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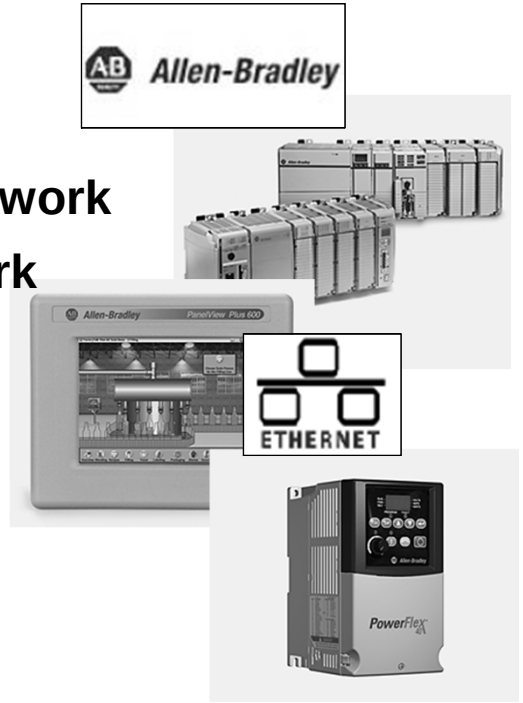
CoNeT Mobile Lab:
Ethernet IP on Allen Bradley platform

Introduction



1 Distributed control architecture

2 Real-time control system and real-time network

3 Monitoring and testing the Ethernet network

4 Introduction to EtherNet/IP technology

5 Introduction to laboratory:
Description of laboratory and basic scenario

6 Software tools

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What is EtherNet/IP?

- **EtherNet/IP** is an industrial application layer protocol (CIP) operating over the Ethernet medium and used for communication between industrial control systems and their components,
- By Ethernet, we mean a TCP/UDP/IP based network
- Typically 100 MBps Twisted Pair, star topology and switch
- Could be
  - 10 MBps Coaxial
  - 1 GBps Fiber
  - 11 MBps Wireless
- By CIP we mean the *Common Industrial Protocol.* **CIP™ is an *application protocol***. It defines rules for organizing and interpreting data and is essentially a messaging structure that is independent of the underlying physical layer. It is freely available and accessible to anyone, and widely supported by many manufacturers.

Specification downloadable at www.odva.org

EtherNet/IP can be easily confused as a combination of Ethernet (the physical layer, link, or medium used in most office and many industrial networking environments) and the Internet Protocol (IP)

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Why is worth to use EtherNet/IP?

- Open industrial networking standard,
- Designed for use in process control, hard real-time systems, industrial automation applications,
- Wide-spread standard (low cost per node),
- Classified as Class 1 Real Time Ethernet (can be extended to class 2),
- Emerged from Common Industrial Protocol,
- TCP/UDP/IP encapsulation,
- Ensures the desired level of service quality (QoS).

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EtherNet/IP in OSI Reference Model

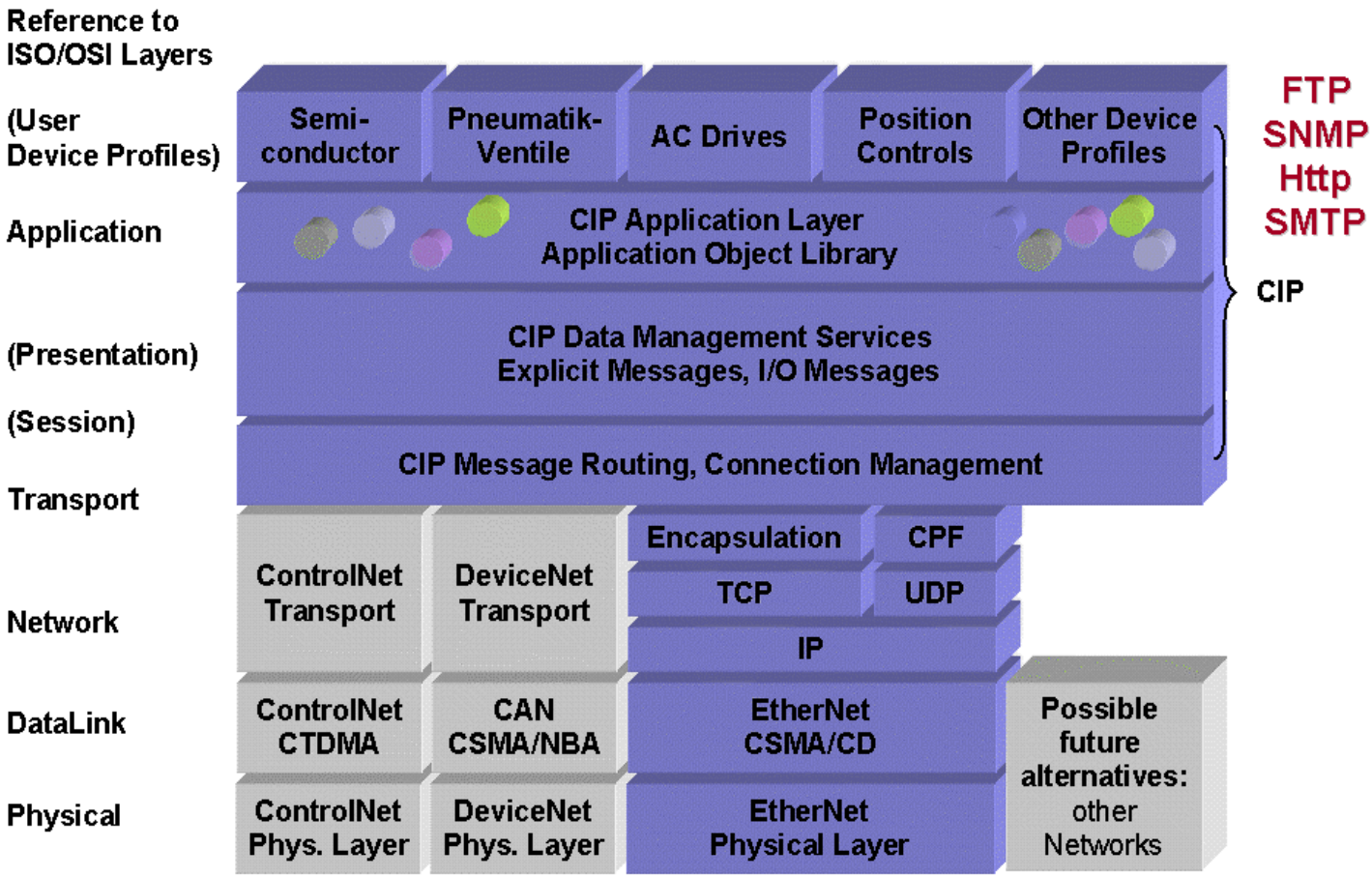

Fig. 4.1. (EtherNet/IP), Comparison of DeviceNet and ControlNet OSI [1]

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Ethernet/IP – type of messages

Explicit:

- Uses TCP/IP connections (port number 0xAF12),
- Client-server type transactions,
- Message connections are point-to-point communication paths between two devices,
- Forms of messaging:
  - Unconnected messaging (should be used only when the application requires very irregular and infrequent request intervals),
  - Connected messaging requires setting up a connection first, useful in applications that require periodic requests).

Implicit (I/O messaging):

- Uses UDP/IP connections (port number 0x08AE),
- Producer-Consumer type transactions,
- Data field contains only real-time data,
- UDP packets are transmitted using multicast communication (a specific device allocated IP multicast address).

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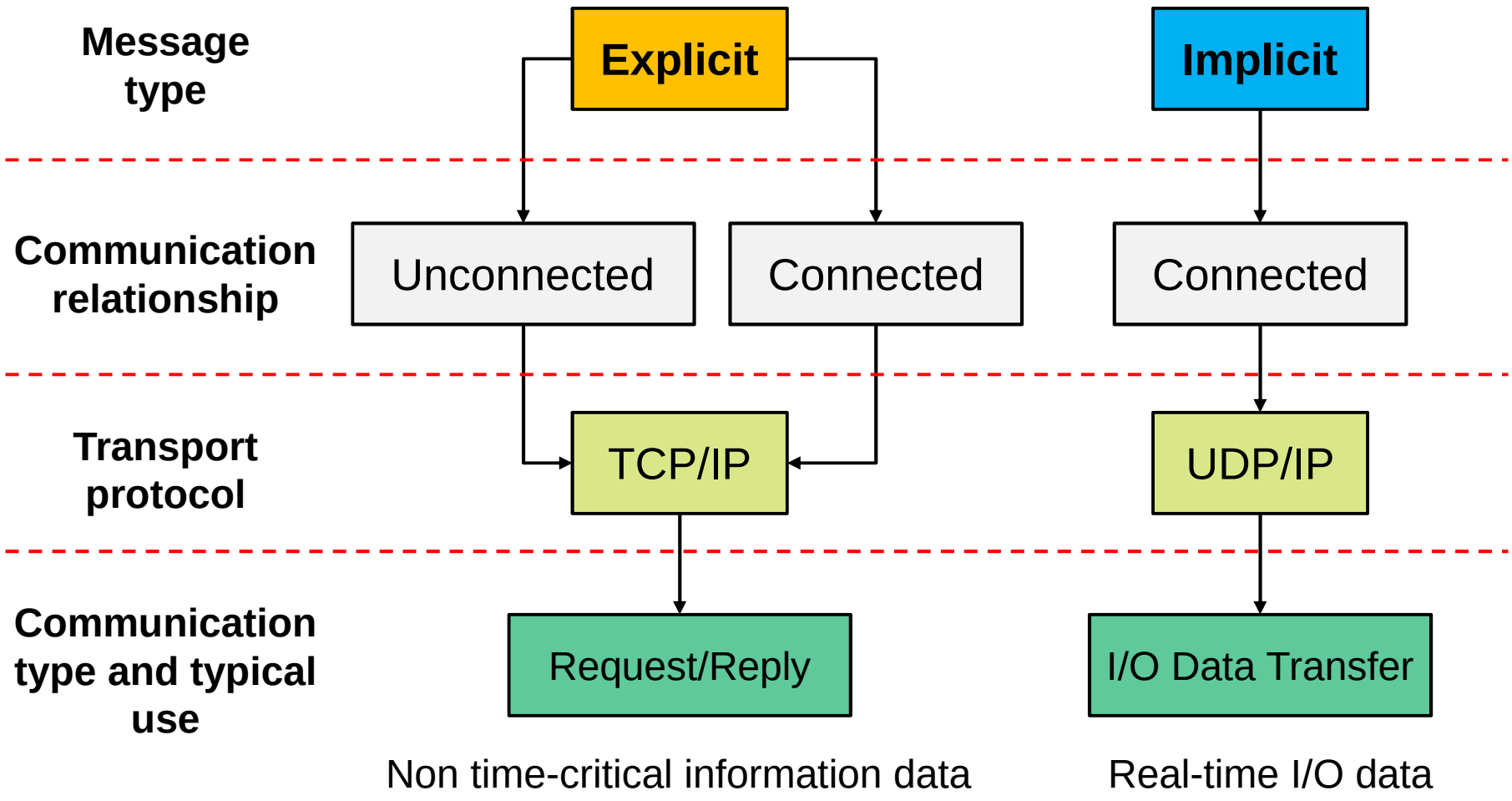
Ethernet/IP – Type of messages - Summary



