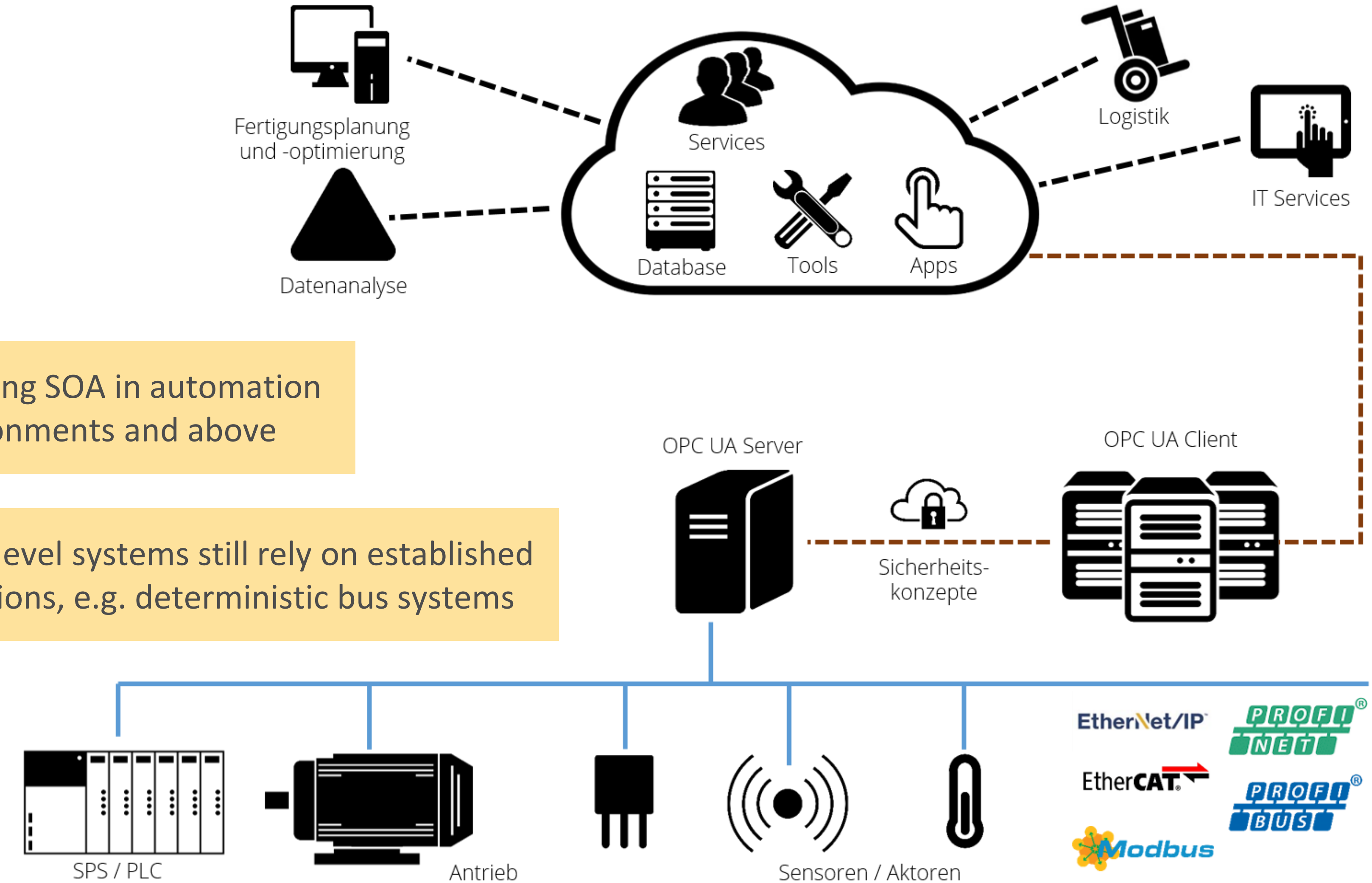
Object-Oriented Programming In Mechatronic Systems

Summer School

Module 7
Aachen, Germany, August 10th, 2018

Cybernetics Lab IMA & IfU
Faculty of Mechanical Engineering
RWTH Aachen University

Field bus protocols and propagation into higher information systems



→ Enabling SOA in automation environments and above

→ Low-level systems still rely on established solutions, e.g. deterministic bus systems

Introduction to real time control

Ambiguity of the term ‚real-time‘

Real time in everyday language

- Real time computer strategy games vs. Turn based (computer) strategy games

- Players actions are *immediately* visible

- Player has to react to opponents actions on time

- Example of a Turn based game: chess
- Opponents act one after the other
- No instant reactions

Ambiguity of the term ‚real-time'

Communication by mail

- My letter might take days to arrive at the recipient
- Day of delivery, even delivery itself is uncertain
- Same holds for the answer

- Realtime? No!

