New Automation Technology

XFC | eXtreme Fast Control Technology

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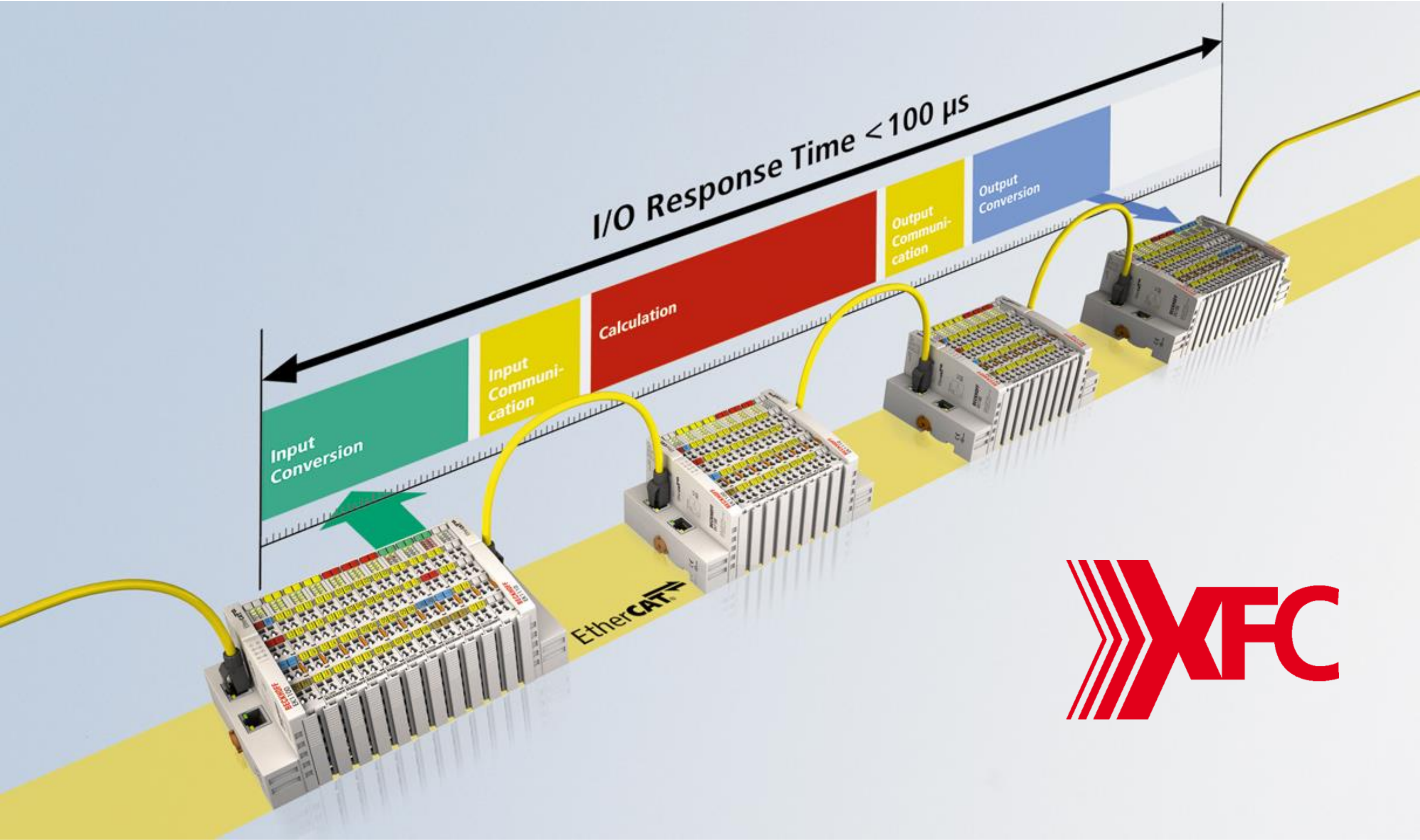
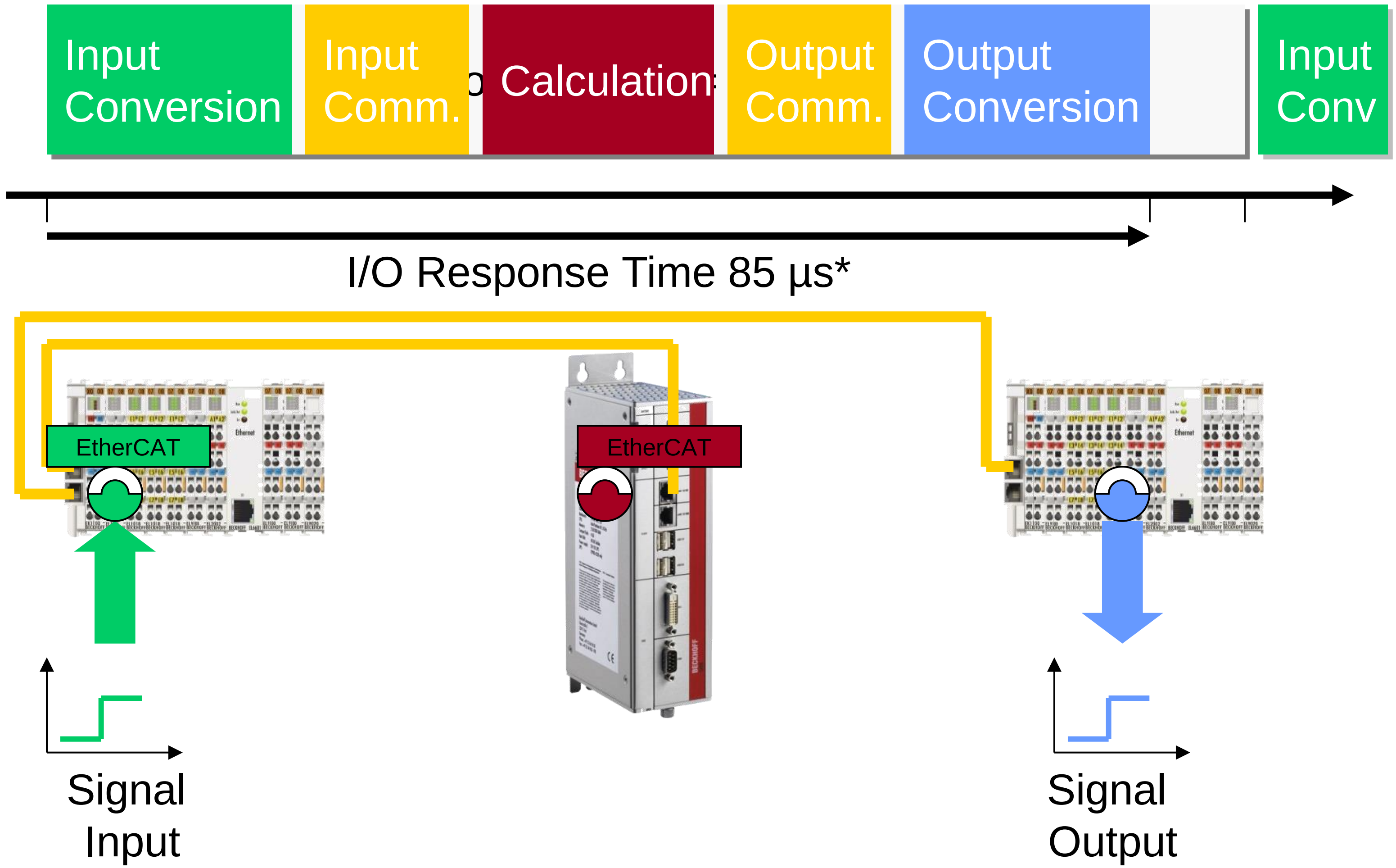
Beckhoff Automation

