Industrial Process Controllers and Simulators

Topic 3

Organization and structure of computers for control purposes

Controller-Object Interaction

1. **Signal exchange**
   - type of signals
   - hardware I/O systems
   - time-driven & event driven exchange
2. **Interaction with the object**

Controller-Object Interaction

1. **Signal exchange**
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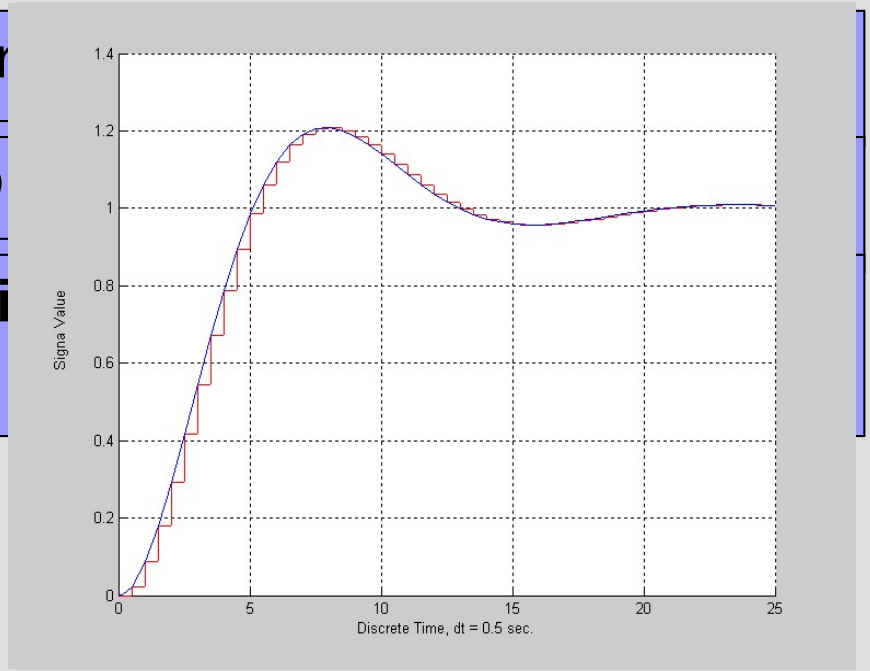
Signal Exchange

Types of signals:

- Analogous
- Discrete
- Pulse



Signal Exchange

Two forms :

- Time-Driven — **The interaction takes place at predefined moments of time**
- Event-Driven — **The interaction takes place when a certain event occurs**

Hardware I/O Systems

- Analogous Input Subsystems (AIS)
- Analogous Output Subsystems (AOS)
- Discrete Input Subsystems (DIS)
- Discrete Output Subsystems (DOS)

AIS organizations

AIS elements:

- *ADC* – Analogous-to-Discrete Converter
- *BSN* – Block for Signal Normalization
- *S&H* – Sample and Hold
- *AM* – Analog Multiplexer
- *CU* – Control Unit
- *IB* – Interface Buffer
- *C, A, D* – Control, Address and Data Bus

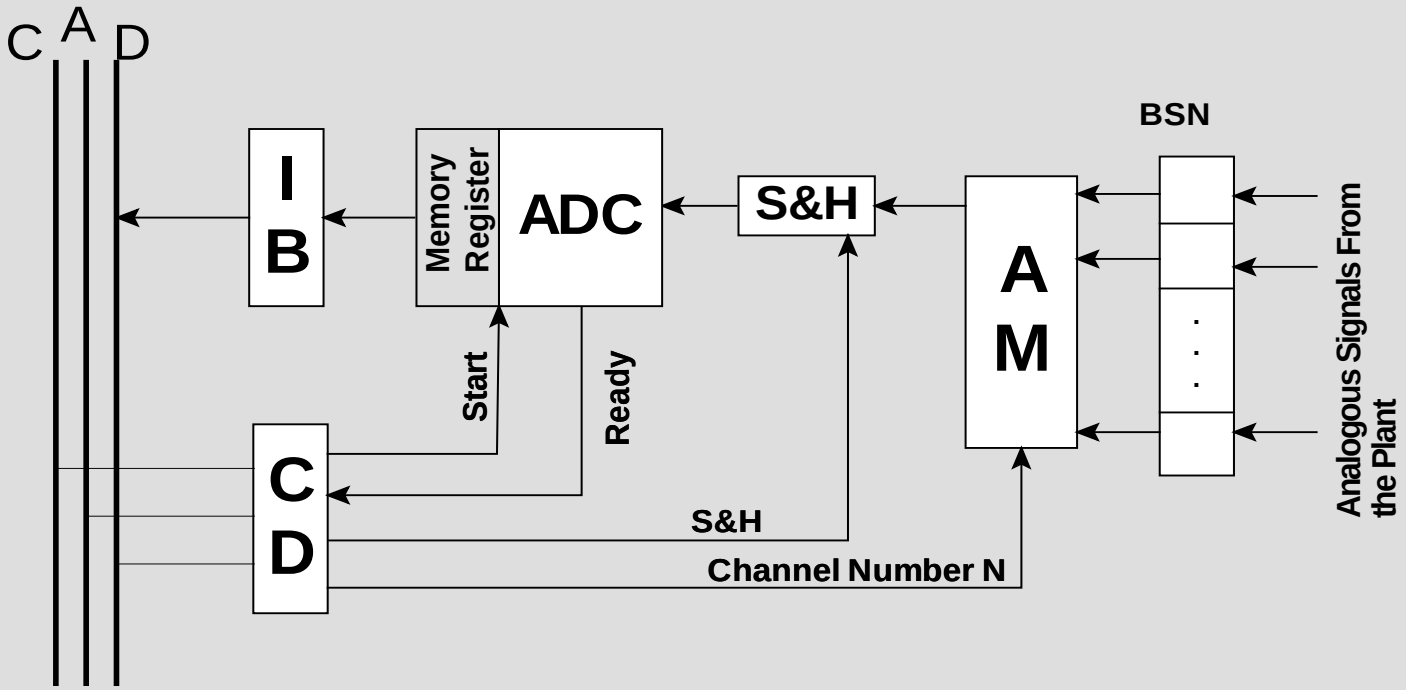
AIS organizations

Realizations of AIS :

- with a single ADC element
- with multiple ADC elements
- with multiple S&H elements
- with Digital Sensors (DS), instead of ADC

