# Foundation Communications

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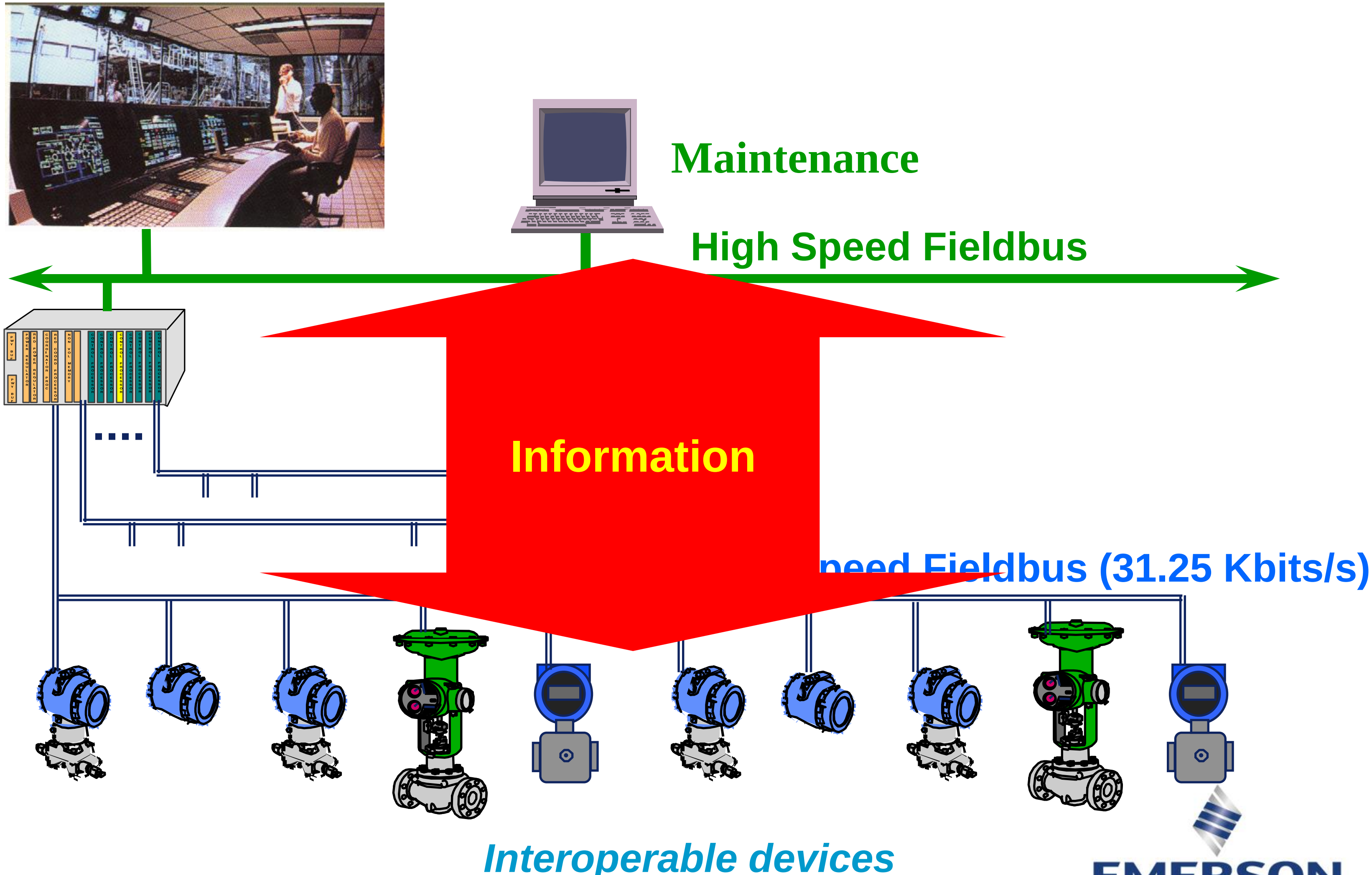
# *Agenda*

- **Foundation Communications Stack**
- **Communication Between Devices**
- **Expected H1 Performance**
- **High Speed Ethernet Support**

# A Plant with Fieldbus

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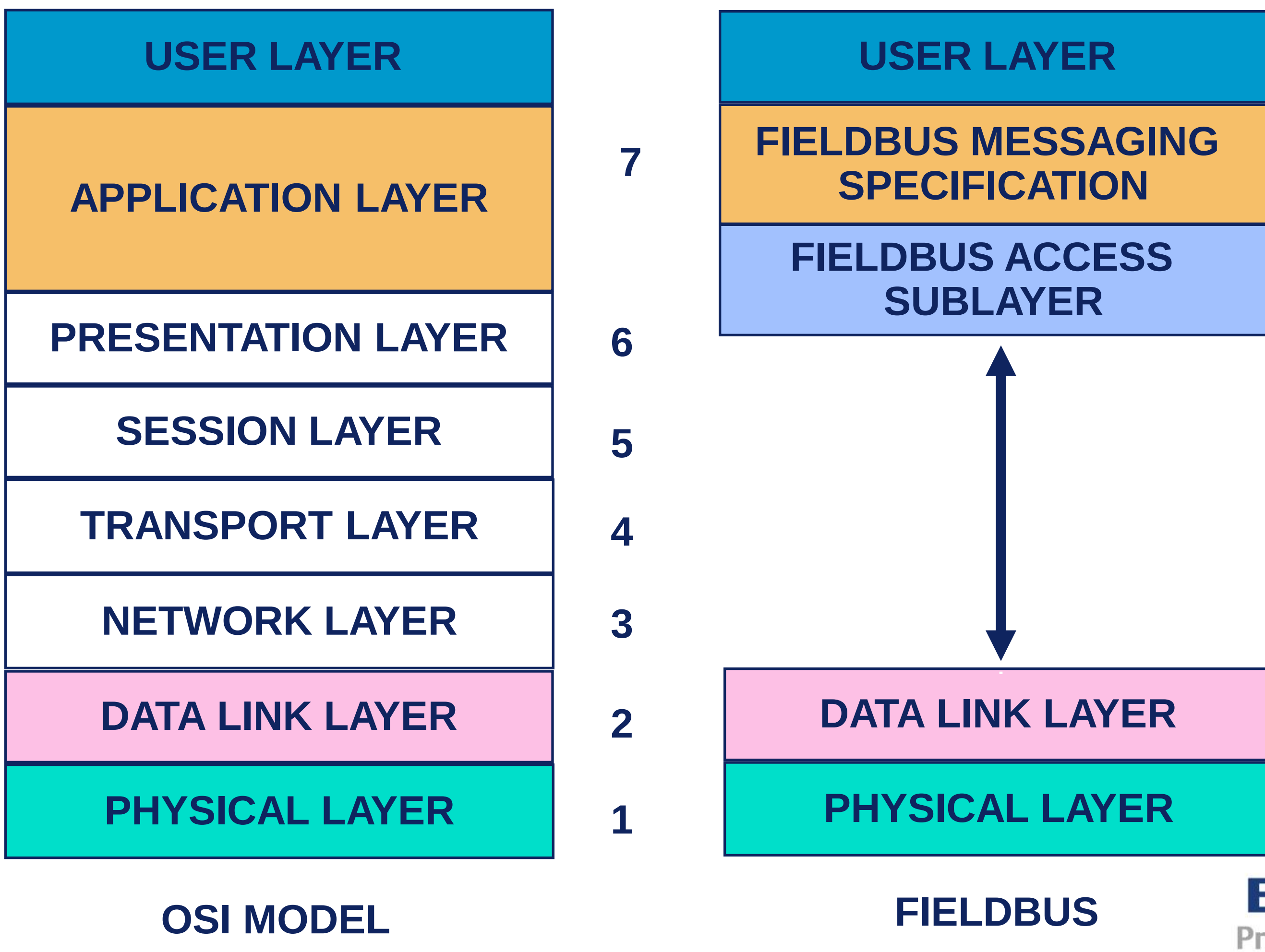
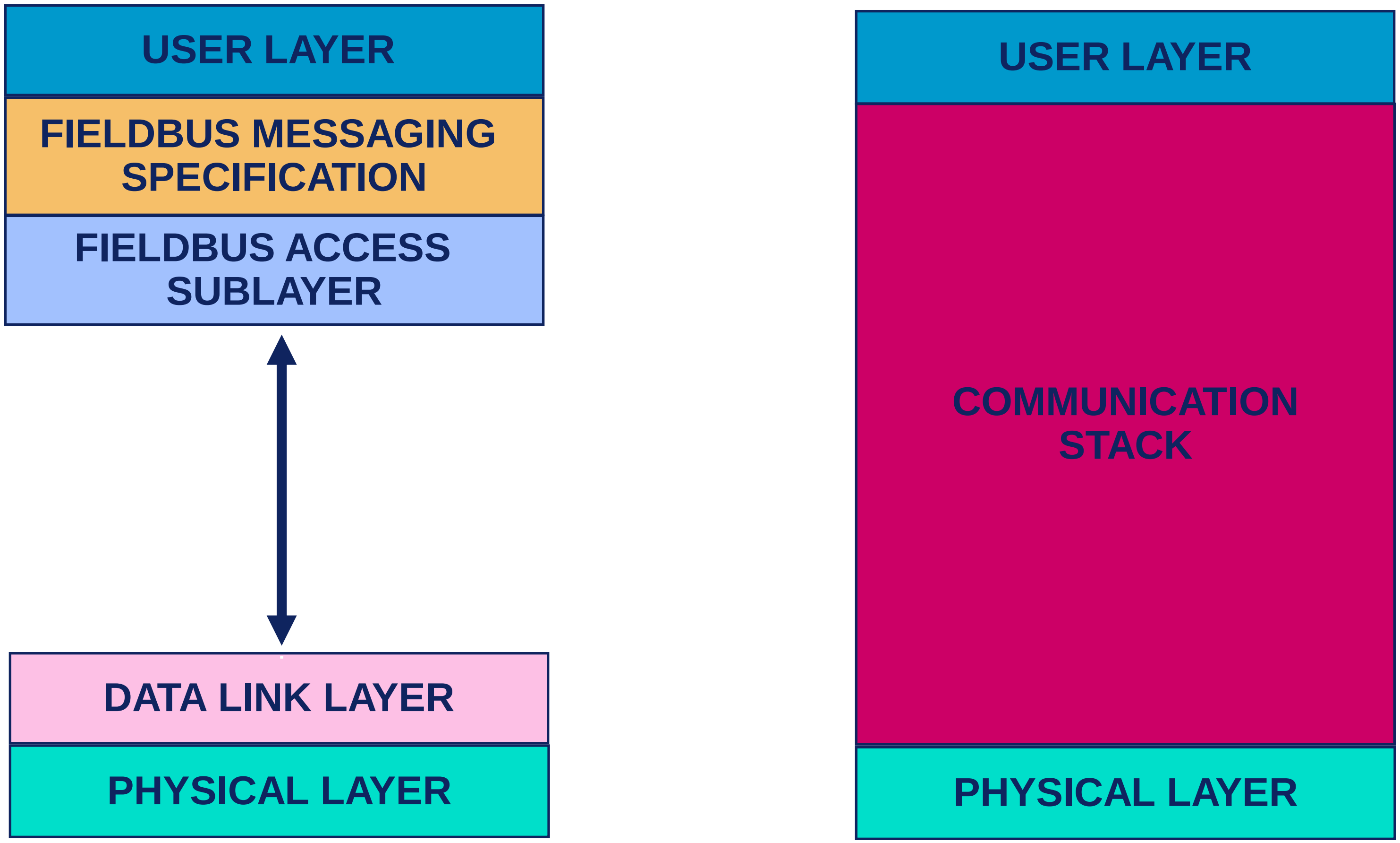
# Fieldbus Technology - Communications

## Comparison to ISO OSI Model



# Fieldbus Technology

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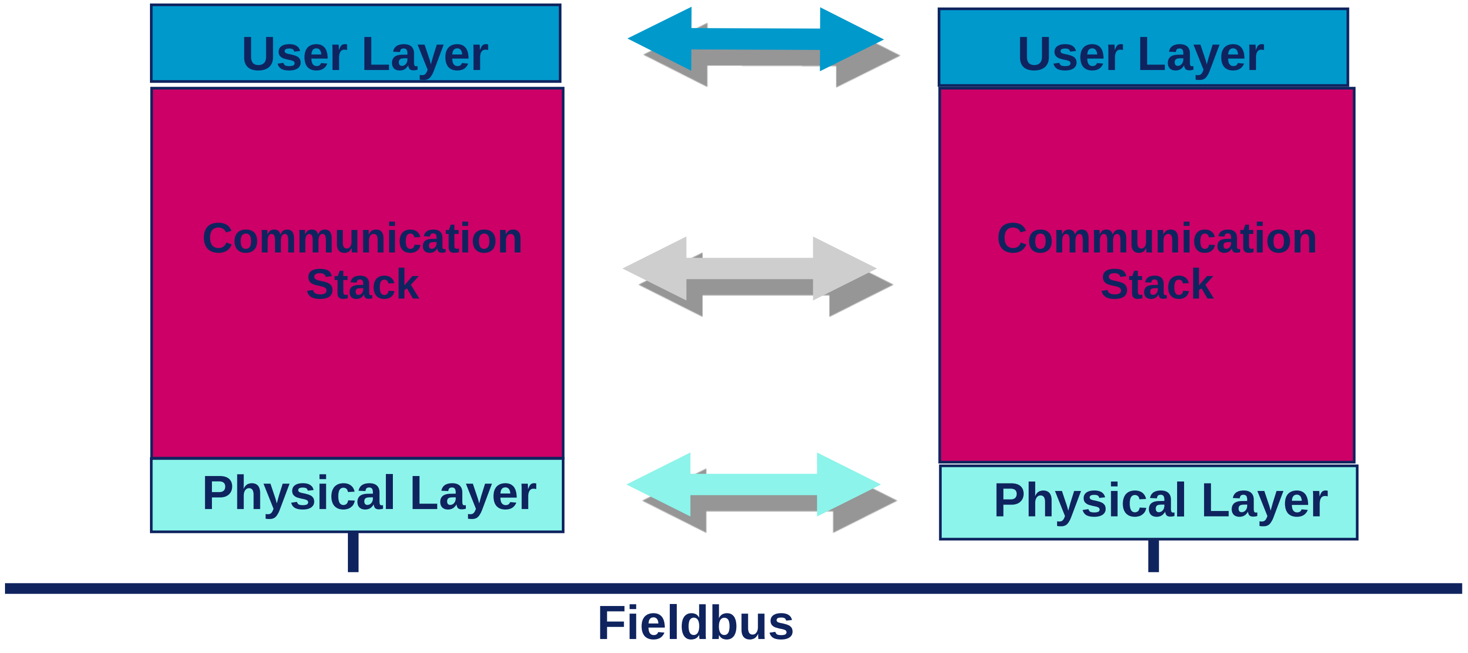
# Fieldbus Technology

## All layers must interoperate.

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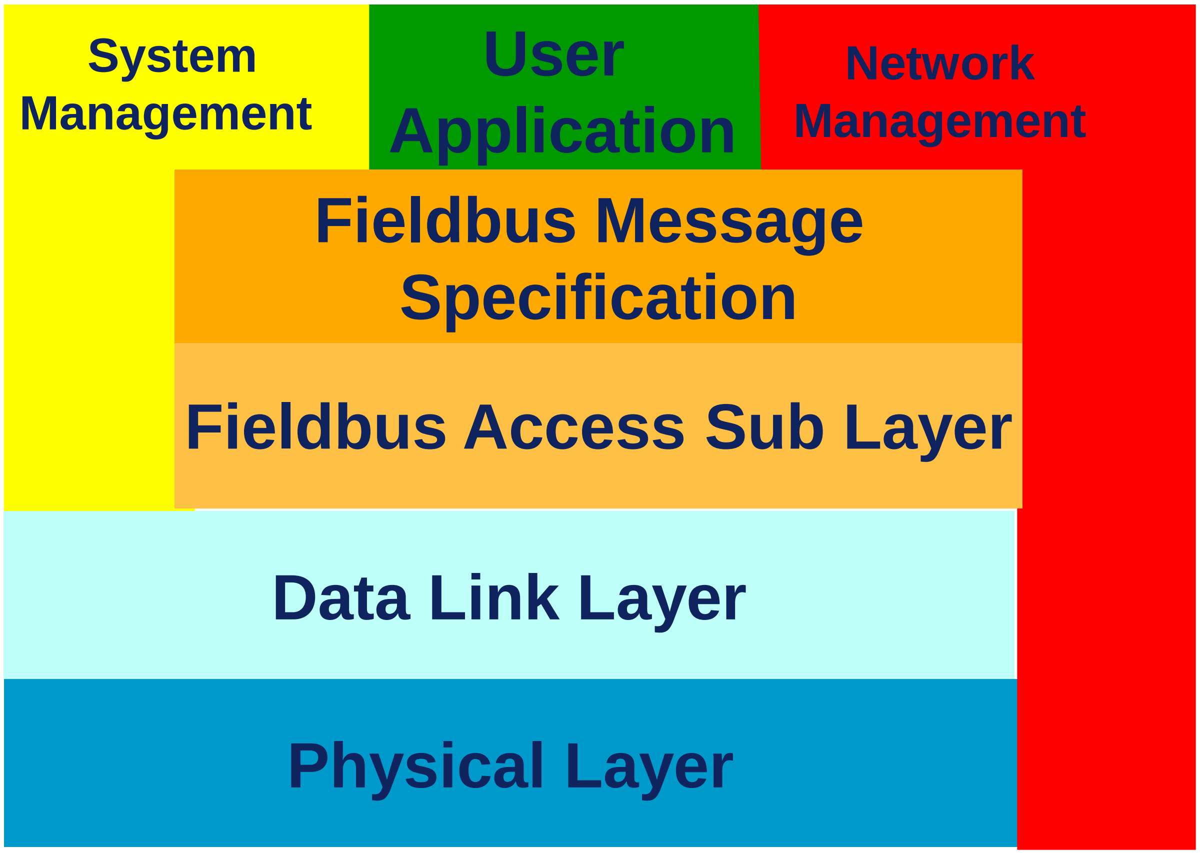
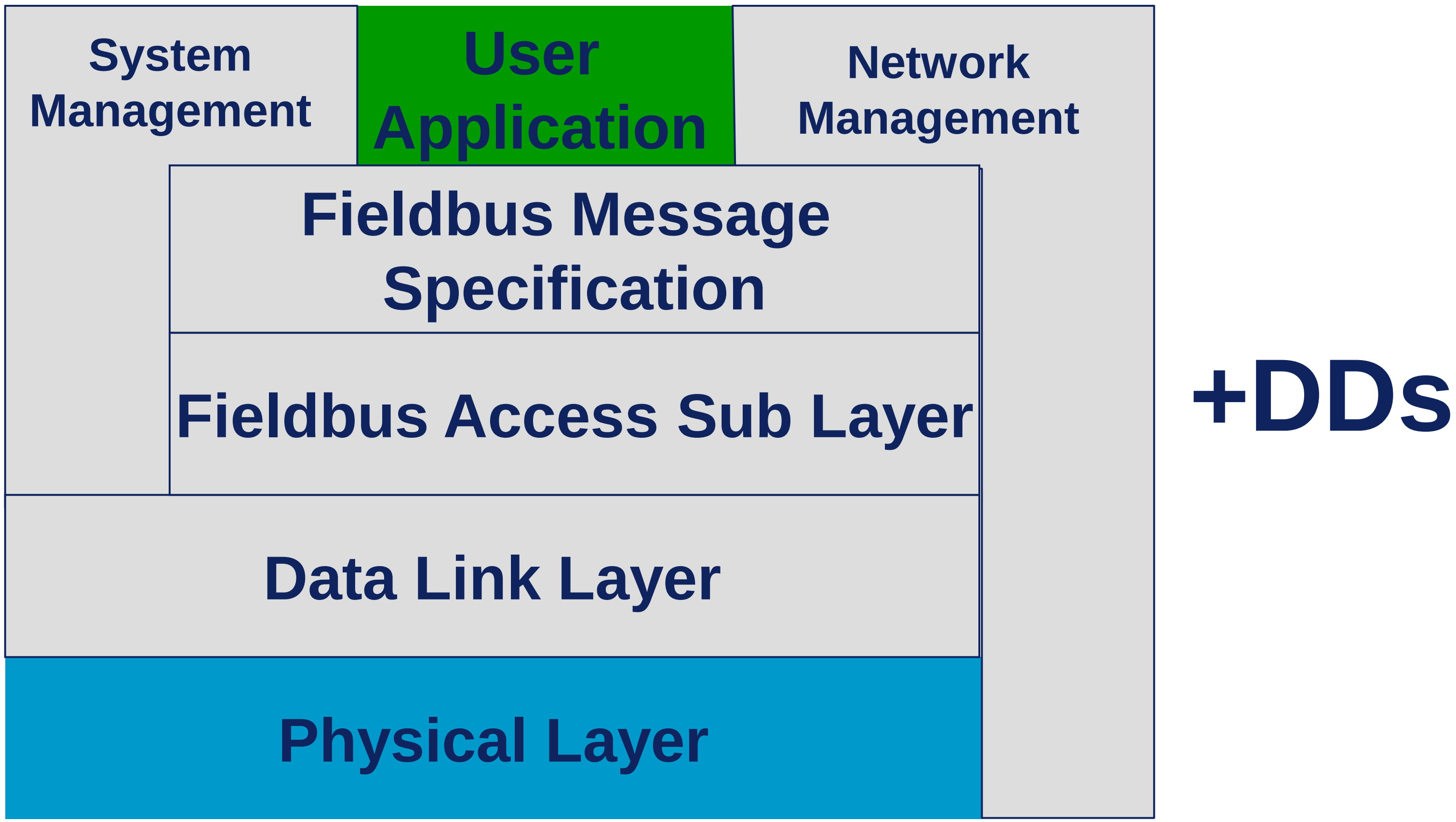
# *Fieldbus Technology*