XFC | eXtreme Fast Control Technology

The new class of Control Performance



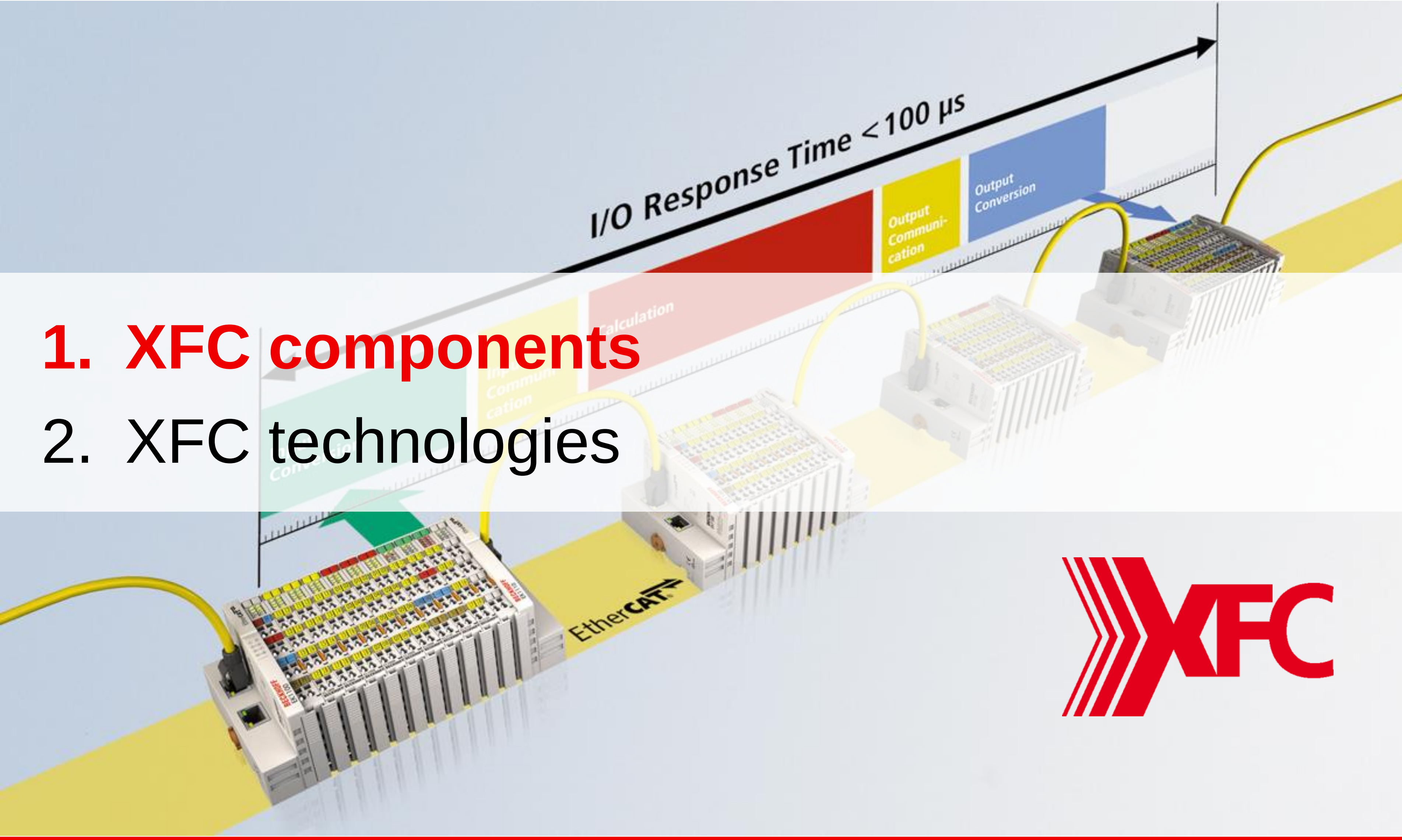
XFC - eXtreme Fast Control Technology



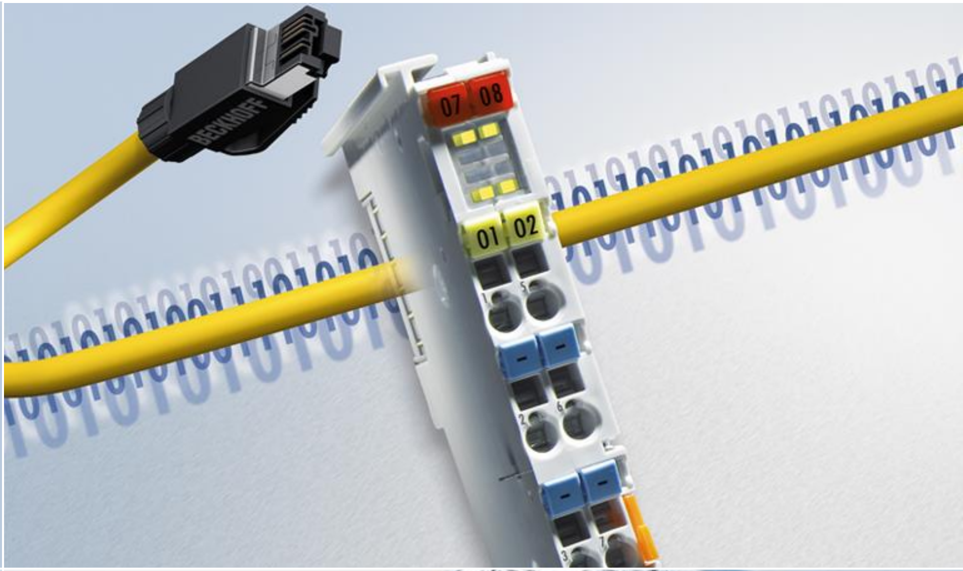
* Best case, because the Input signal comes asynchronous to the internal cycle.

Contents

1. **XFC components**
2. XFC technologies



XFC components



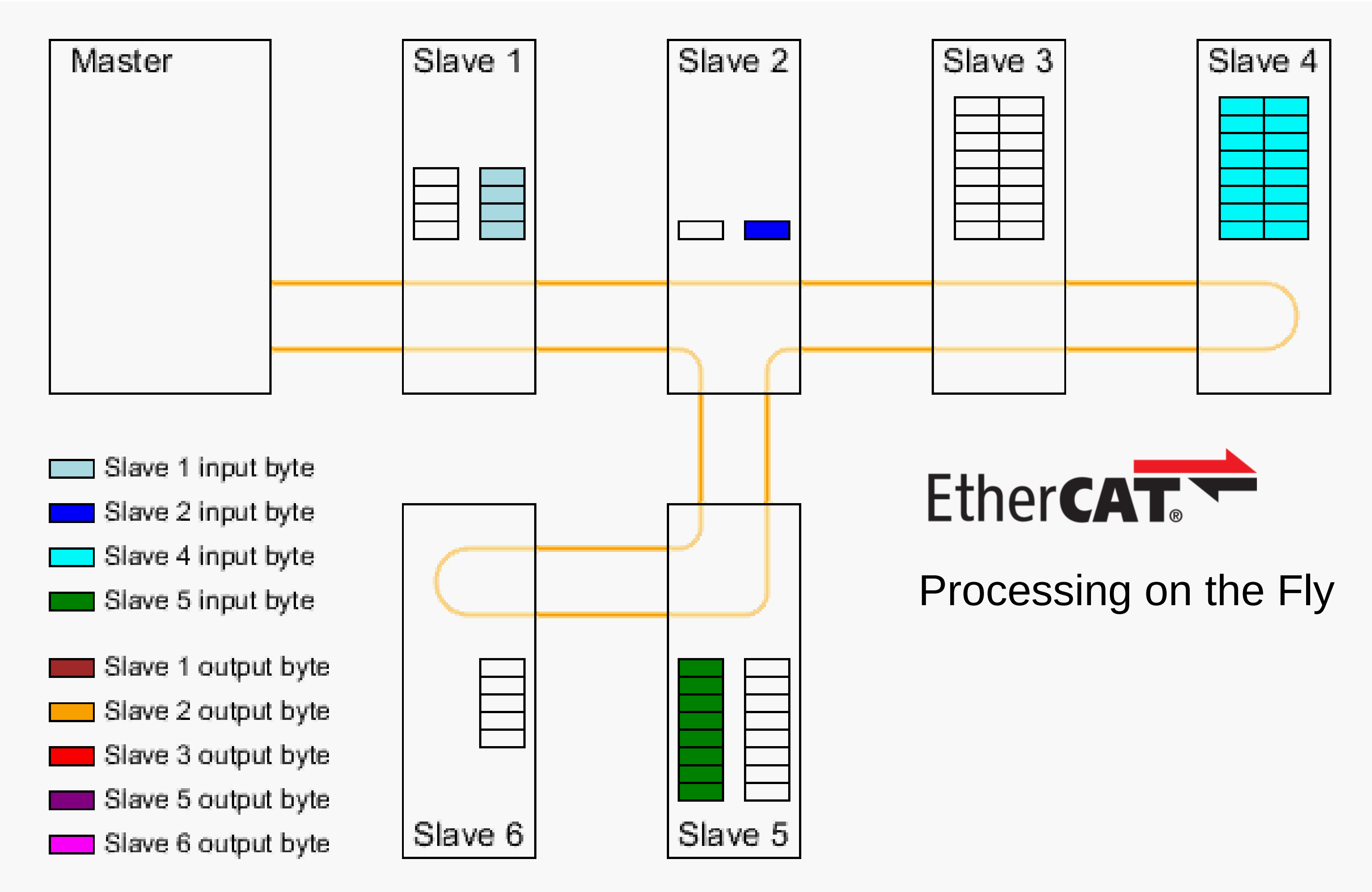
XFC components

EtherCAT | eXtreme fast control communication technology

Optimised control and communication architecture for highest performance

- 1,000 distributed digital I/Os in 30 µs
- EtherCAT down to the individual I/O terminals, no sub bus required
- optimised use of standard Ethernet controllers, e.g. Intel® PC chipset architecture
- advanced real-time feature based on distributed clocks:
  synchronisation, time stamping, oversampling

EtherCAT | eXtreme fast due to unique Functional Principle



- Efficient: Typically only one Ethernet Frame per Cycle
- Ideal Bandwidth Utilization for maximum Performance

EtherCAT Terminals | eXtreme fast I/O technology

Optimised control and communication architecture for highest performance

- full range I/O line for all signal types
- high-speed digital and analog I/Os
- Time stamping and oversampling features allow extreme high timing resolution (down to 10 ns).

IPC | eXtreme fast control CPU

Optimised control and communication architecture for highest performance

- Industrial PC based on high performance real-time motherboards
- compact form factors optimised for control applications

TwinCAT | eXtreme fast real-time control software

Optimised control and communication architecture for highest performance

- real-time under Microsoft Windows down to 50 µs cycle time
- standard IEC 61131-3 programming in XFC real-time tasks
- Standard features of Windows and TwinCAT are XFC-compliant.