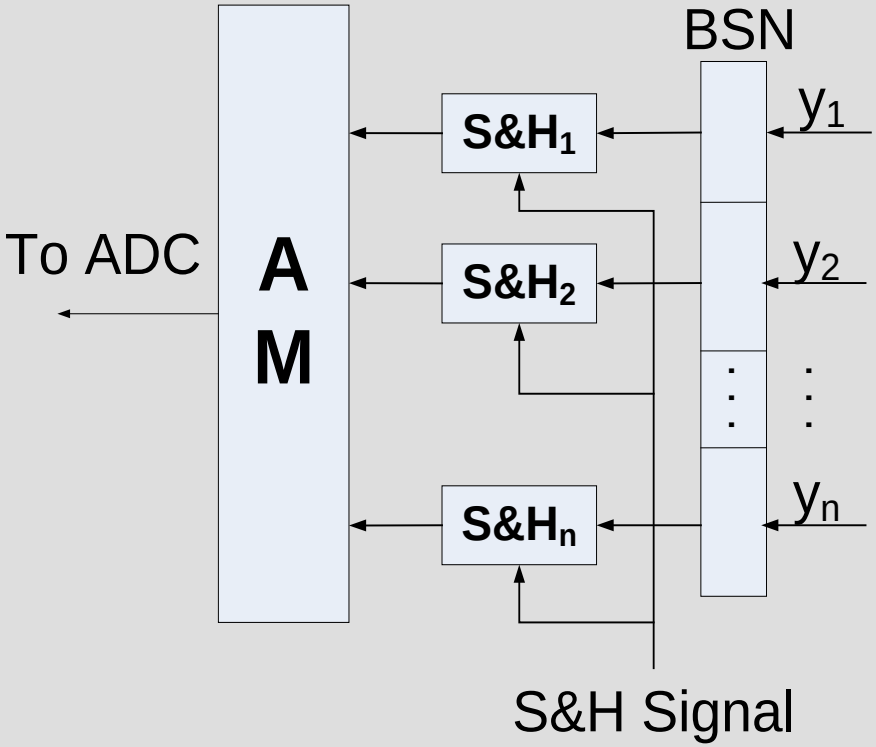
AIS organizations

AIS with single ADC Element



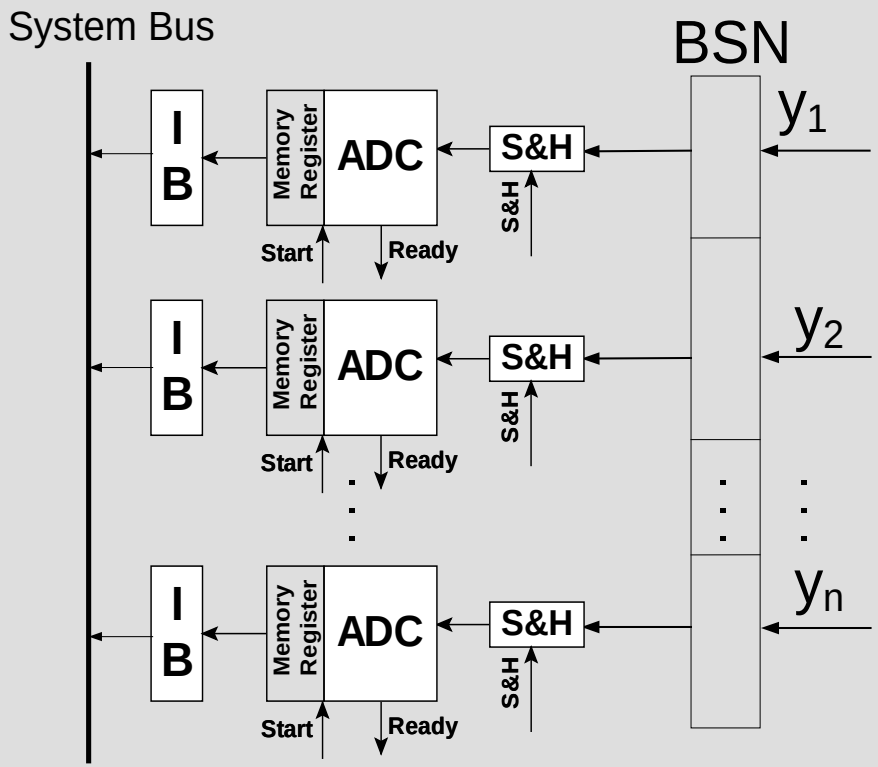
AIS organizations

AIS with multiple S&H elements



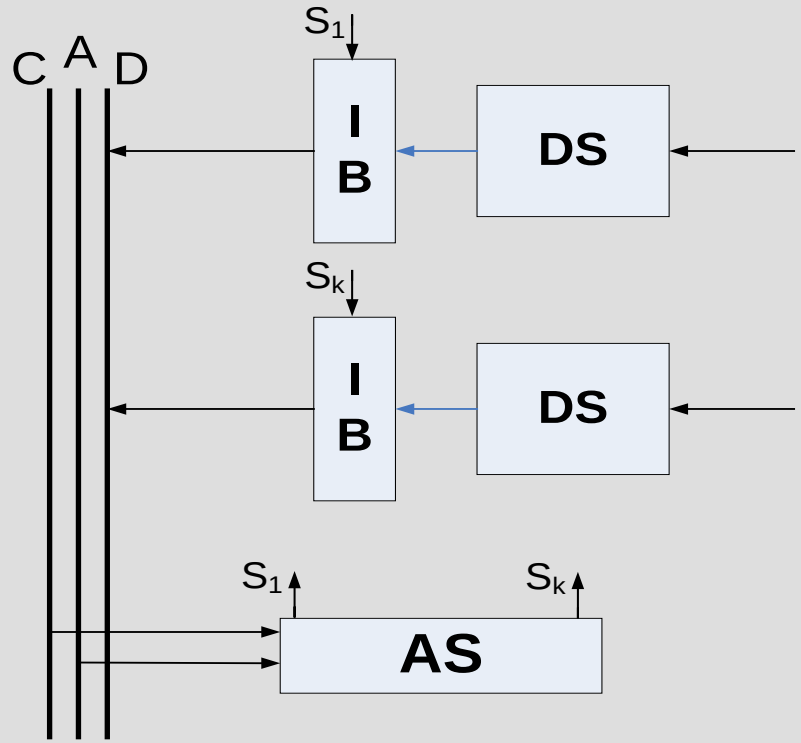
AIS organizations

AIS with multiple ADC elements



AIS organizations

AIS with Digital Sensor



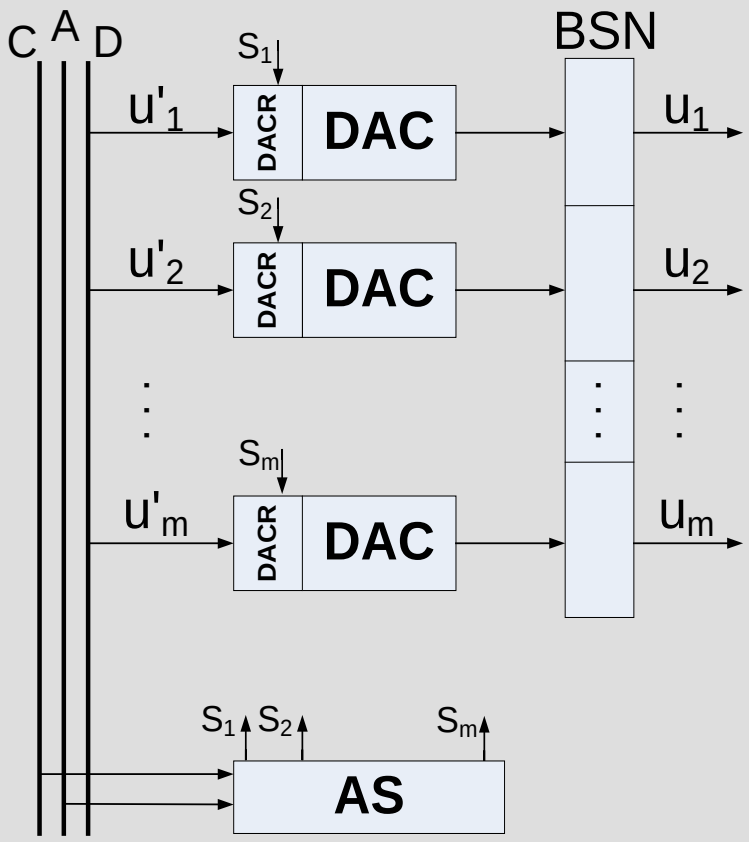
AOS organizations

AOS elements:

1. Output devices -> generally two kinds are used:
   - ♦ DAC – Digital-to-Analogous Converter
   - ♦ PWM – Pulse-Width Modulation
2. SHB – Sample and Hold Block
3. AS – Address Selector
4. DACR – DAC Register