Communication by eMail

- eMail is typically delivered after a short amount of time (seconds or minutes, not days)
- But: Time of delivery, even delivery itself is still uncertain
- Same holds for the answer

- Realtime? No!

Introduction to real time control

Ambiguity of the term ‚real-time'

Communication by telephone

- My message is delivered instant
- Delivery of message < 1 second
- Recipient can answer instantly
- Connection sometimes of bad quality, not everything someone said can be understood

- Realtime? Kind of…

Can a common definition be derived from the foreseen examples?

- Keywords used so far:
  - Fast
  - Instantly
  - Guaranty of Delivery

- Strong definition needed of the terms described before

Definition of the term ‚real-time'

! There exists an upper bound of time after which a response to a certain event is seen.

Soft real-time

- Answers have to arrive in a fixed time
- Some answers might be lost
- Answers that are too late are useless, but will not break the system

- Telephone (VoIP)
- Video Streaming

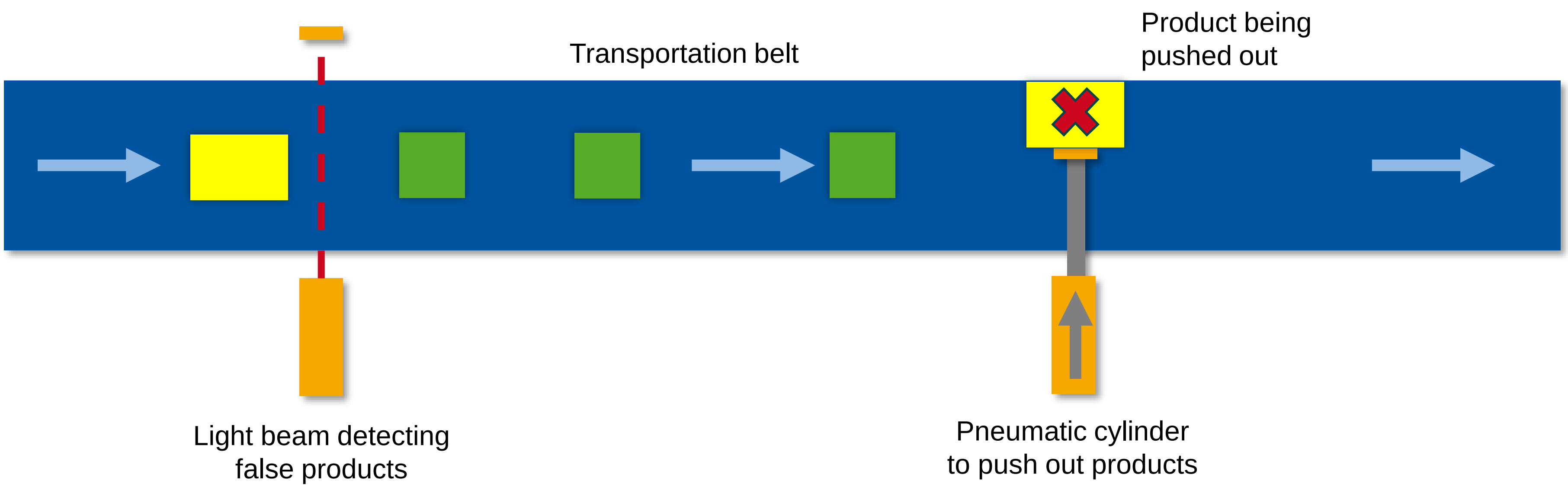
Hard real-time

- Answers have to arrive in a fixed time
- No Answer might be lost
- Answers that are too late are useless and will furthermore break the system

- ESP, ABS, Airbag Control in cars
- Machine control

A typical task in automation: Sensor-Actor coupling

- Detection of false products on a transportation belt by a light beam (e.g. products that are too large)
- A pneumatic cylinder will push out false products
- To push out the correct product, the cylinder has to react at exactly the right time
- Being a little too early or a little too late will result in failures