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CIP device representation

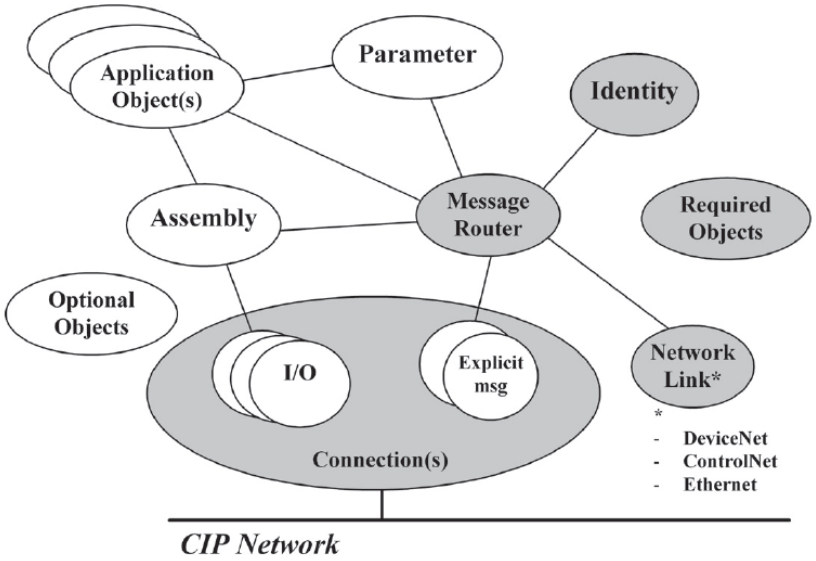

Fig. 4.2. . A typical CIP device representation

The objects required in a typical device:

- Connection Object,
- Identity Object,
- Network-specific link objects (depends on network),
- Message Router Object.

Access to the device requires object number, instance number and attribute number

The CIP Family of Protocols contains a large collection of commonly defined objects. The overall set of object classes can be subdivided into three types:

- General-use,
- Application-specific,
- Network-specific.

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CIP – Exemplary objects

The following group of objects is

Identity object

Mandatory Attributes:

- Vendor ID
- Device Type
- Product Code
- Revision
- Status
- Serial Number
- Product Name

Optional Attributes:

- State
- Configuration Consistency Value
- Heartbeat Interval
- Languages Supported

Application-specific object:

- AC/DC Drive
- Analog Group
- Analog Input Group
- Analog Output Group
- Analog Input Point
- Analog Output Point
- Block Sequencer
- Command Block
- Control Supervisor
- Discrete Group
- Discrete Input Group
- Discrete Output Group
- Discrete Input Point
- Discrete Output Point
- Group
- Motor Data
- Overload
- Position Controller
- Position Controller Supervisor
- Position Sensor
- Presence Sensing
- S-Analog Actor
- S-Analog Sensor
- S-Device Supervisor
- S-Gas Calibration
- S-Partial Pressure
- S-Single Stage Controller
- Safety Supervisor
- Safety Validator
- Softstart Starter
- Trip Point

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CIP – Device profiles

Devices of similar functionality have been grouped into Device Types with associated profiles

CIP profile contains the full description of the object structure and behavior:

- Communication networks,
- Objects

Device profiles:

- AC Drives Device (0x02)
- Communications Adapter (0x0C)
- Contactor (0x15)
- ControlNet Physical Layer Component (0x32)
- ControlNet Programmable Logic Controller (0x0E)
- DC Drives (0x13)
- DC Power Generator (0x1F)
- Encoder (0x22)
- Fluid Flow Controller (0x24)
- General Purpose Discrete I/O (0x07)
- Generic Device (0x00)
- Human Machine Interface (0x18)
- Inductive Proximity Switch (0x05)
- Limit Switch (0x04)
- Mass Flow Controller (0x1A)
- Motor Overload Device (0x03)
- Motor Starter (0x16)
- Photoelectric Sensor (0x06)
- Pneumatic Valve (0x1B)
- Position Controller (0x10)
- Process Control Valve (0x1D)
- Residual Gas Analyzer (0x1E)
- Resolver (0x09)
- RF Power Generator (0x20)
- Safety Discrete I/O (0x23)
- Softstart Starter (0x17)
- Turbomolecular Vacuum Pump (0x21)
- Vacuum/Pressure Gauge (0x1C)

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CIP connections

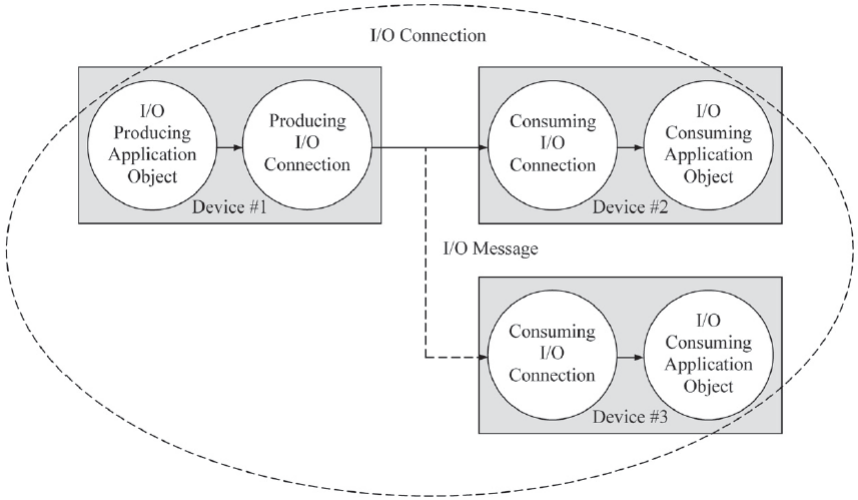

Fig. 4.3. Multicast I/O connection [1]

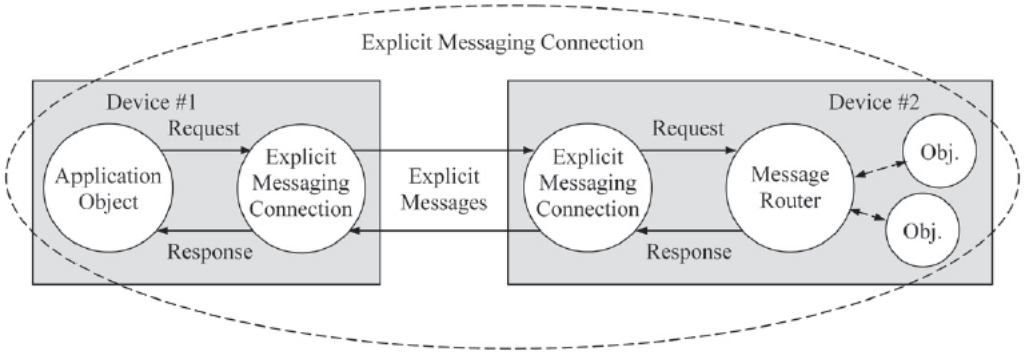

Fig. 4.4. Explicit connection [1]

All connections on EtherNet/IP are established using a UCMM (Unconnected Message Manager) Forward_Open message

When a connection is established, the transmissions associated with that connections are assigned a Connection ID (CID). If the connection involves a bidirectional exchange, then two Connection ID values are assigned