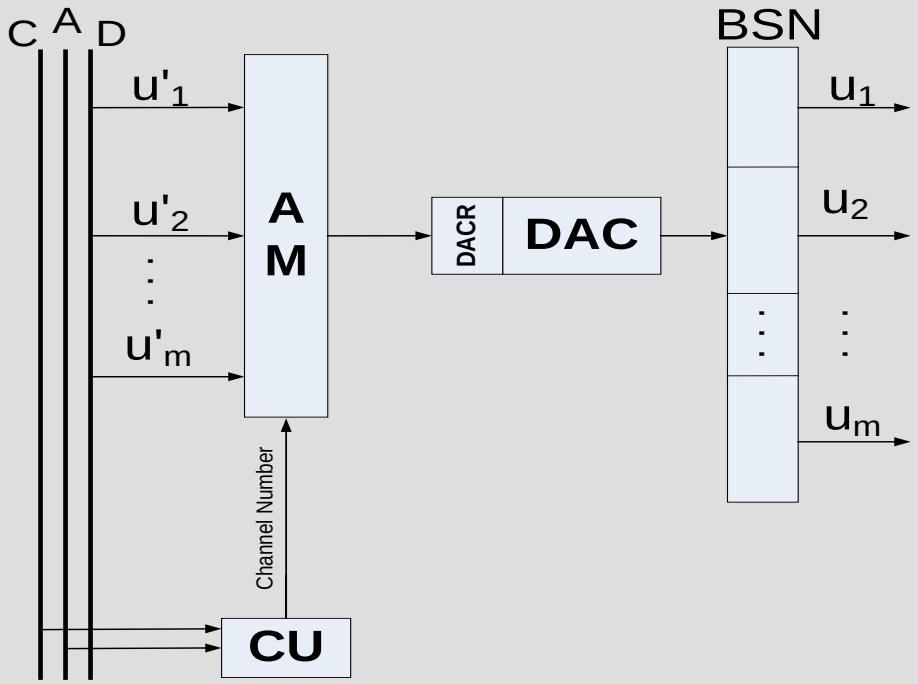
AOS organizations

Basic organization



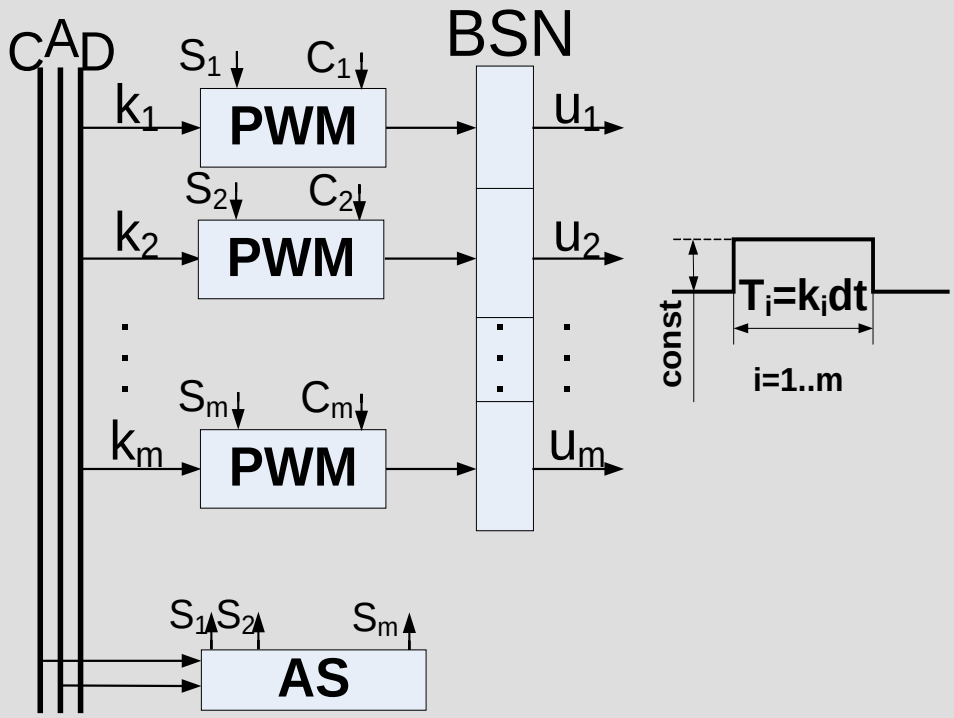
AOS organizations

AOS with single DAC

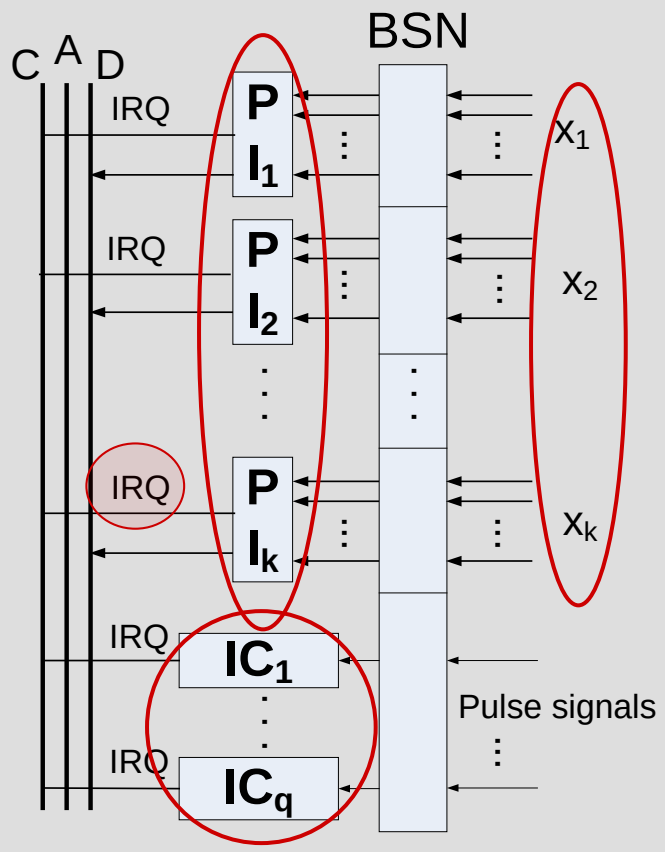


AOS organizations

AOS with Pulse-Width Modulators



Structure of DIS