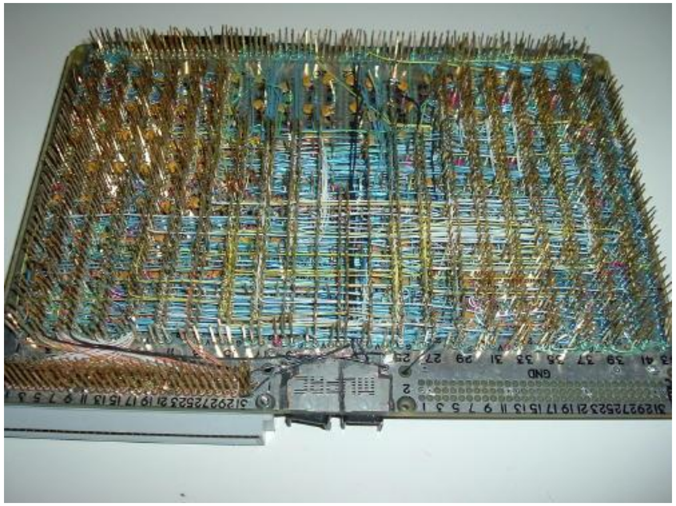
Introduction to real time control

Machinery control based on PLCs

- PLC – **P**rogrammable **L**ogic **C**ontroller
- SPS – **S**peicher**p**rogrammierbare **S**teuerung

- Allow programming of logical control functions by means of a program resisting in memory

Dick Morley, Tom Bossevain, George Schwenk, and Jonas Landau with the first ever PLC "MODICON 084" in 1969



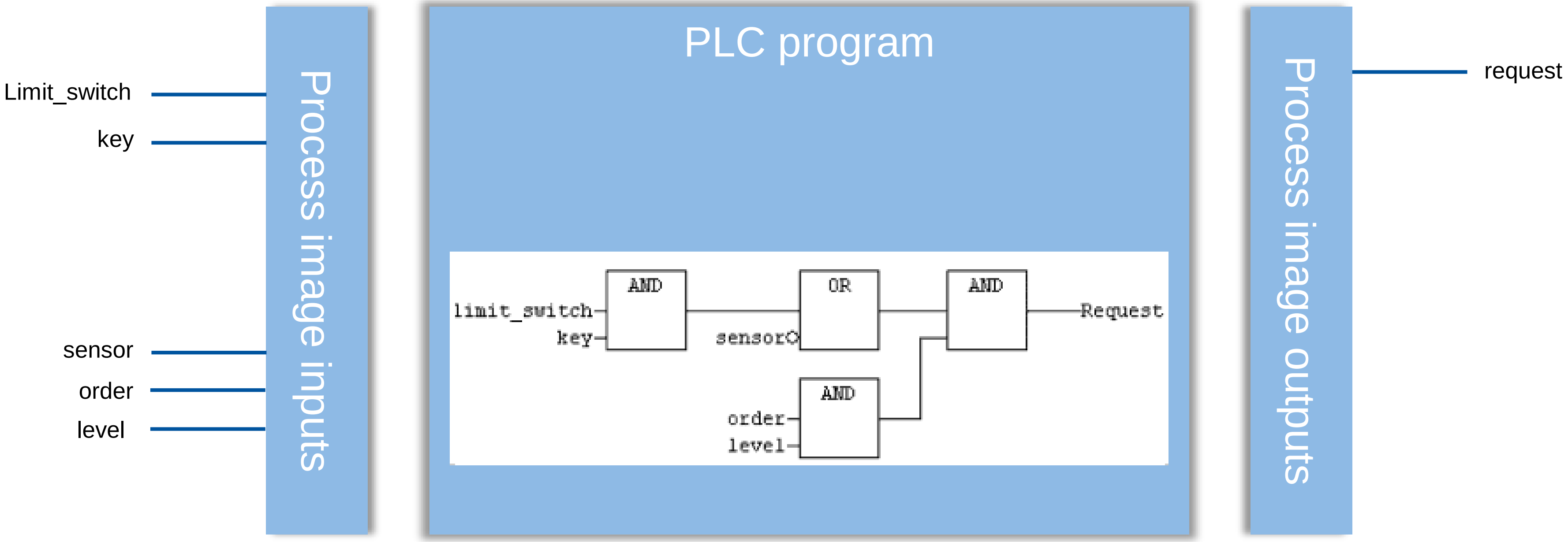
Example of a „wire-wrap“ logical controller board

- Former machinery control did not allow memory residing control flows, instead everything had to be hard wired

- Still visible today in the different programming languages used in PLCs

The basics of a PLC

- Process image of input and outputs
  - Data representation of physical input and outputs as well as virtual inputs and ouputs
- PLC program
  - Logic control function setting outputs depending on inputs