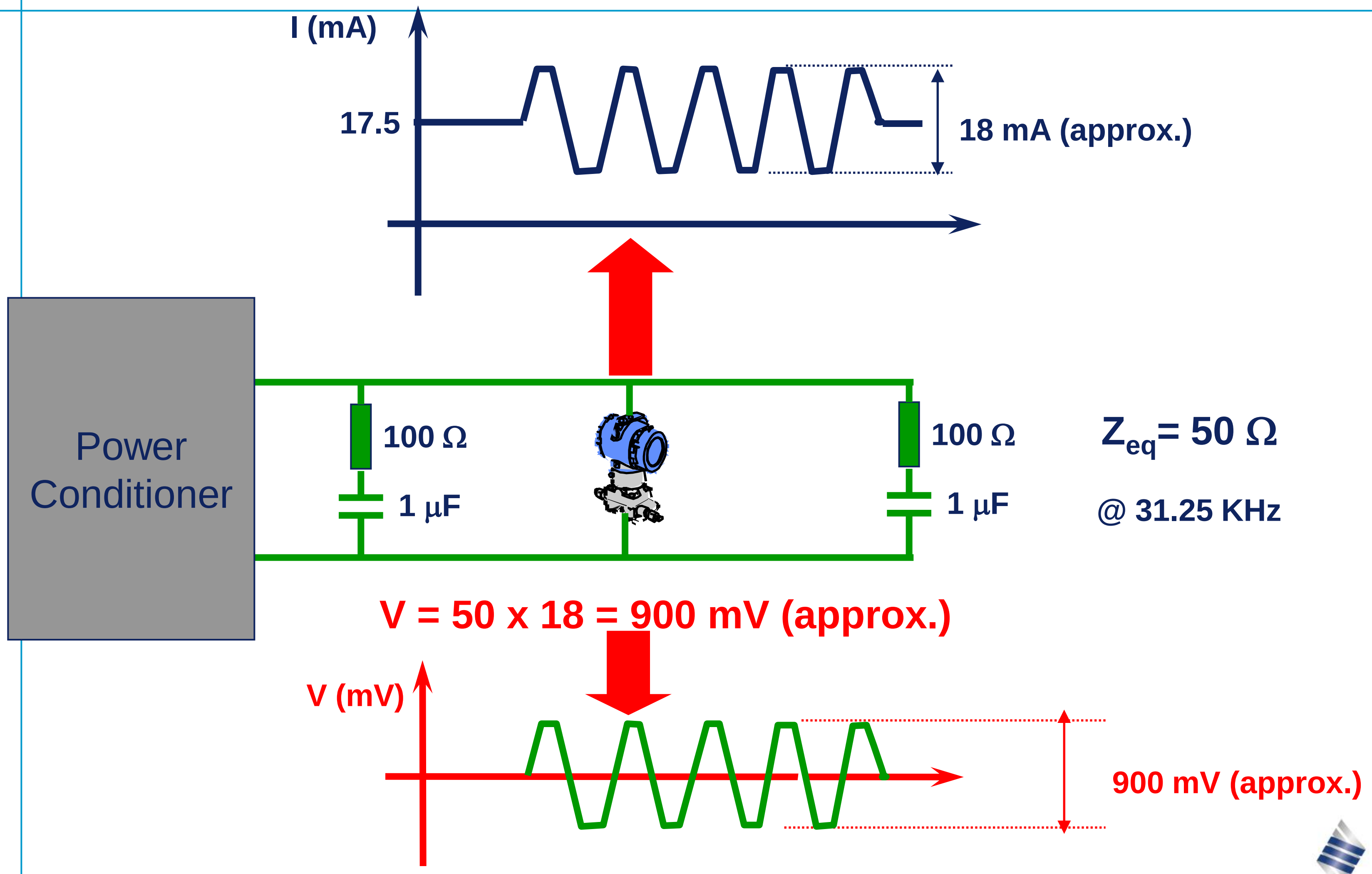



**+DDs**

# Fieldbus Technology



# Fieldbus Signal

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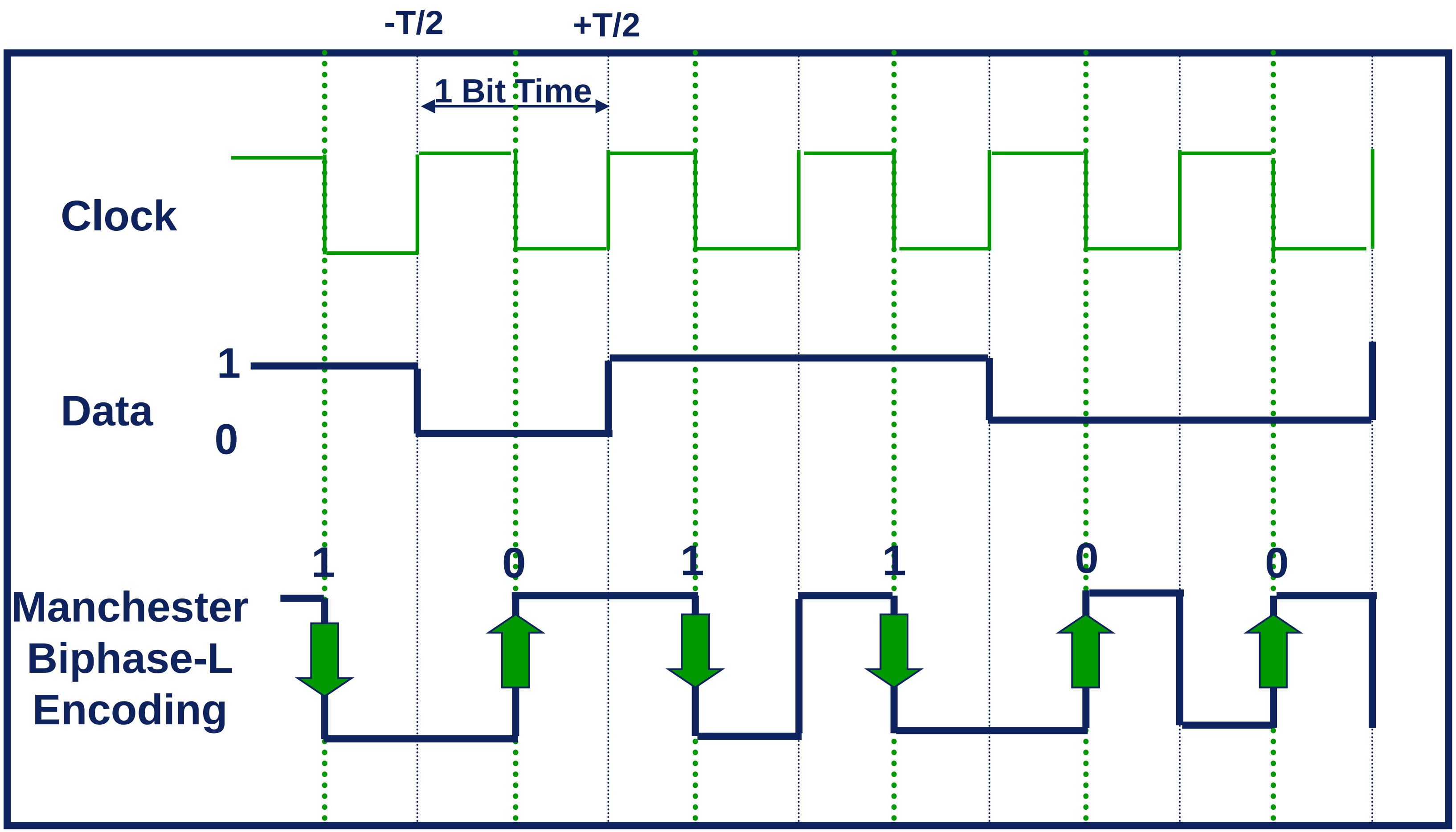
# Signal Encoding

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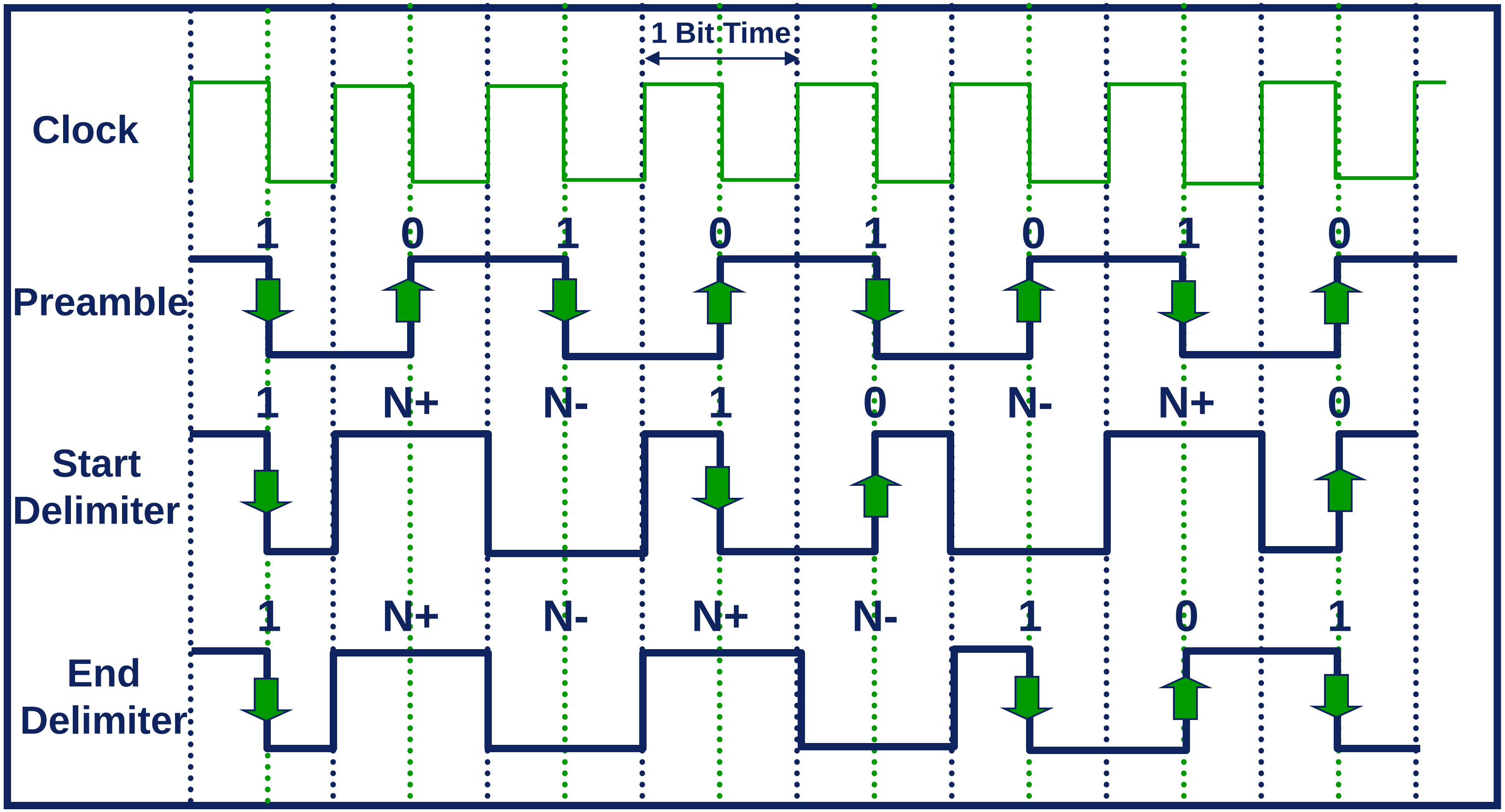
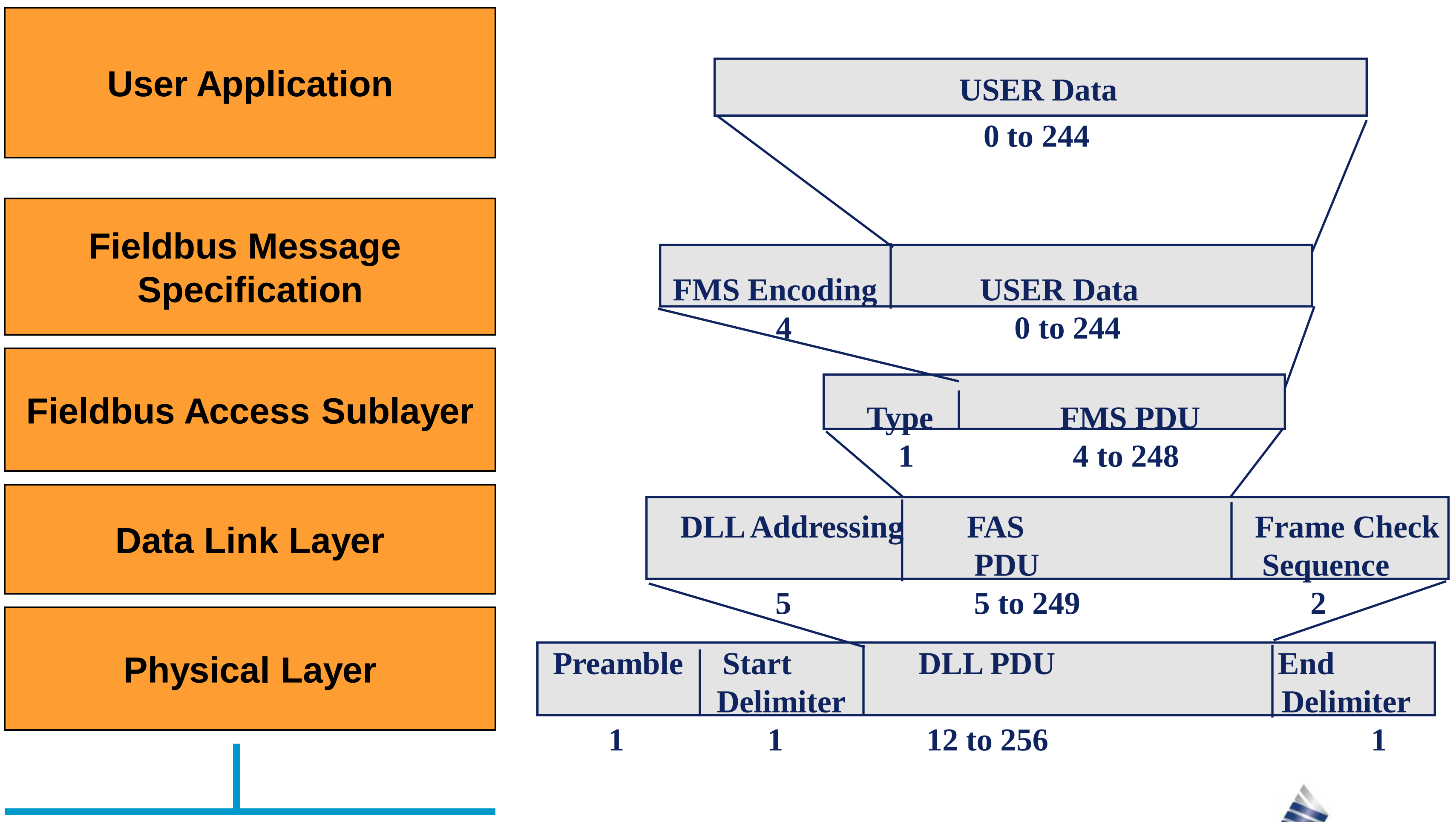
# Signal codification: preamble and delimiters



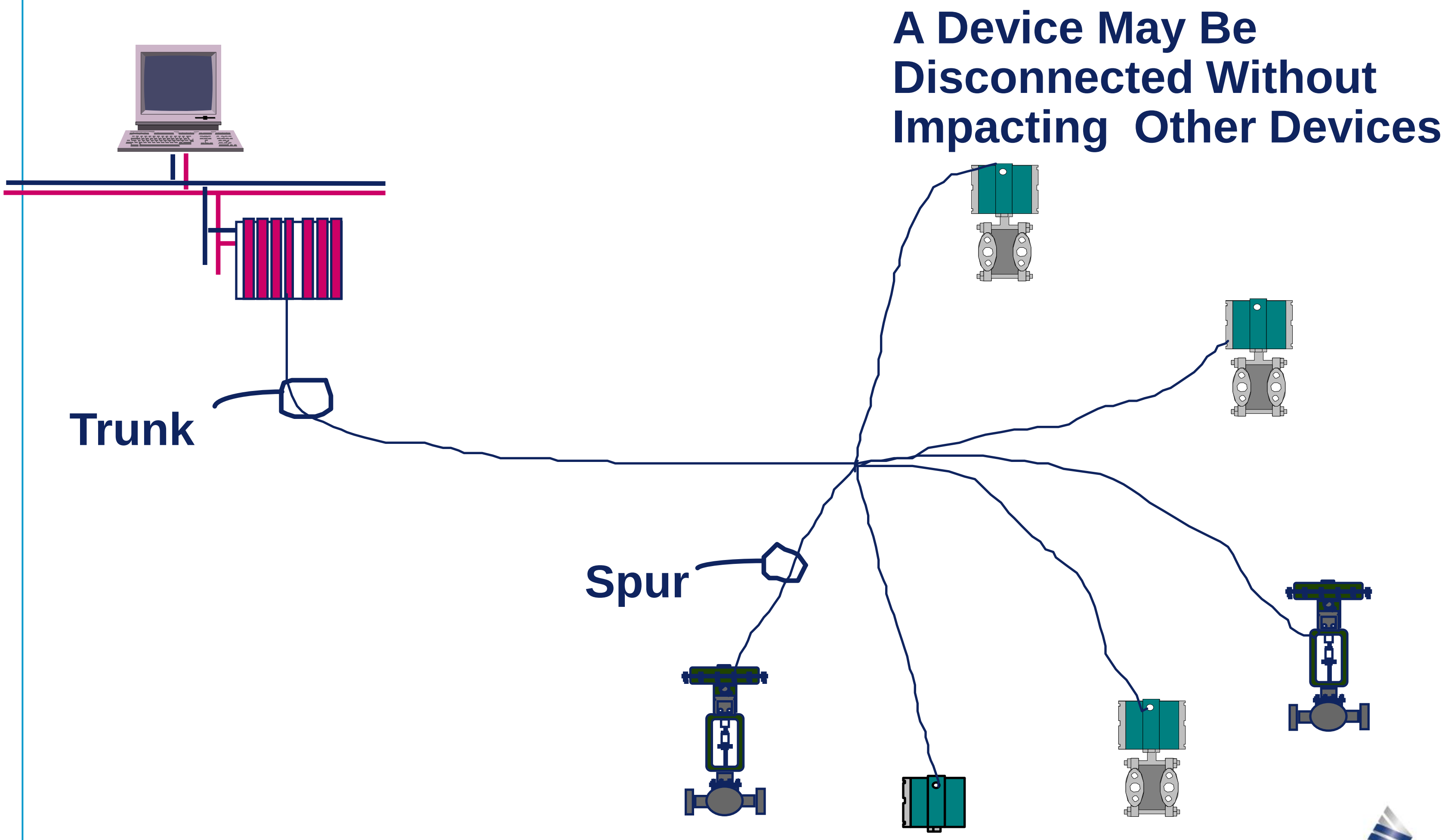
# Coding and decoding of messages



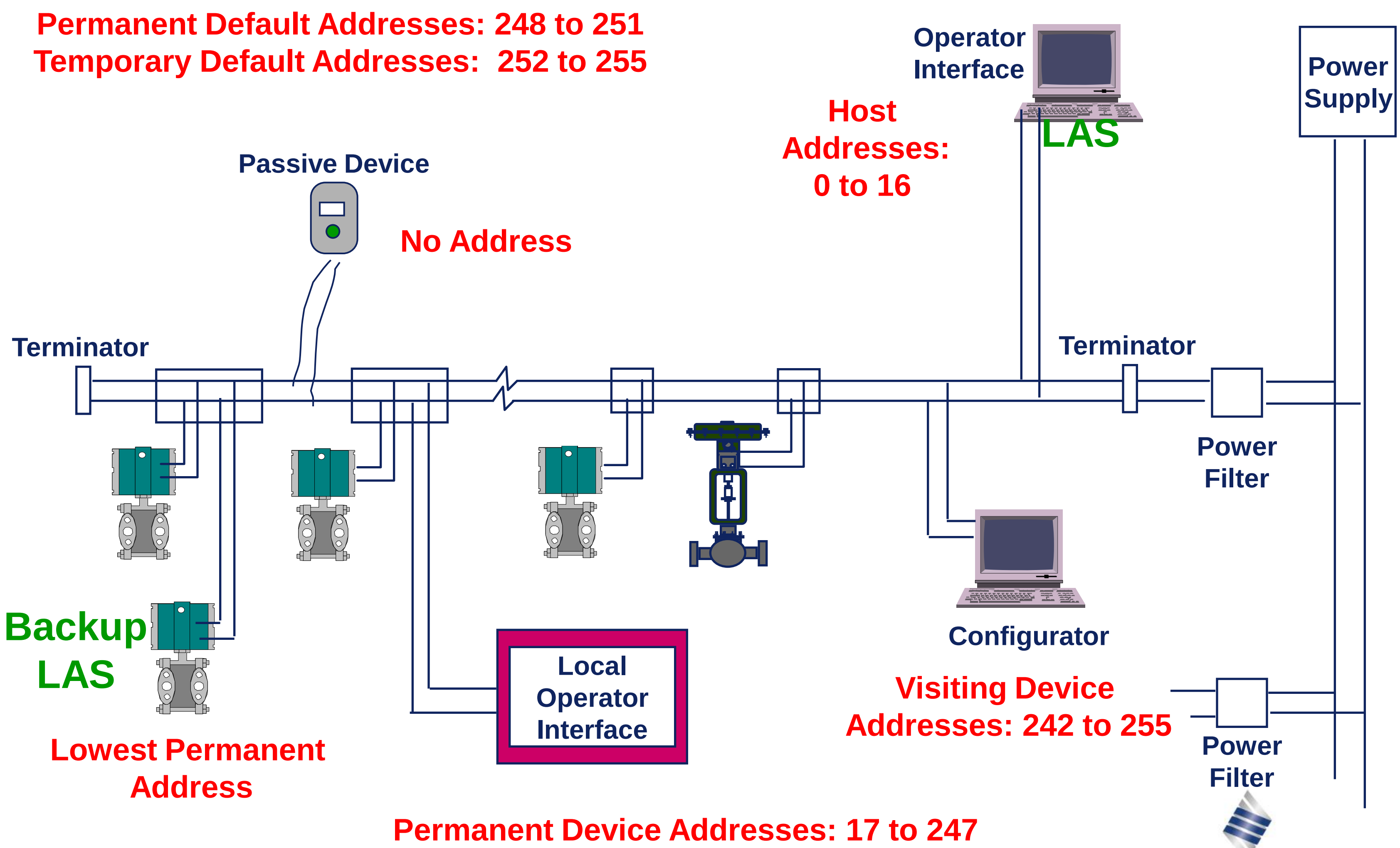
# Data Security

- Sophisticated frame error checking. Hamming distance of 4 over the longest possible Fieldbus message, and Hamming distance 5 over tokens and all other short control messages (to about 15 bytes total length).
- Messages are confirmed – acyclic communications
- Stale data counter on loss of cyclic communications
- Live list maintenance – devices detected on segment
- Timeouts on confirmed communication
- Network parameters defined to prevent message overlapping

# Tree Topology



# Addressing

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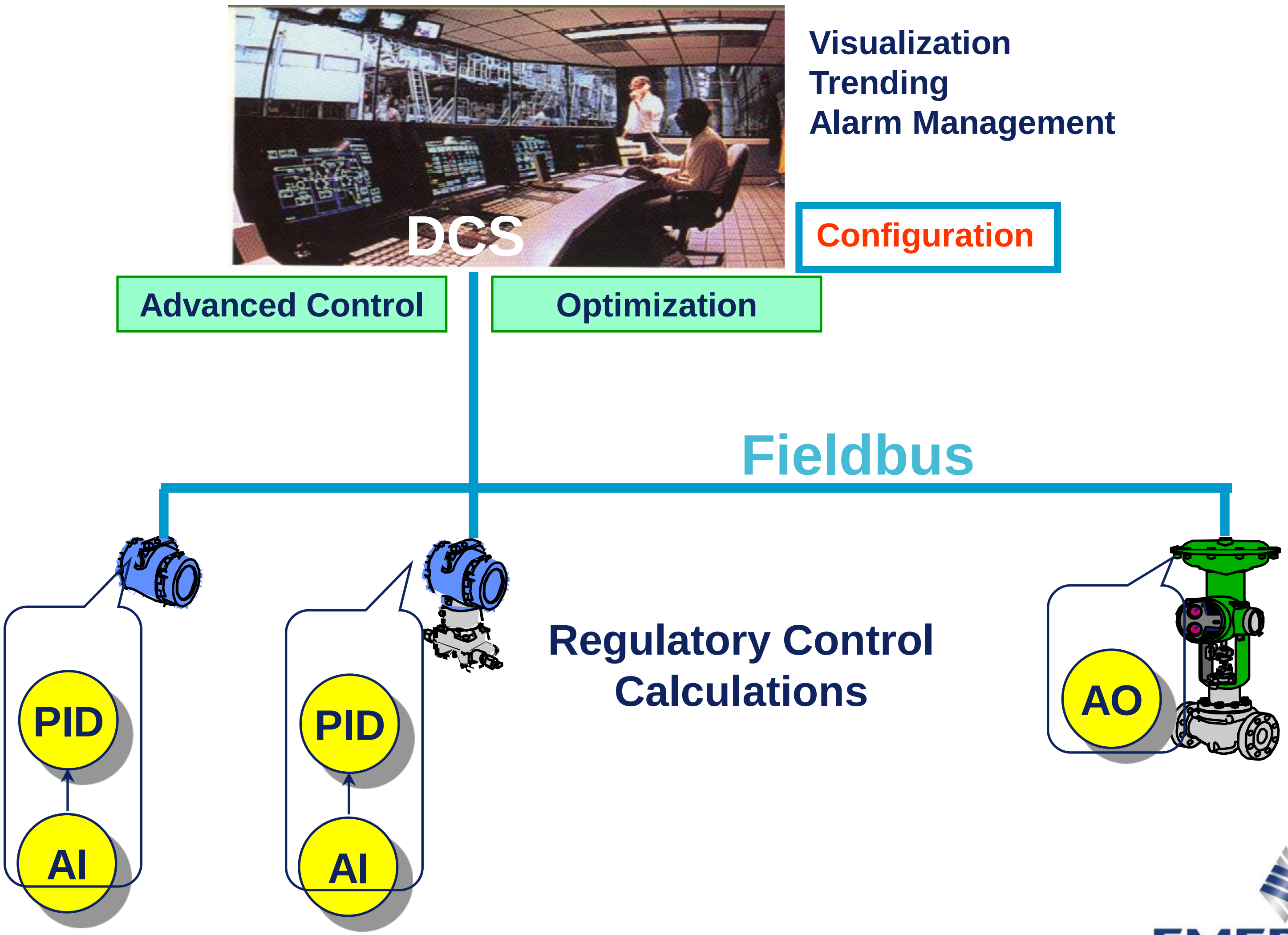
# Control in the field