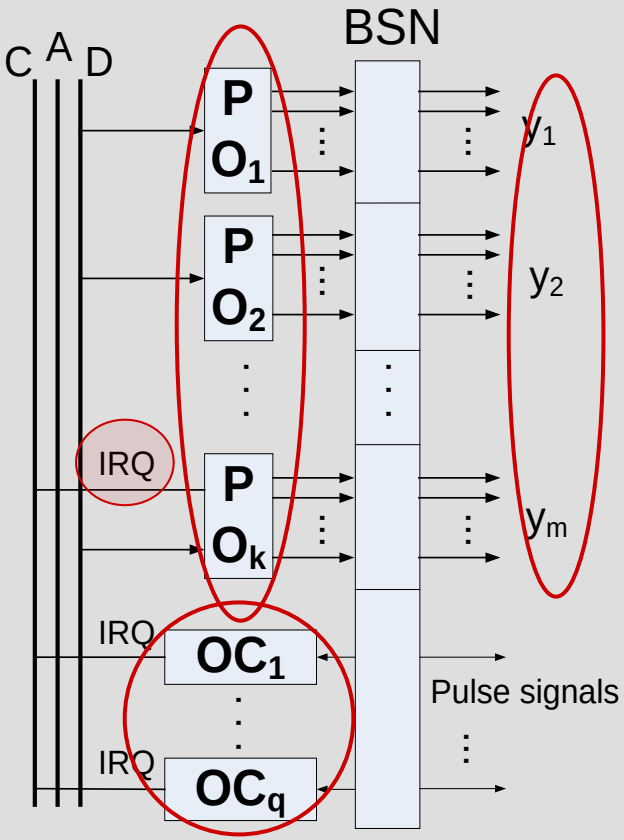
DIS elements:

- PI – Parallel Input
- IRQ – Interrupt Request Line
- X = Ux_i (i=1..k) – The set of discrete input signals
- IC – Input Pulse Counter
- BSN – Binary Signals Normalization

Structure of DOS

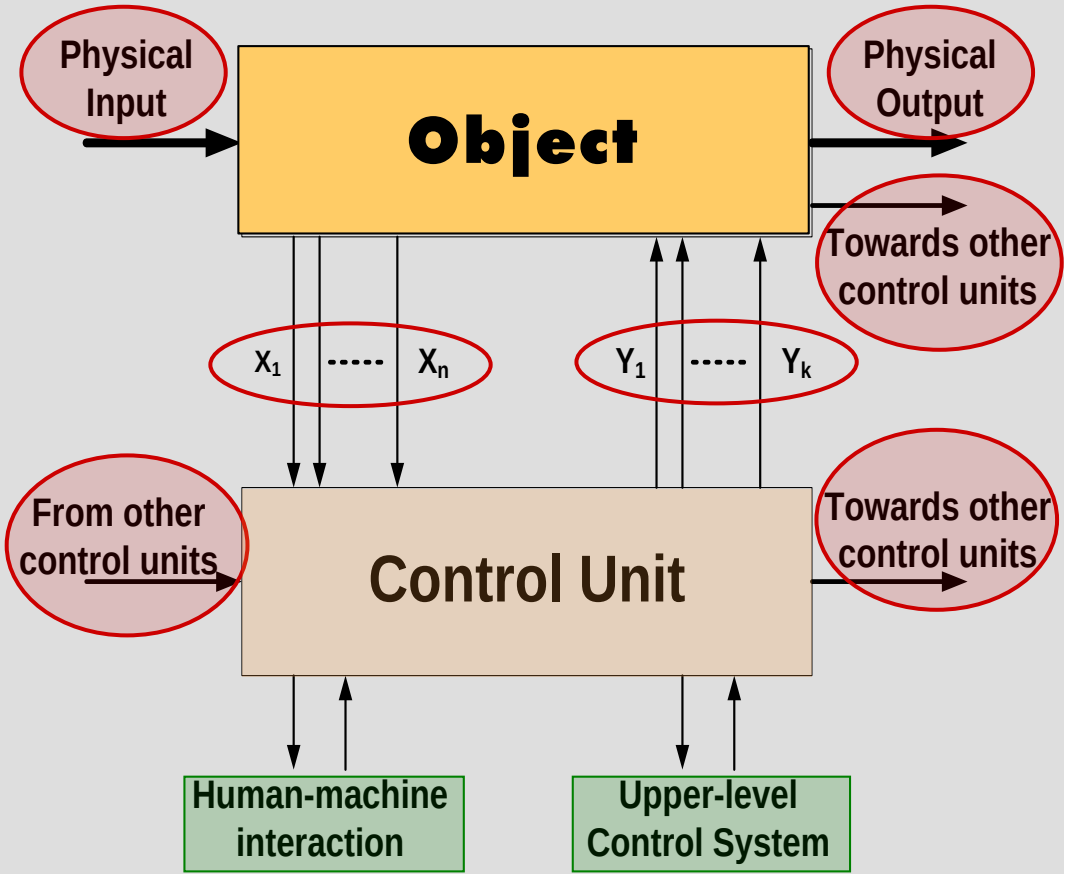
DOS elements :