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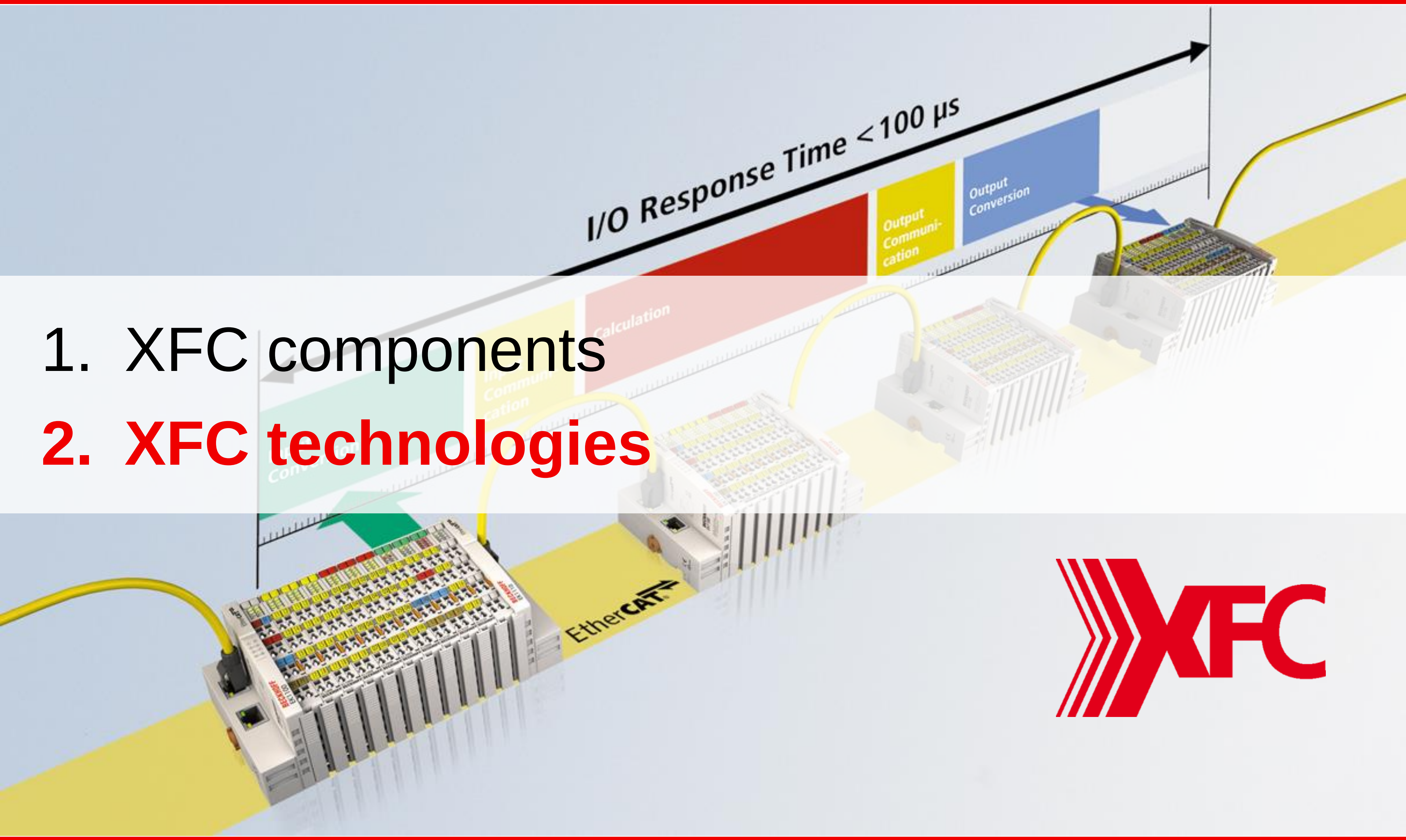
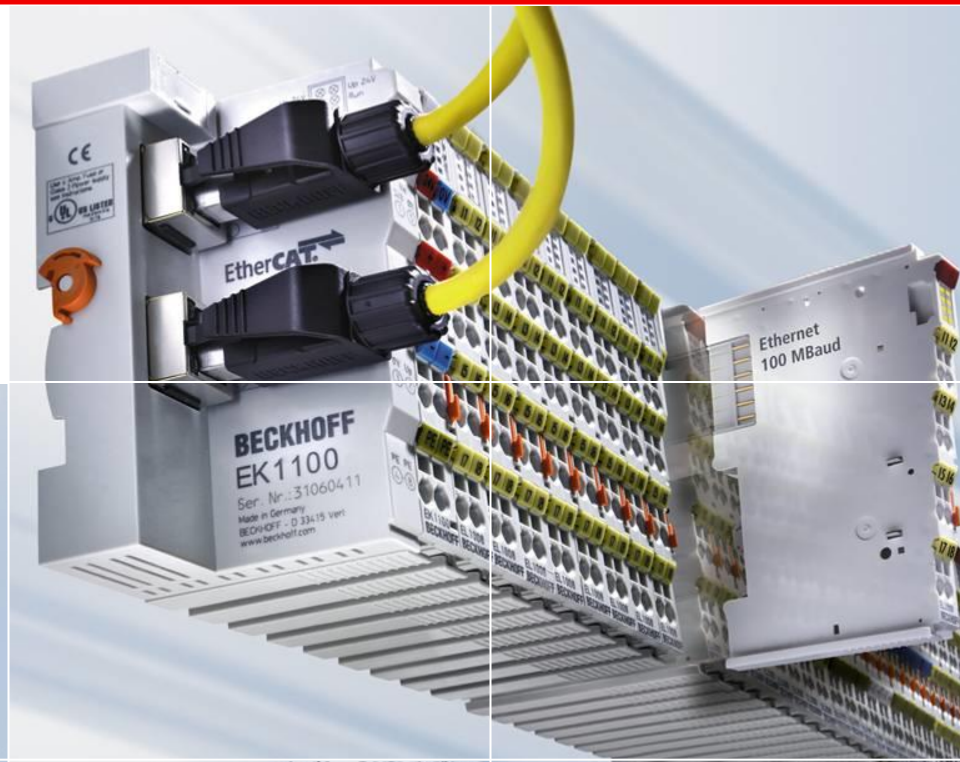
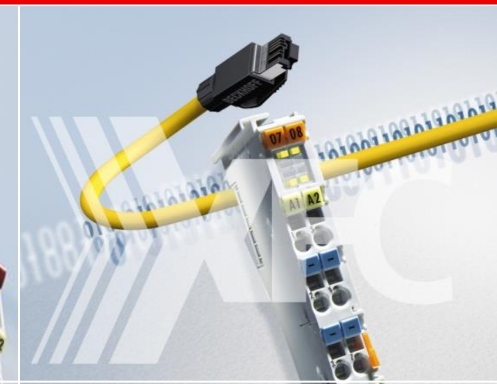