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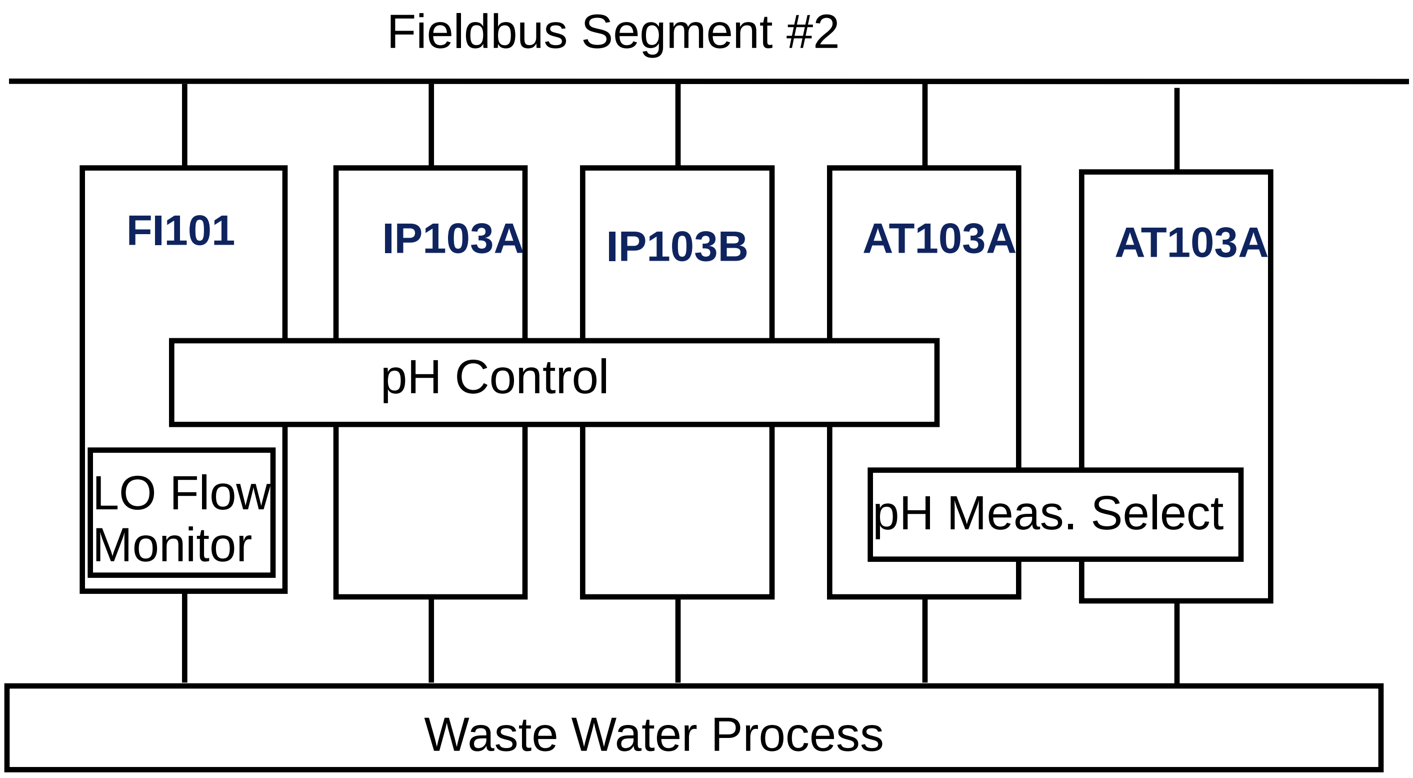
# *FF Allows Control Applications To Be Distributed*



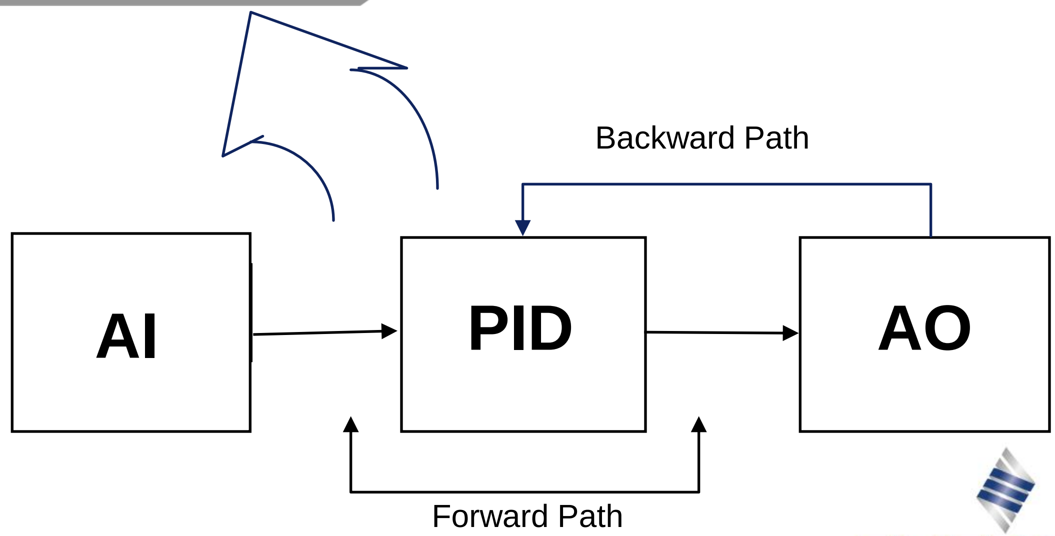
# *Information Flow Between Function Blocks*

**Function Block Inputs and Outputs**

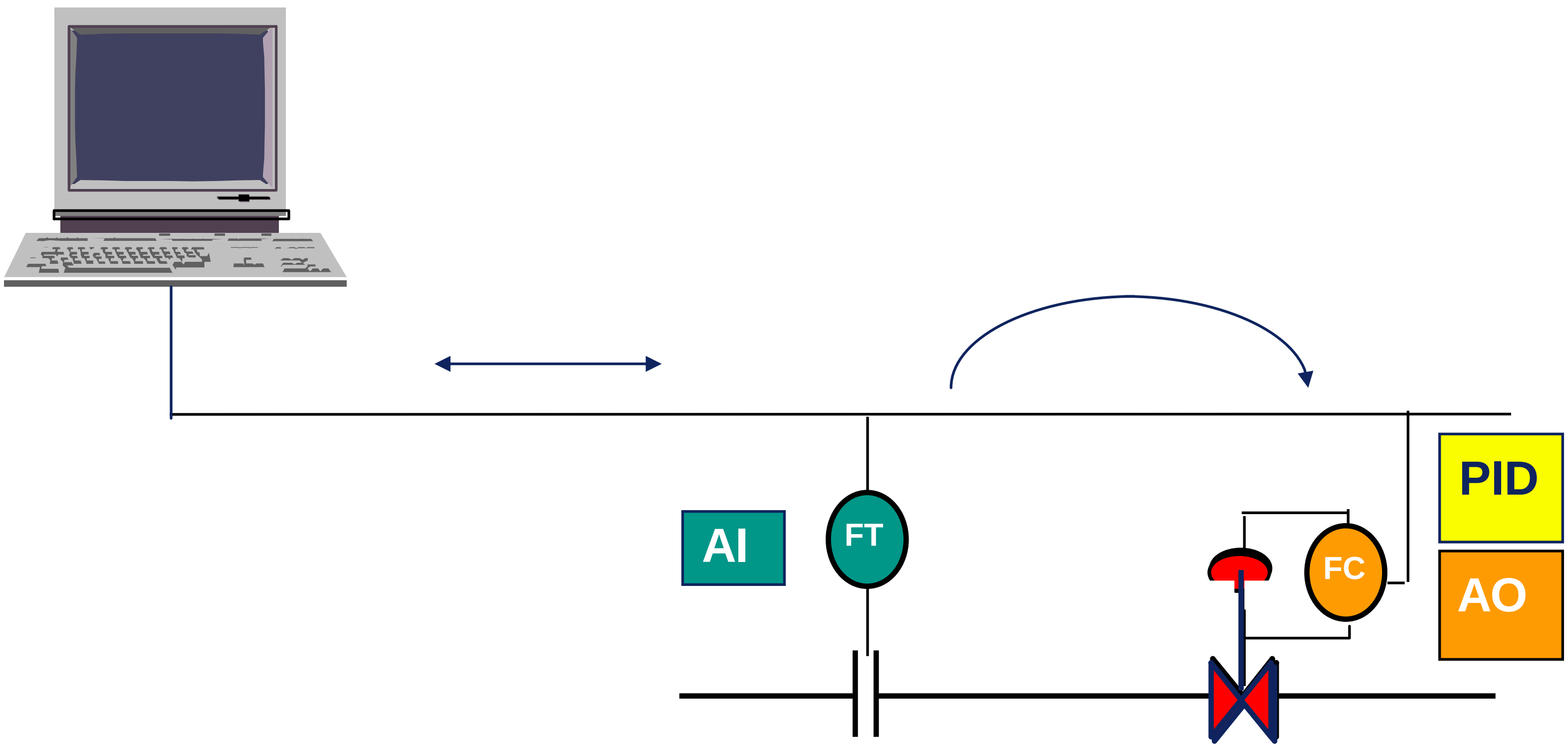
**Communicate Value + *STATUS***

**Where Status Indicates:**

**Quality = Good, Uncertain, Bad**
**Quality Substatus = Highest priority error or alarm condition**
**Limit - limit condition associated with value**



# Cyclic and Acyclic Communication



# *Common sense of time*

- All devices in the network share a common sense of time, which allows precise scheduling of activities.
- The Application Clock Time Distribution function synchronizes all fieldbus devices. The devices maintain their application clocks between synchronization messages.

The application time allows the devices to time stamp data (variables, alarms etc.).

Scheduling provides tighter control.

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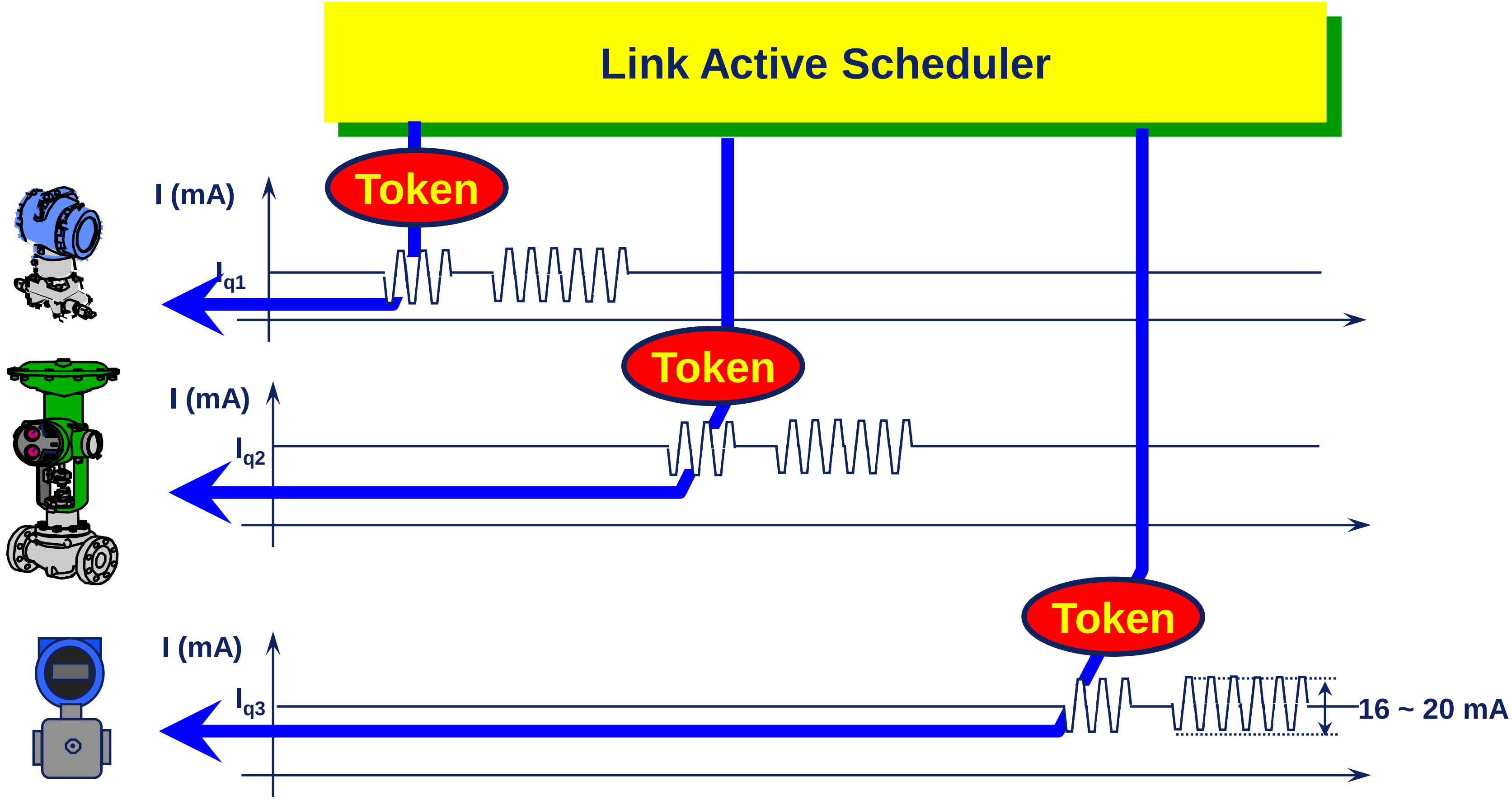
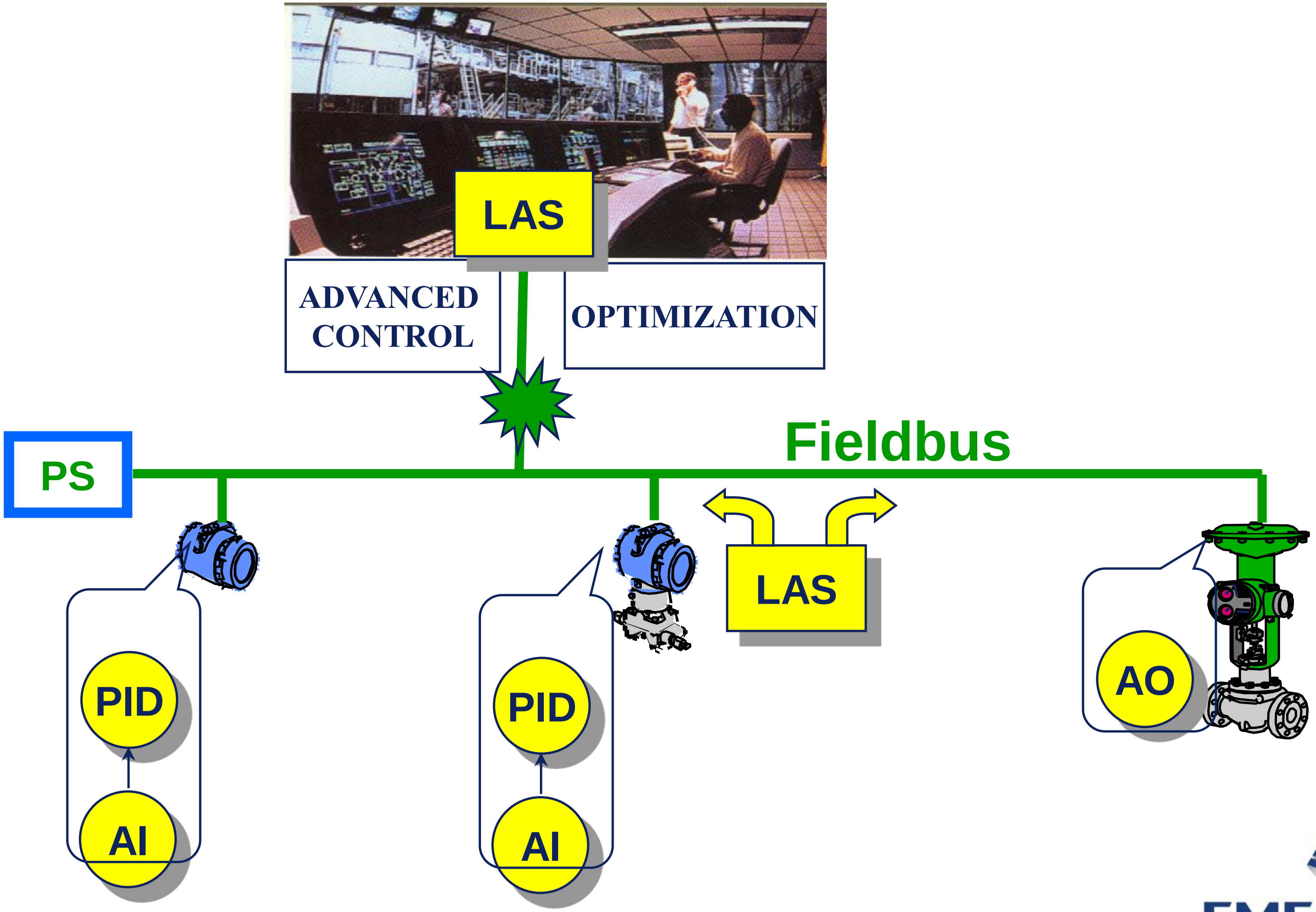


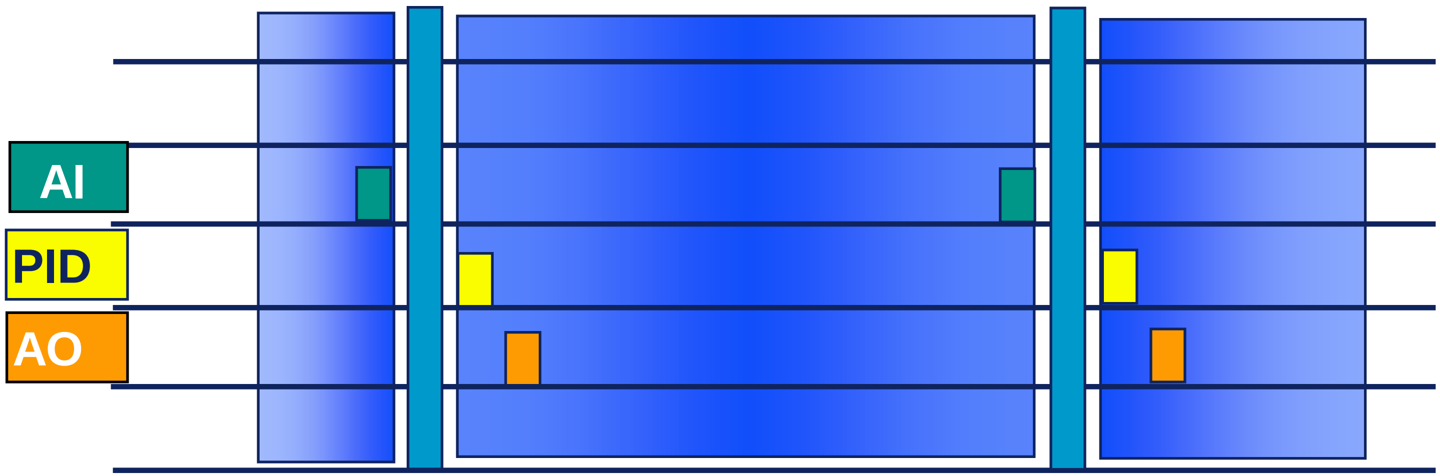

**Total Current = $I_{q1} + I_{q2} + I_{q3} + \ldots\ldots\ldots\ I_{qn}$**

# Backup LAS



LAS
ADVANCED CONTROL
OPTIMIZATION
Fieldbus
PS
LAS
PID
AI
PID
AI
AO

# *Sample PID Execution & Communications*




**Scheduled Cyclic**

- Publish/Subscribe

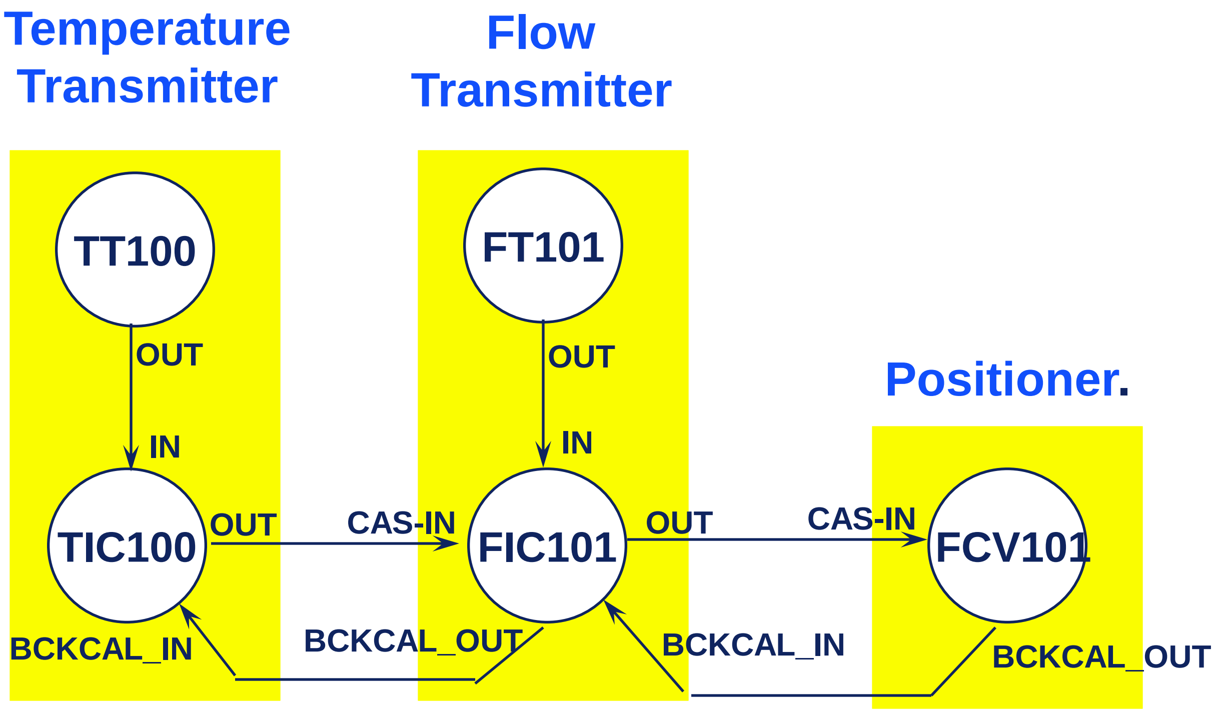
**Acyclic Communication**

- Alarms/Events
- Maintenance/Diagnostic Information
- Program Invocation
- Permissives/Interlocks
- Display Information
- Trend Information
- Configuration