- PO – Parallel Output
- IRQ – Interrupt Request Line
- Y = Uy_i (i=1..m) – The set of discrete output signals
- OC – Output Counter



Structure of a Cyber-Physical System

Physical organization



Control Systems

Main types :

- Continuous — Continuous interaction signals – they need conversion in both interaction
- Discrete — Discrete signals in both directions
- Hybrid — The plant operates in a mixed mode

Control Systems

Main types :

- Continuous
- Discrete
- Hybrid

Control Systems

Main types :

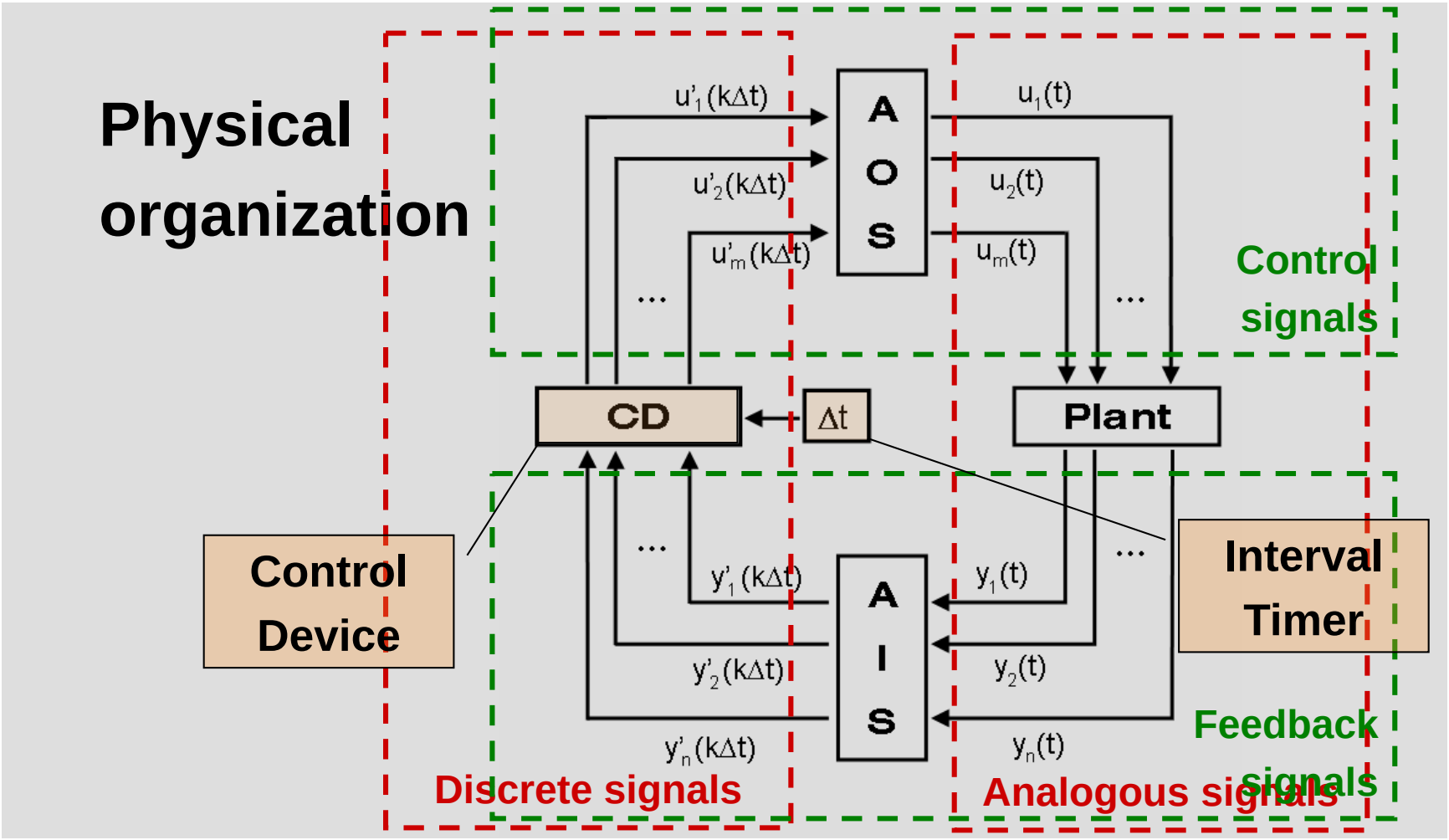
- Continuous
- Discrete
- Hybrid

Continuous Objects

Interaction :

- The controller is a discontinuous machine.
- Both incoming and outgoing signals from the controller are continuous.
- Requires analogous I/O subsystems
- Two types of signal quantifying
  - By level
  - By time