The PLC Scan Cycle

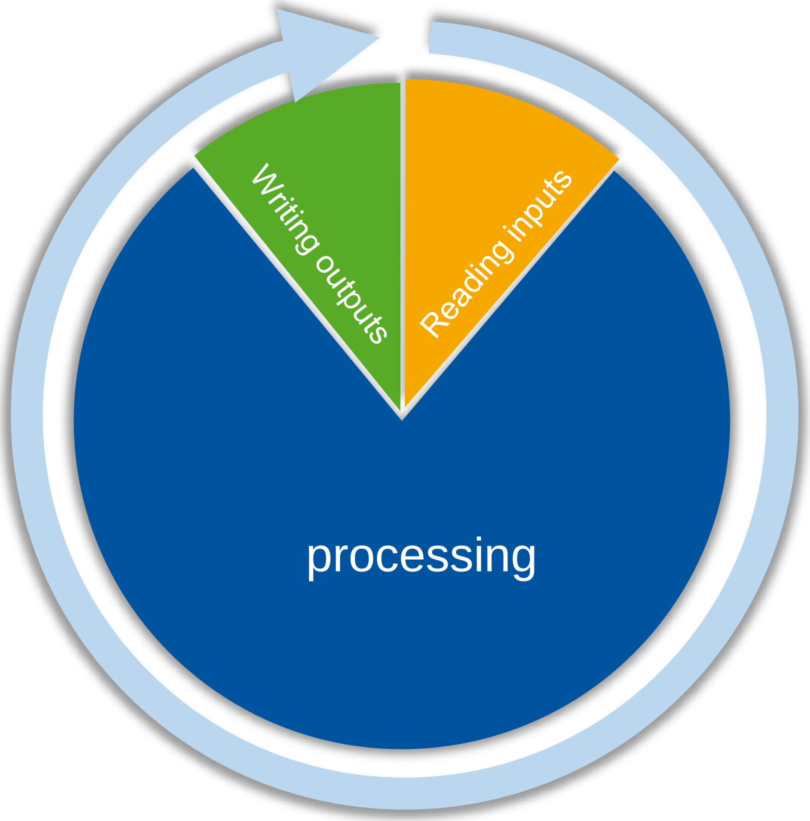
- PLC programs are cyclic programs, they never terminate (purposely)

- Reaction time is predictable
- Upper bound is fixed

- Cycle scan consists of
  1. Reading Inputs
  2. Processing
  3. Writing outputs

- Worst case reaction time to changing inputs?

$$t_{react,max} \leq 2 * t_{cycle}$$



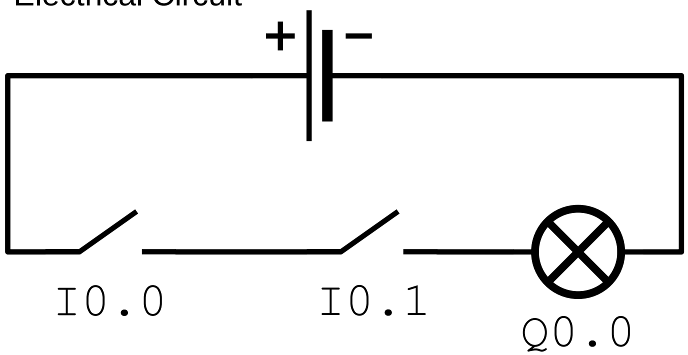
1. There will be no reaction to inputs pulses shorter than cycle time
2. Outputs won‘t be written until output cycle

Logical Operators
AND

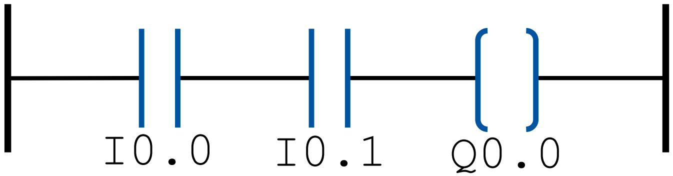
Example

Turn on the light (Q0.0), if, and only if, the two switches I0.0 and I0.1 are switched on.