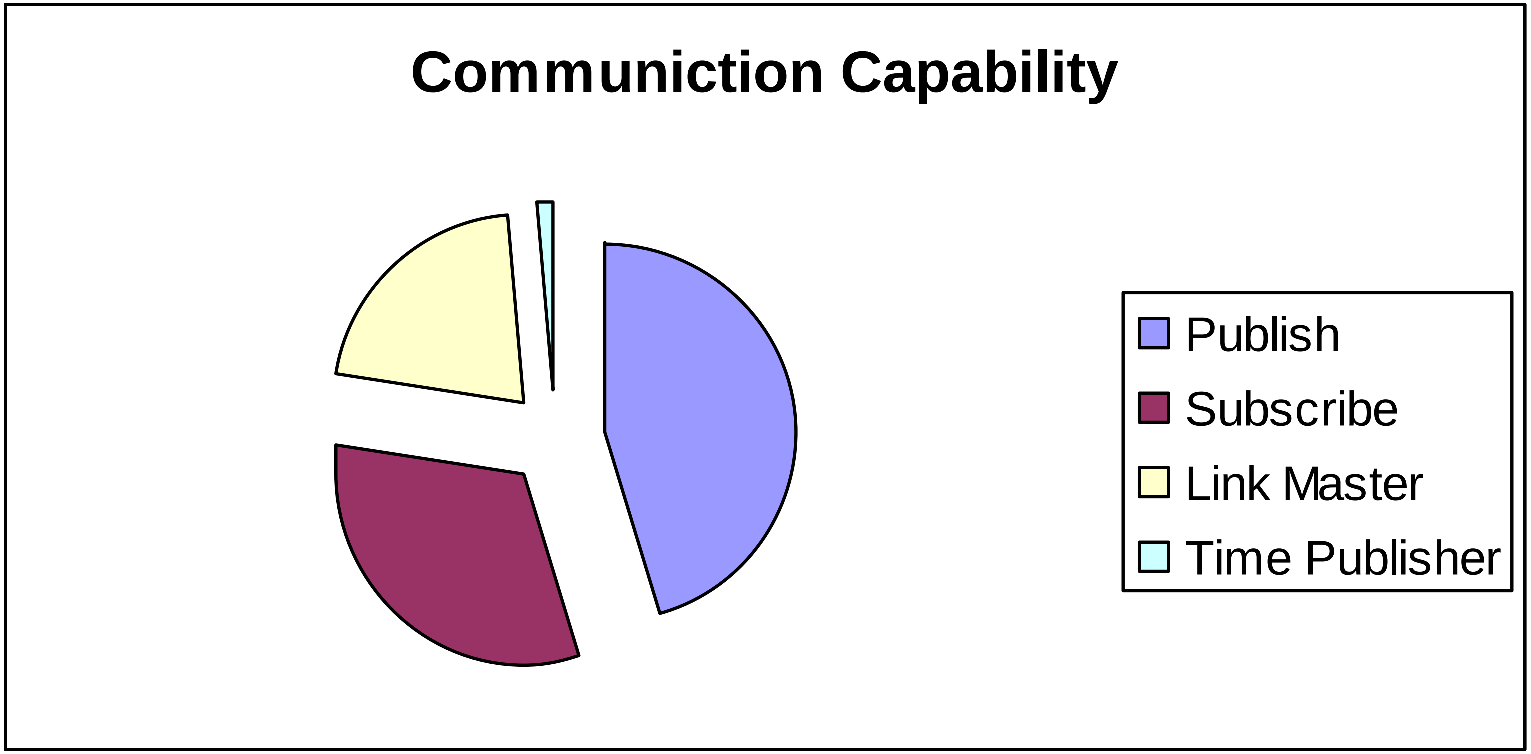
**Function Block Scheduling**

AI PID AO

# Example – Cascade Control



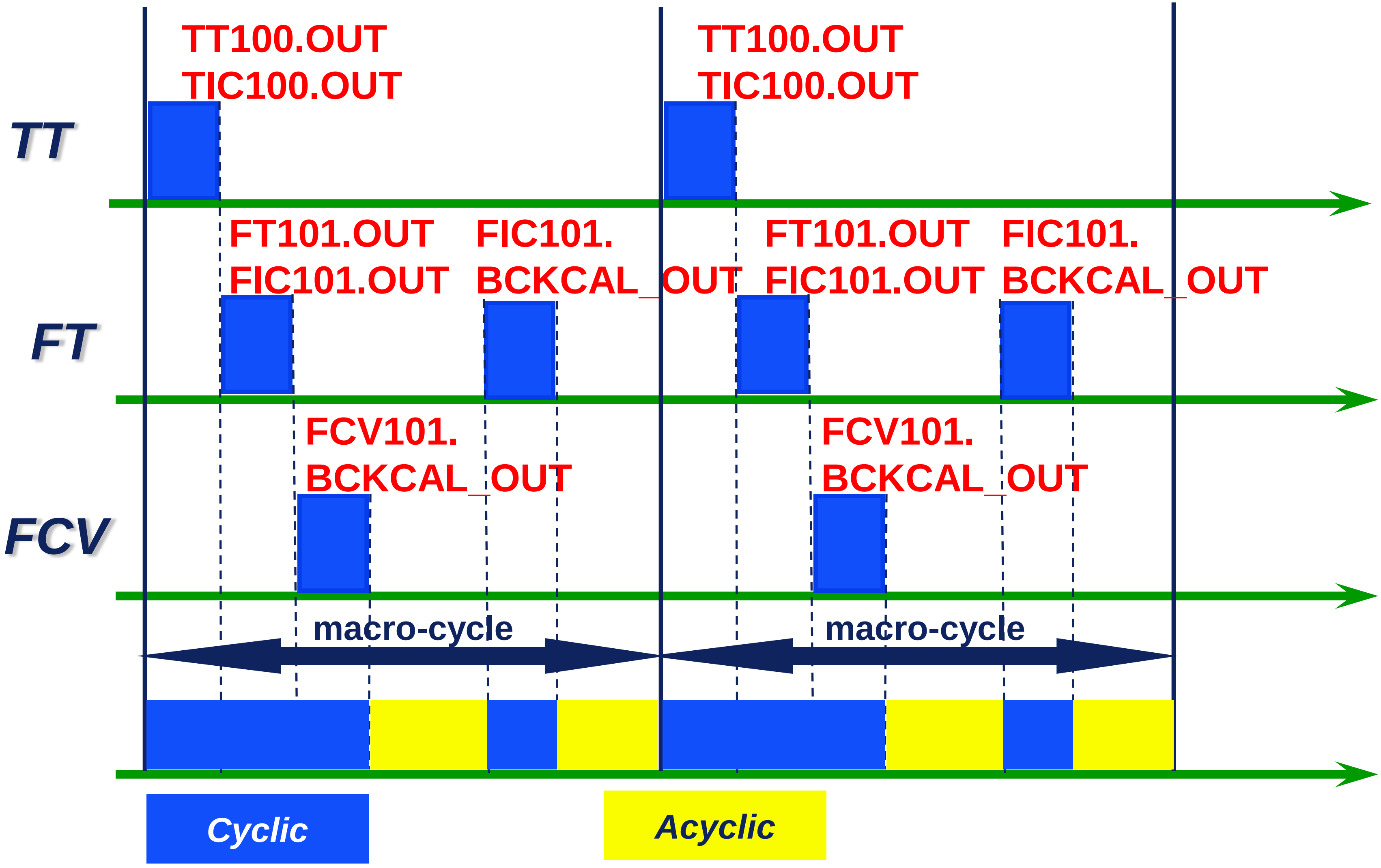
# Registered Fieldbus Devices




**Basic Device** = Publish or Publish & Subscribe

**Linkmaster Device** = Basic + Capability to control communications on a fieldbus segment

# Data sequence



# Macrocycle

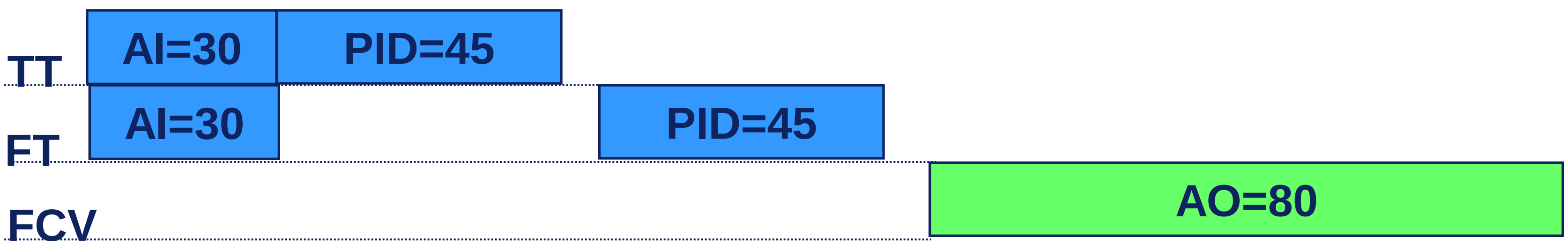
**A Macrocycle is determined by:**

- **Function Block Execution times.**
- **Transmission time of the cyclic messages.**
- **Gaps between messages determined by the Network parameters.**
- **Time reserved for acyclic messages**

# Macrocycle

- Function Block execution time depends on the type of block and on the hardware and software design.
- The execution times from today will be reduced five times or more within two years.
- In the time calculation, only blocks that must be executed consecutively are considered.

**Cascade Control Example**




Block Execution Time = 30+45+45+80 = 200 ms

*Note that the AI in the flow device is executed in parallel.

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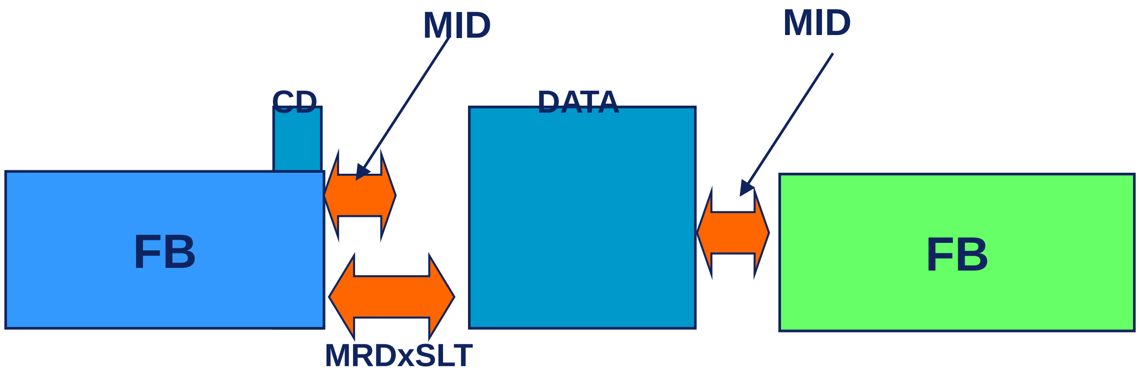
# Macrocycle



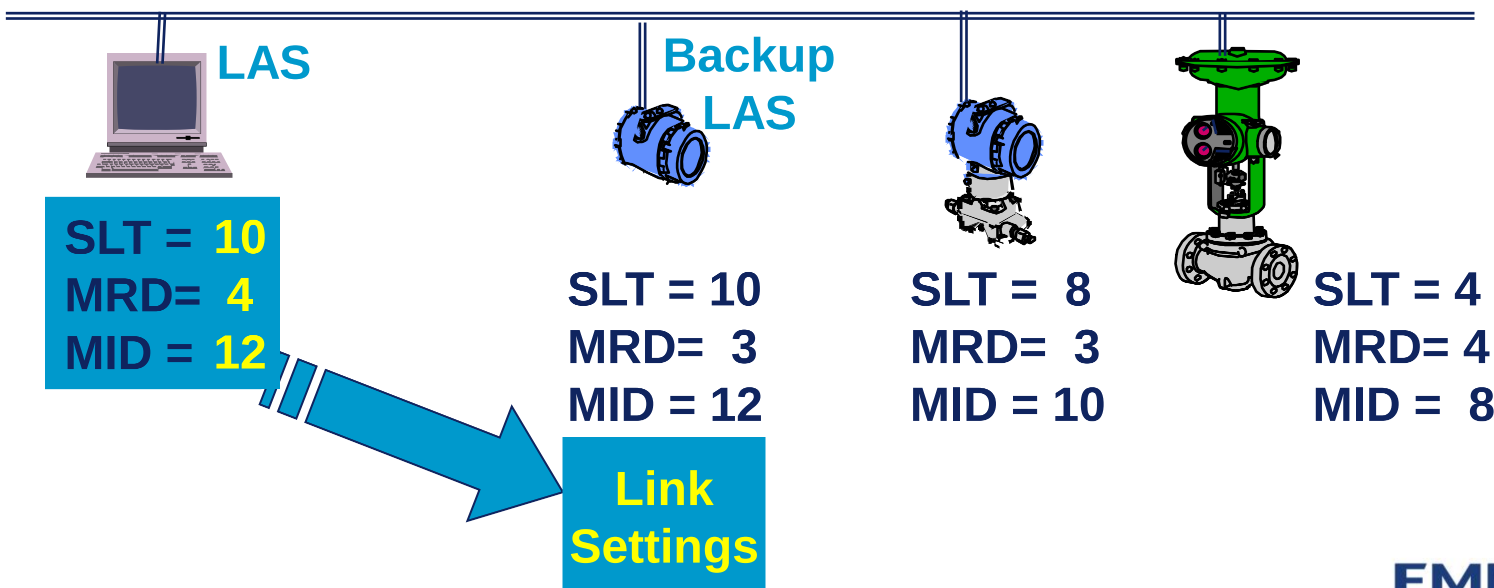

**SLT - Slot time**
**MRD - Maximum Response Delay**
**MID - Minimum Inter PDU Delay**

**As for the Function Blocks, the Network parameters will be reduced dramatically in the next two years**

# Network Parameters

**Network Parameters establish how the network operates.**

**The LAS must be set with the larger parameter values of the devices participating in the Network.**

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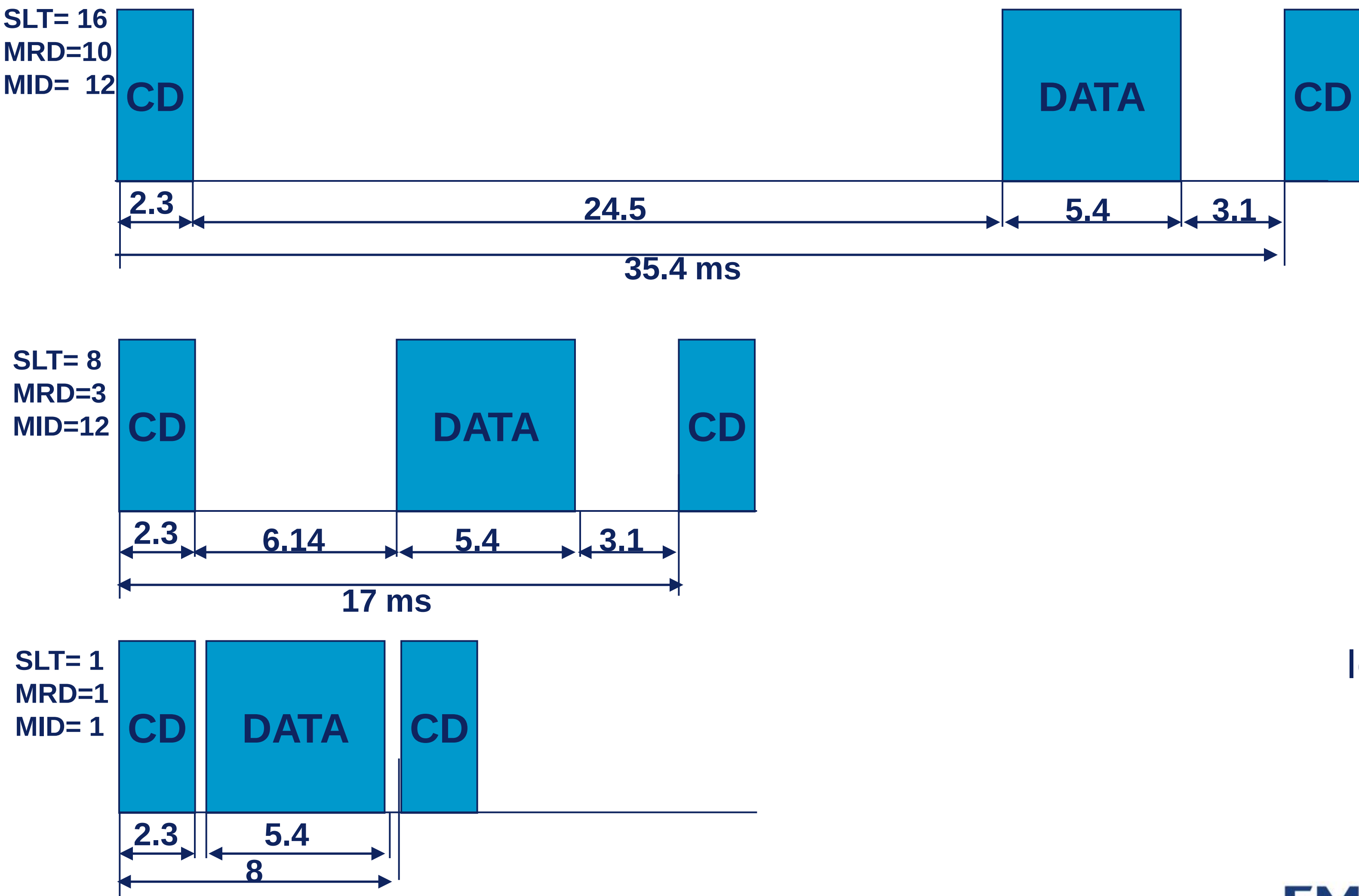


Ideal Max.
**28 / s**

Ideal Max.
**58 / s**

Ideal Max.
**125 / s**

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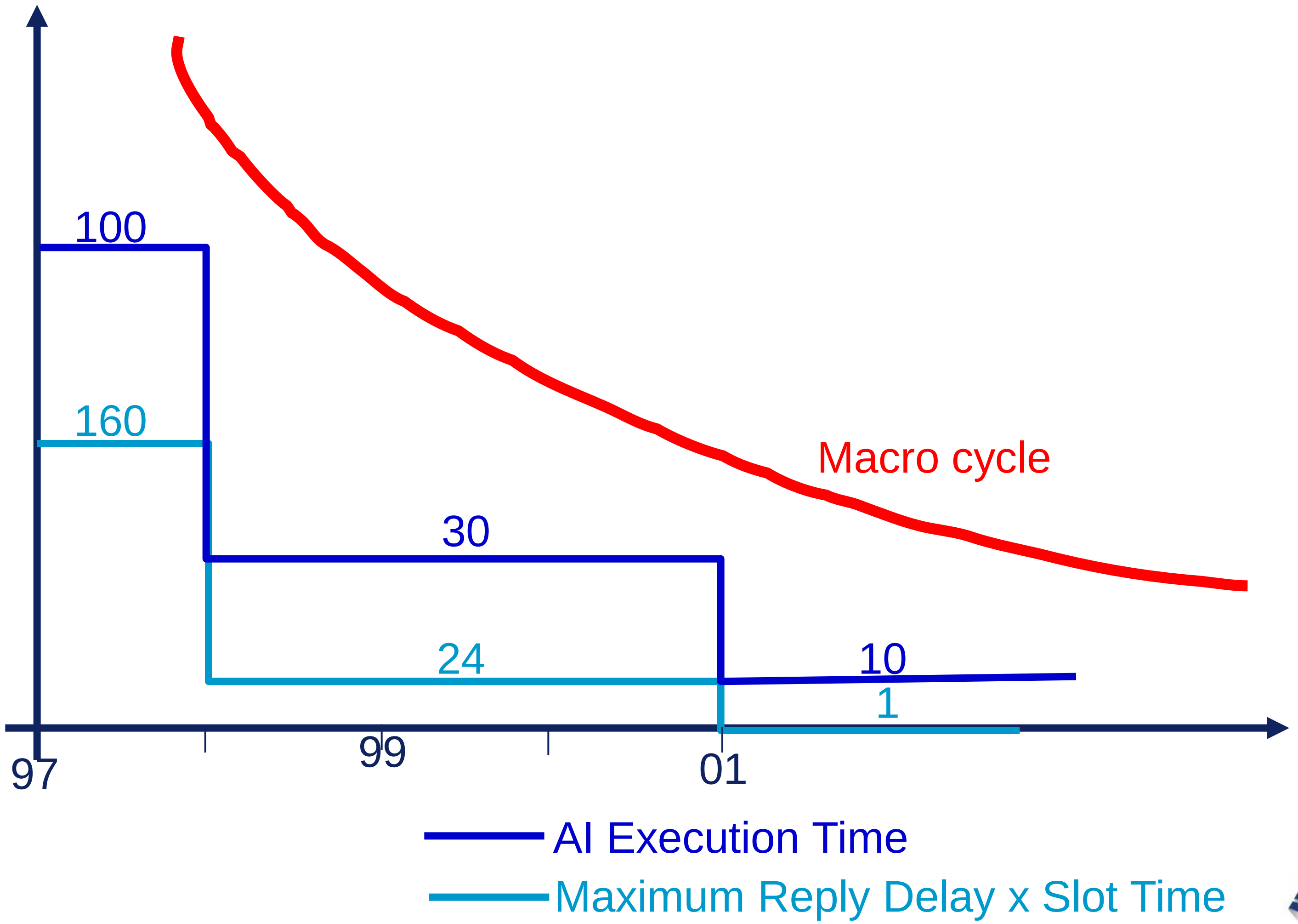
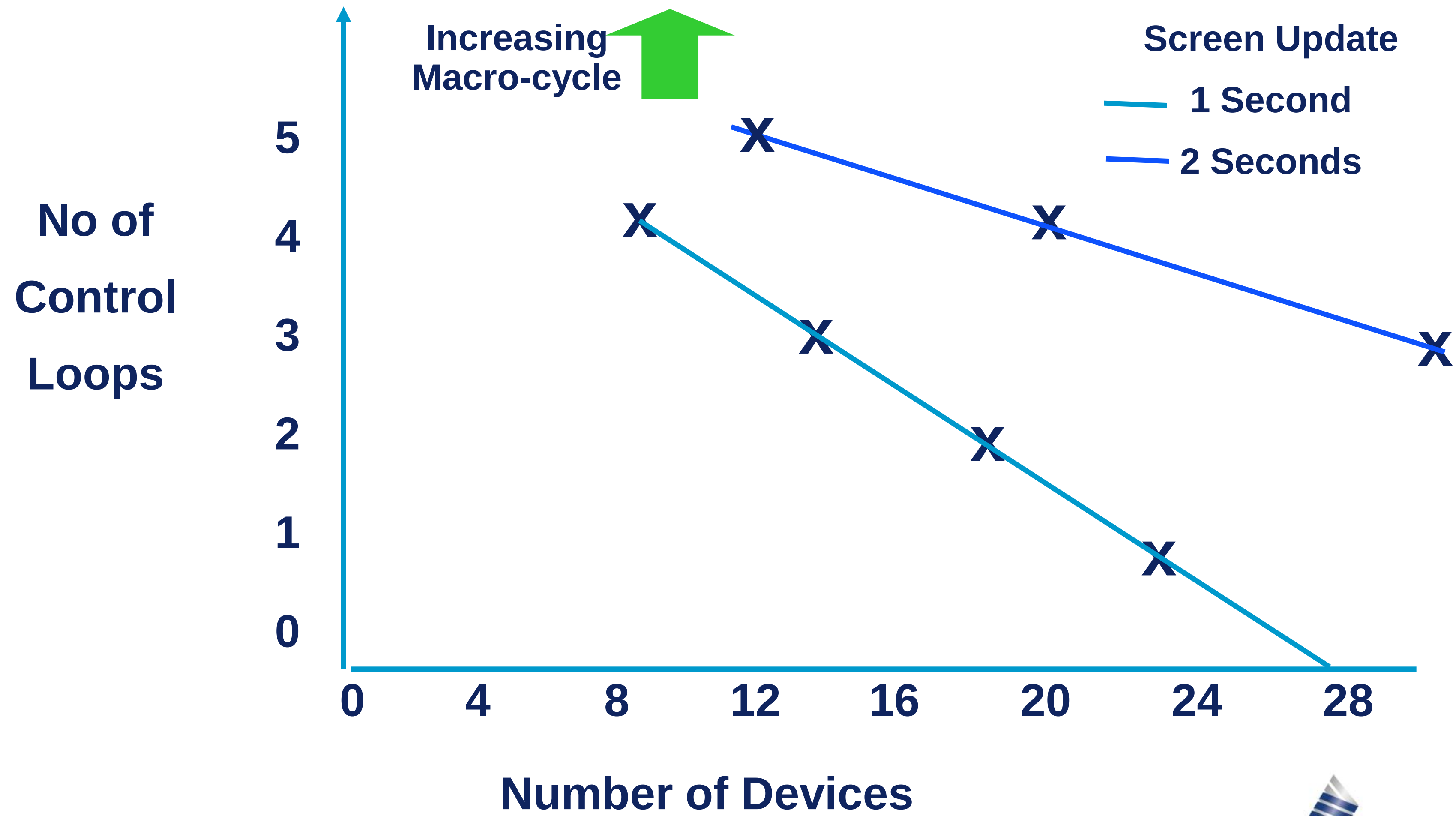
# *Evolution*



100
160
30
24
10
1
Macro cycle
97
99
01
AI Execution Time
Maximum Reply Delay x Slot Time