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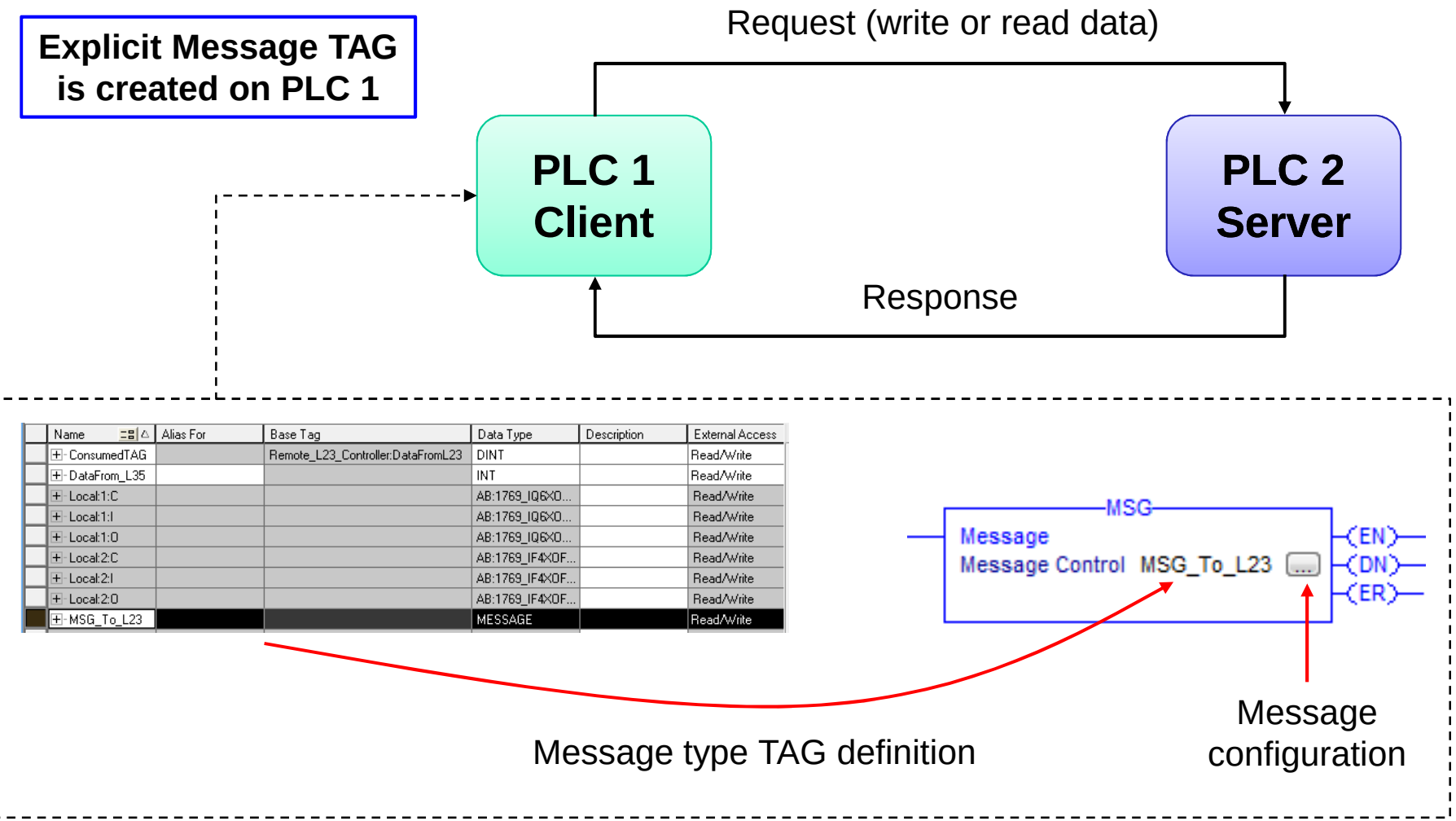
Explicit message – exemplary configuration

Explicit Message TAG is created on PLC 1



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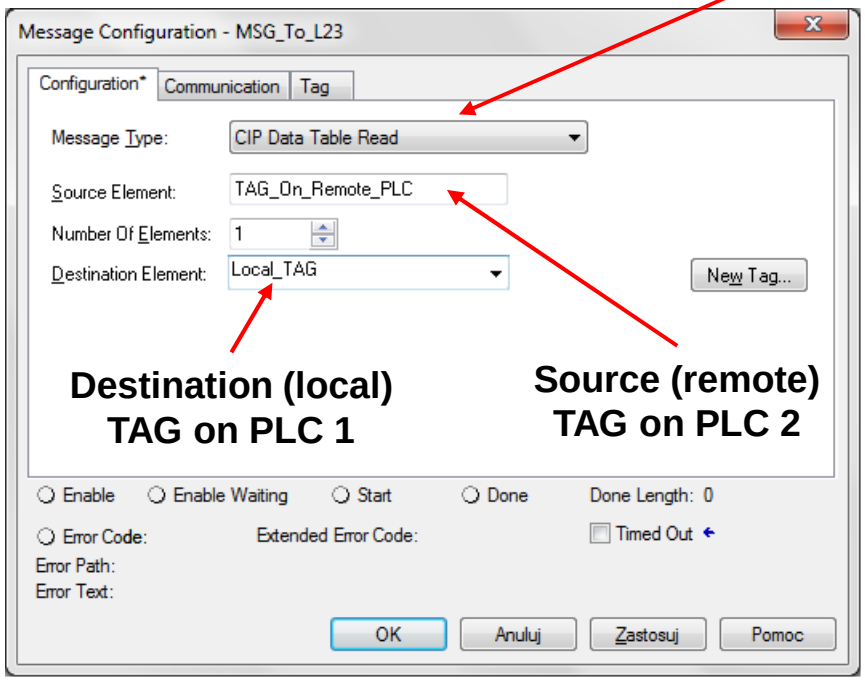
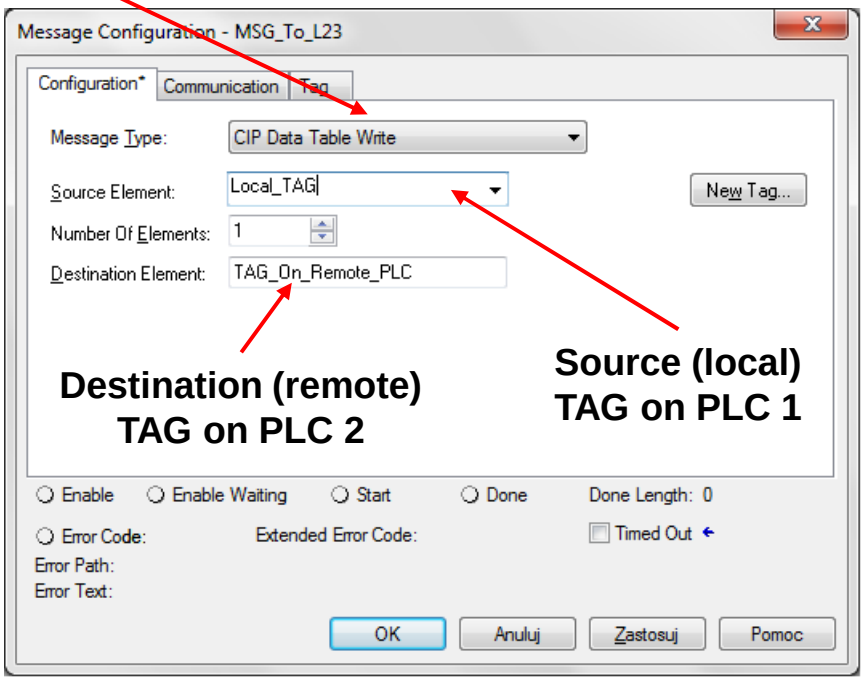
Explicit message – connection configuration

Explicit Message over Ethernet/IP must be:

- CIP Data Table Read – PLC 1 reads data from PLC 2.
- CIP Data Table Write – PLC 1 writes data to PLC 2.



