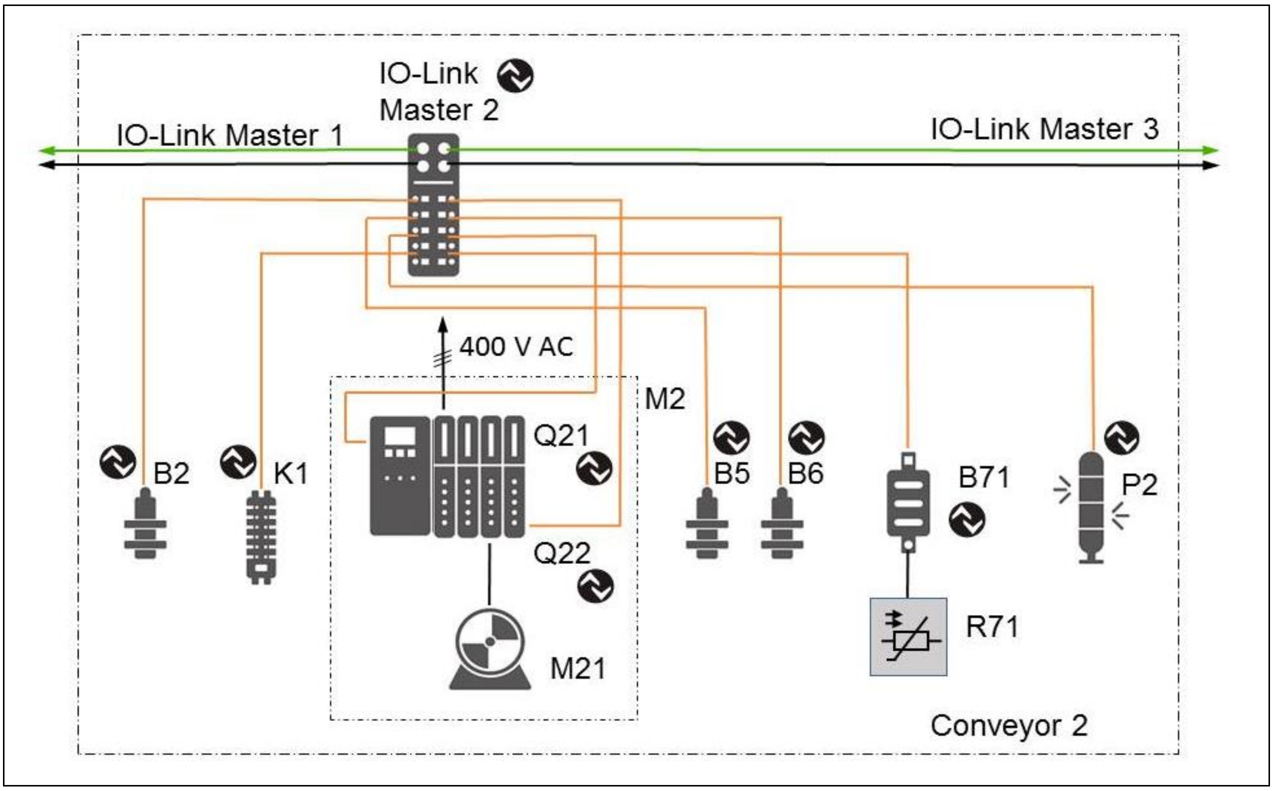

Figure 17: Topology of conveyor 2

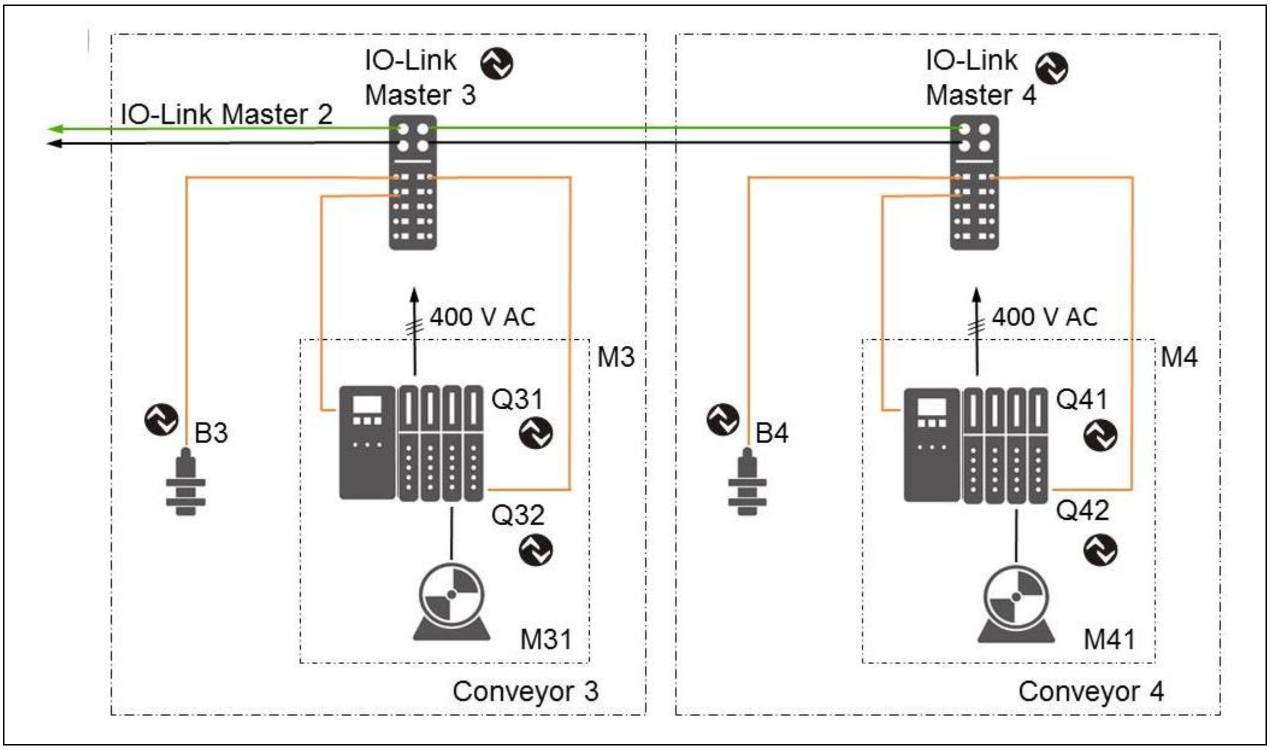

Figure 18: Topology of conveyors 3 and 4

3 Summary

This IO-Link Design Guideline is intended to familiarize the readers by means of action-oriented explanations with the planning and engineering of an automation system with IO-Link components. An exemplary model system helps to explain the difficulties that may arise in the course of the electrical engineering process and develop solutions for these problems.

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