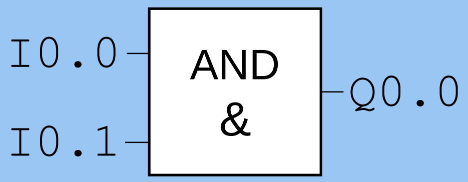
Electrical Circuit



Ladder Diagram (FBD)



Function Block Diagram (FBD)



Instruction List (IL)

```
LD      I0.0
AND     I0.1
=       Q0.0
```

Truth Table

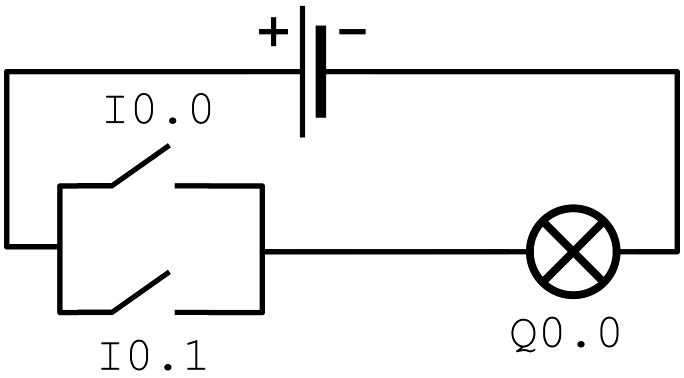
I0.0	I0.1	Q0.0
0	0	0
0	1	0
1	0	0
1	1	1

Logical Operators
OR

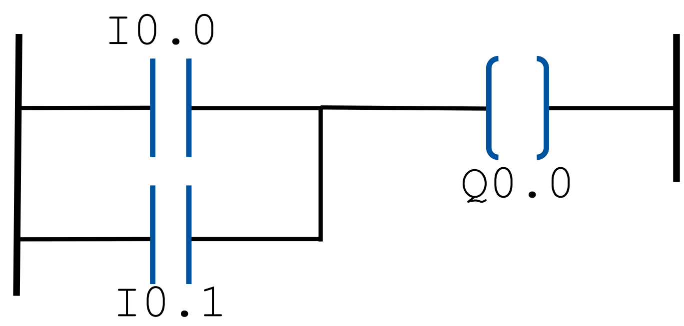
Example

Turn on the light (Q0.0), if either of the two switches I0.0 and I0.1 is switched on.

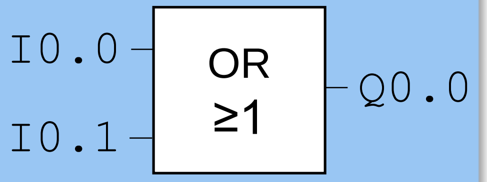
Electrical Circuit



Ladder Diagram (FBD)



Function Block Diagram (FBD)



Instruction List (IL)

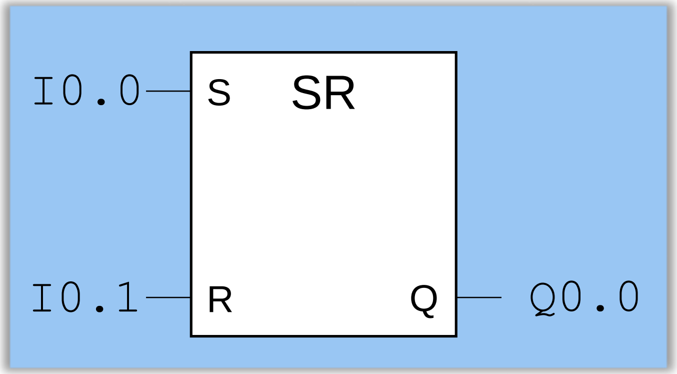
```
LD     I0.0
OR     I0.1
=      Q0.0
```