Read message



Write message

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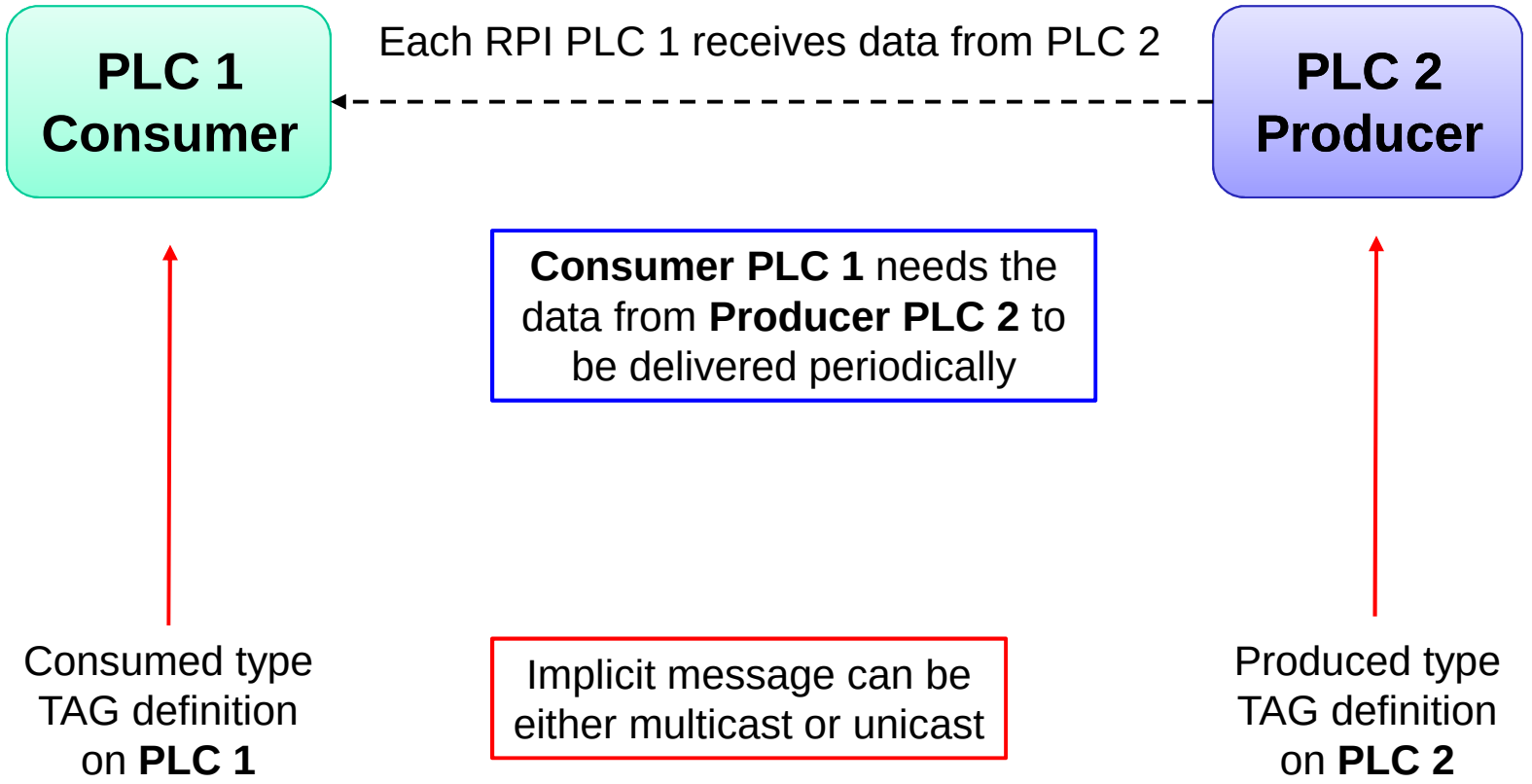
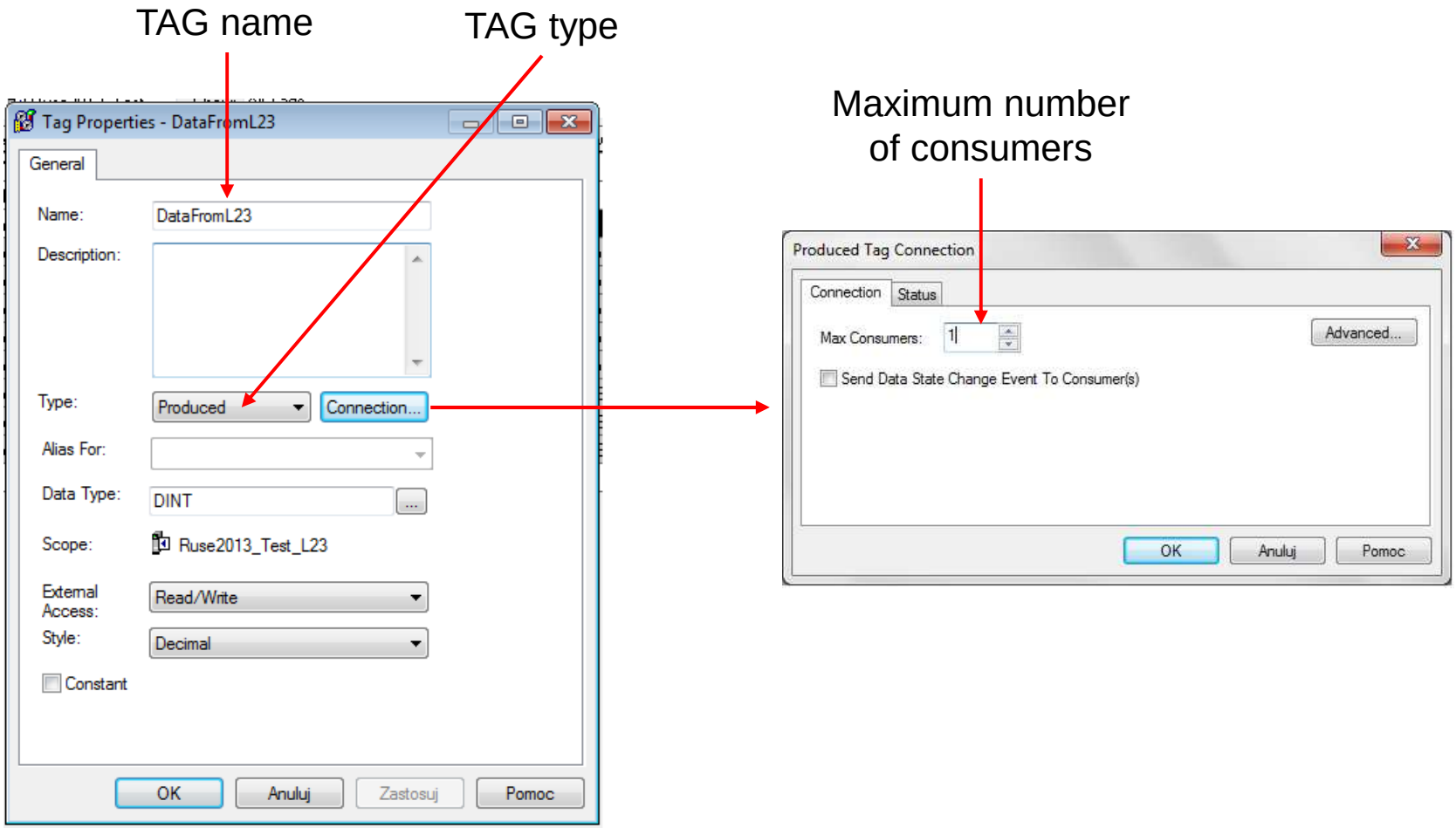
Implicit message – exemplary configuration



Producer TAG properties



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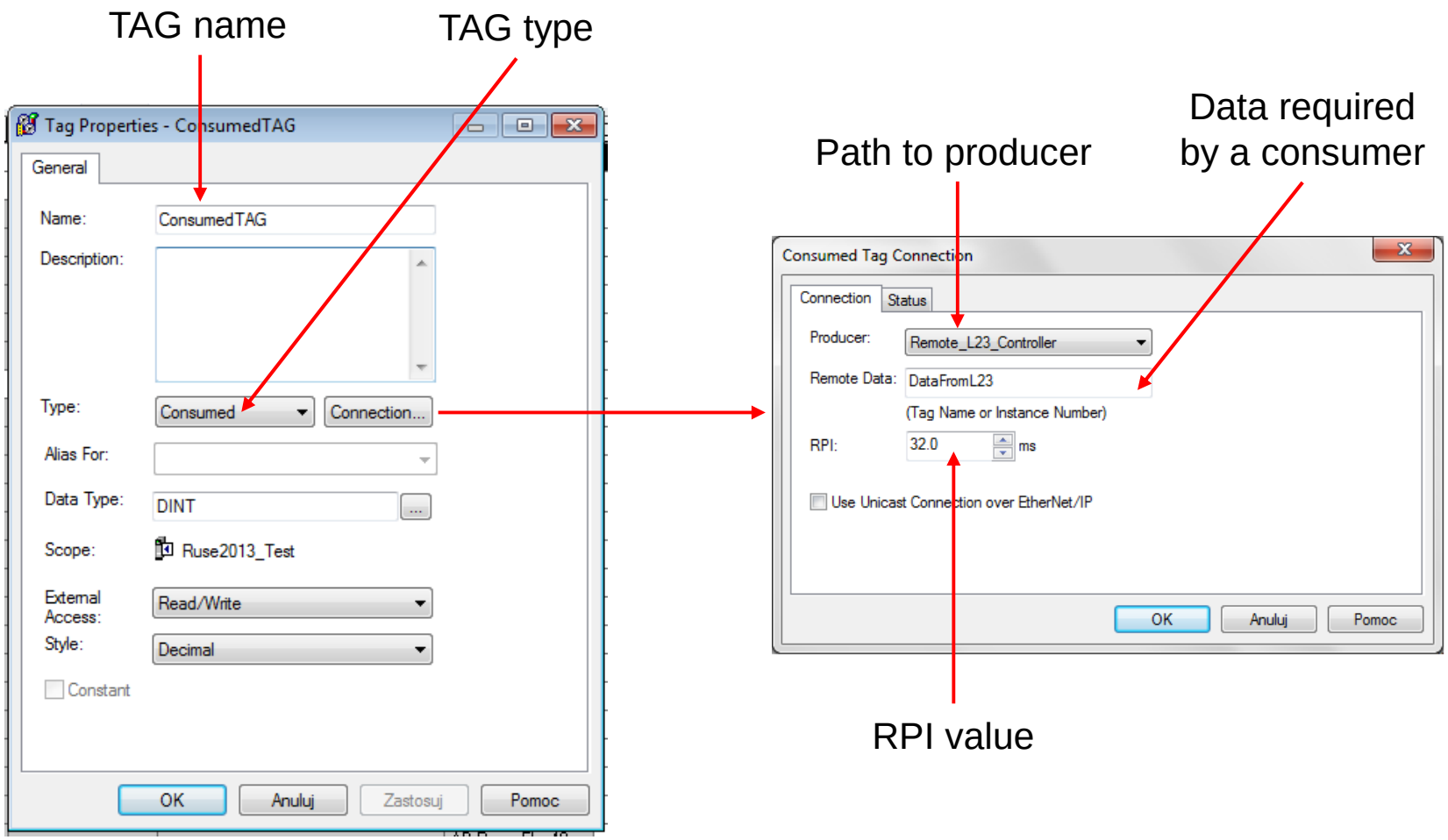
Consumer TAG properties



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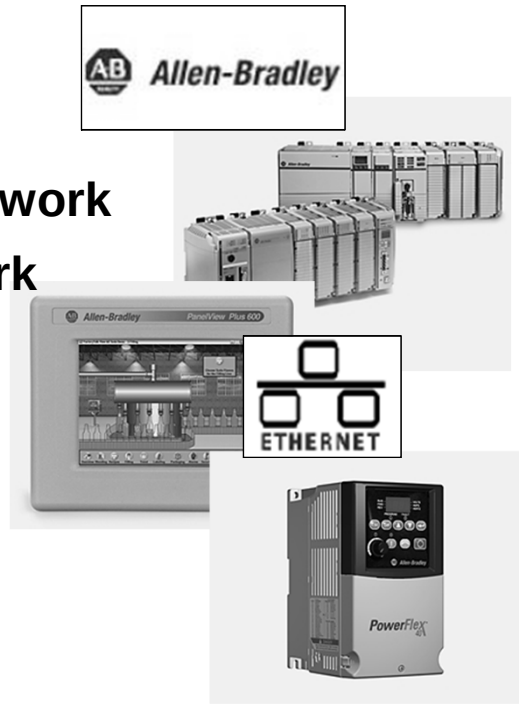