XFC technologies

Time stamp





Fast I/O

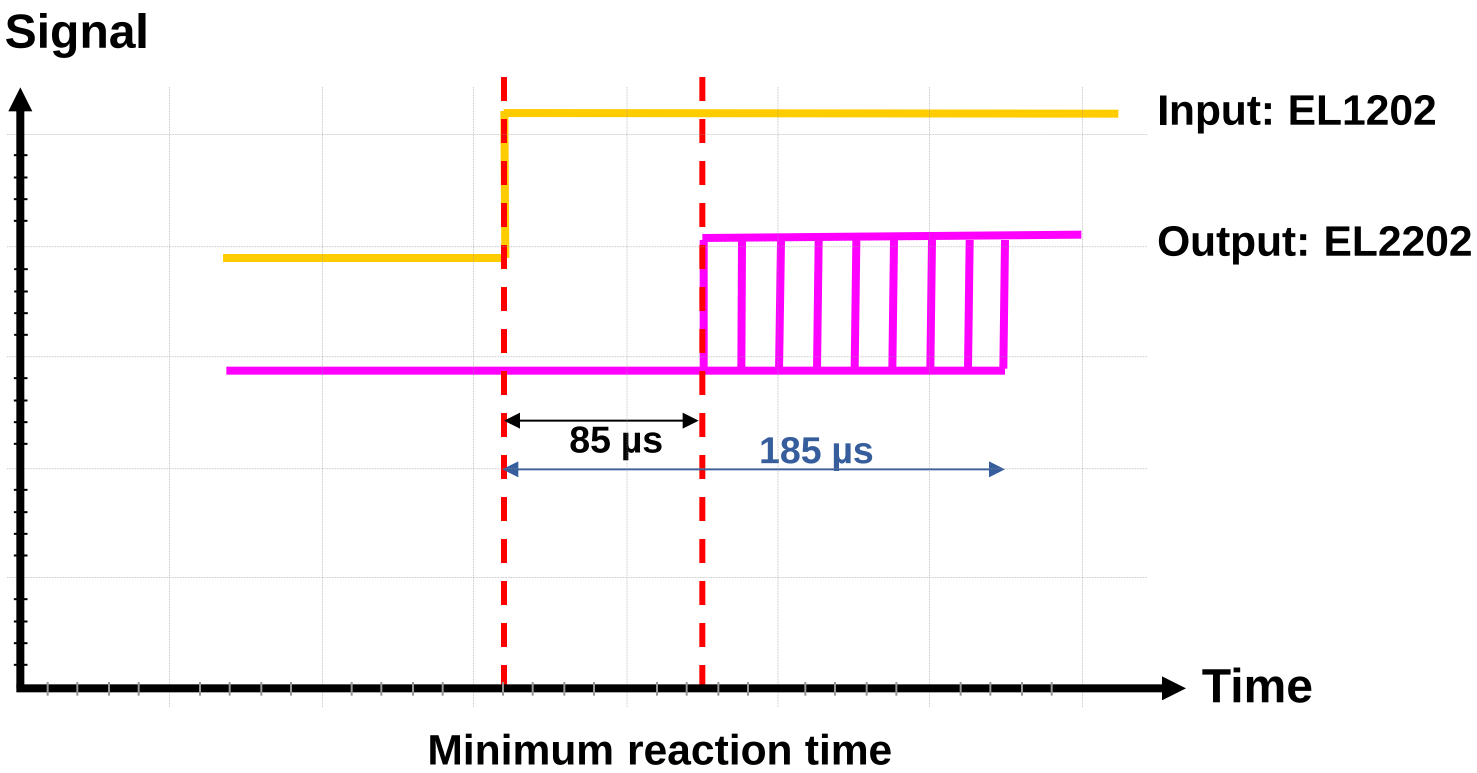
Oversampling

Distributed clocks

XFC

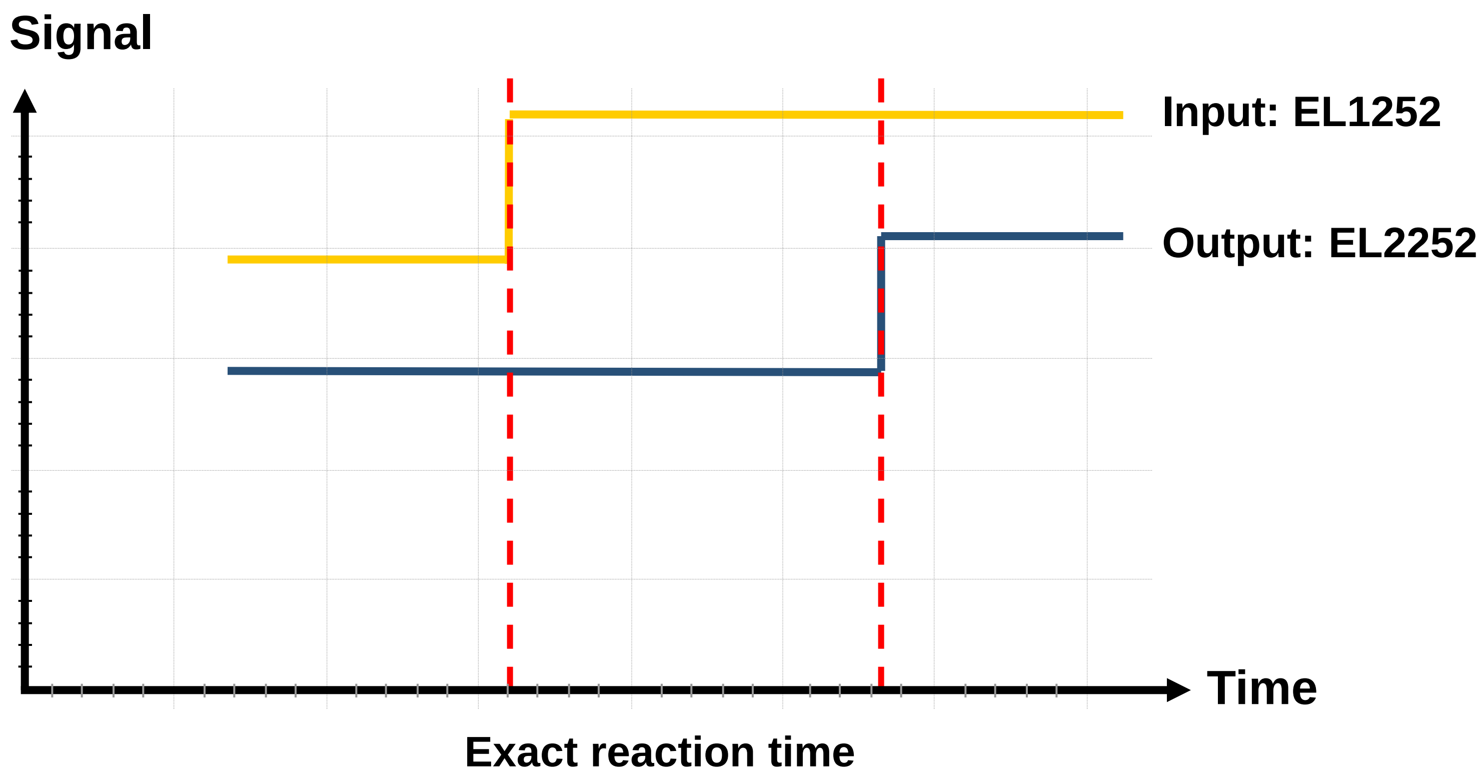
Fast I/O terminals 1 µs TON/TOFF

- Fast I/O with short conversion time



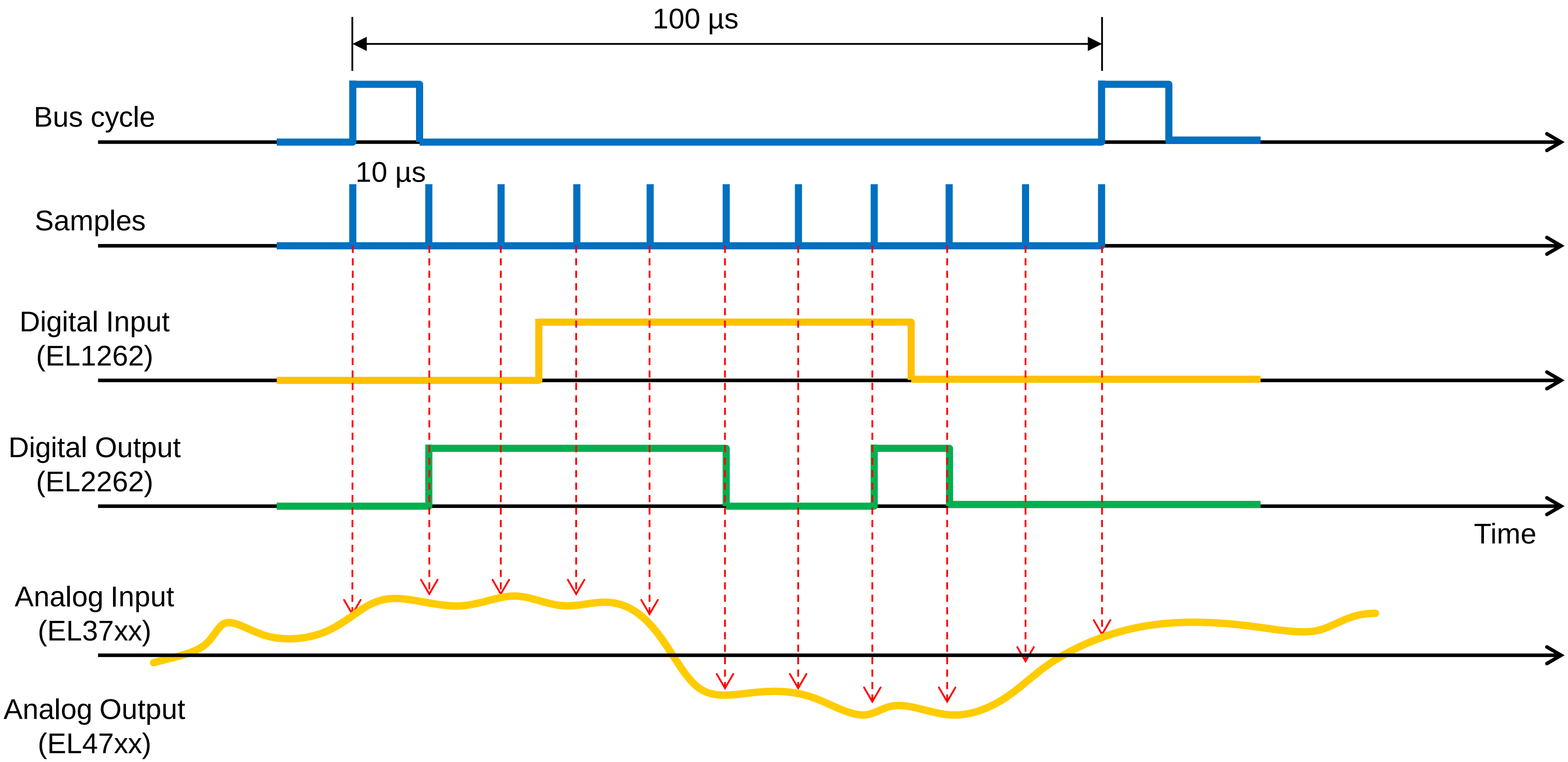
Time stamp terminals

- Exact time resolution with DC
- Synchronised responses



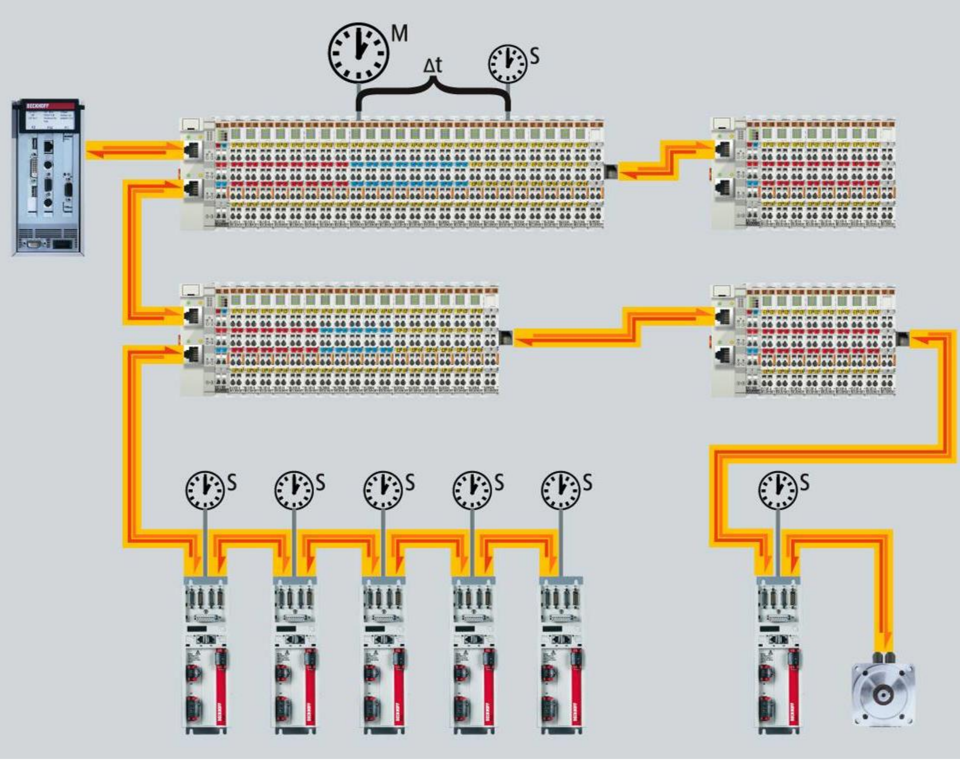
Oversampling terminals

- Fast signal sampling with oversampling
- Output of short pulses



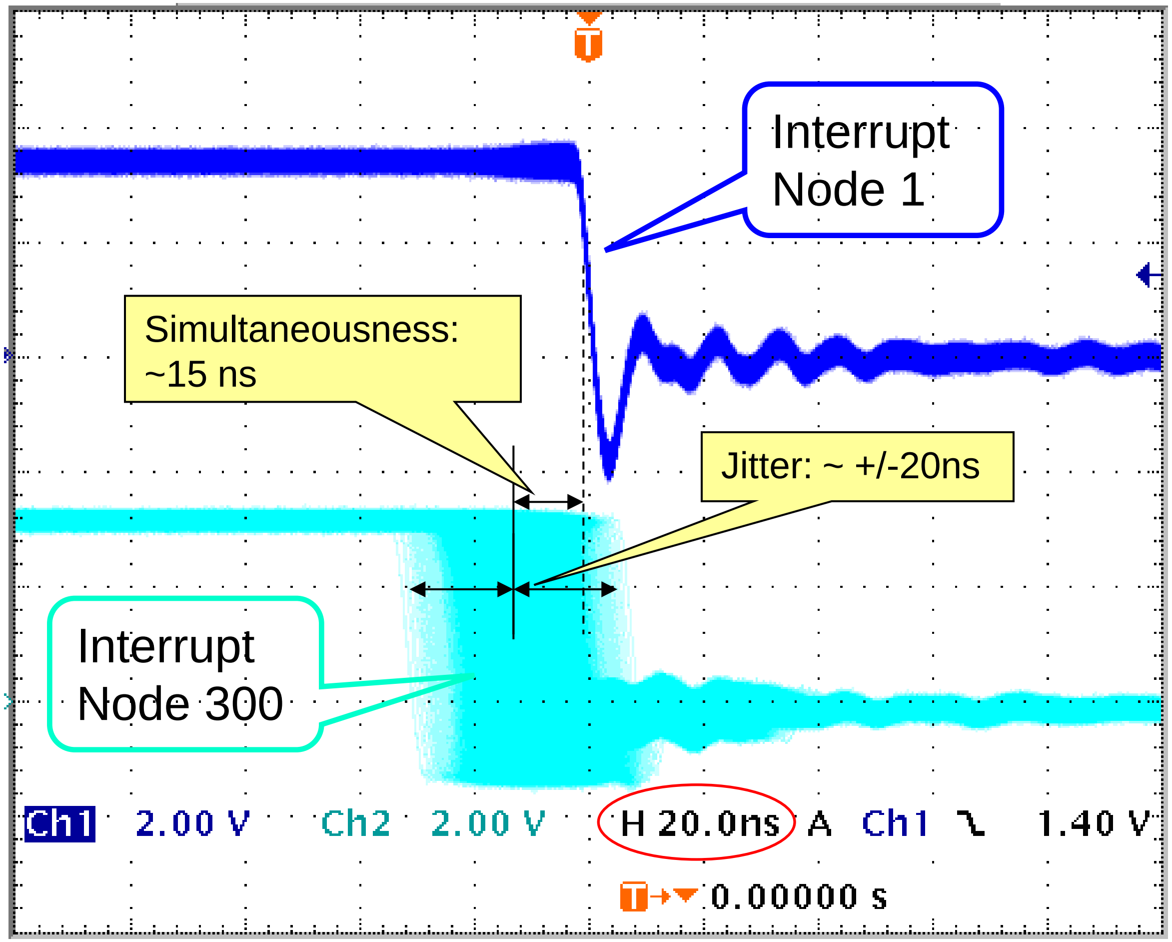
Distributed clocks

- Shifting accuracy to the I/O level
- Distributed absolute system synchronization
  - CPU
  - I/O
  - drive devices
- Resolution: 10 ns
- Accuracy: < 100 ns