# *Loop Execution of 250msec*

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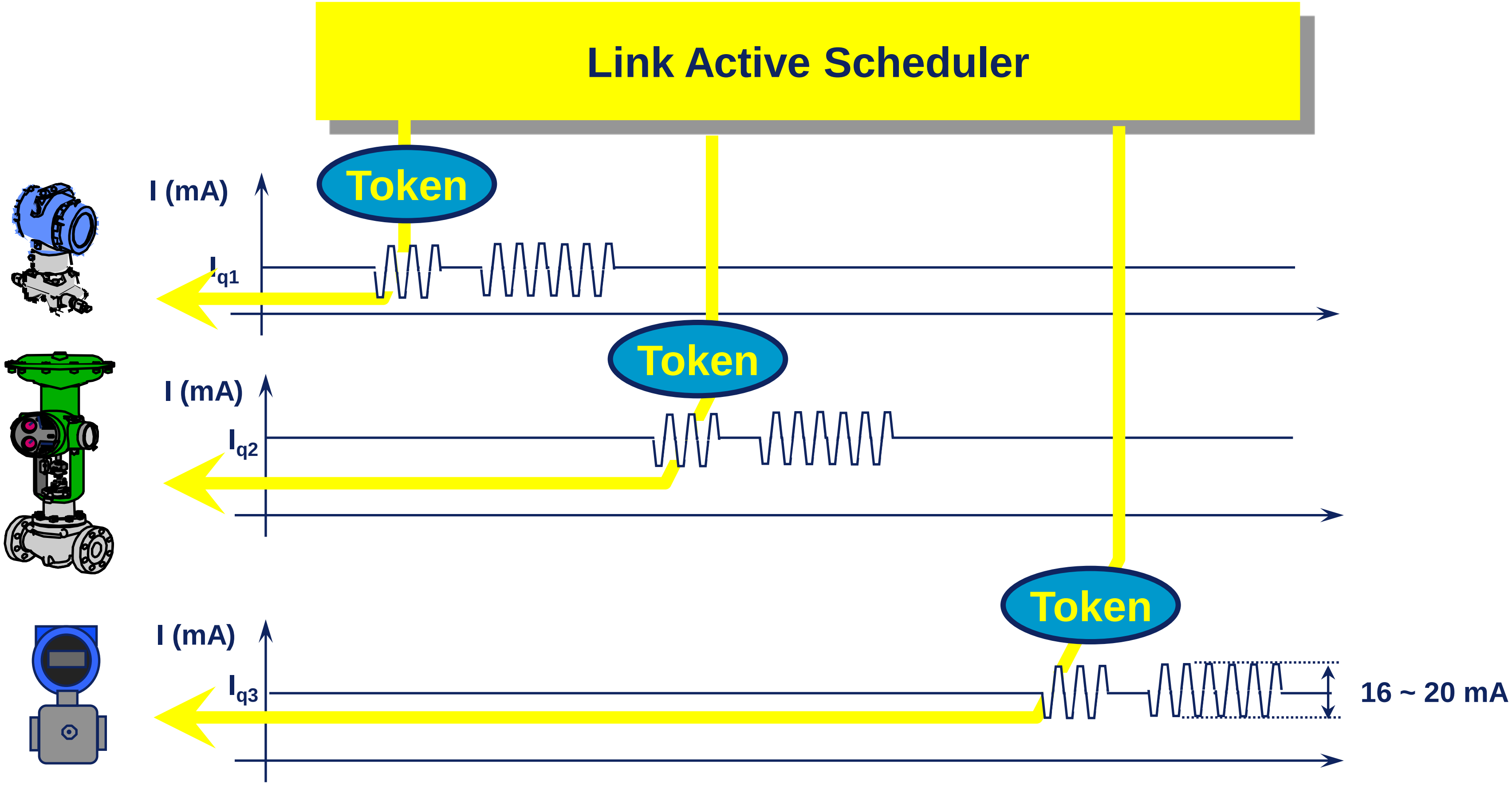
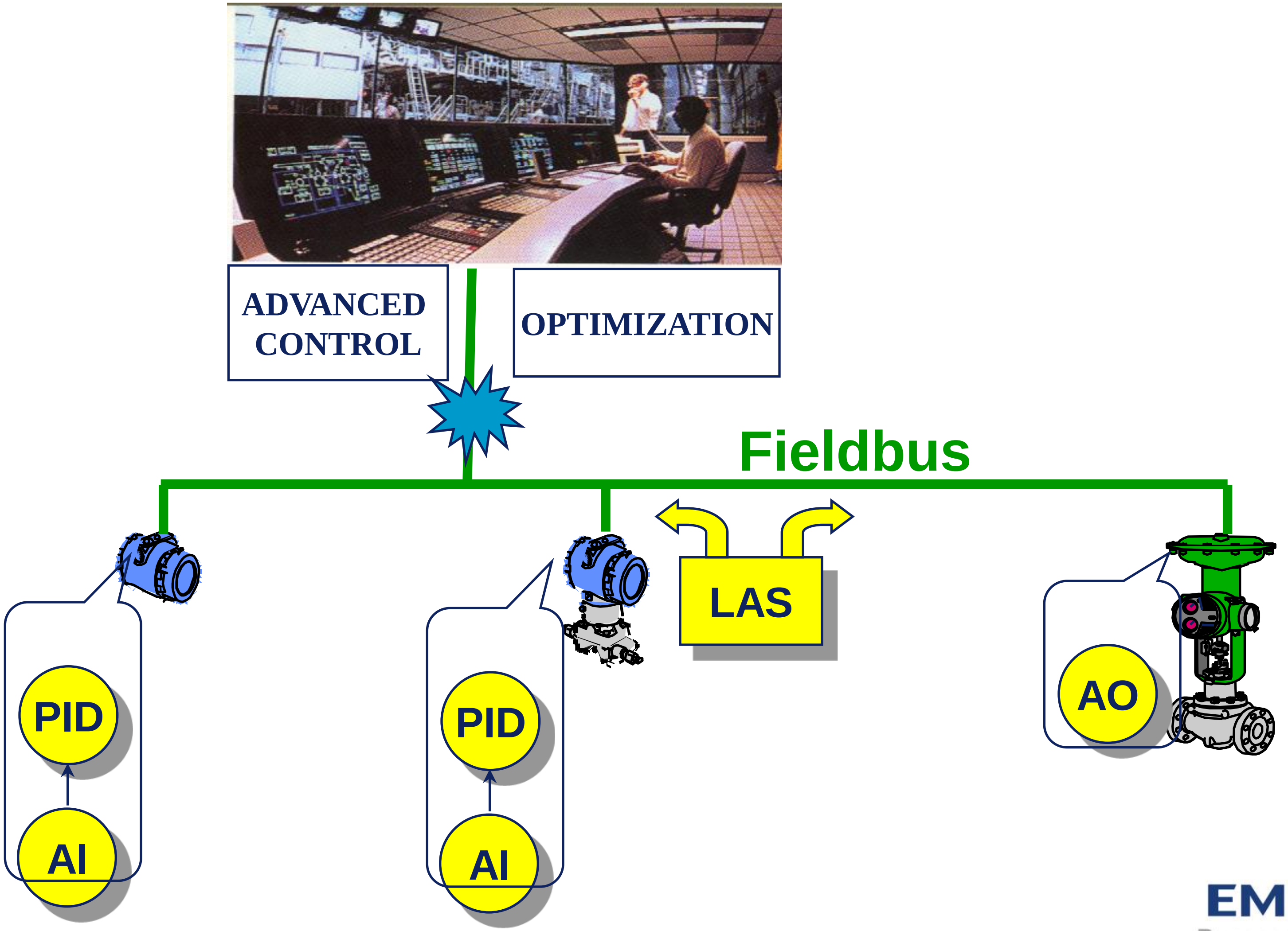



**Total Current = $I_{q1} + I_{q2} + I_{q3} + \ldots\ldots\ldots I_{qn}$**

# Backup LAS

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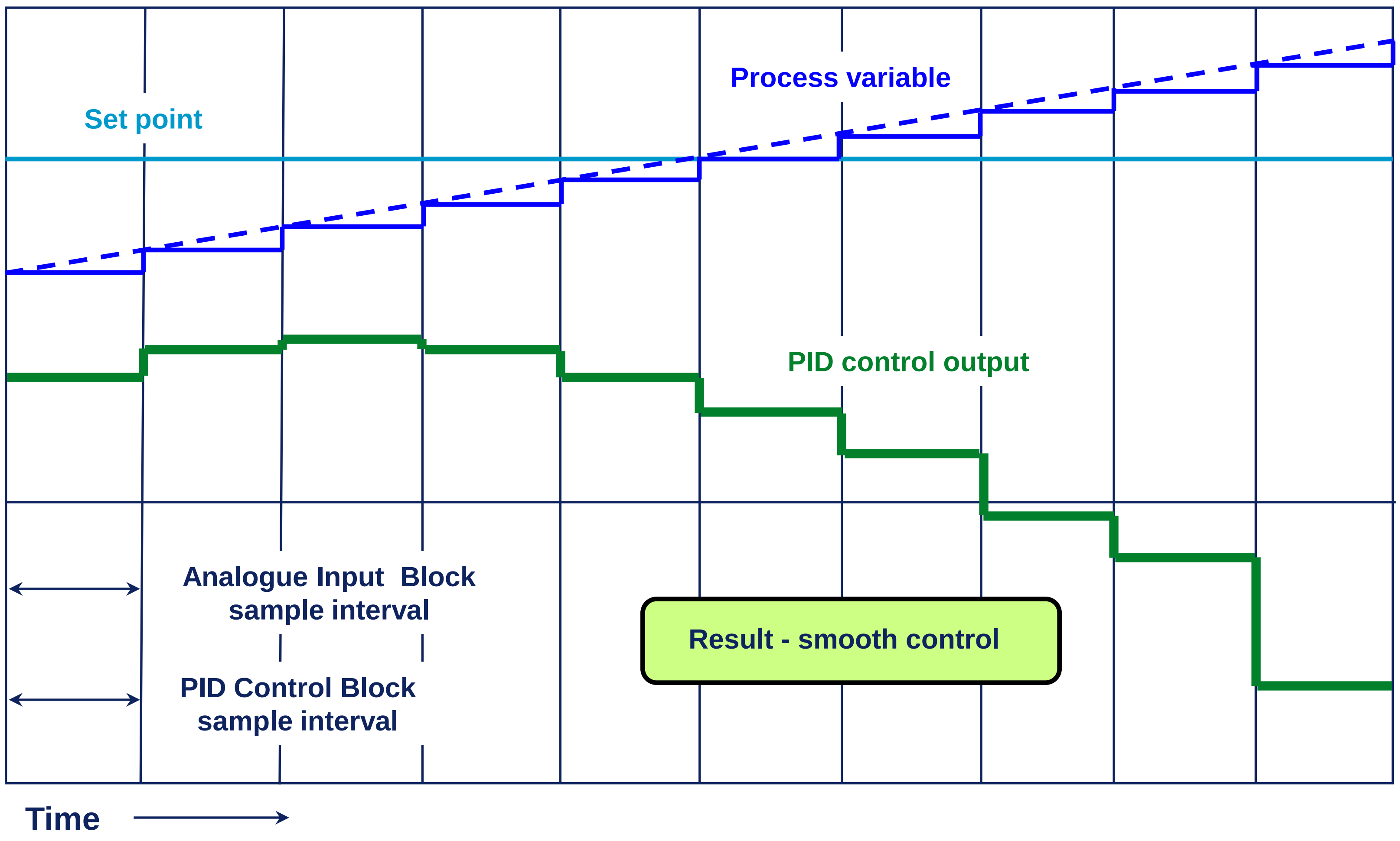
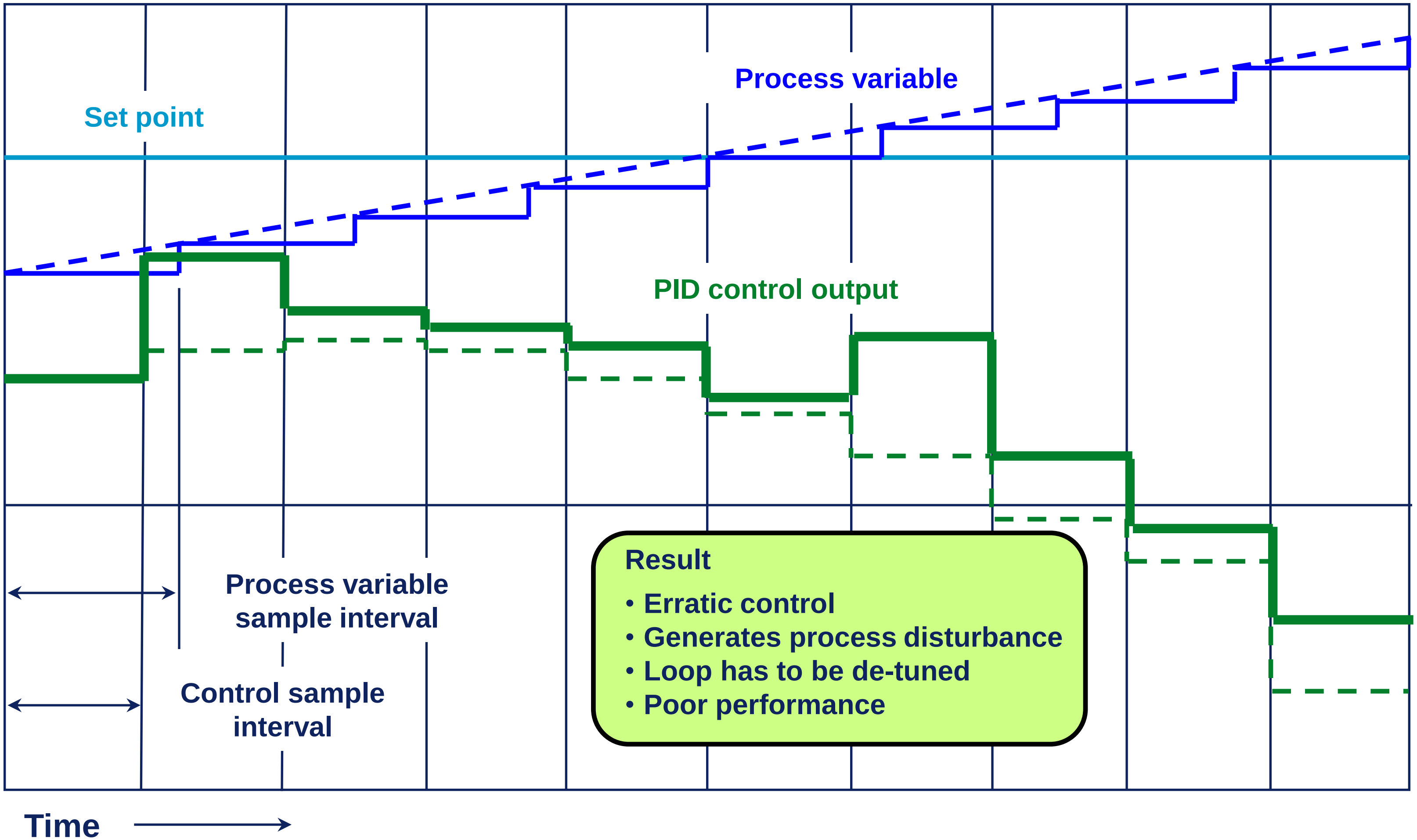
# Importance of Synchronised Function Block Execution

Synchronised process sampling and control -Open Loop



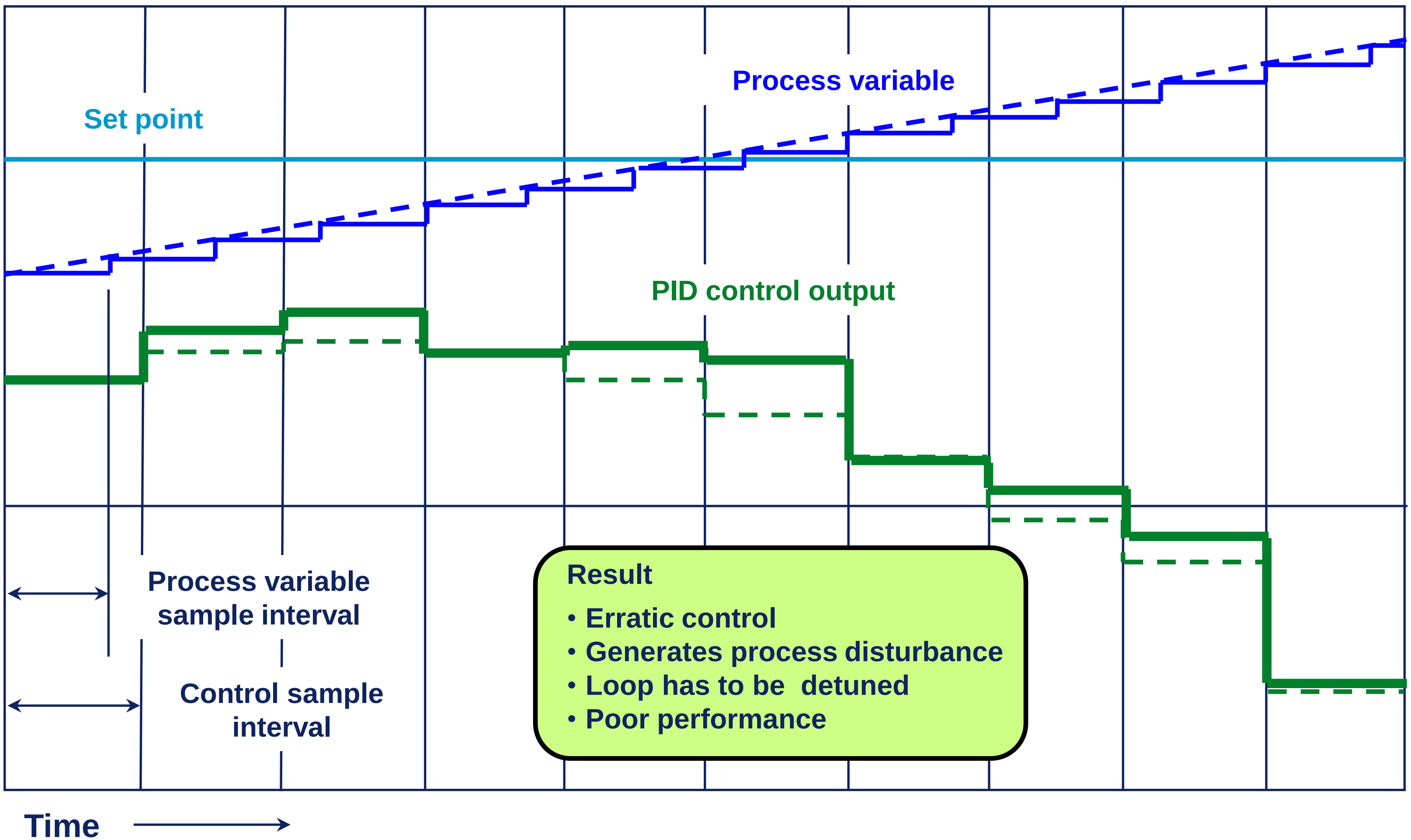
# Importance of Synchronised Function Block Execution

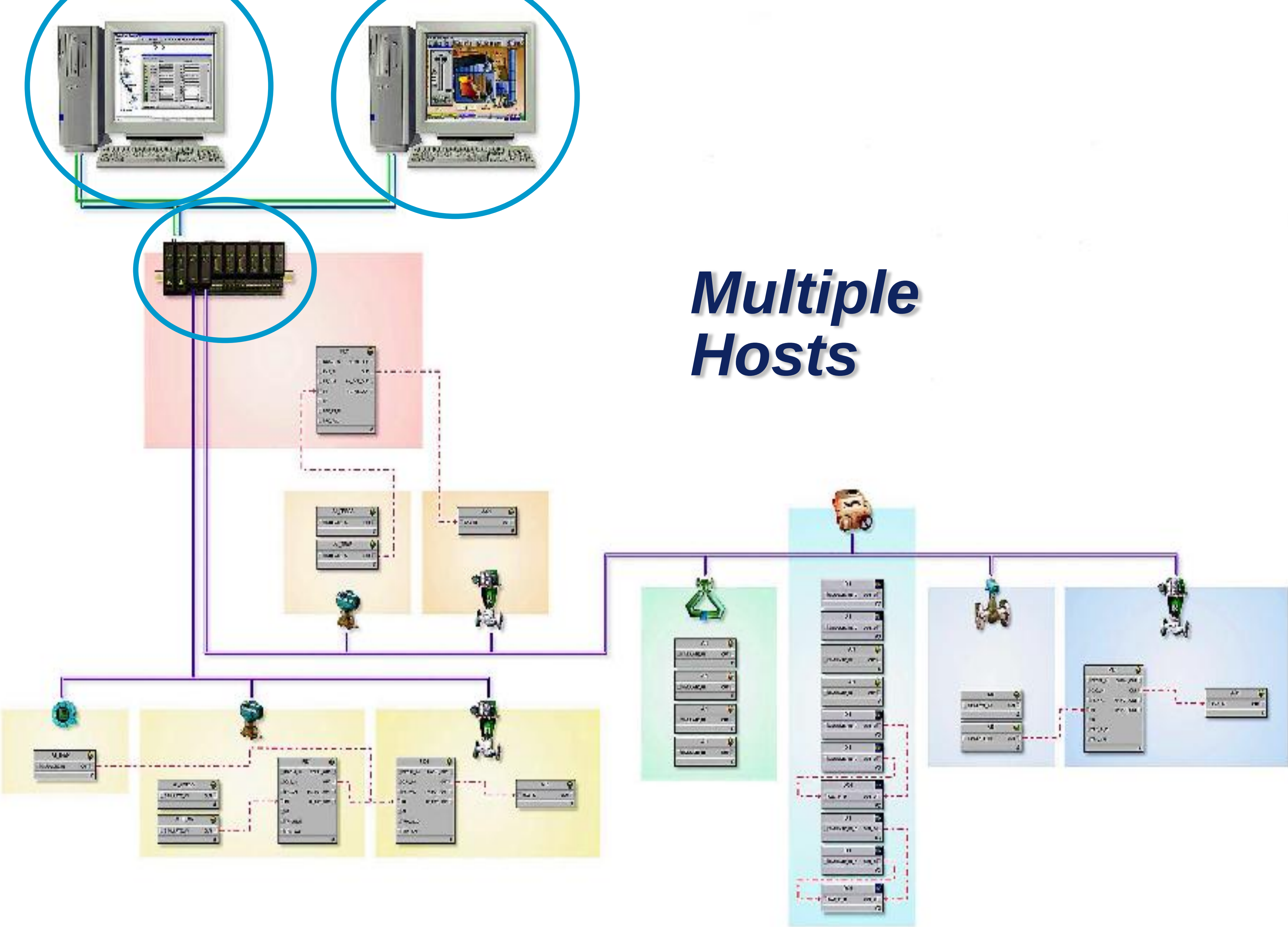
## Non-synchronised process sampling and control - Open Loop



# Importance of Synchronised Function Block Execution

## Non-synchronised process sampling and control - Open Loop





# *Multiple Hosts*

# Control Performance Achieve Using Fieldbus

- Function block execution, maximum response time for compel data and slot time ( dependent of the device technology/design – specific to manufacturer)
- Whether control is done in the field or in the control system (customer decision)
- Scheduling of block execution and communications on the FF segment (dependent of control system design)

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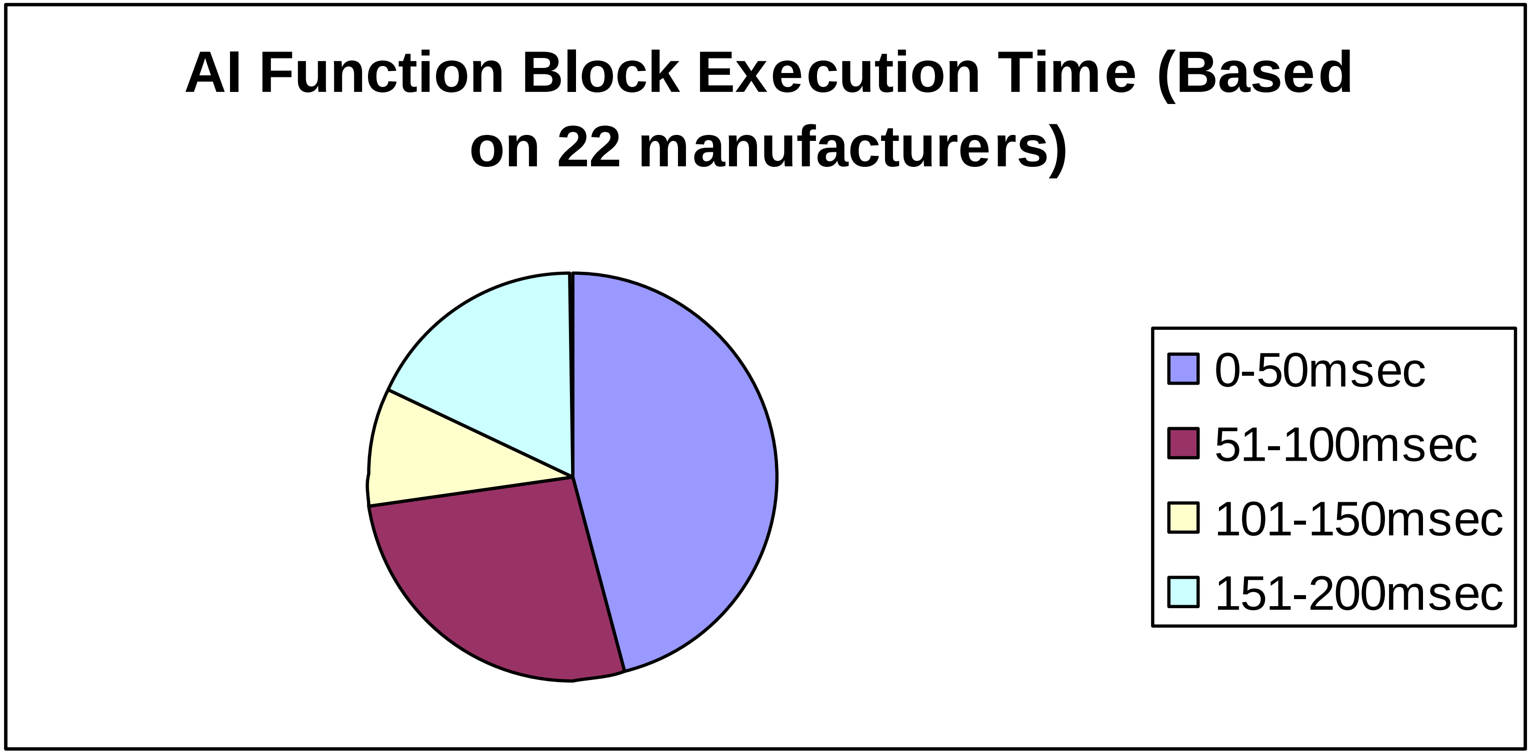
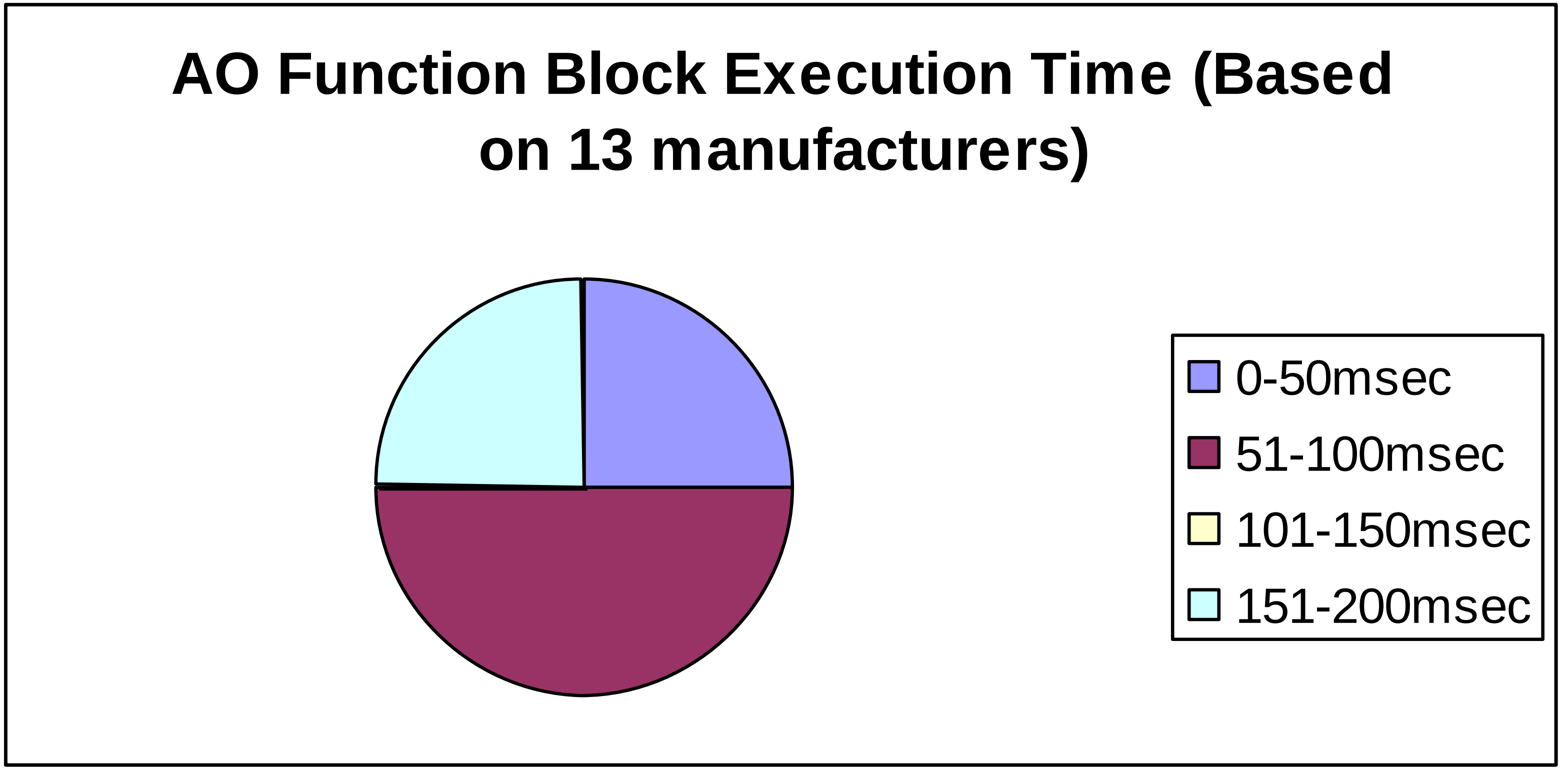
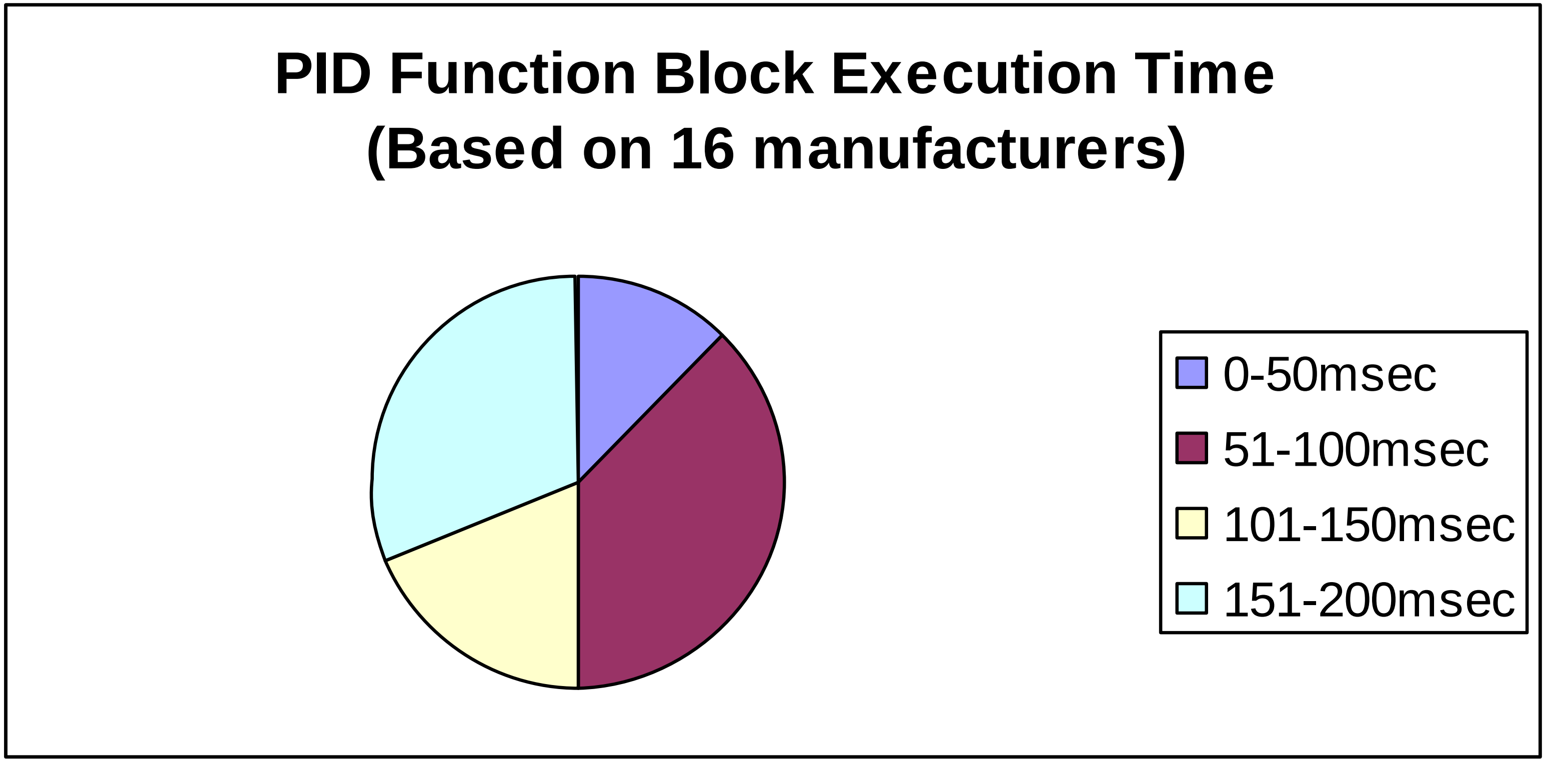
# AI Function Block Execution Time