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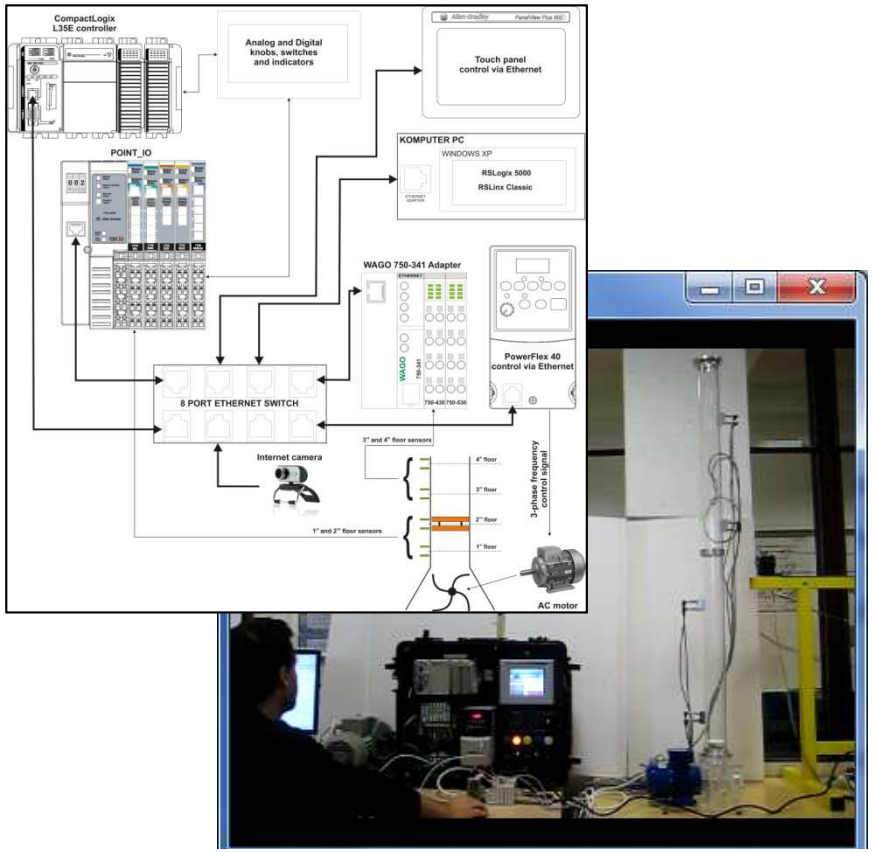
<5 Introduction to laboratory: Description of laboratory and basic scenario >

5.1 System architecture

5.2 Aerolift overview

5.3 Network structure

5.3 References



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System Architecture

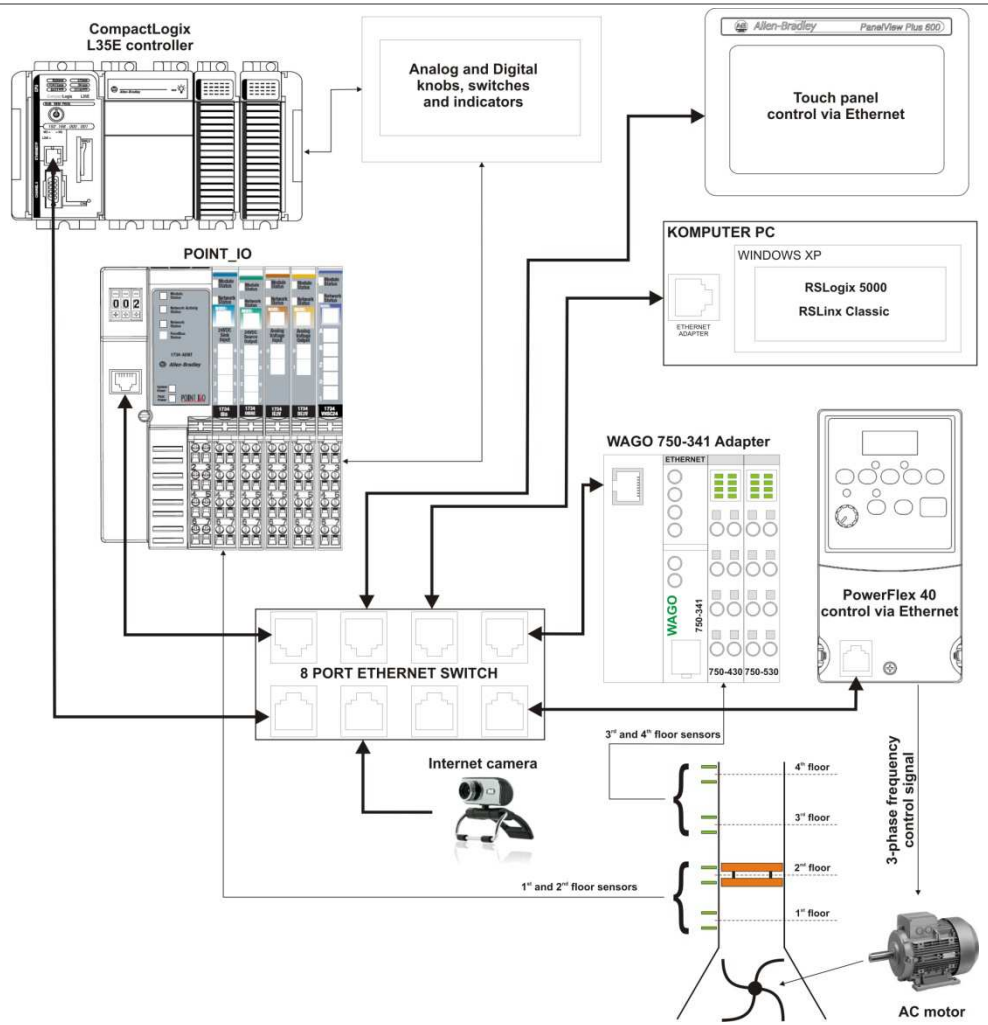

Fig. 5.1. Schematic diagram of the laboratory setup

Six nodes:

1. CompactLogix L35E PLC
2. POINT_IO: 1734-AENT
3. PowerFlex 40 inverter
4. WAGO 750-341 Coupler
5. Internet Camera (WebCam)
6. PanelView 600 Plus – Touch Panel (now unused)

Features:

- All nodes communicate via EtherNet/IP protocol
- All nodes are placed in a specially designed Allen-Bradley demo case
- PC is used as a development and Ethernet monitoring platform
- WebCam generates a noises in the network packet traffic

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Compact Logix Controller 1769-L35E

PLC CLC 1769-L35E is equiped with:

- CPU (Central Processing Unit)– firmware revision 19.0, 1.5 MB internal memory,
- One RS232 serial port and one 100Mb/s EtherNet/IP port,
- Compact Flash card socket,
- Power supply Allen-Bradley 1769-PA2: input:120/240VAC, output: 24VDC,
- Max. 30 local IO modules,
- EtherNet/IP Connections: 32 TCP/IP – 32 CIP.

Local I/O Modules:

- the Digital I/O module Allen-Bradley 1769-IQ6XOW4 (firmware revision 2.1 series B),
- the analog I/O module Allen-Bradley 1769-IF4XOF2 (firmware revision 1.1 series A),
- the terminal of the CompactBUS Allen-Bradley 1769-ERC.

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Compact Logix Controller 1769-L35E - local I/O Modules

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Table 5.1. The main parameters of the CompactLogix L35E local I/O modules

1756-ENBT	1769-IQ6XOW4	1769-IF4XOF2
• Interface for a ControlLogix controller to communicate with other devices over an EtherNet/IP network, • Adapter for 1756 I/O modules, • Web server to provide diagnostic and status information, • Communication via produced/consumed tags and MSG instructions.	• 6 digital inputs 24V DC (sinking/sourcing), operating voltage range 10 to 30 V, • 4 digital outputs 24V relay (AC/DC), operating voltage range 5 to 265V AC and 5 to 125V DC • I/O diagnostic LEDs.	• 4 analog inputs (differential or single-ended), analog normal operating ranges: voltage 0-10V, current 0-20 mA, resolution: 8-bits plus sign, response time: 5 ms/channel, • 2 analog outputs (single-ended), analog normal operating ranges: voltage 0-10V, current 0-20 mA, resolution: 8-bits plus sign, response speed: 0.3 (resistance, inductor), 3 ms (capacitance).

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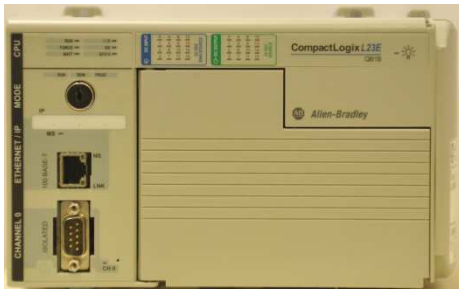
Compact Logix Controller 1769-L23E

The 1769-L23E CompactLogix system is a packaged controller for smaller, machine-level control applications.

PLC CLC 1769-L23E is equiped with:

- CPU (Central Processing Unit)– firmware revision 19.0, 512 kB internal user memory,
- Max. 128 I/O points,
- One RS232 serial port and one 100Mb/s EtherNet/IP port,
- EtherNet/IP Connections: 8 TCP/IP – 32 CIP,
- 16 DC inputs: 24VDC,
- 16 DC outputs: 24VDC,
- Max. 3 local IO expansions.