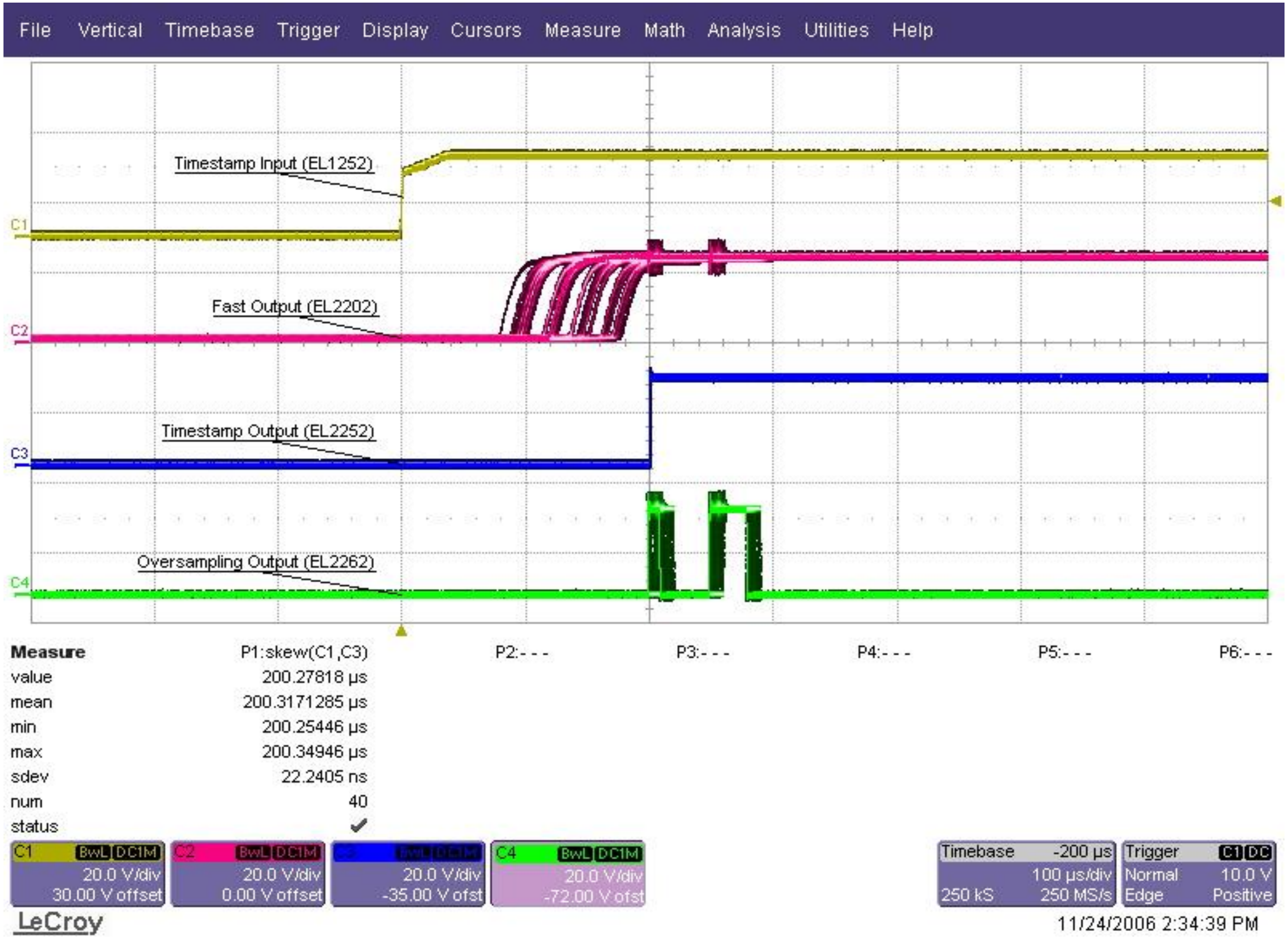
Distributed clocks: Accuracy

- Long Term Scope View of two separated devices
- 300 Nodes in between, 120m Cable Length



XFC technologies

XFC verified!

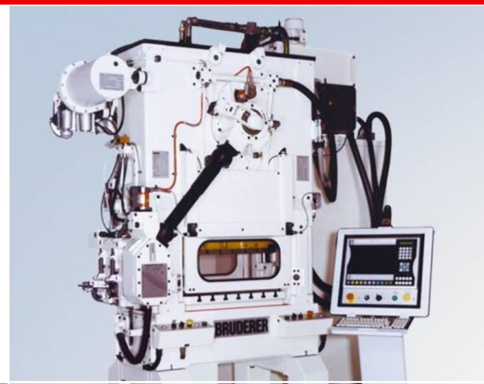


XFC performance data

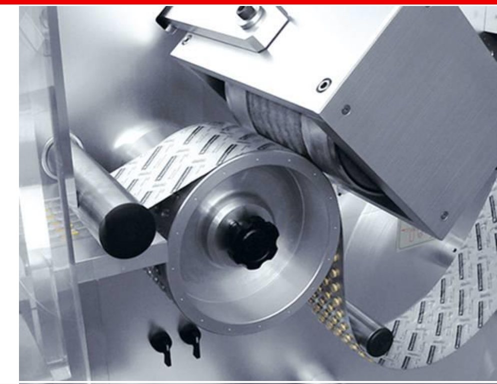
- System performance
  - cycle time: 100 µs (min. 50 µs)
  - I/O response time: 85 µs ... 185 µs
- Distributed clocks
  - resolution: 10 ns
  - accuracy: < 100 ns
- Signal oversampling
  - sample rate: 1 MHz
  - time resolution: 1 µs
  - accuracy: < 100 ns
- Time stamping resolution
  - resolution: 10 ns
  - accuracy: < 100 ns

XFC in practice

Printer position control



Digital cam



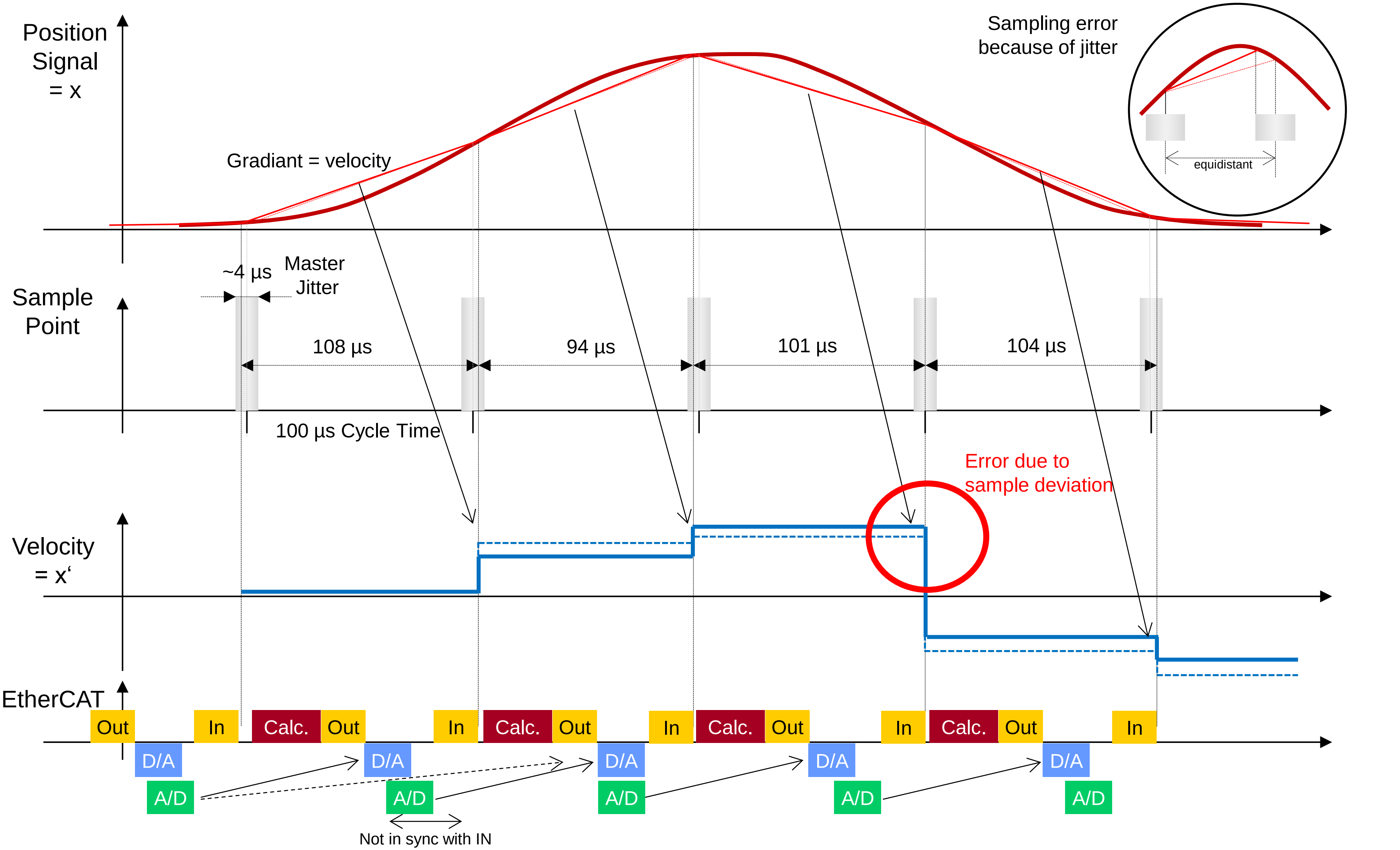
Glue application

Closed-loop control

Linear path control

Part tracking

Timing – Synchronous with telegram



Timing – Synchronous with telegram

Problems of this approach:

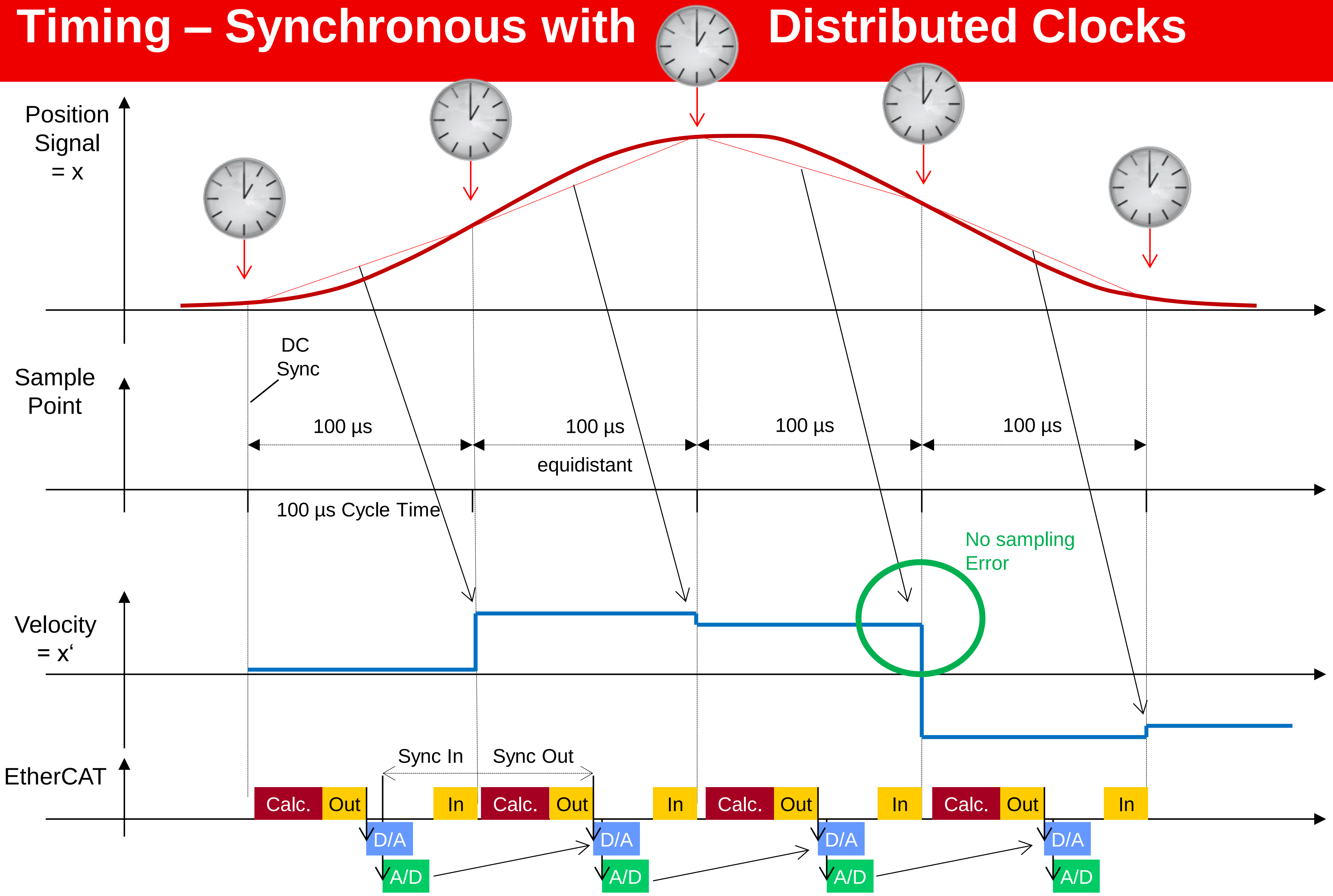
- I/O signal timing comes from Master
- Modern (multicore) CPU systems will always jitter in the range of 1.. 5 µs

→ Measuring error due to sample deviation

Conclusion

- IO-Signal timing must come from Distributed Clock System
  - Fully synchronized
  - Independent from System architecture
  - System wide synchronicity <100 ns

Timing – Synchronous with Distributed Clocks



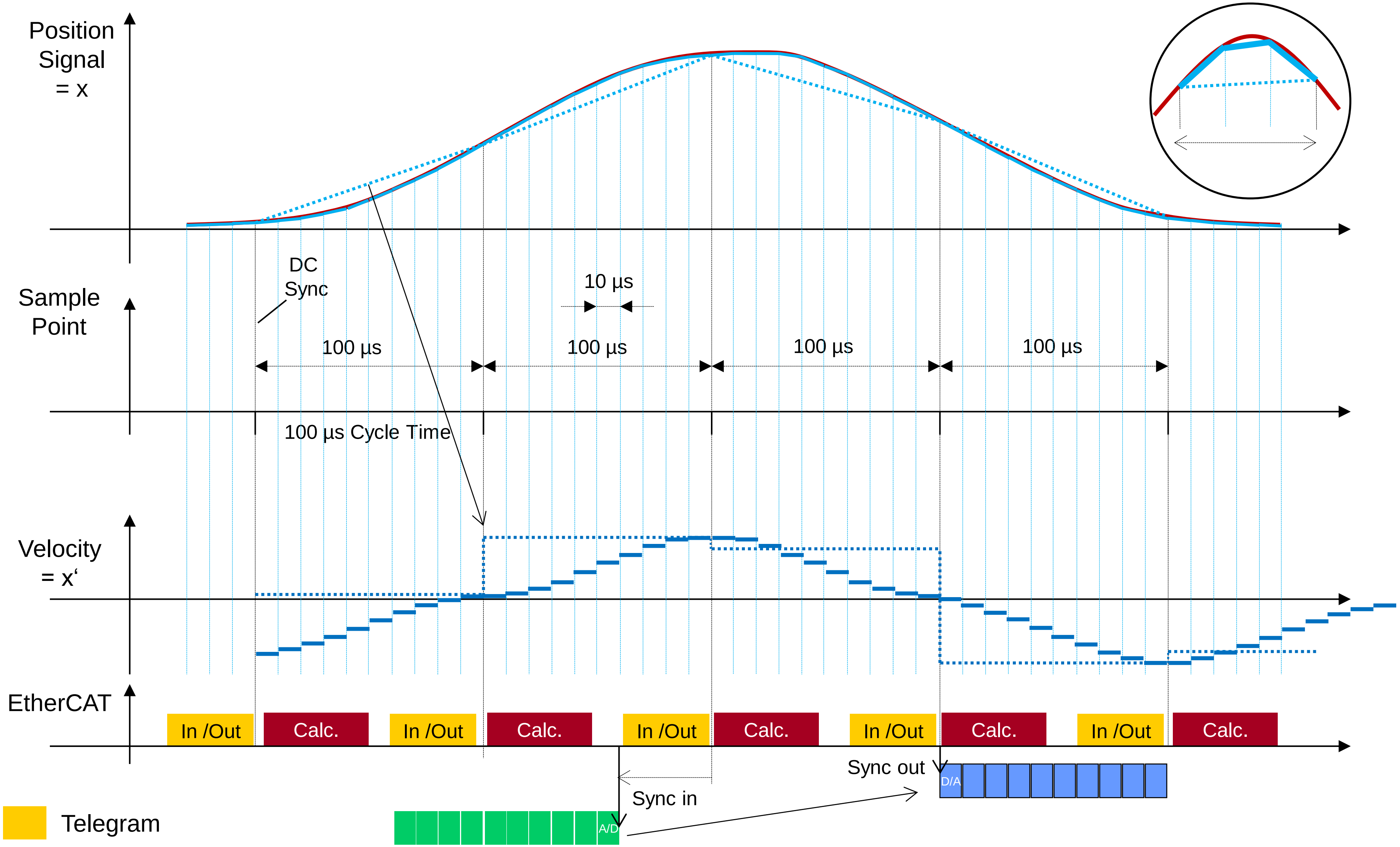
Timing – Synchronous with Distributed Clocks