Truth Table

I0.0	I0.1	Q0.0
0	0	0
0	1	1
1	0	1
1	1	1

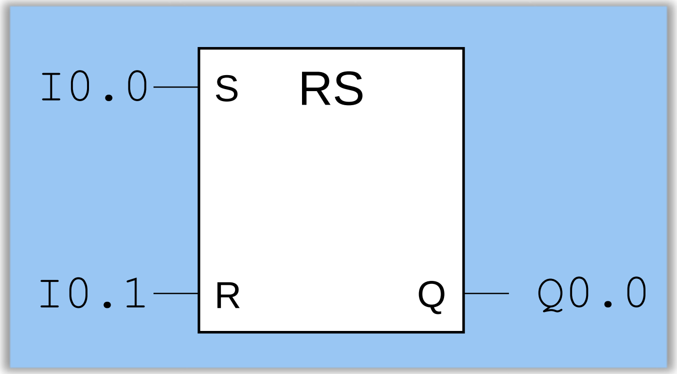
Flip Flops
RS, SR

Example
Permanently switch a light on with a single button press



dominant set
if both set and reset are true, Q will also be true

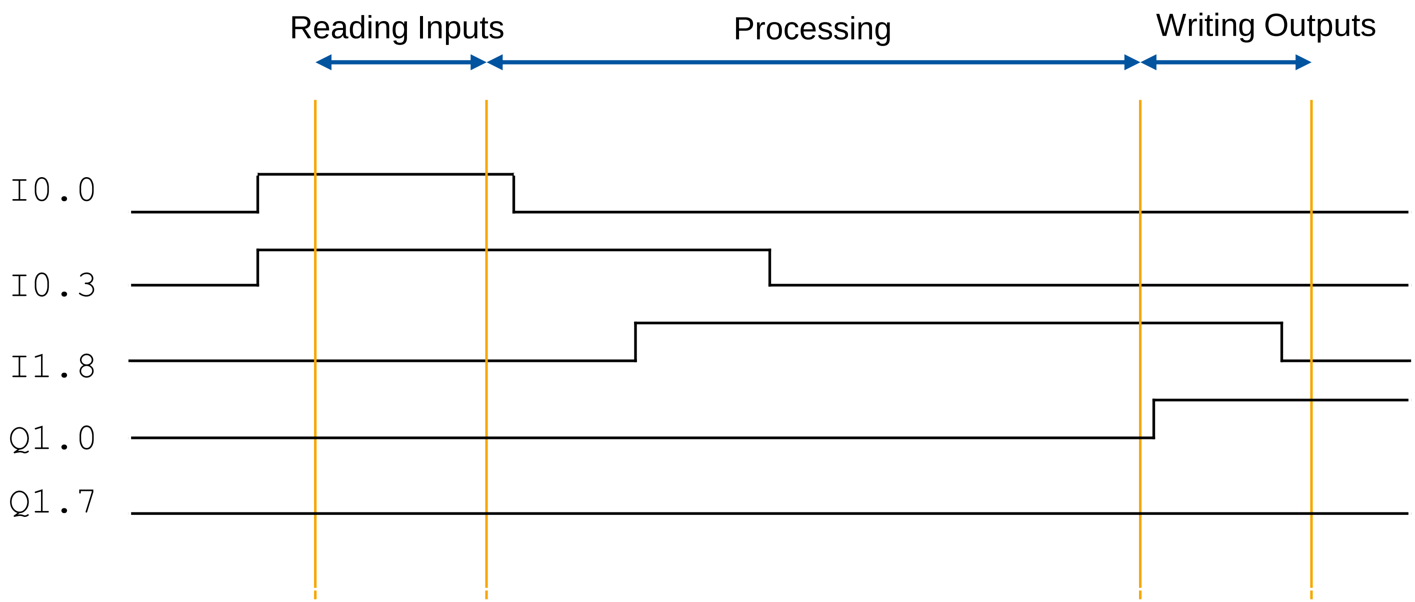
I0.0	I0.1	Q0.0
0	0	0
0	1	0
1	0	1
1	1	1

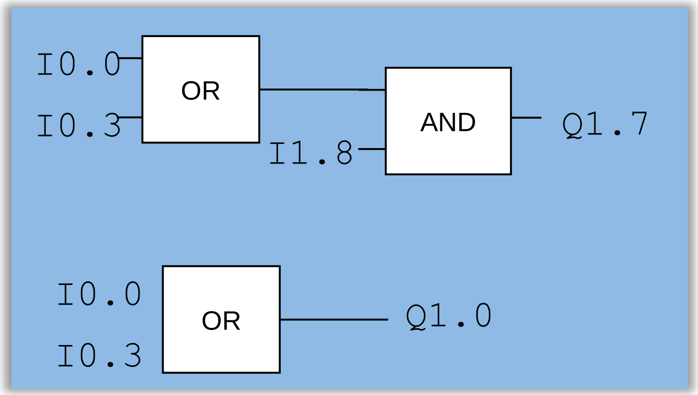


dominant reset
if both set and reset are true, Q will be false

I0.0	I0.1	Q0.0
0	0	0
0	1	0
1	0	1
1	1	0

Example of signals within PLC scan cycle





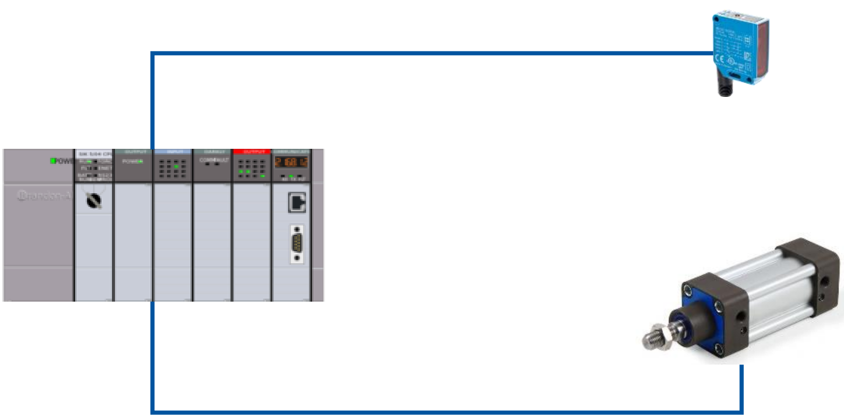

```
LD      I0.0
OR      I0.3
AND     I1.8
=       Q1.7

LD      I0.0
OR      I0.3
=       Q1.0
```

Connecting Sensors and Actors
Centralized Automation System

- PLCs are single point of intelligence within the whole machine
- All sensors and actors are wired into large switching cabinets

Quelle: Klotter Elektrotechnik GmbH

- A lot of wiring work has to be done
- Different devices demand different wiring strategies