Continuous Objects

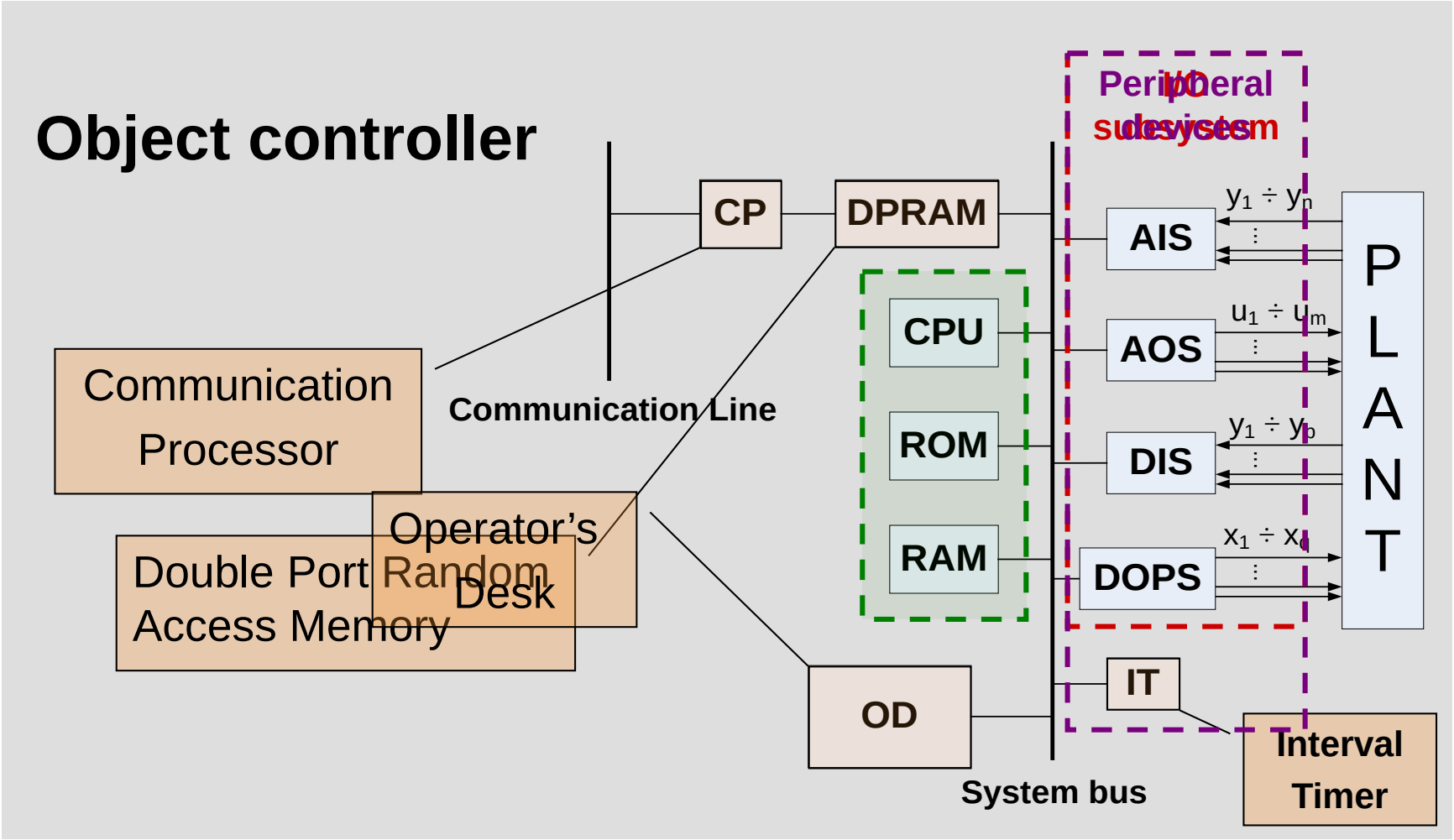


Continuous Objects

Signal Conversions :

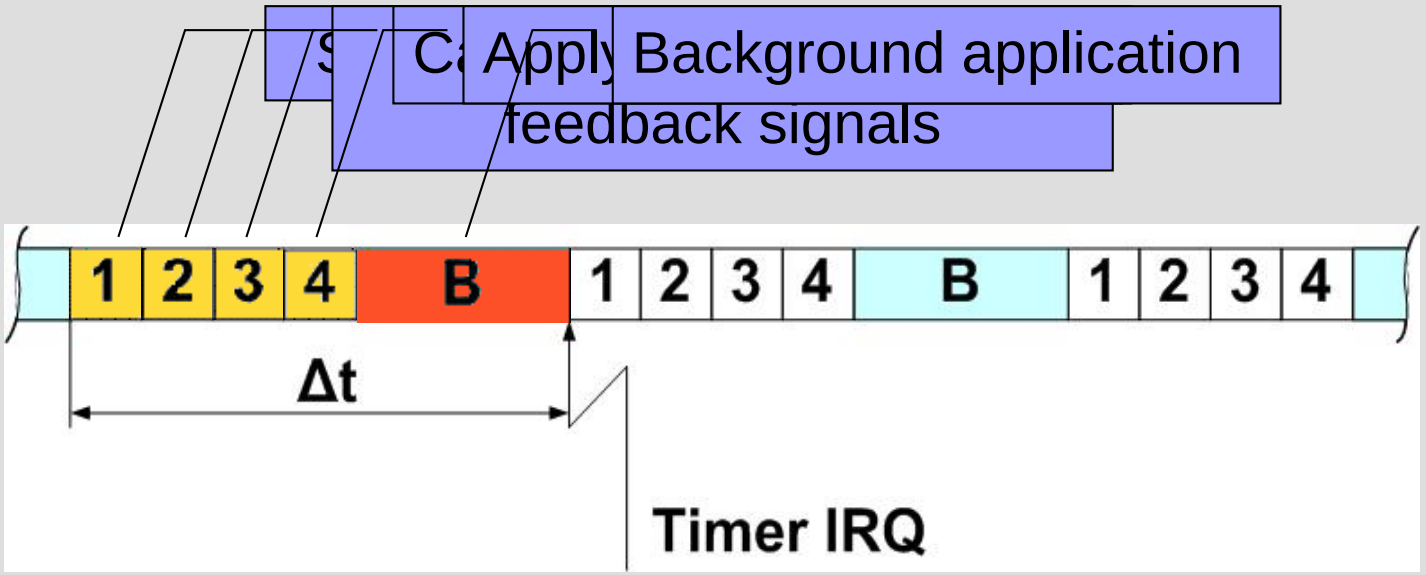
- Quantifying by level — **Performed by the ADC**
- Quantifying by time — **Performed by timers**
- Discrete-to-analogous — **Performed by the DAC**