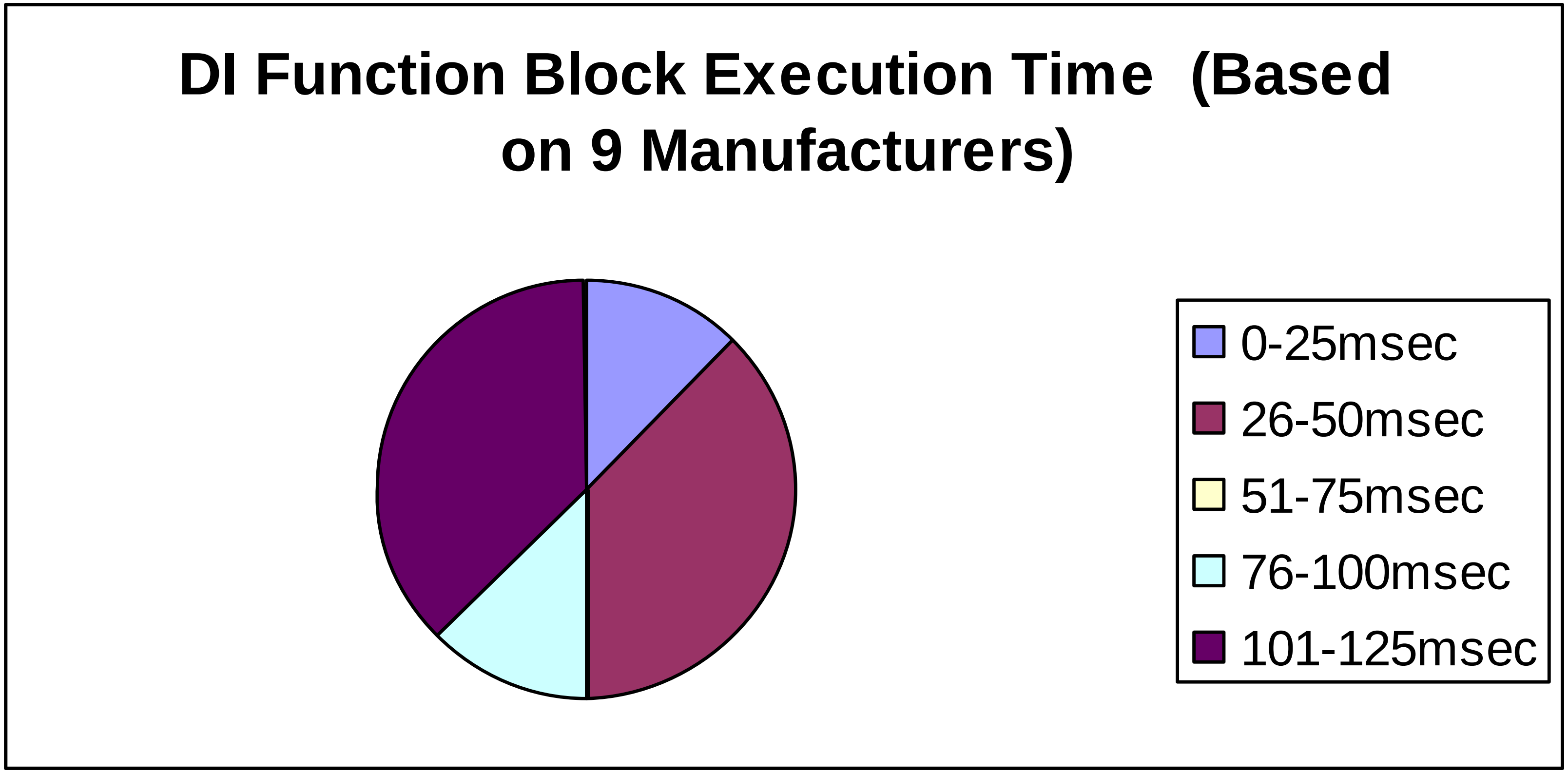
# AO Function Block Execution Time



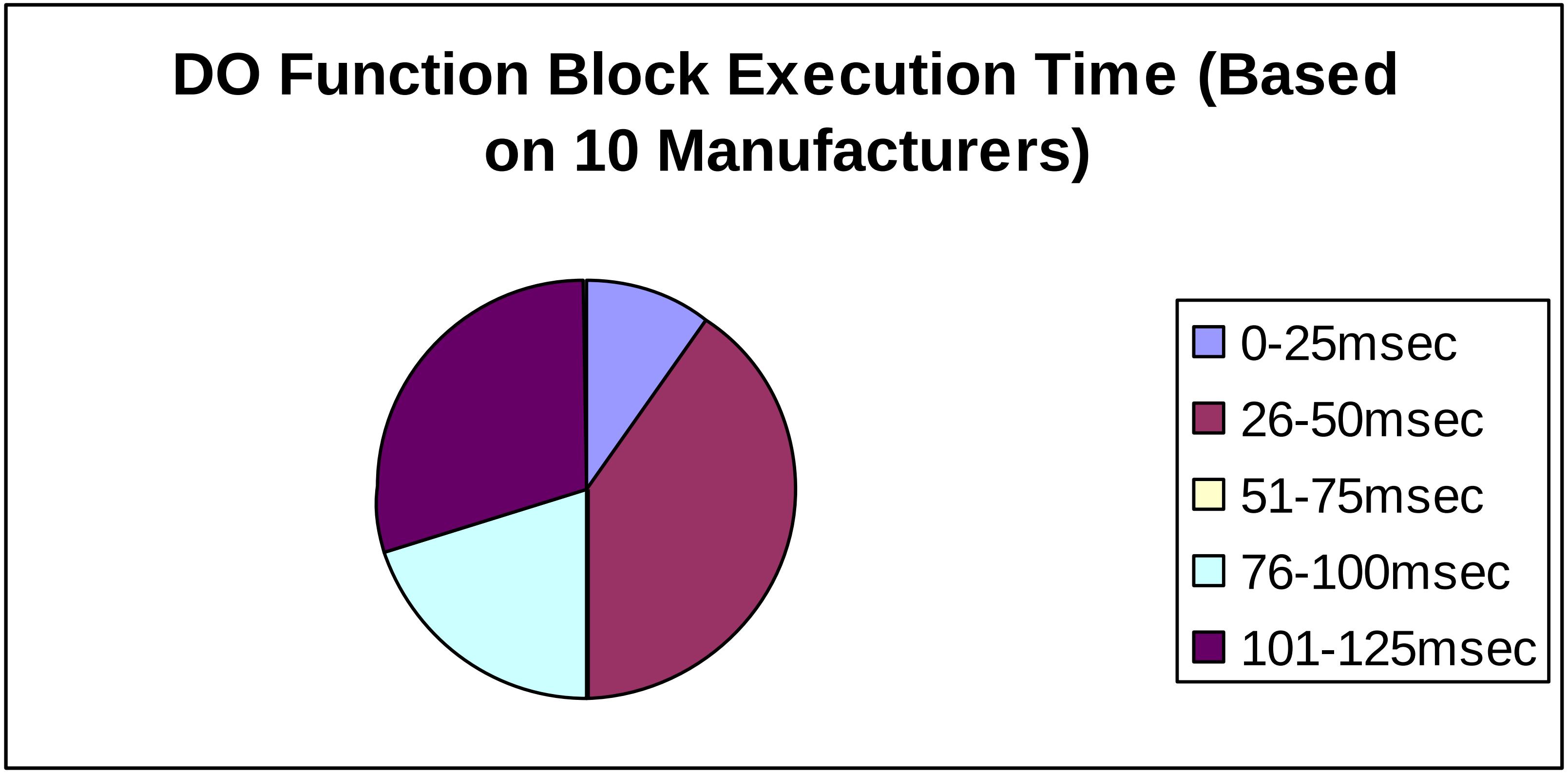
# PID Function Block Execution Time



# *DI Function Block Execution Time*



# DO Function Block Execution Time

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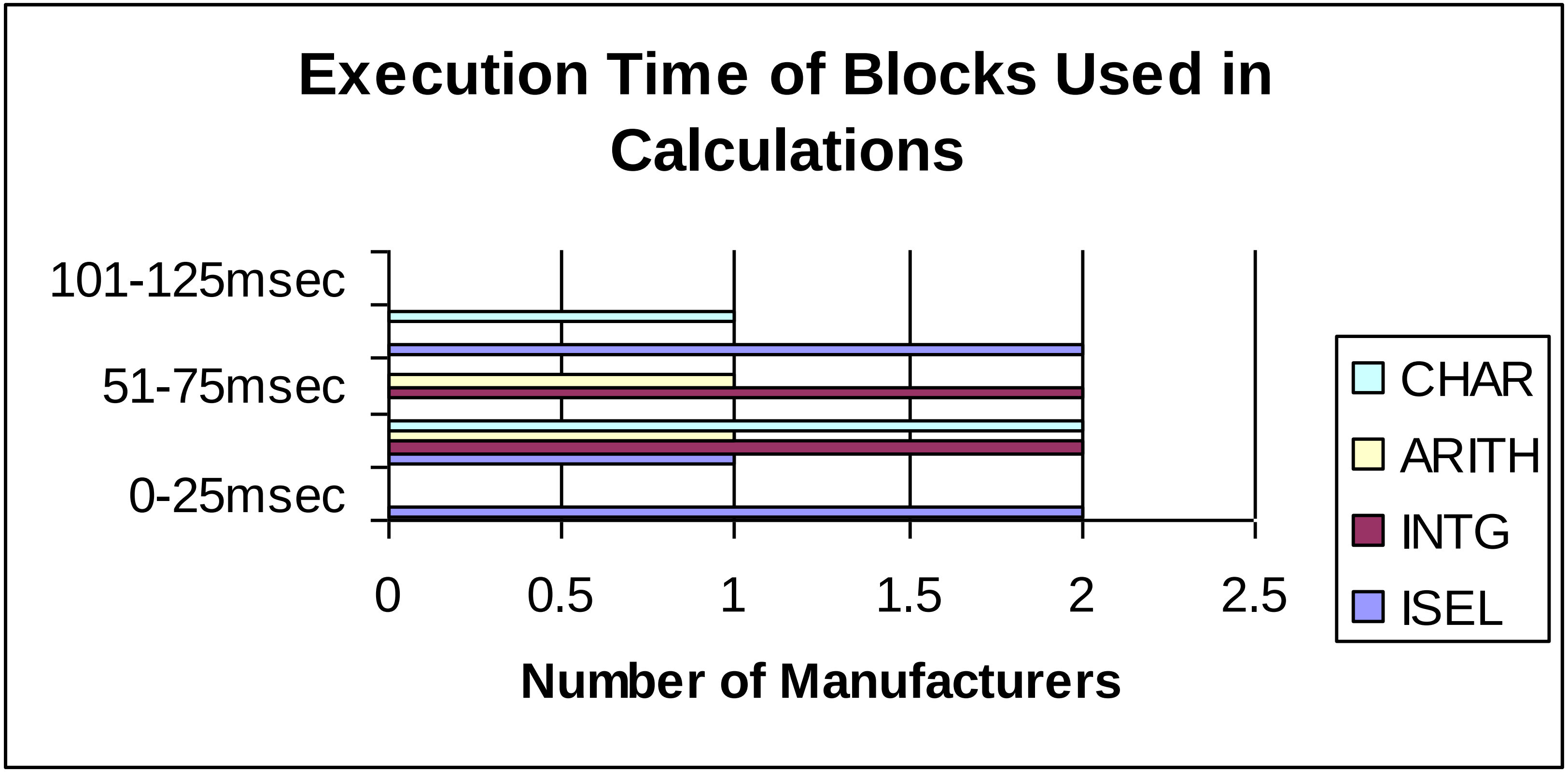
# Calculation Block Execution Times



# *Third Generation Devices Offer Significant Improvement if Block Execution Time*

*Example*:*

| Second Generation | | Third Generation | Improvement |
|---|---|---|---|
| AI = 30ms | → | AI = 20ms | 33% |
| PID = 45ms | | PID = 25ms | 44% |

** Execution times based on Rosemount 3051*

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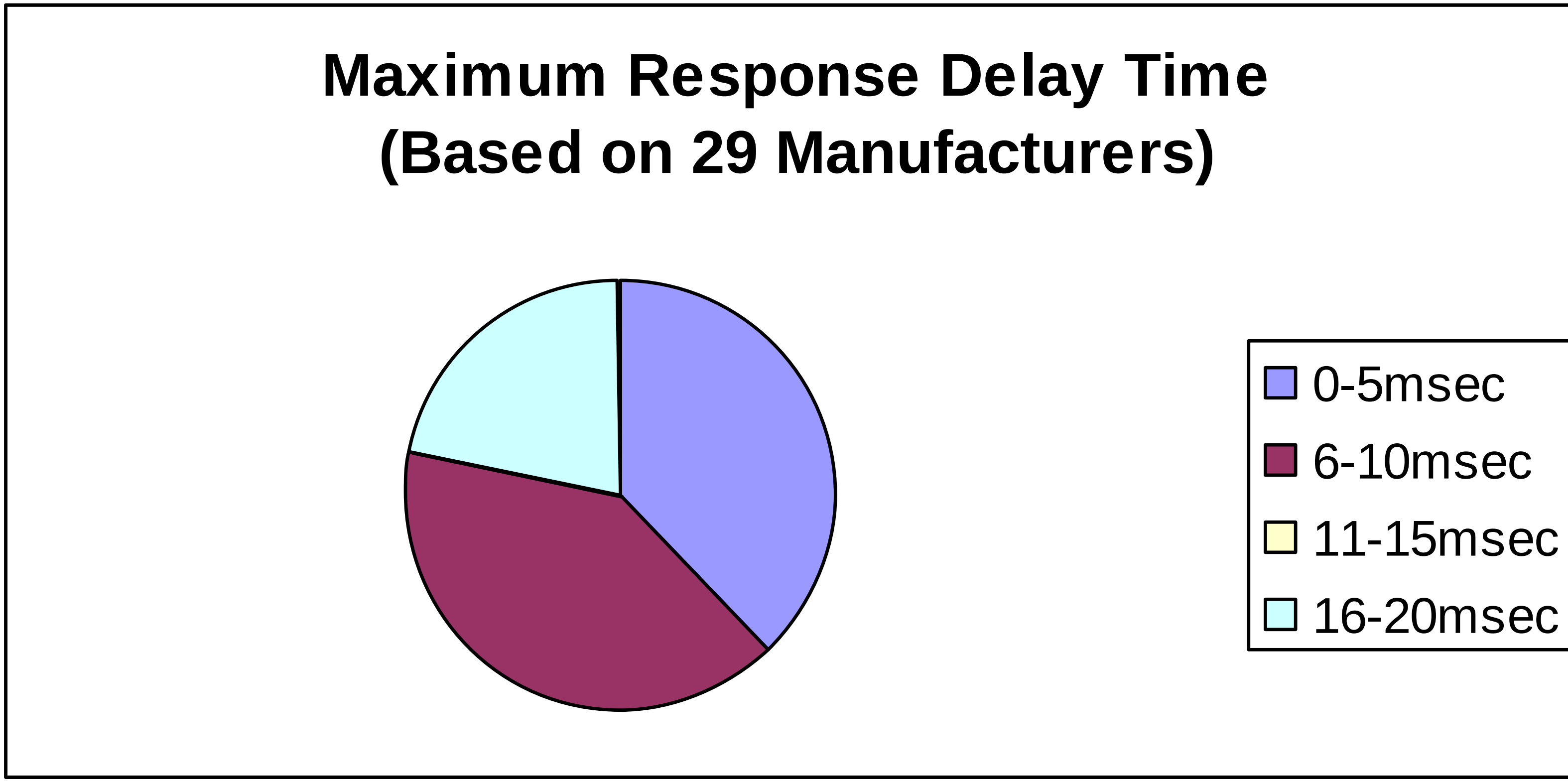
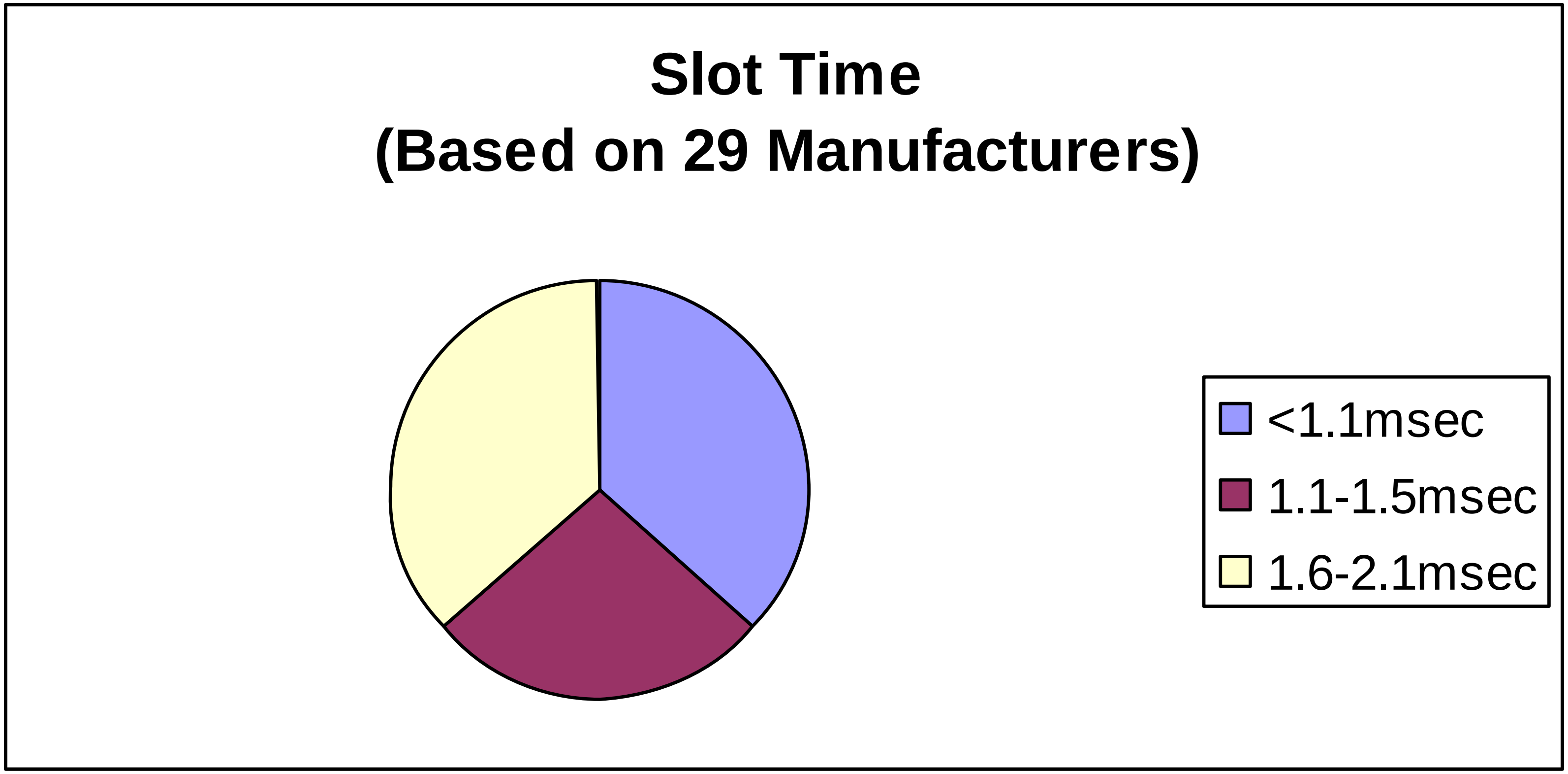
# *Variation in Device Response Time of Different Fieldbus Devices*



# Typical Slot Time for Different Devices



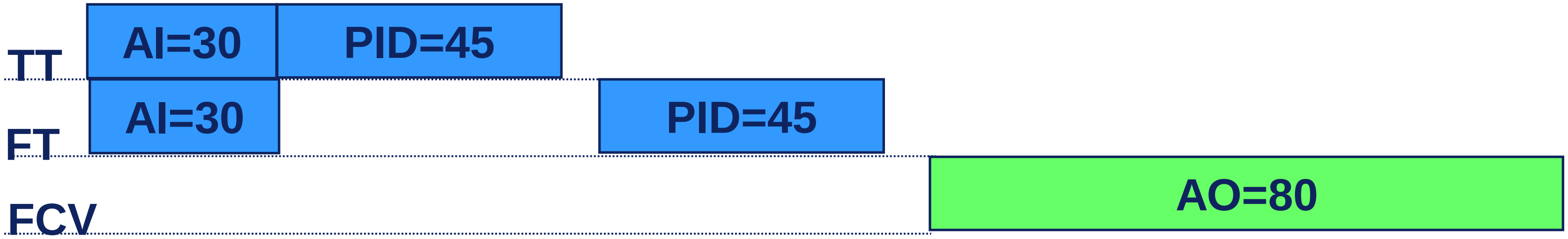
# Control Execution is Scheduled Based on the Segment Macrocycle

## A Macrocycle is determined by:

- Function Block Execution times.
  - Transmission time of the cyclic messages.
    - Gaps between messages determined by the Network parameters.
      - Time reserved for acyclic messages

# Macrocycle

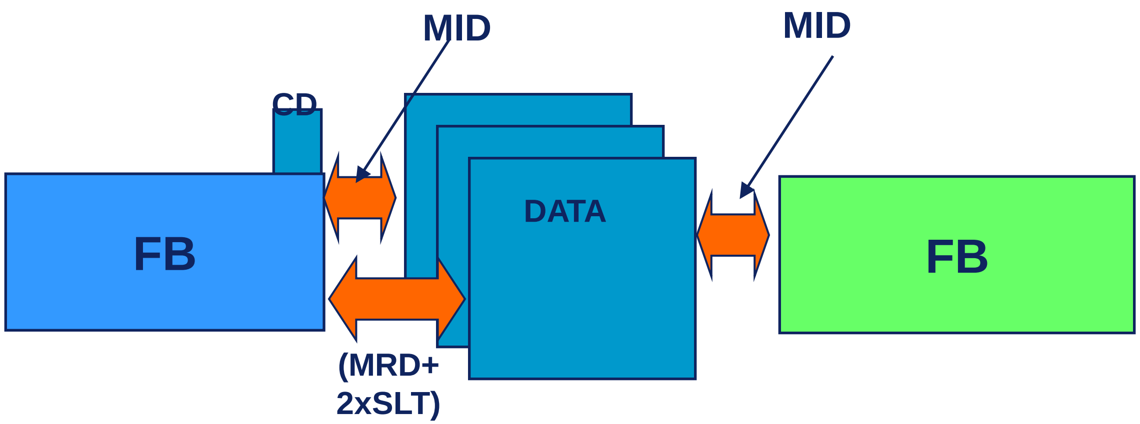
- Function Block execution time depends on the type of block and on the hardware and software design.
- In the time calculation, only blocks that must be executed consecutively are considered.