  - Binary devices
  - Analog devices
  - …
- Sensor and actor are often right next ot each other, but have to be wired separately
- No other information of a sensor than the pure value



Quelle: Elektro Berners GmbH & Co. KG

Connecting Sensors and Actors
Decentralized automation systems

Can‘t we minimize the wiring effort?

- Standardizing interconnection between devices
- Exchanging data instead of physical signals
- Multiple signals transported on the same wire
- Using smart sensors and smart actors with own intelligence
  - Can be configured at runtime
  - Offer more data than only On/Off or continuous analog value
    - Device Information like type and manufacturer
    - Status Information
    - Complex Data Values (RFID Tags, QR codes, Bar codes, …)
- Distributing PLCs inside the machine
- Details will be discussed in later session!

Fieldbus Protocols (traditional communication in industrial systems)

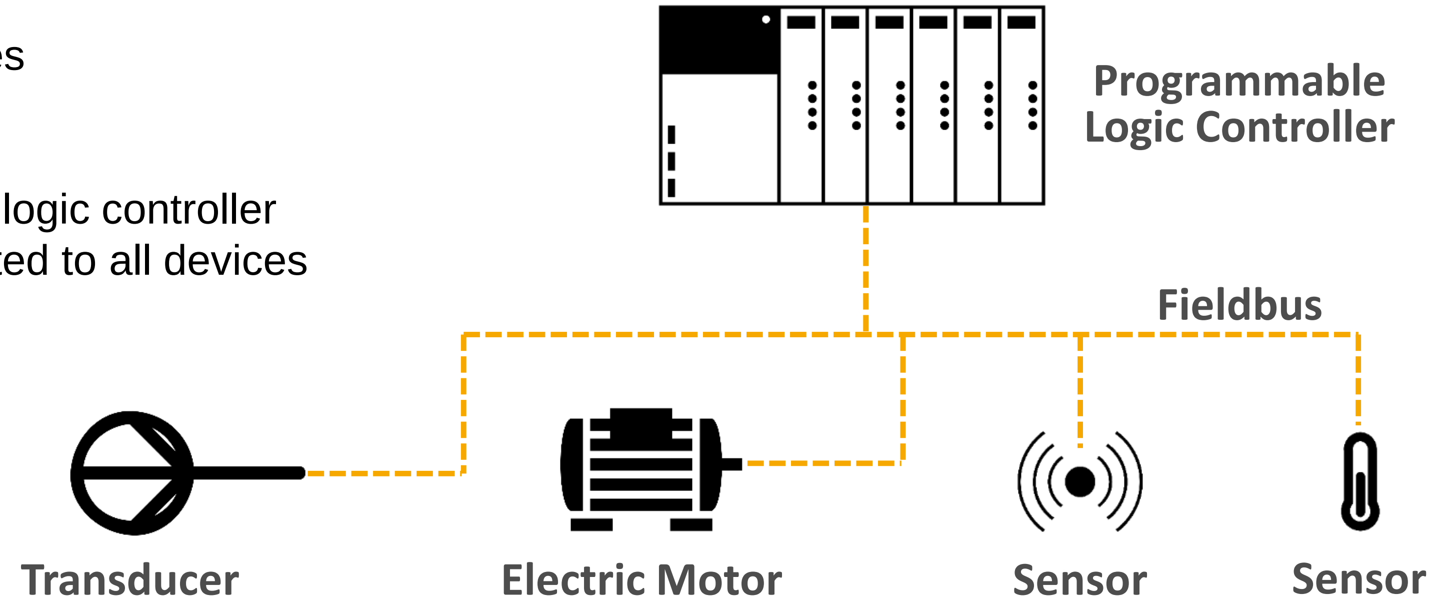
Fieldbus – Definition:

The fieldbus is a communication system that is based on serial data transfer. Fieldbus systems are generally used within industrial automation systems and process control applications

From a conceptual point-of-view, a field bus is a system that forms an industrial communication network that intends to include measurement and control devices, such as:

- Sensors
- Actuators
- Control devices
- Transducers

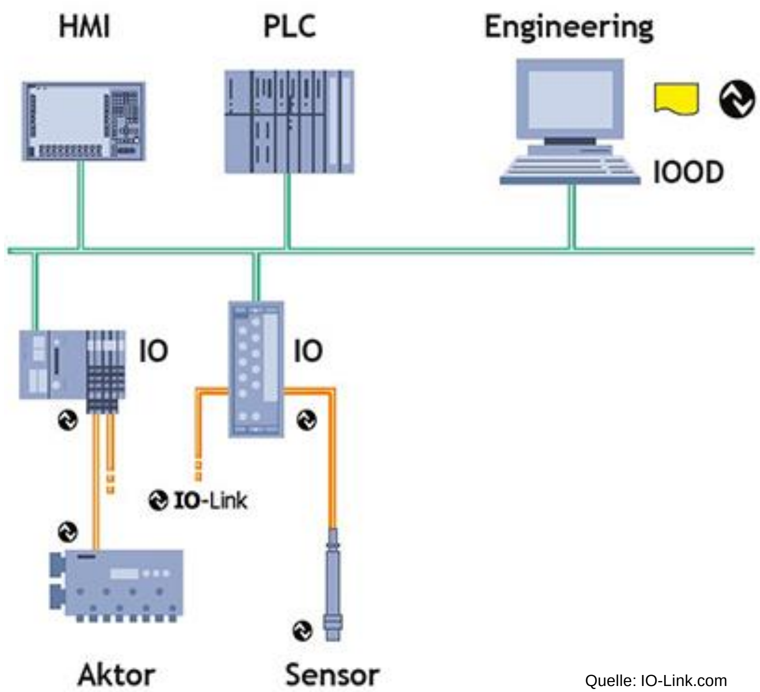
A programmable logic controller might be connected to all devices



The IO Link Protocol – IEC 61131-9

- Standardized protocol for interconnection of simple sensors an actors
- Supports switching, measuring, binary, multichannel and mixed signal devices
- Online parameterization
- Process data, status information, events
- 0-32 Bytes for each device, cyclic (process data) or acyclic (status, events)
- 3 wires per device (VCC, GND, signal)
- 24V, max. 200mA per device

- Cyclic telegram example:



Quelle: IO-Link.com

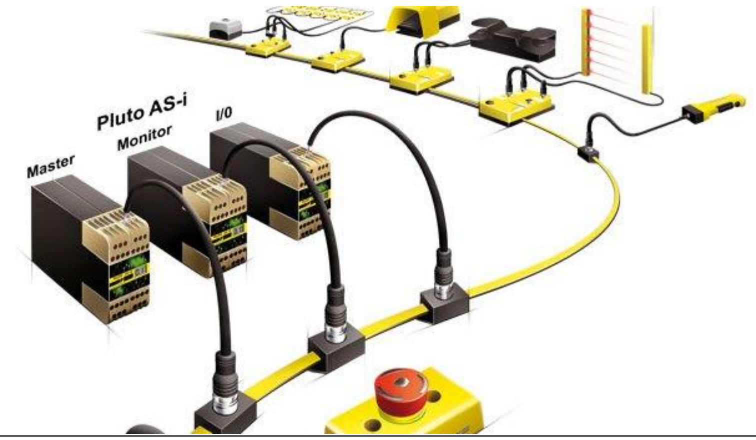
Connecting Sensors and Actors
Low Level Protocols

The AS-i (Actor-Sensor-Interface) protocol

- two-wire-connection, power supply (24V) and data are on the same wire
- Typically used within safety critical applications
  - Door sensors
  - Lockout mechanisms
  - Safety light curtains

- Simple installation, devices can be connected to cable directly

ASi NTERFACE



Thank you very much!

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