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POINT_IO Modules

Table 5.2. Parameters of the distributed POINT_IO modules

1734-AENT	• Serves as a bridge between POINT I/O modules and the Ethernet/IP network, • Provides communication for *CompactLogix*, *ControlLogix* controllers (supports of connections from multiple controllers simultaneously), • Communication via produced/consumed tags, • EtherNet/IP messages encapsulated within standard TCP/UDP/IP protocol, • Half/full duplex 10 Mbit or 100 Mbit operation (RJ-45, interfacing via category 5 rated twisted pair cable).
1734-IB8	• 8 digital inputs module: 24 V DC, sink, • Operating voltage range: 10…28.8 V DC. • Allows input filter time in the range of 0…63 ms.
1734-OB4E	• 4 digital outputs module: 24 V DC, source, • Output current rating max. 1 A/channel, • Outputs are not isolated, • Operating voltage range: 10…28.8 V DC.

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POINT_IO Modules

Table 5.2. Parameters of the distributed POINT_IO modules

1734-IE2V	• 2 analog inputs module. Operating ranges voltage: -10... +10 V. • Input resolution: 15-bits plus sign (–32,768...+32,767), • The module produces 6 bytes of input data and fault status data: 2-bytes data/channel, 1-byte status/channel, • Operates in unipolar or bipolar mode.
1734-OE2V	• 2 analog outputs module. Output voltage signal range: 0... +10 V or -10... +10 V, • Output resolution: 13-bits plus sign (–32,768...+32,767), • The module consumes 4 bytes of output data: 2-bytes/channel, • The module produces 2 bytes of fault status data: 1-byte/channel, • Operates in unipolar or bipolar mode, 20μs conversion rate.
1734-VHSC24	• Very High Speed Counter module: 24V, • Accepts feedback from an encoder (either single ended or differential), pulse generators, or mechanical limit switches at frequencies up to 1 MHz, • Allows filtering with four settings (50Hz, 500Hz, 5kHz or 50kHz).

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Allen-Bradley PowerFlex 40 AC

Main features of the PowerFlex40 AC drive:

- Integral keypad for simple operation and programming,
- 4 digit display with 10 LED indicators for display of drive status,
- Communication with PC using the RS-485 interface, Ethernet/IP (also DeviceNet, PROFIBUS DP, LonWorks and ControlNet interface are available),
- Autotune allows to adapt to individual motor characteristics,
- Sensorless Vector Control provides exceptional speed regulation and very high levels of torque across the entire speed range of the drive,
- Built-in PID cotroller,
- Timer, Counter, Basic Logic and StepLogic functions,
- Built-in digital and analog I/O (2 analog inputs, 7 digital inputs (4 fully programmable), 1 analog output, 3 digital output),
- Easy set-up over the network (RS NetWorx property).

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PanelView Plus 600 & EtherNet/IP Configuration

- Works as an operator interface,
- Works under Windows CE operating system,
- Communication via Ethernet interface,
- Has possibilities in data presenting, trends and data collection,
- Visualization can be implemented using RSView Studio environment.

The information required to configure the network:

- Parameters of the Ethernet network: IP address, Subnet mask, Gateway address.
- Types and parameters of the installed modules.
- Requested Packet Interval (RPI) time.

The **RPI** is a common parameter configuration for all the modules connected to a network. It specifies the period at which data is updated over a connection.

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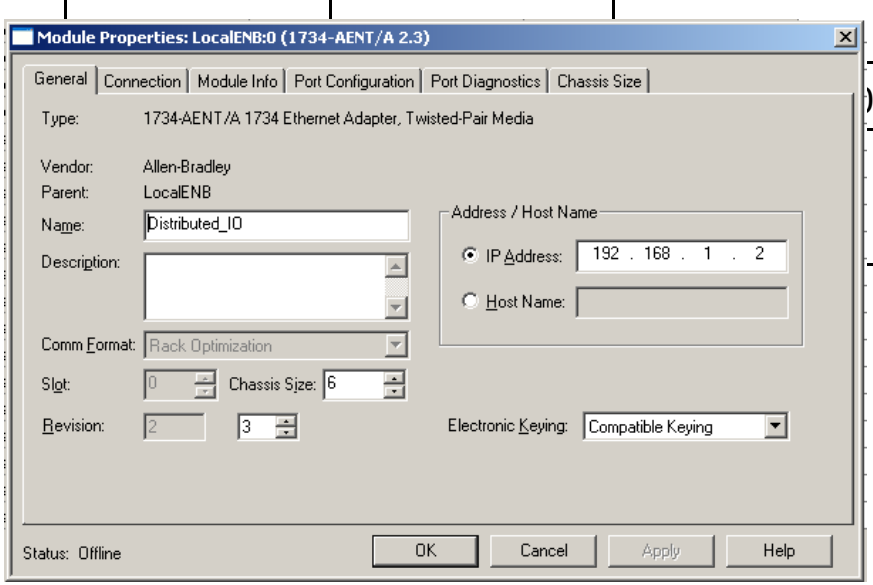
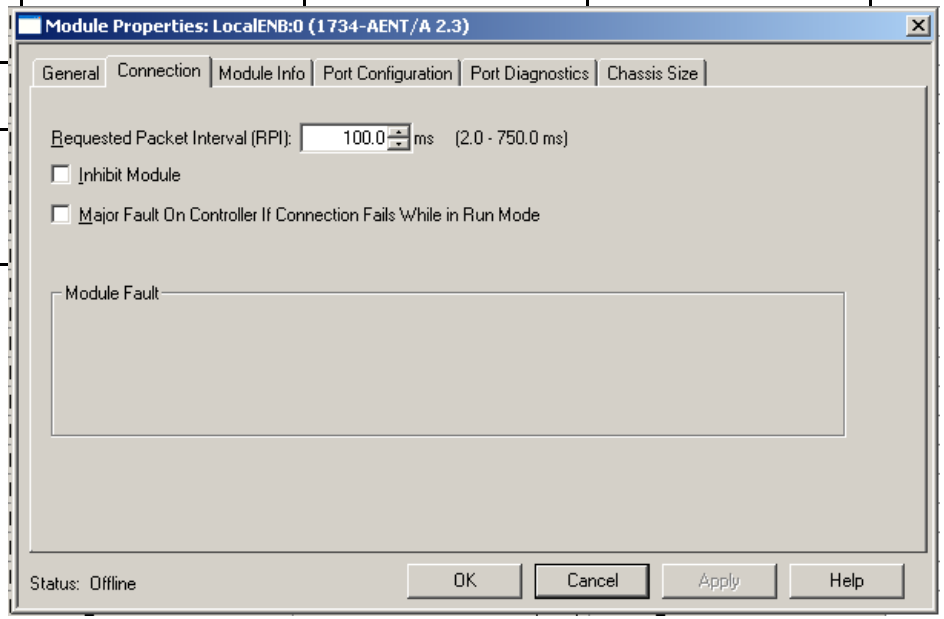
EtherNet/IP Configuration

Configuration is performed using RSLinx and RSLogix 5000 software.

Table 5.4. Ethernet/IP parameters of the laboratory setup modules

	CompactLogix L35E	1734-AENT	PanelView Plus 600	PowerFlex40	CompactLogix L23E





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Aero-Lift Test Rig

- 4 floor building model.
- Sensors – meassure the cart position and detect the cart motion.
- High level control – automata that have 8 inputs and one output.