**Cascade Control Example**

- Block Execution Time = 30+45+45+80 = 200 ms
- *Note that the AI in the flow device is executed in parallel.

# Macrocycle

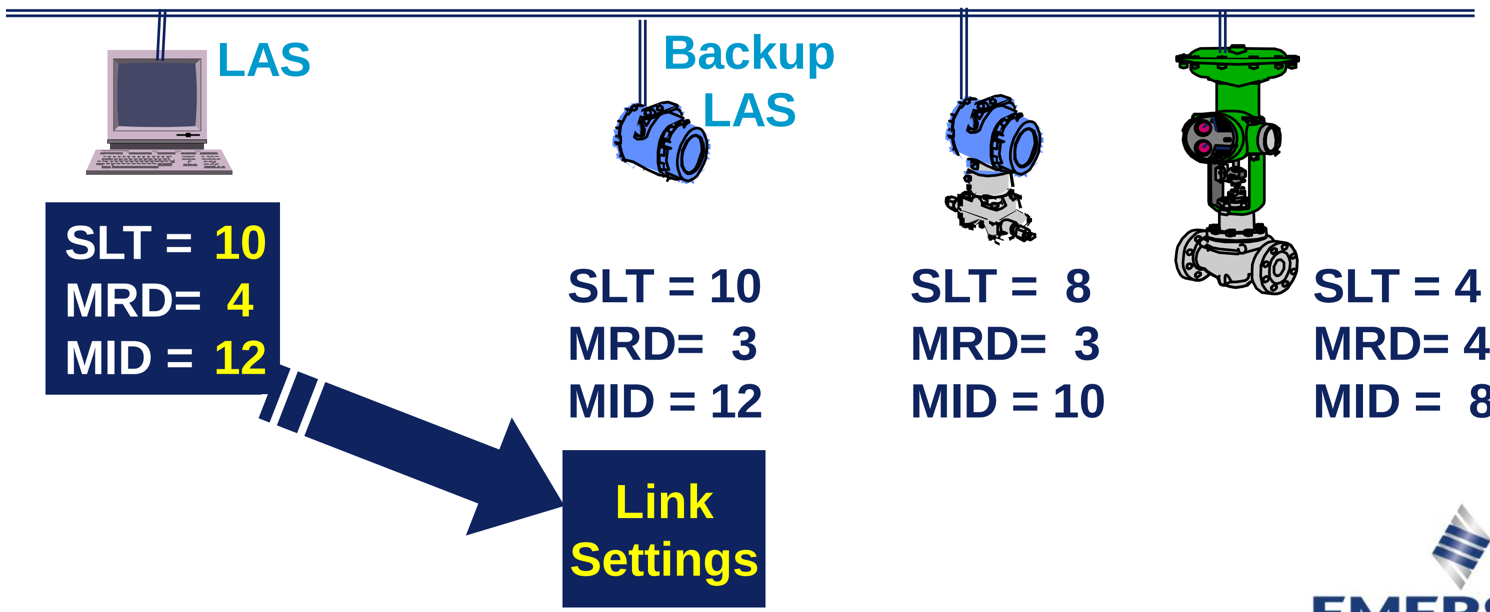



**SLT - Slot time**
**MRD - Maximum Response Delay**
**MID - Minimum Inter PDU Delay**

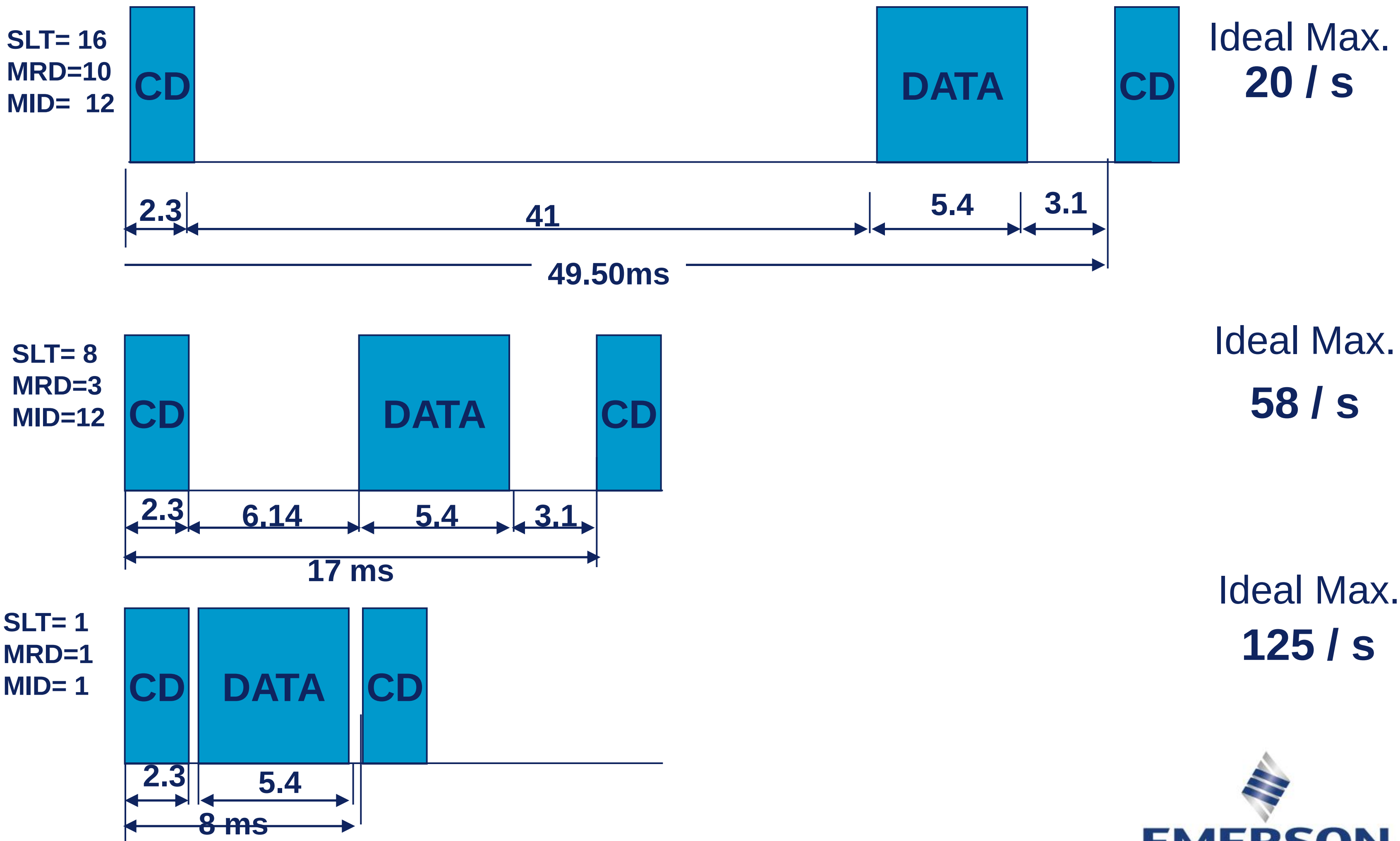
**Some manufactures may by default assume conservative constant values for MRD and SLT. The user may change these values.**

# *Network Parameters*

- Network Parameters establish how the network operates.
- The LAS must be set with the larger parameter values of the devices participating in the Network.



# Impact of Network Paramters on Maximum Number of Communcaions/Second

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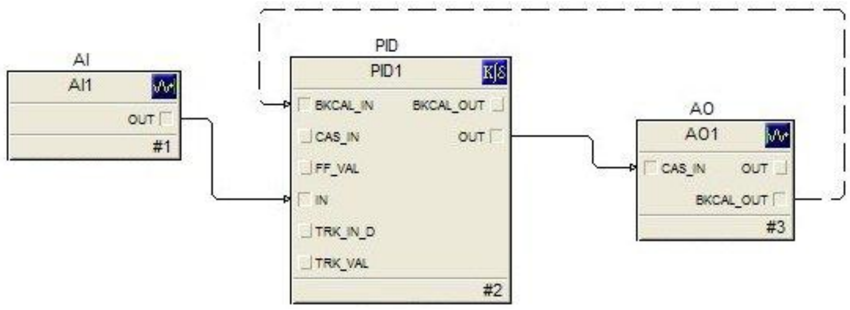
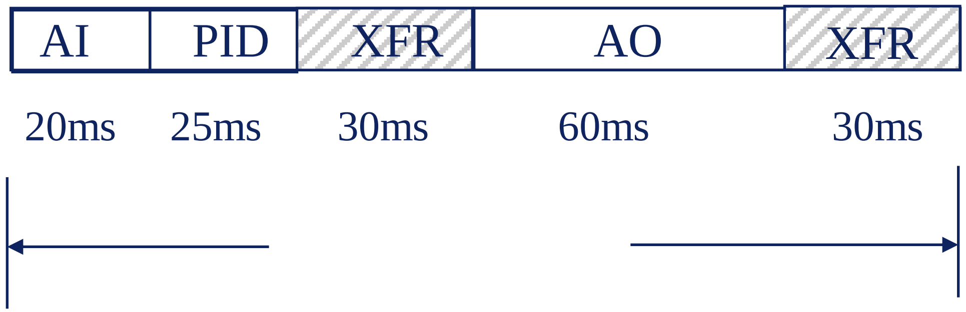
# Minimum Execution Time With Only One(1) Control Loop on an H1 Segment




Macrocycle = 165 ms

*Assumptions: 3rd Generation Transmitter, AI&PID executed in Transmitter, Second generation Valve executes AO*

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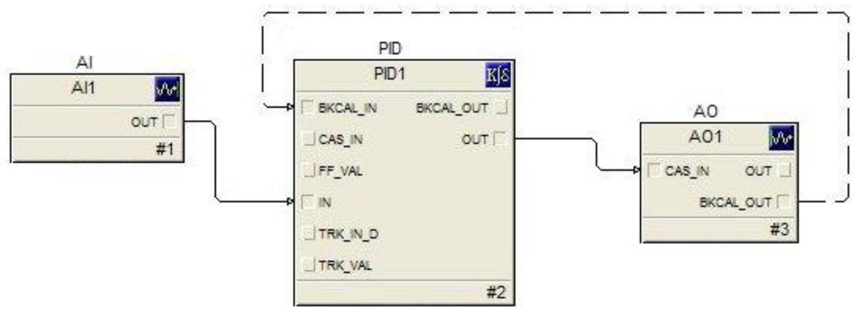
# Executing PID in the Valve Reduces the Nuber of Communications But Increases Loop Execution Time




| AI | XFR | PID | AO |
|---|---|---|---|
| 20ms | 30ms | 120ms | 60ms |

Macrocycle = 230 ms

*Assumptions: 3rd Generation Transmitter, AI executed in Transmitter, Second generation Valve executes AO&PID*

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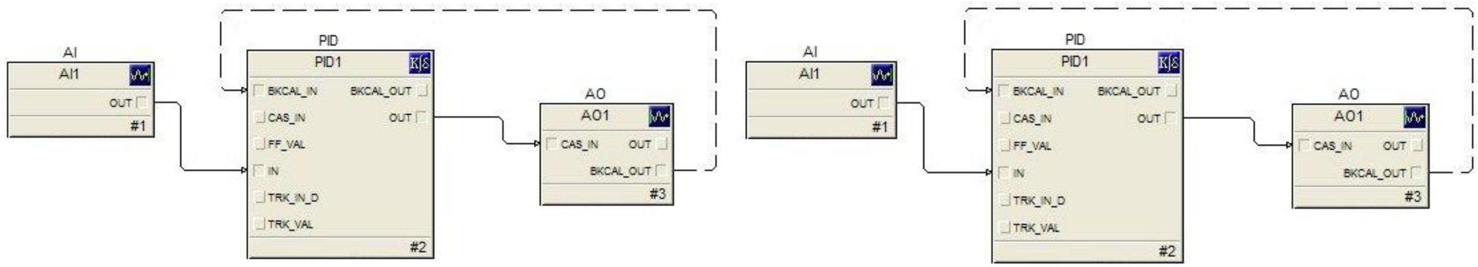
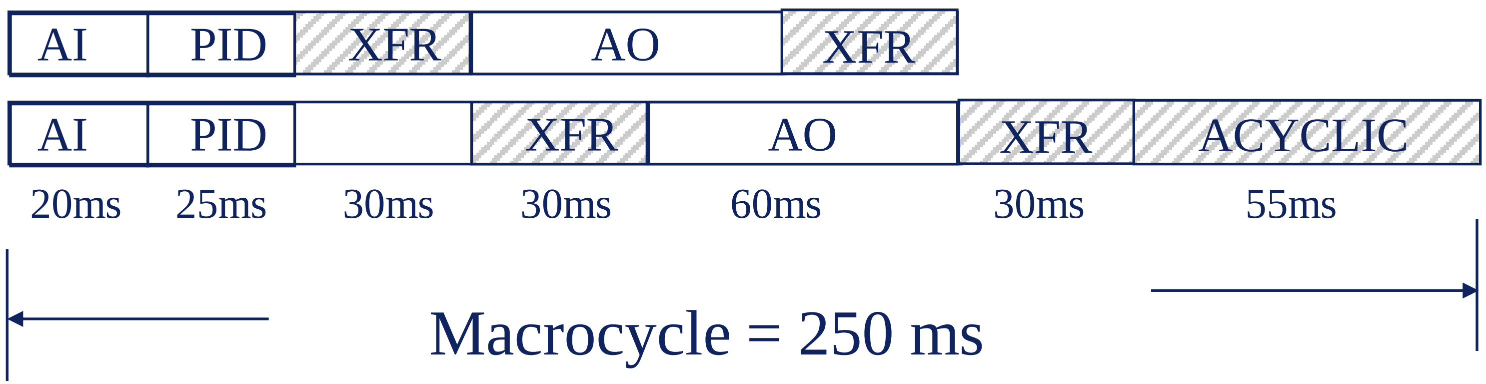
# Minimum Execution Time With Only Two(2) Control Loop on an H1 Segment




*Assumptions: 3rd Generation Transmitter, AI&PID executed in Transmitter, Second generation Valve executes AO, 50ms for every 125ms of the execution schedule (for display update)*

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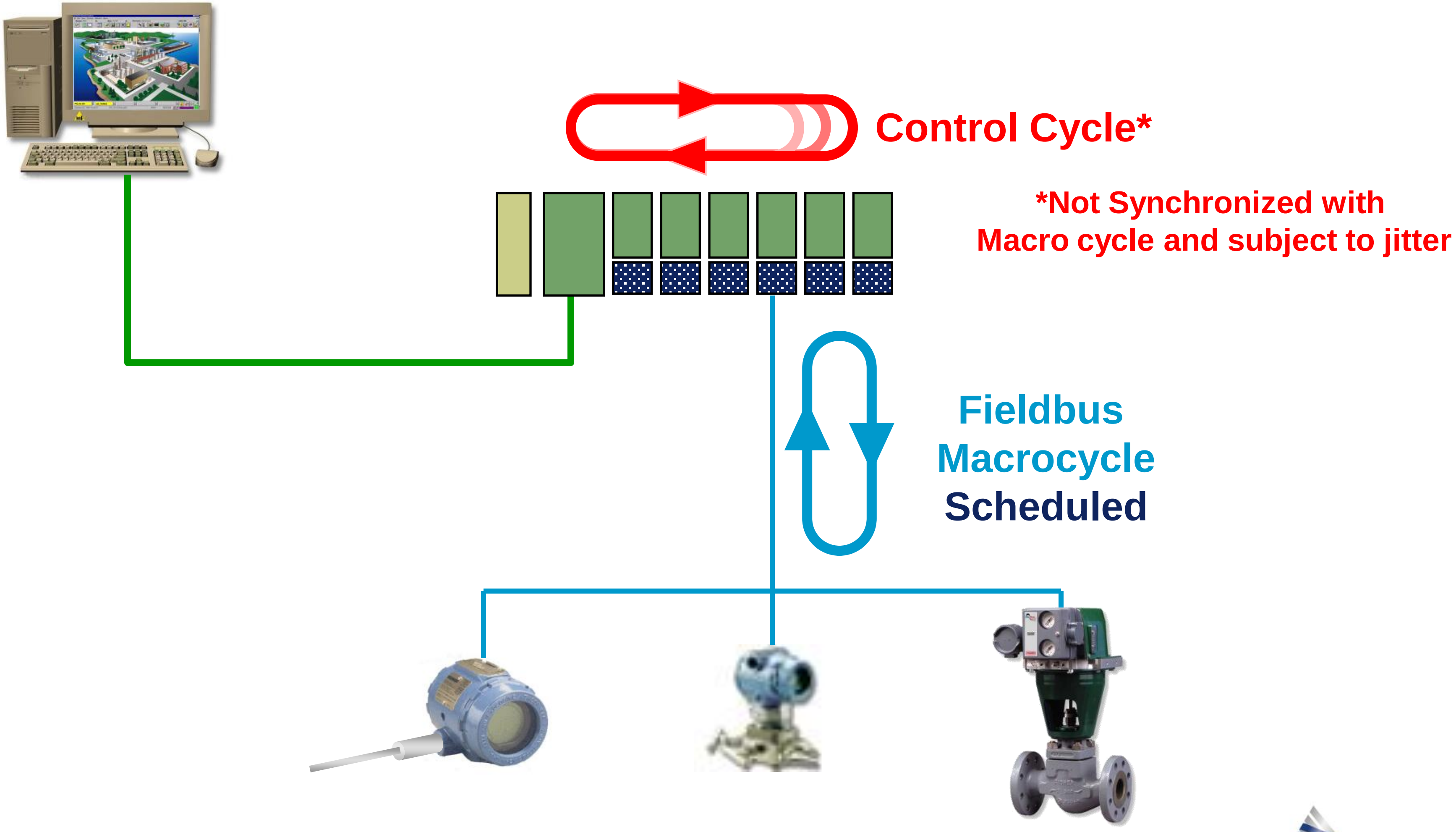
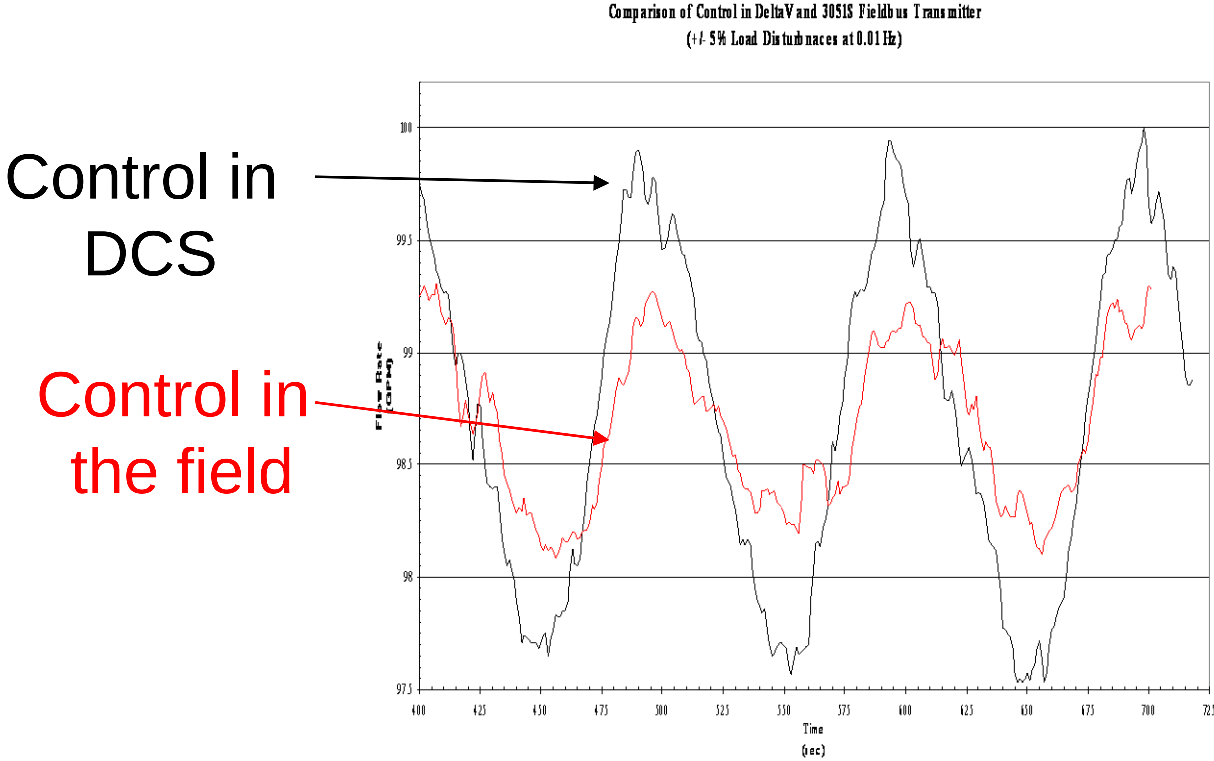
# An installation with Fieldbus



# *Why control in the field?*

- Control in the field provides loop integrity, increasing control loop availability and reliability.
- Control in the field provides better performance than control in the DCS, reducing variability.

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# *Impact of Splitting Control Between Fieldbus and Control System*

- Execution in the control system is typically not synchronized with function block execution on fieldbus segments.
- Lack of synchronization introduces a variable delay into the control loop as great as the segment macrocycle e.g. 1/2 sec loop may have up to 1/2 sec variable delay.
- Added delay will *increase variability* in the control loop.

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# Recommendation on Splitting Control Between Fieldbus and Control System

- Oversampling of the fieldbus measurement to compensate for lack of synchronization  i.e. setting macrocycle faster than control execution is often not practical if the loop execution is fast
- Conclusion: Execute control loops in Fieldbus for better performance.
- If target execution is ½ sec or faster, then limit the number of control loops to no more than two(2) per segment.