Continuous Objects



Continuous Objects

Analogous ICS -> time chart of operation



Continuous Objects

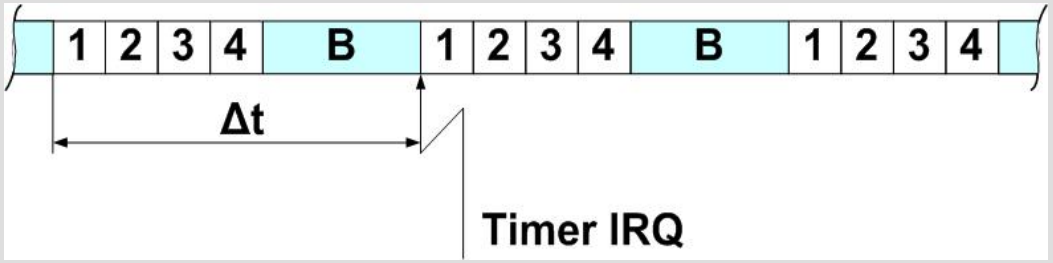
Analogous ICS -> how does it works

- Control device periodically executes a specific control task
- Period depends on the plant dynamics
- Period is based on interrupt requests
- Fluctuations of the moment for execution of phase 4 may occur

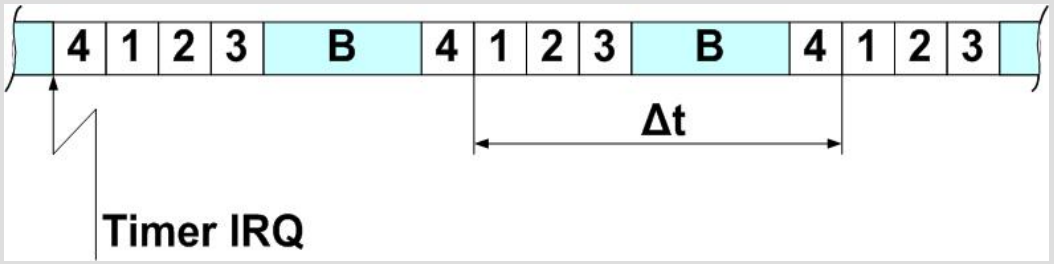
Continuous Objects

Analogous ICS -> avoiding output jitter

Old time chart

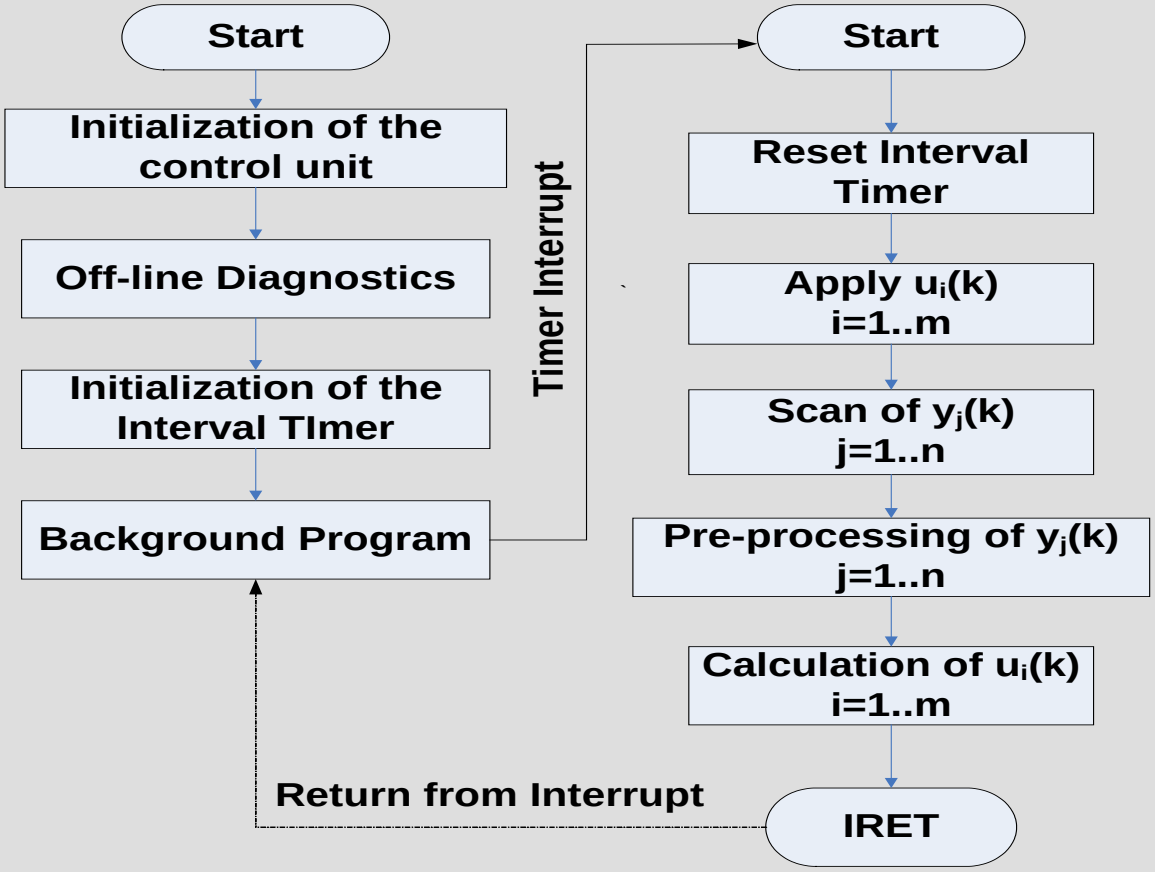


New time chart



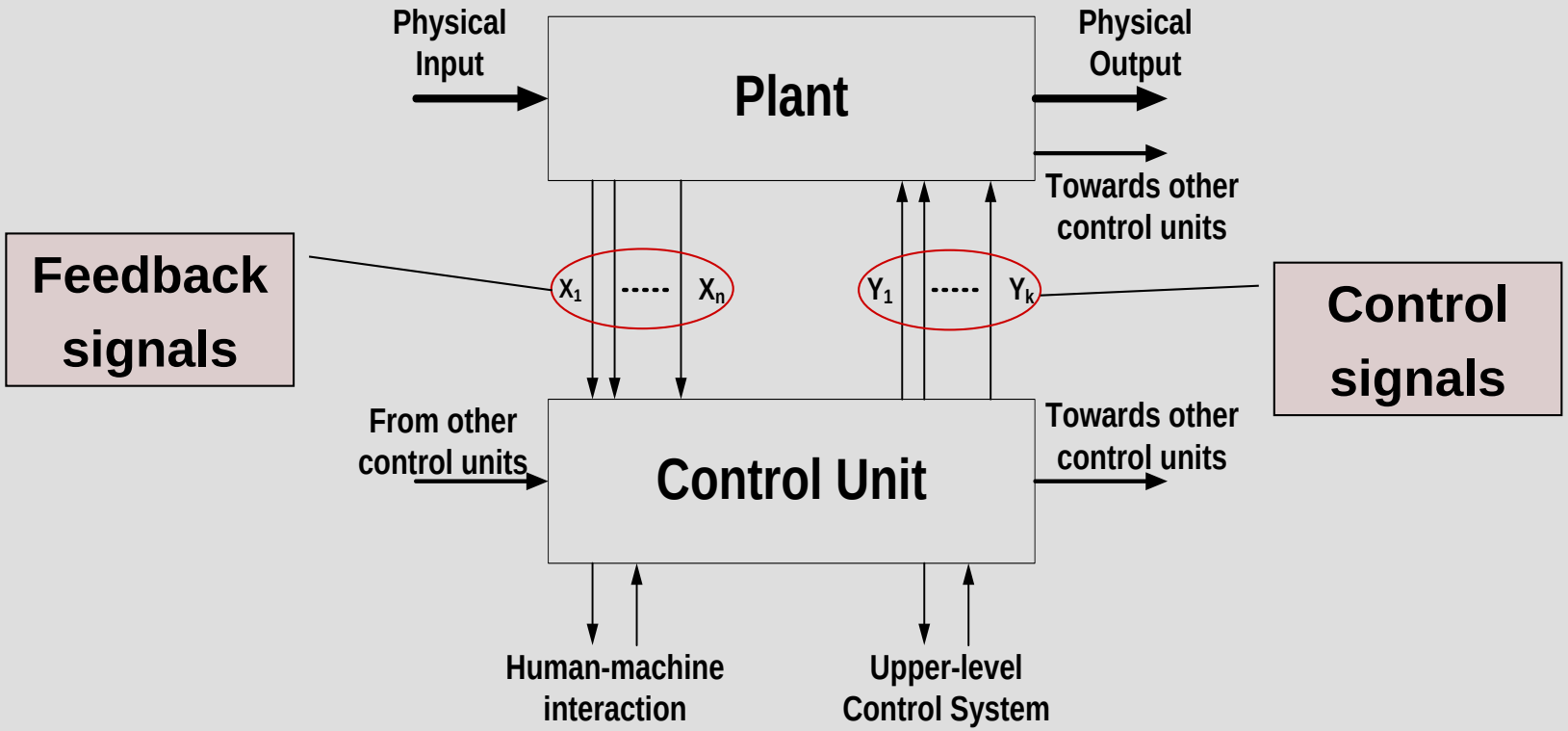
Continuous Objects

Algorithm essentials



Discrete Objects

Interaction:



Discrete Objects

Basics of the interaction :

- Typical for the machinery construction industry and the transport industry.
- Both the plant and the control unit function discretely
- Exchanged signals are usually discrete
- Analogous signals used to create additional control conditions