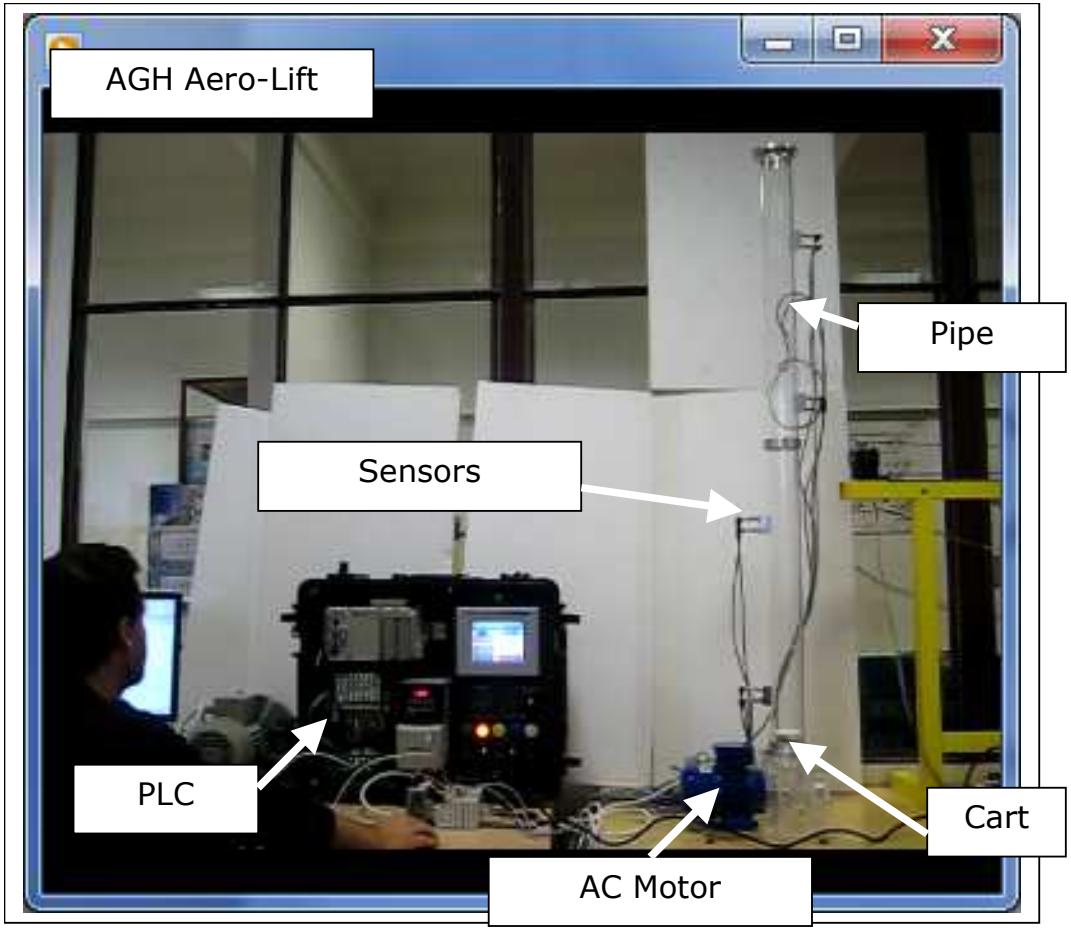

Fig. 5.2. Aero-Lift - laboratory test-rig

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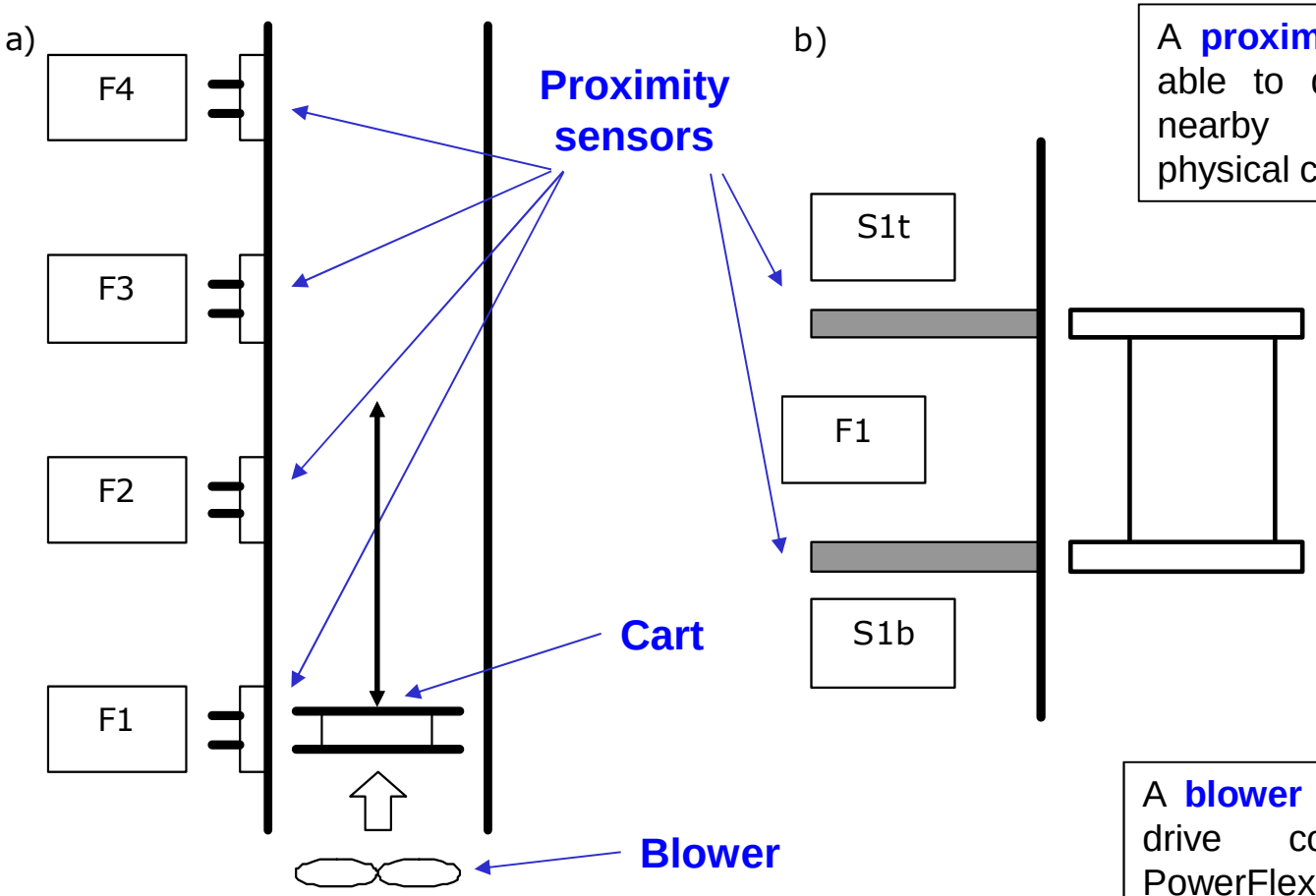
Aero-Lift Test Rig



A **proximity sensor** is a sensor able to detect the presence of nearby objects without any physical contact

A **blower** is supplied by 3-phase drive controlling from the PowerFlex inverter

Fig. 5.3. Aero-Lift test rig: a) system overview, b) floor configuration

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Basis of the PLC controller

PLC controller is an industrial computer, which works under the real time operation system.