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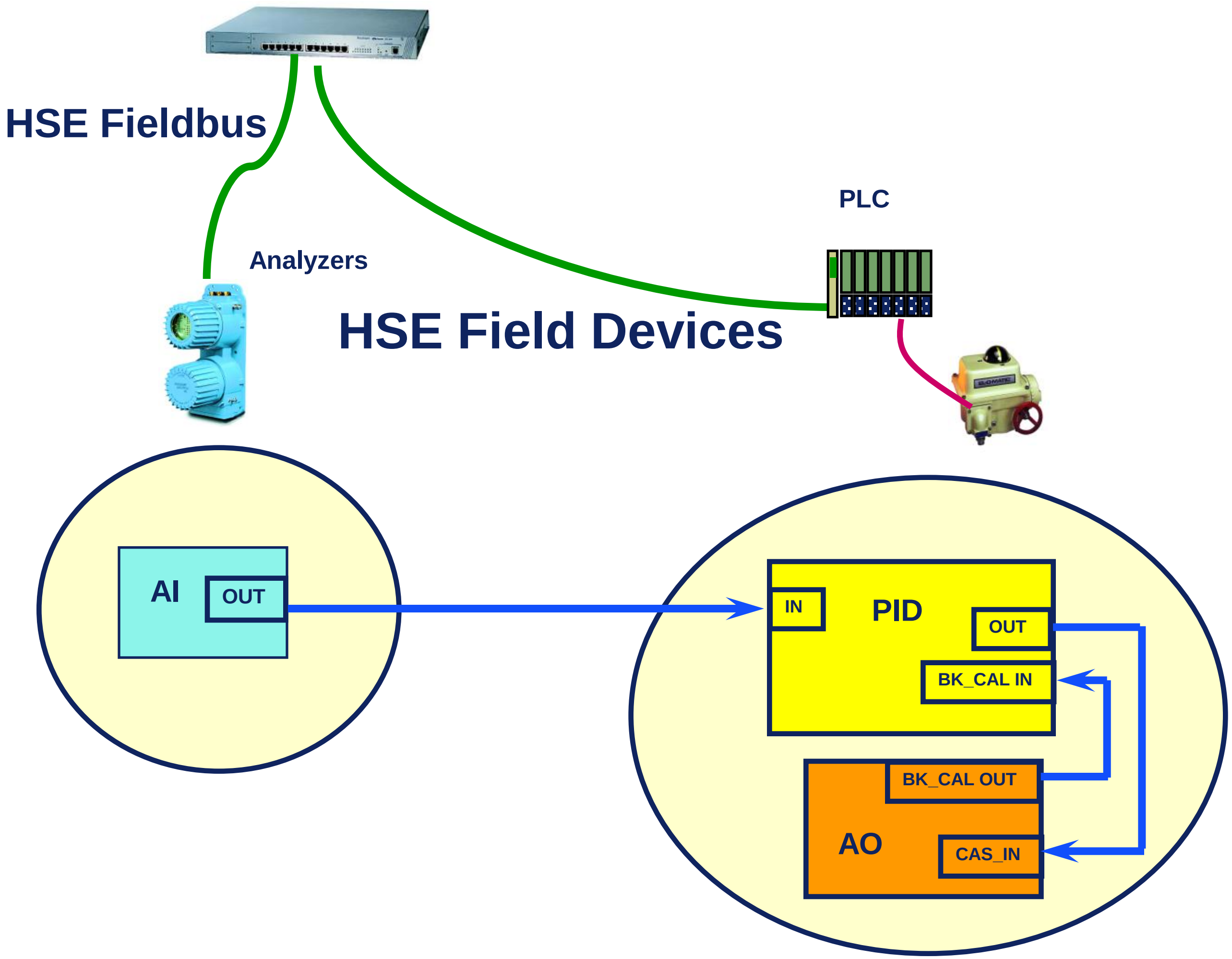
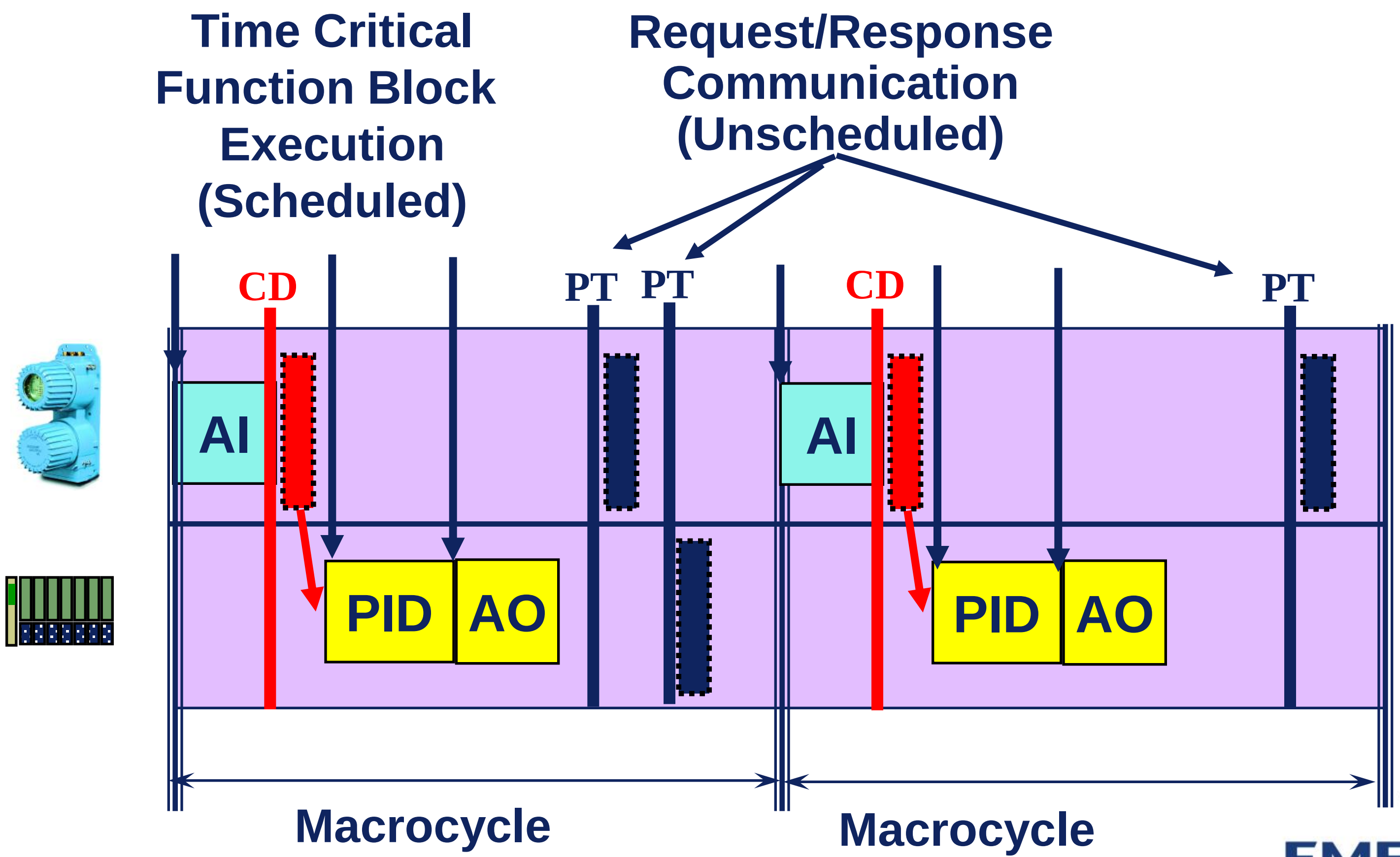
# HSE Scheduling Example

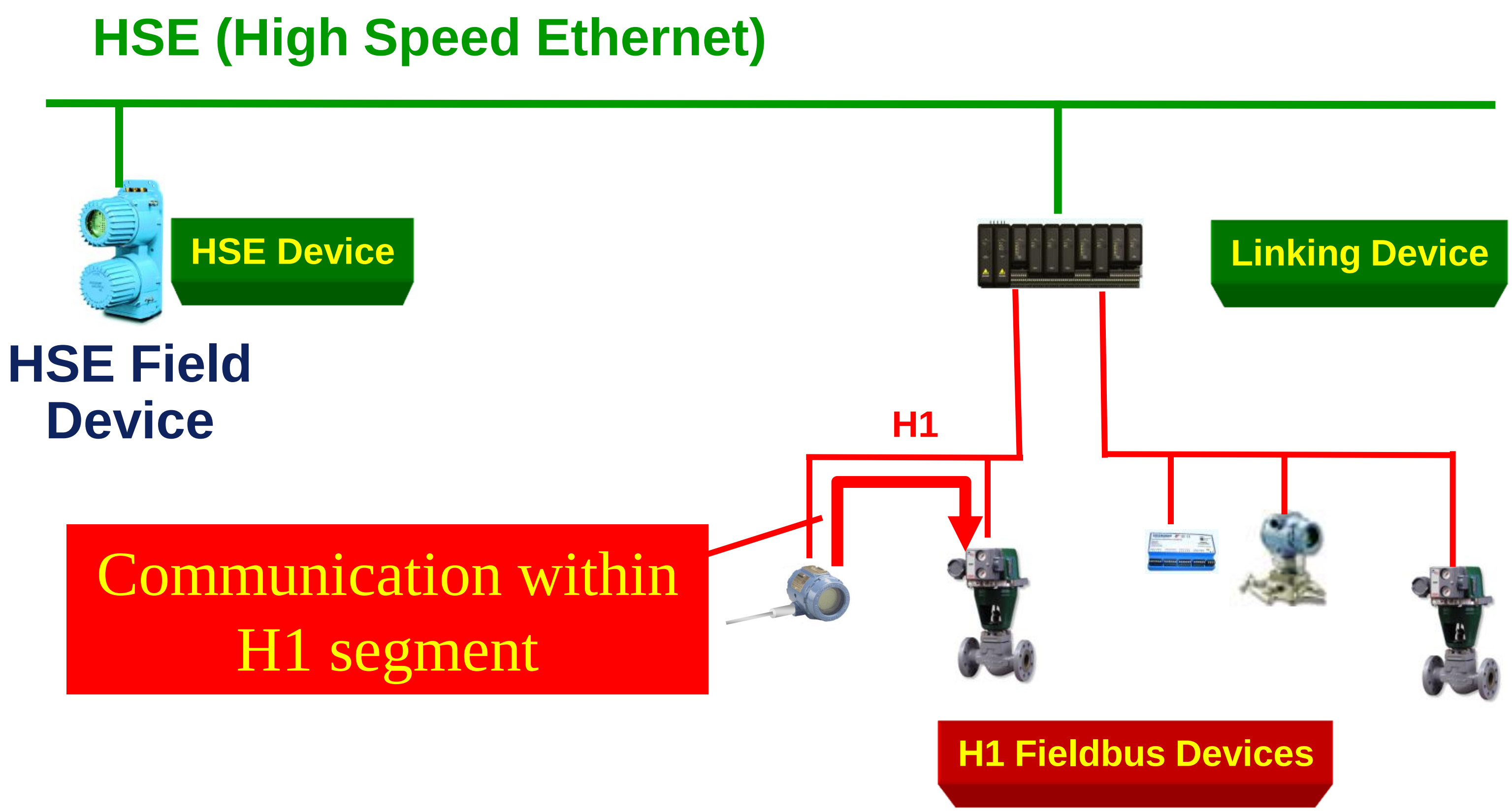


# HSE Scheduling Example

## Function Block Communication is Immediate



# *HSE and H1 Function Block links*

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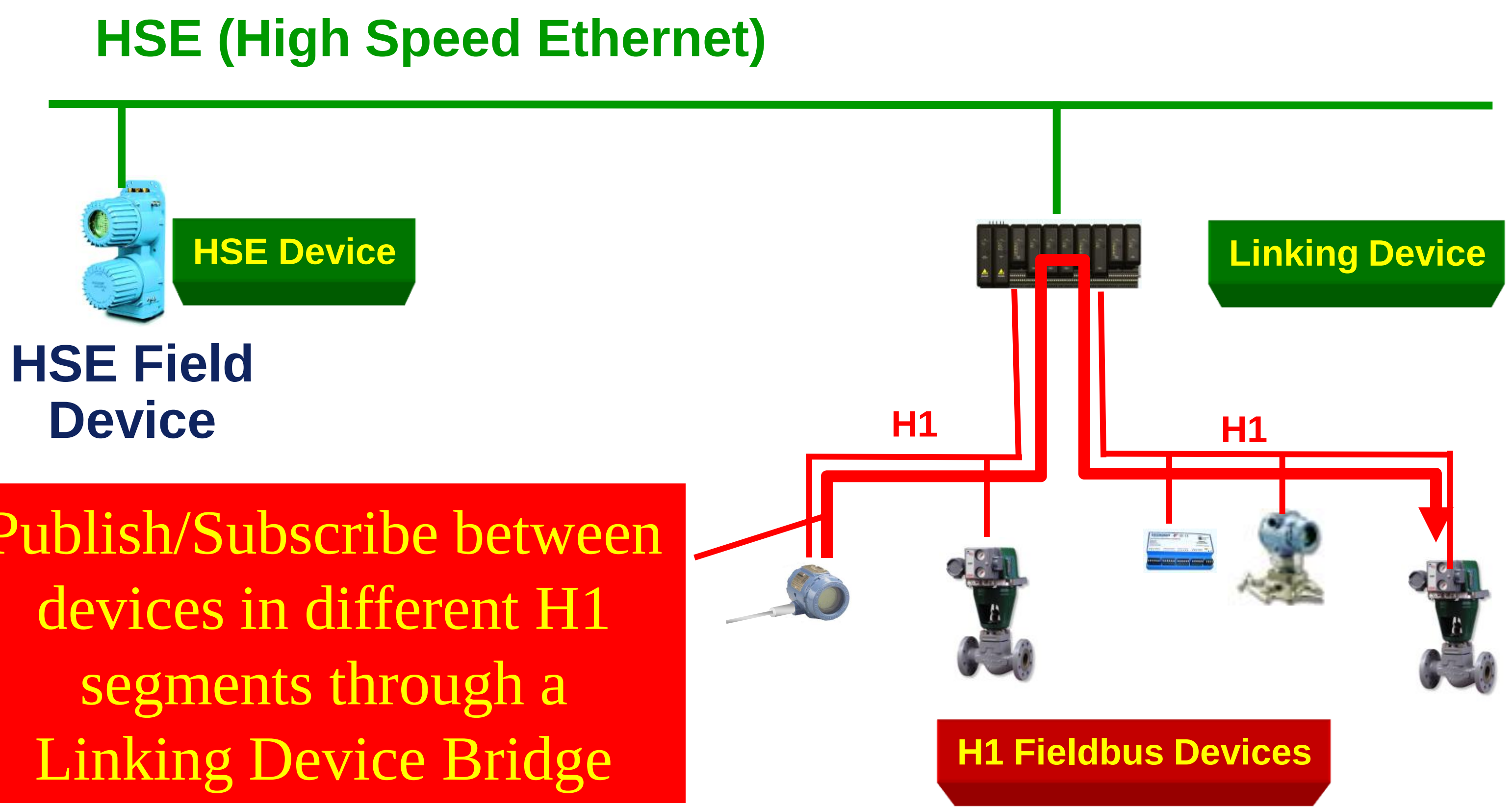
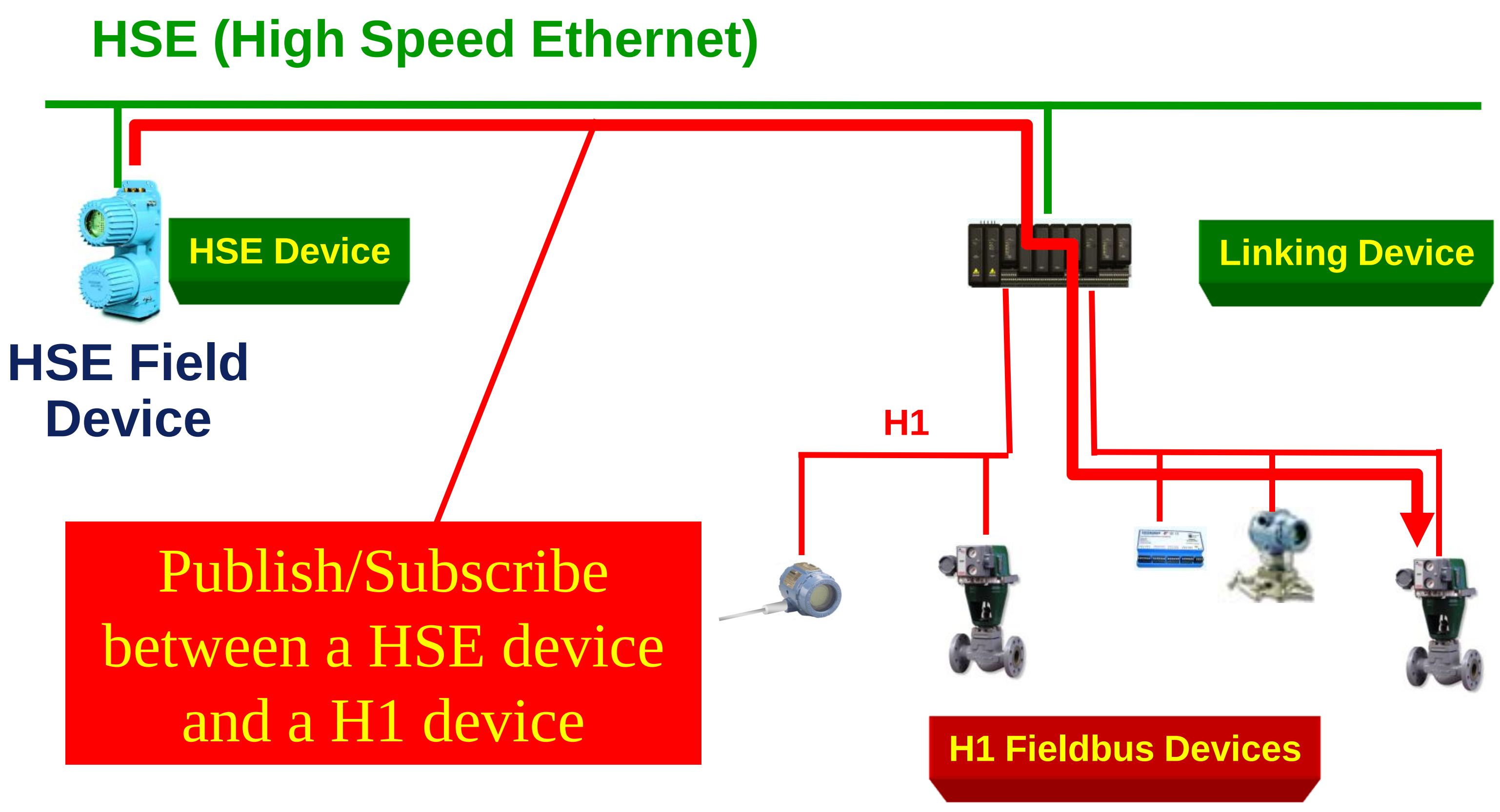
# HSE and H1 Function Block links

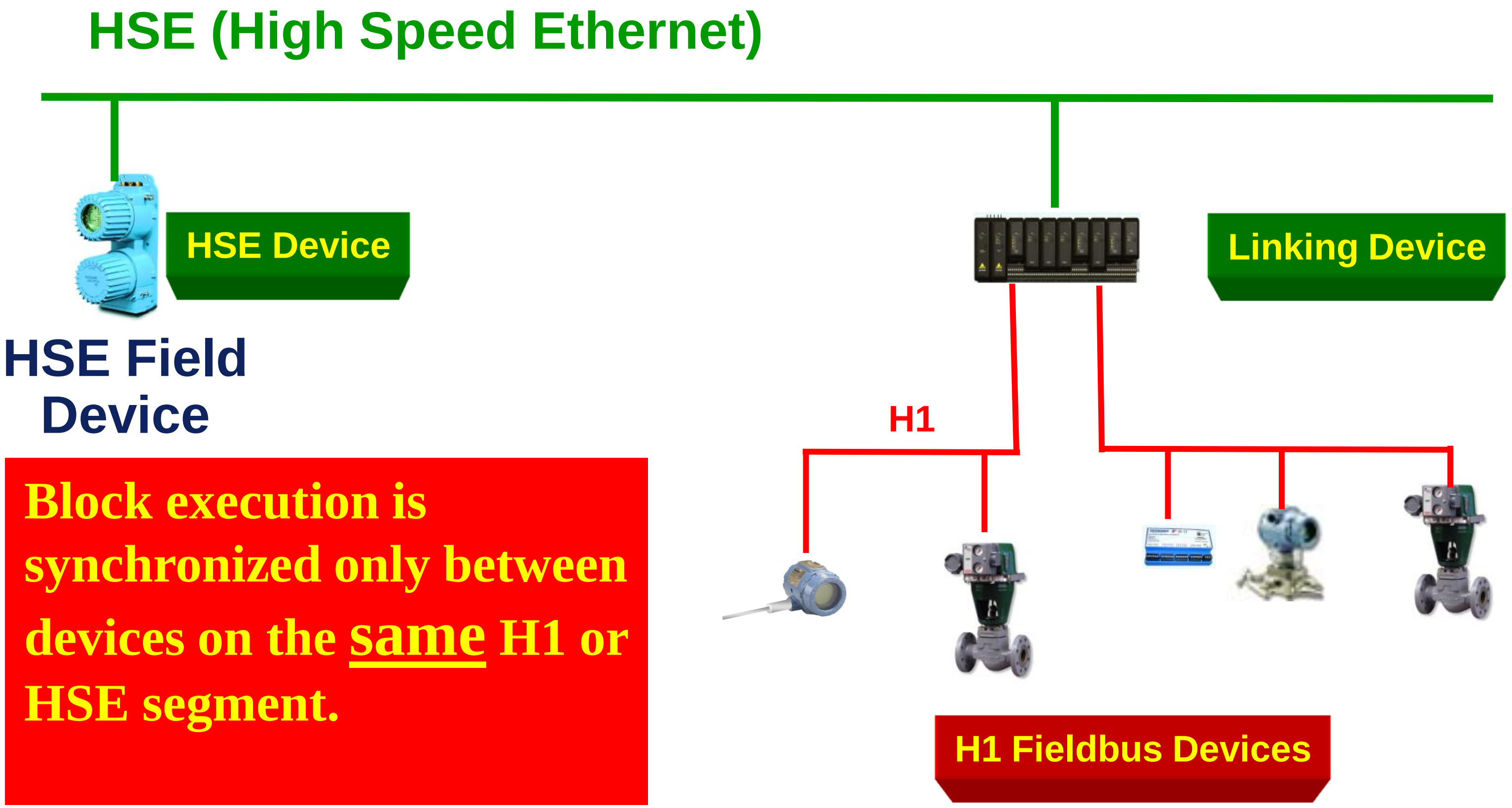



Publish/Subscribe between devices in different H1 segments through a Linking Device Bridge

# HSE and H1 Function Block links



# HSE and H1 Function Block links




**Block execution is synchronized only between devices on the <u>same</u> H1 or HSE segment.**

# Summary - Fieldbus Foundation Solution

- Both Continuous and Discrete Requirements Are Met By FF Function Block Set Capability

# Ethernet Field Device

| Capability | Device Class 41a | 41b | 41c | 41d |
|---|---|---|---|---|
| Data Server | X | X | X | X |
| Publish Data | X | X | X | X |
| Subscribe to Data | | X | X | X |
| Alert and Tend Reporting | | X | X | X |
| Basic Flexible FB | | | X | X |
| Extended Flexible FB | | | | X |

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# *Linking Device*

| Capability | Device Class | | | |
|---|---|---|---|---|
| | 42a | 42b | 42c | 42d |
| H1 Configuration by HSE Host | X | X | X | X |
| Monitioring of H1 by HSE Host | | X | X | X |
| Linking between HSE and/or H1 | | | X | X |
| Flexible Function Block support | | | | X |

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# Interface and Host Devices

- Class 43 - I/O Gateway Device

  Support of FMS services that are supported by Class 42c.

- Class 44 - Simple Host

  This class of device is an HSE host of some kind, for example, it might be a Process Operator Workstation. It supports subscription to FB data and can be a report sink.

- Class 45 - Configurator Host

  This class of device is an HSE host with configuration capabilities. It is capable of dealing with the MIBs in HSE and H1 devices and configuring HSE LAN Redundancy Information in HSE Devices. In practice, it may require multiple hosts to do all of the configuration implied by this profile class. In such cases all of the hosts would be registered as a group.

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# Device Characterization

- Class 46 - Device Redundancy
  - D1 does not support device redundancy
  - D2 supports externally controlled device redundancy
  - D3 supports autonomous device redundancy
- Class 47 - LAN Redundancy
  - I1 has one interface to the HSE network
  - I2 has two interfaces to the HSE network
- Class 48 - Time Handling
  - Tc is capable of being a Time Client. For Linking Devices, is capable of synchronizing H1 Data Link time and SM Application time to HSE time
  - Ts is capable of being a Time Client and a Time Serve
  - $T_N$ Has no time synchronization capabilities
- Class 49 – Obtaining IP Address
  - $A_Y$ IP Address is obtained using DHCP
  - $A_N$ IP Address is obtained using local means

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# Link Device Certification Testing

Since the HSE specification was released, the following manufacturers have successfully completed FF Linking device certification testing (class 42a)

- Smar
- ABB
- Emerson Process Management

# High Speed Ethernet

## Summary

- High speed backbone at 100 Mbit/s (1 Gbit/s future)
- Ready availability of standard Ethernet equipment
  HSE field device running standard function blocks
- Fault tolerant communications and linking devices
- Interface to other protocols
- Flexible Function Blocks
- Wire and fiber optic media
- Low cost

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