Discrete Objects

Discrete Industrial Control Systems (DICS)

Evolution:

- Relay Schemes
- Digital Electronic Circuits
- Programmable Controllers
  - Programmable Logic Controllers
  - State Logic Controllers
- Synchronous vs. Asynchronous DICS

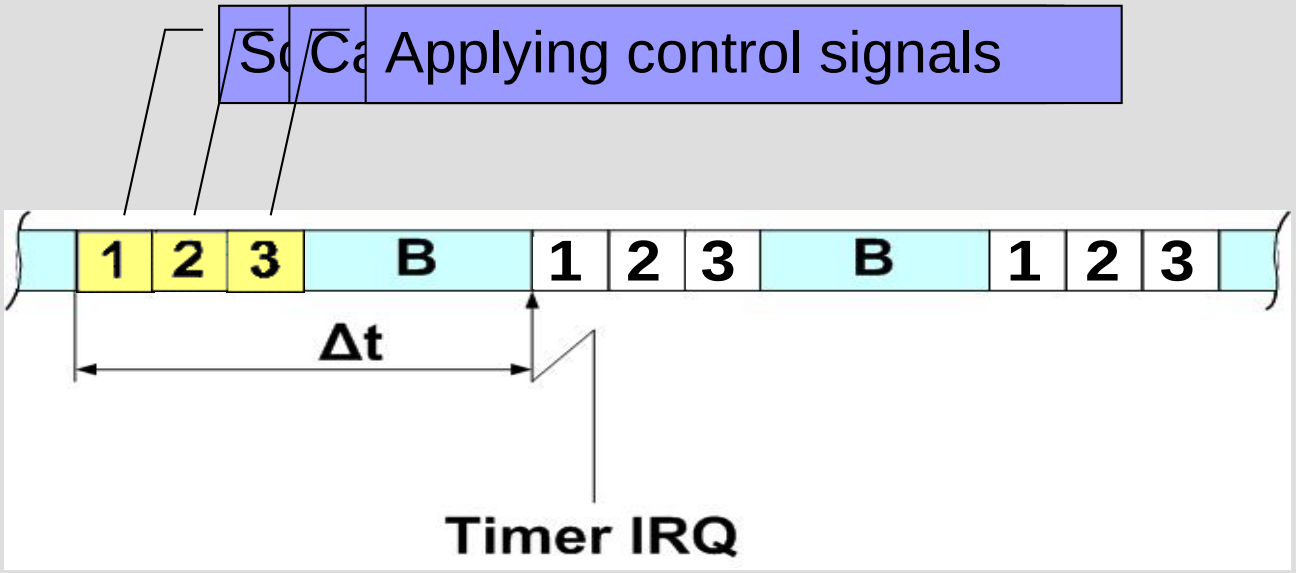
Discrete Objects

Object and control device modeling and design

- Automata models
- Operational and control automaton
- Abstract synthesis of control automaton
  - Mealy Automata
  - Moore Automata
  - Petri Nets
  - etc.
- Structural synthesis of control automata

Discrete Objects

Programmable controller -> time chart



Discrete Objects

DICS programming

1. Different approaches for SLC and PLC
   - Abstract Synthesis for SLC
   - Structural Synthesis for PLC
2. Languages -> specialized languages exist for both controllers types
   - PLC – IEC 61131 Standards
   - SLC – Petri Nets, FSM, or other visual language

The END