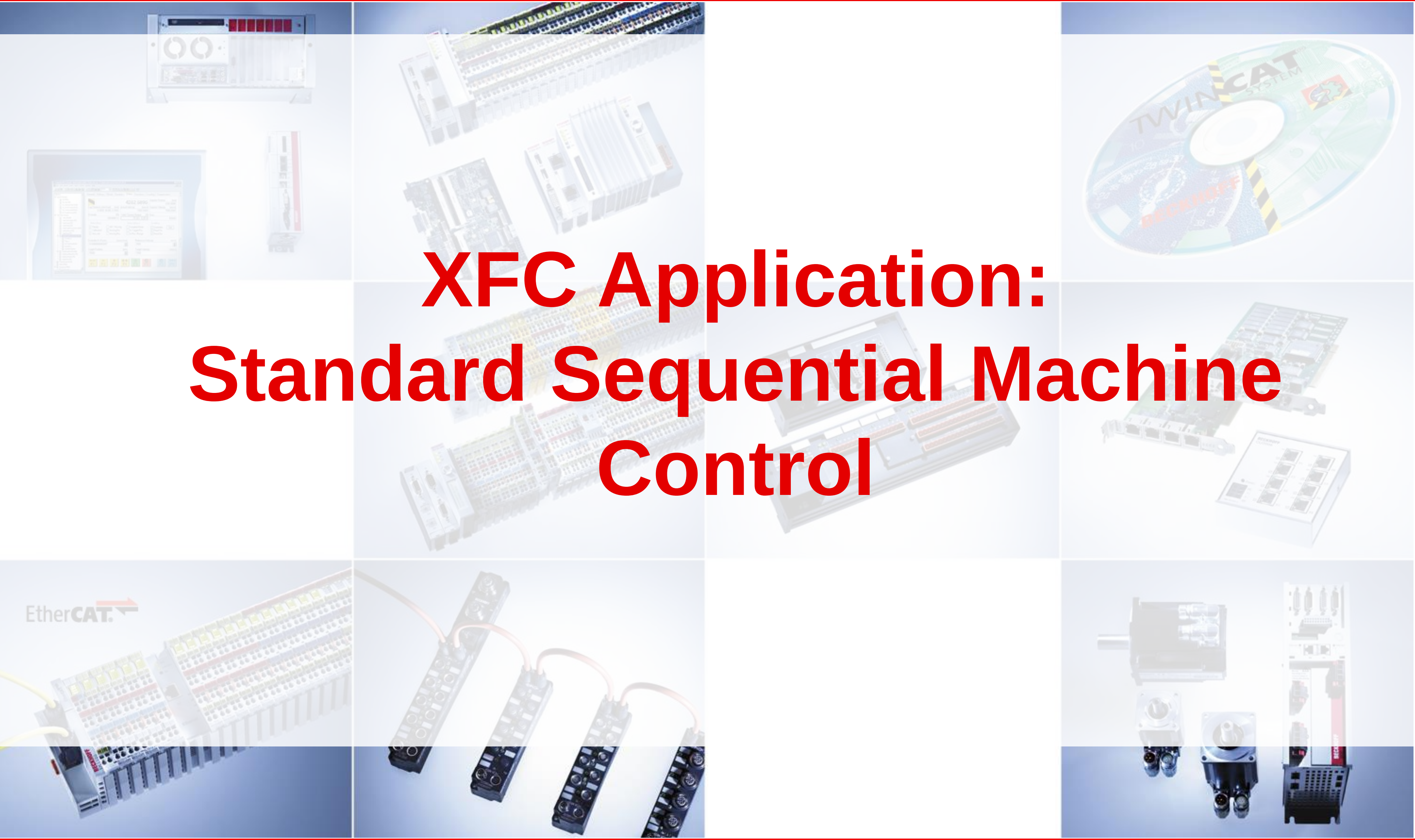
Advantages of this approach:

- High precise synchronous signal-timing by DC
- No errors due to sample deviation
- All filter algorithms and factors in control loops run without errors

→ Equidistant signal latching with Distributed Clocks improves quality of measuring

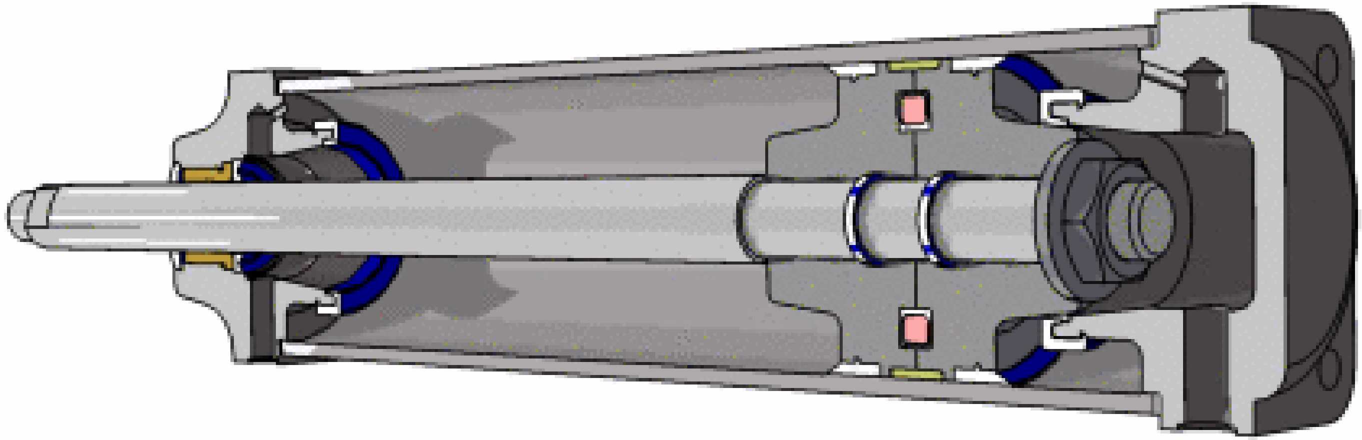
Timing – Synchronous with DC, Oversampling





XFC Application: Standard Sequential Machine Control

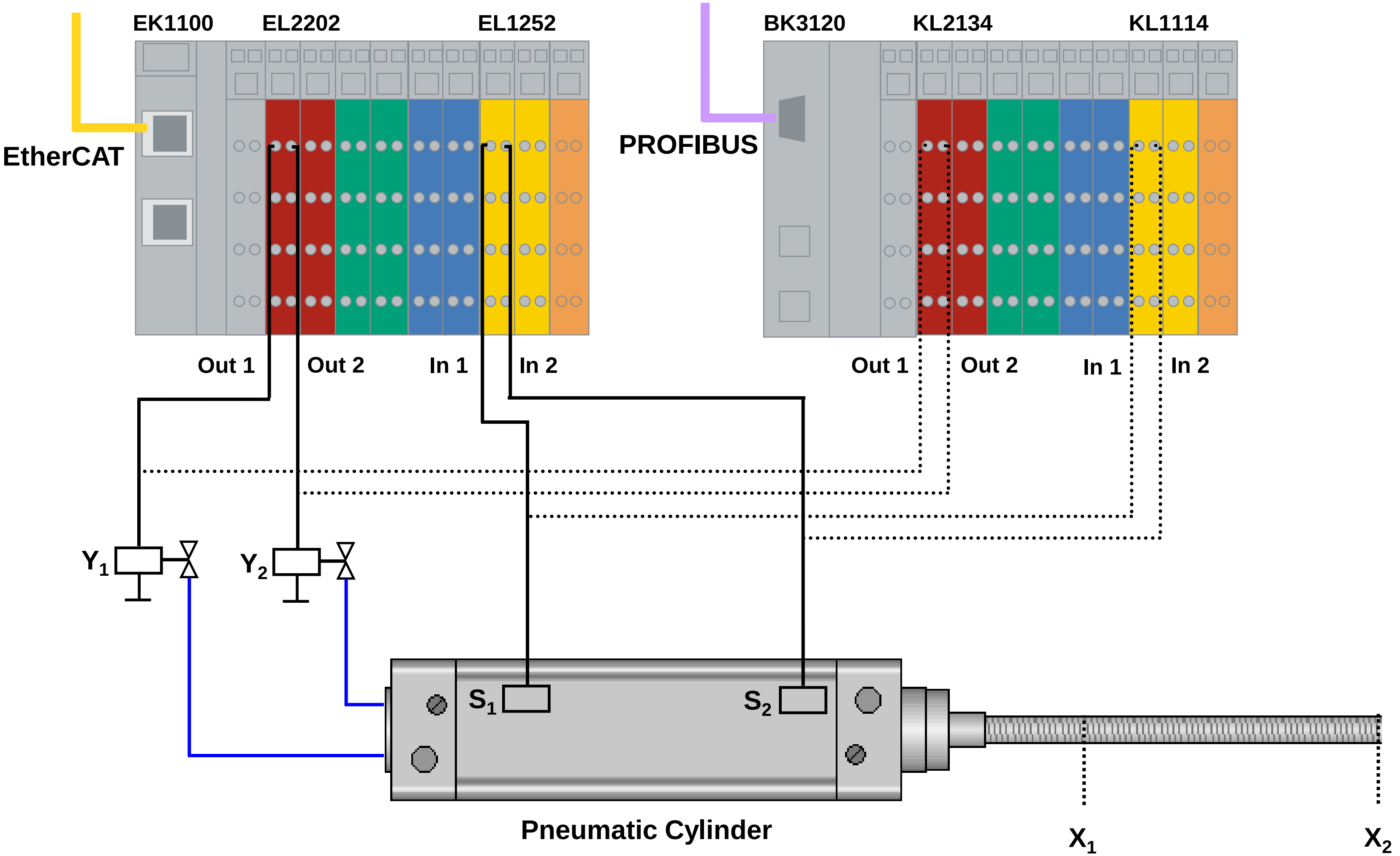
XFC/Profibus: Standard Machine Test Application



Simple Pneumatic Cylinder, going back and forth

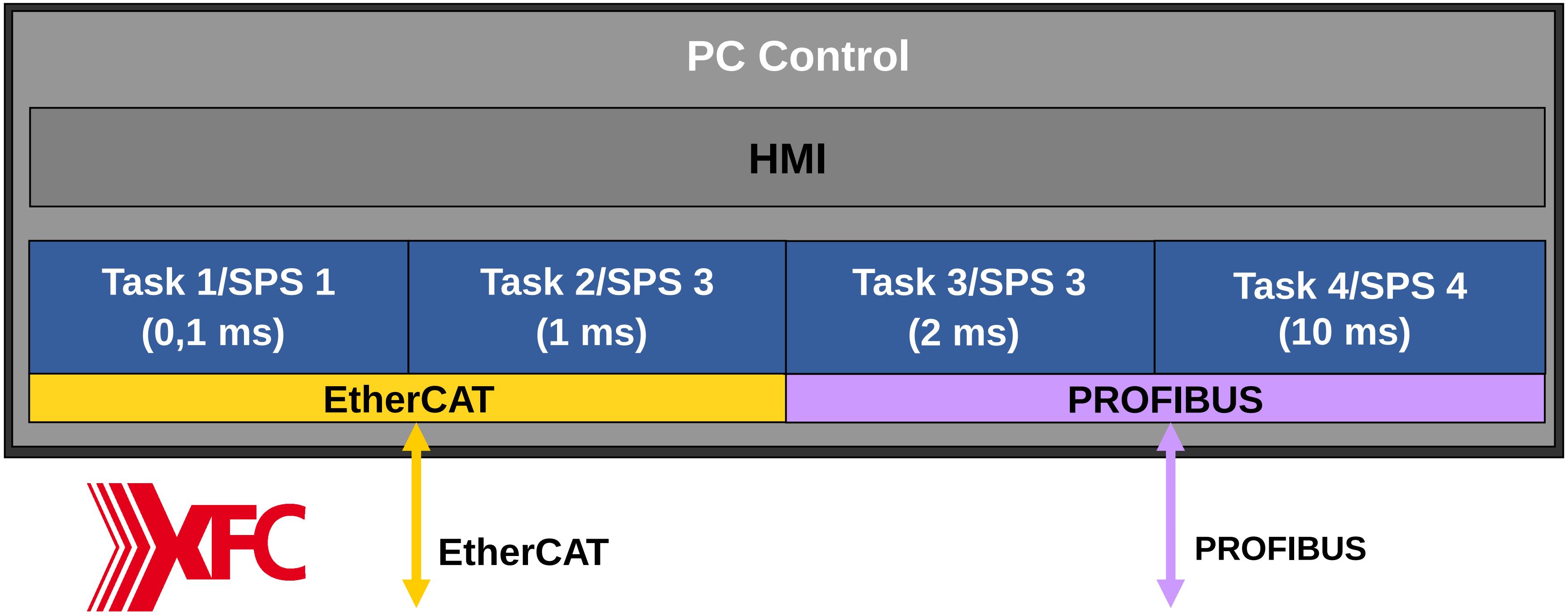
How does the communication and control system influence its performance?