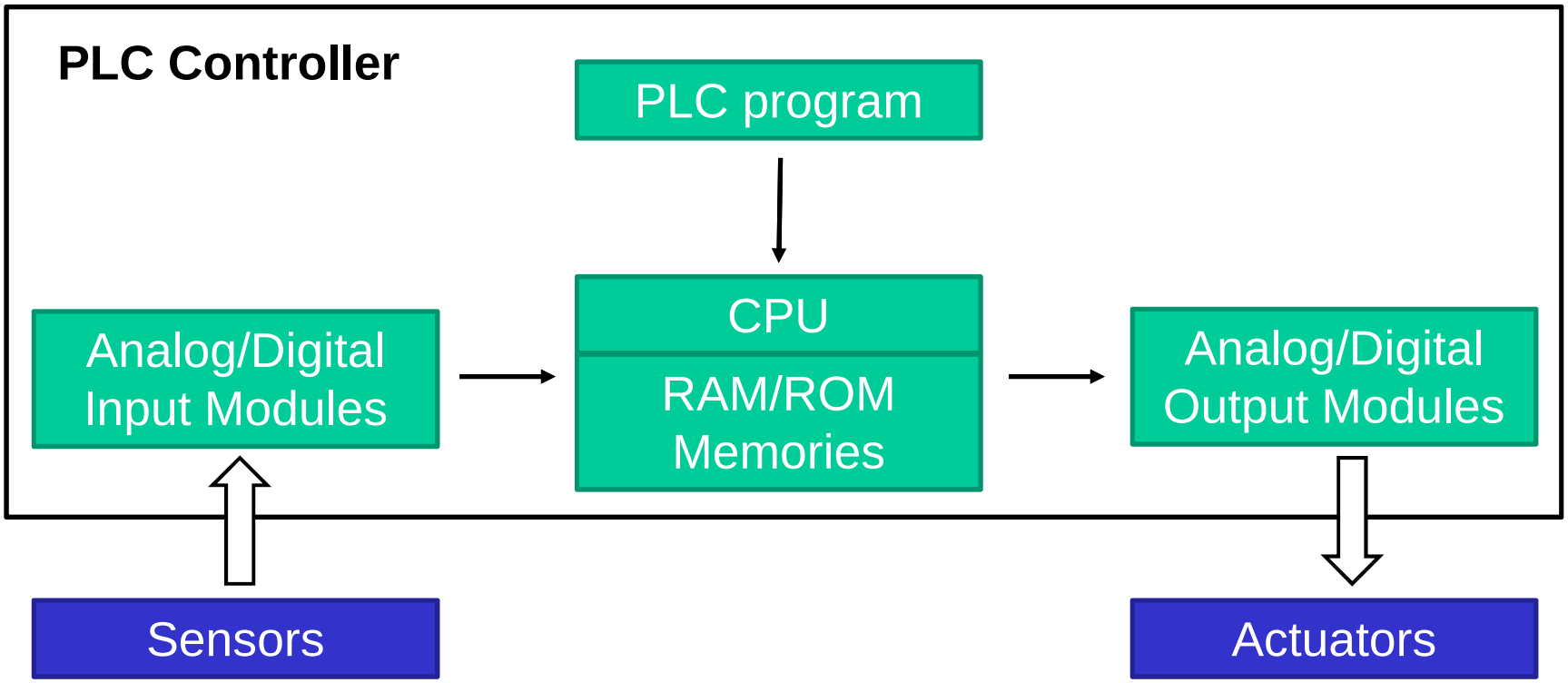

Fig. 5.4. Components of the PLC system

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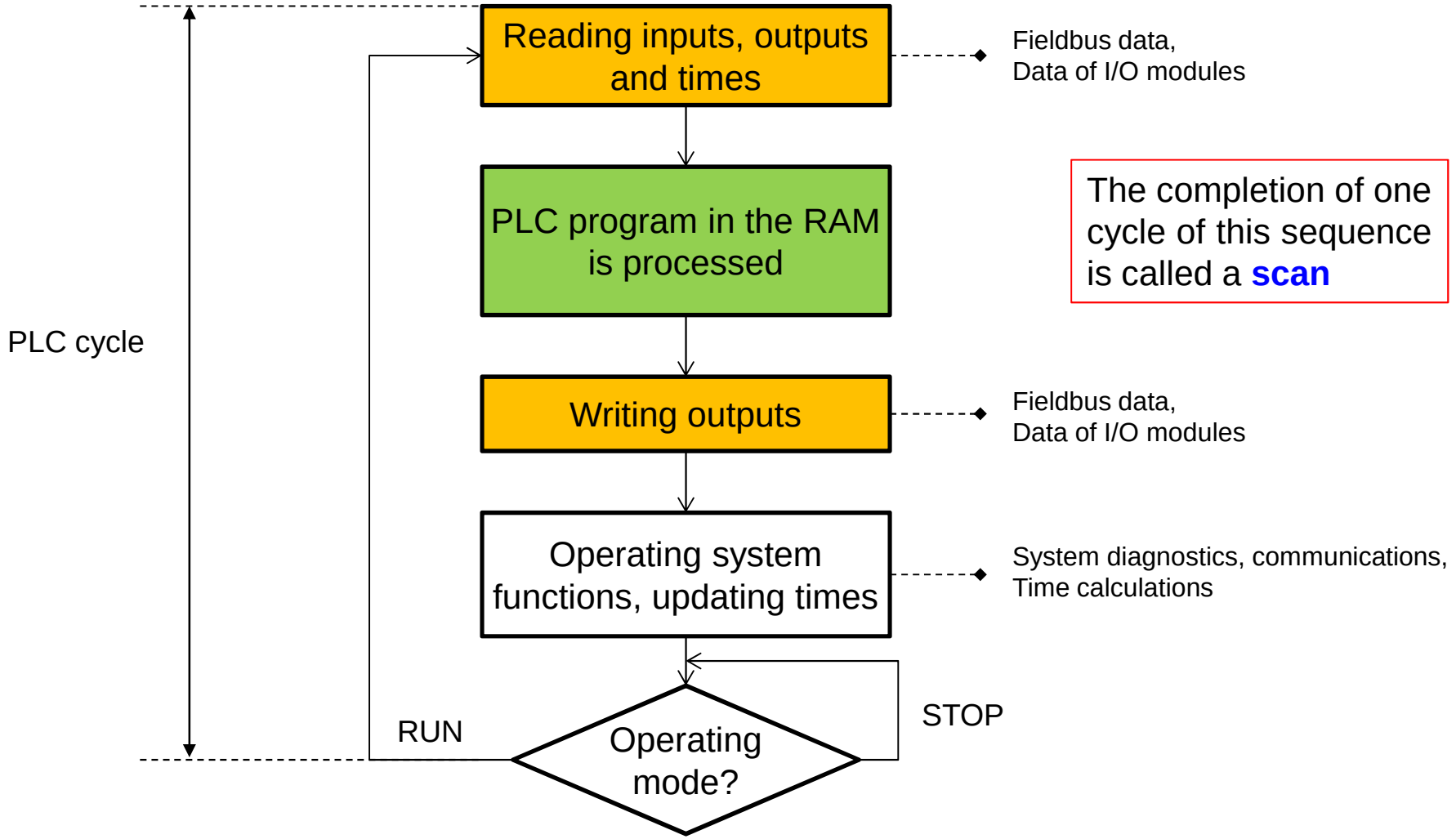
PLC operating cycle



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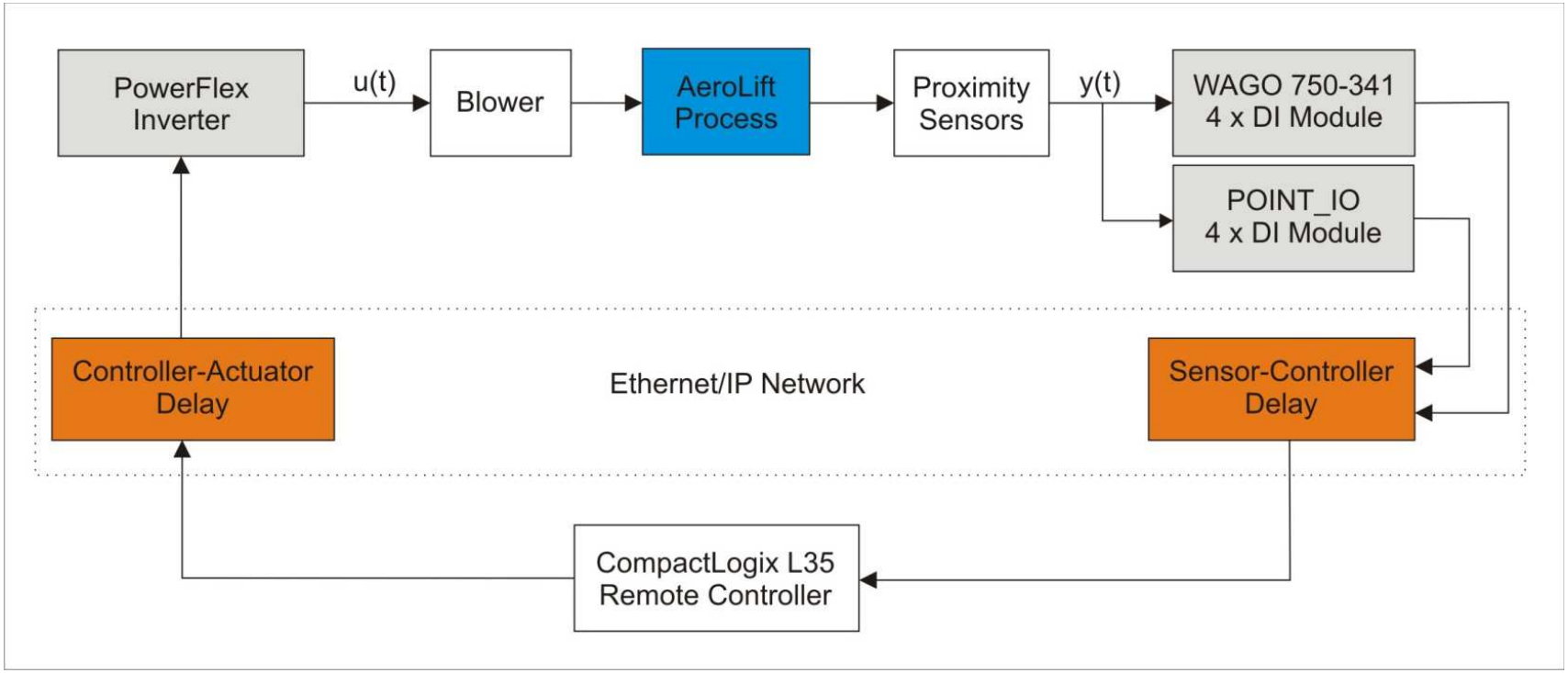
Real-time network structure



The presented structure can be used to demonstrate the performance of the Ethernet/IP protocol and observe propagation time delays between sensor - remote controller and remote controller - actuator.

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Configuration User Interface

Aero-lift – the dynamical system sensitive for sampling time and latency in data transmission

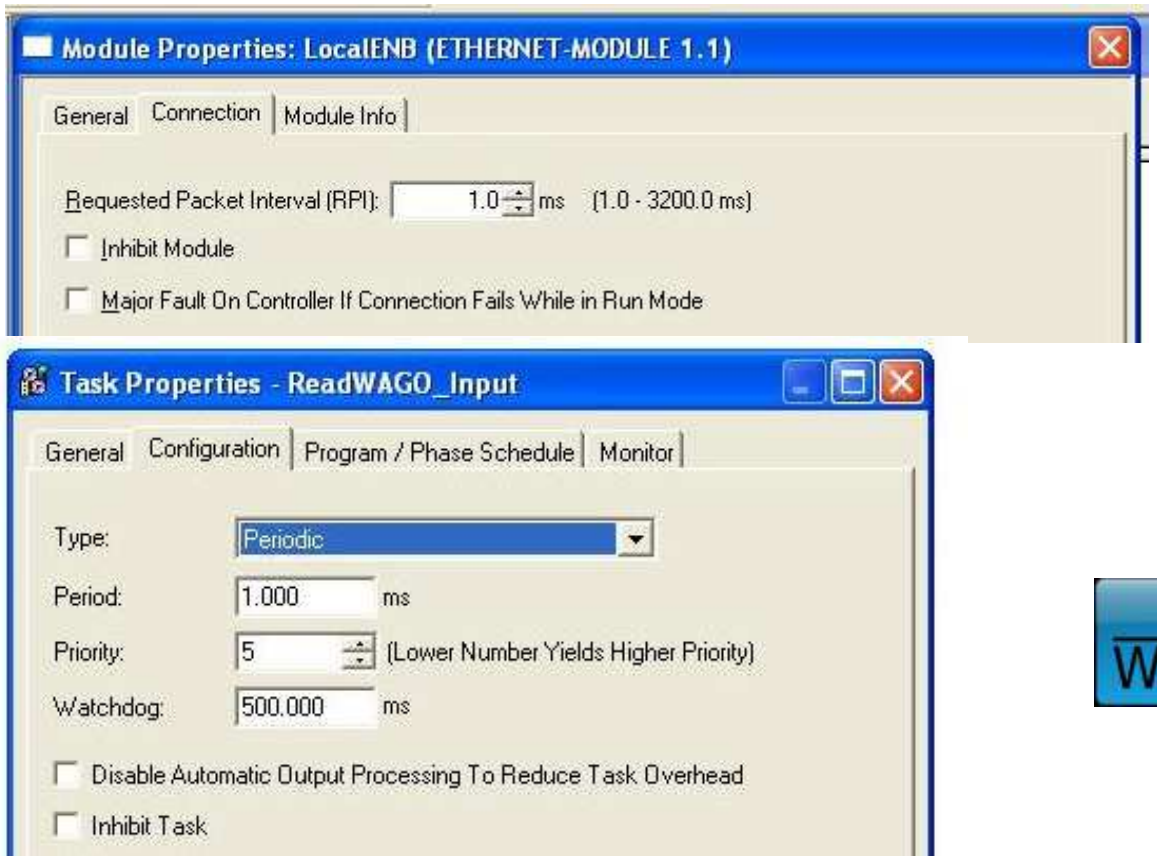

Fig. 5.4 User Configuration Interface

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Real-time network structure

What are the parameters deciding about a network control system quality and performance?

1. Scan time of a PLC.
2. Period time of an implemented Periodic Task.
3. Requested Packet Interval (RPI) time.
4. Latency in a data transmission.

Possible problems to be solved on the laboratory setup:

1. Analyzing an influence of the sampling frequency and/or the RPI on the AeroLift stability and controllability.
2. Determination of a propagation time delays between sensor-remote controller and actuator in the Ethernet/IP network based on packet analysis.
3. Analyzing an influence of the latency time, observable as a jitter in the data delivery, on performance and quality of the control network system (to diagnose these effect the WireShark application can be used).

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References

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