XFC/Profibus: Standard Machine Test Application



Pneumatic Cylinder

XFC/Profibus: Standard Machine Test Application



- Identical PLC program in all 4 Tasks
- Identical Mechanics + Sensors

Efficiency Gain Demonstrator: Results

PROFIBUS Cycle time (ms)	EtherCAT Cycle time (ms)	Efficiency Increase (%)
20	1	11,7 %
10	1	5,7 %
2	0,1	1,17 %

- EtherCAT and XFC: Increase the Efficiency of each „Standard“ Machine
- Just by using an EtherCAT powered Control System:
  - No faster sensors / actuators needed

XFC/Profibus:
Machine Efficiency and Control Cycle Time

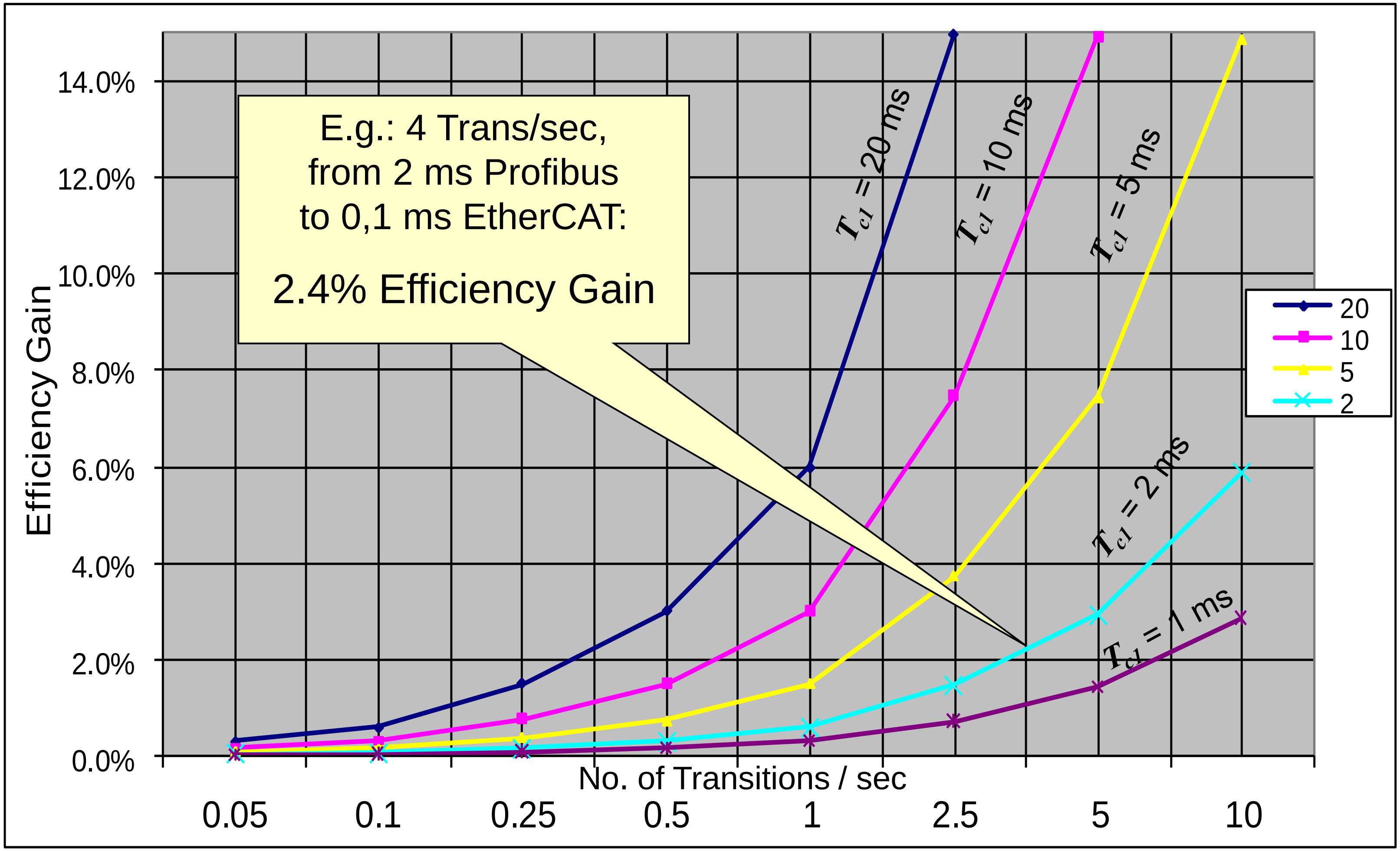
Machine Cycle Time Reduction in %
(= Increase in machine efficiency)

$$T_{d\%} = \frac{N_{r2} \bullet T_{c2} - N_{r1} \bullet T_{c1}}{T_t}$$

$T_{d\%}$ = Machine Cycle Time Reduction (%)

N_{r1} = Average Number of Control Cycles for I/O response of Control 1
N_{r2} = Average Number of Control Cycles for I/O response of Control 2
T_{c1} = Control Cycle Time 1 (shorter cycle time)
T_{c2} = Control Cycle Time 2 (longer cycle time)
T_t = Time between 2 control transitions

Cycle Time Reduction = Efficiency Increase



with: N_{r1} = 3, N_{r2} = 1,5, T_{c2} = 0,1 ms

XFC Example: Raw Material Reduction @ Plastics Machine

Husky HyPAC Injection Molding Machine

Initially presented at *Siemens Industrial Ethernet Symposium*, *Chicago, October 2006*

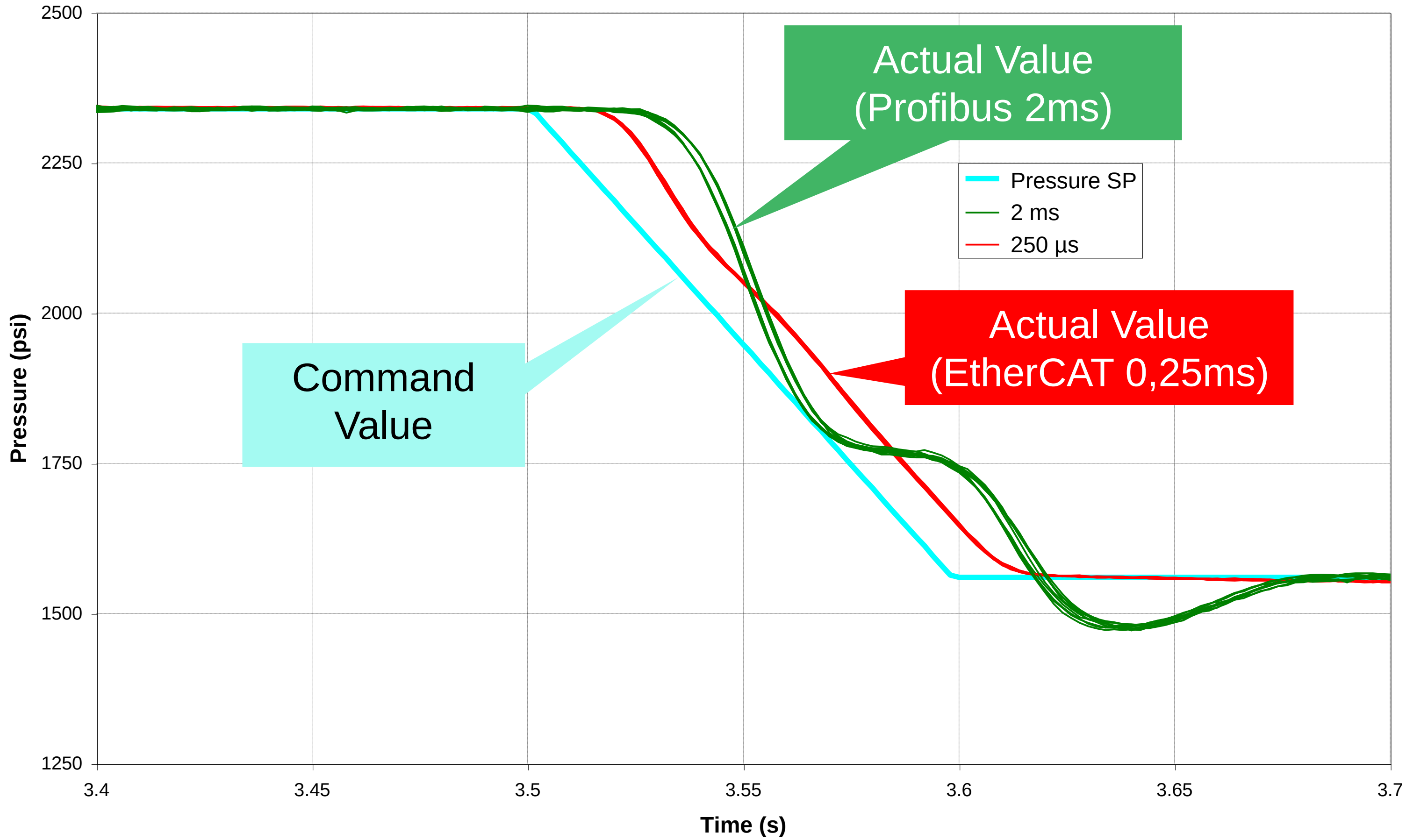
(please find presentation at http://www.ethercat.org/pdf/english/Speed_without_Haste_Chris_Choi_IIES_2006.pdf)

XFC Example: Raw Material Reduction @ Plastics Machine

Husky (Canada): HyPAC Injection Molding Machine

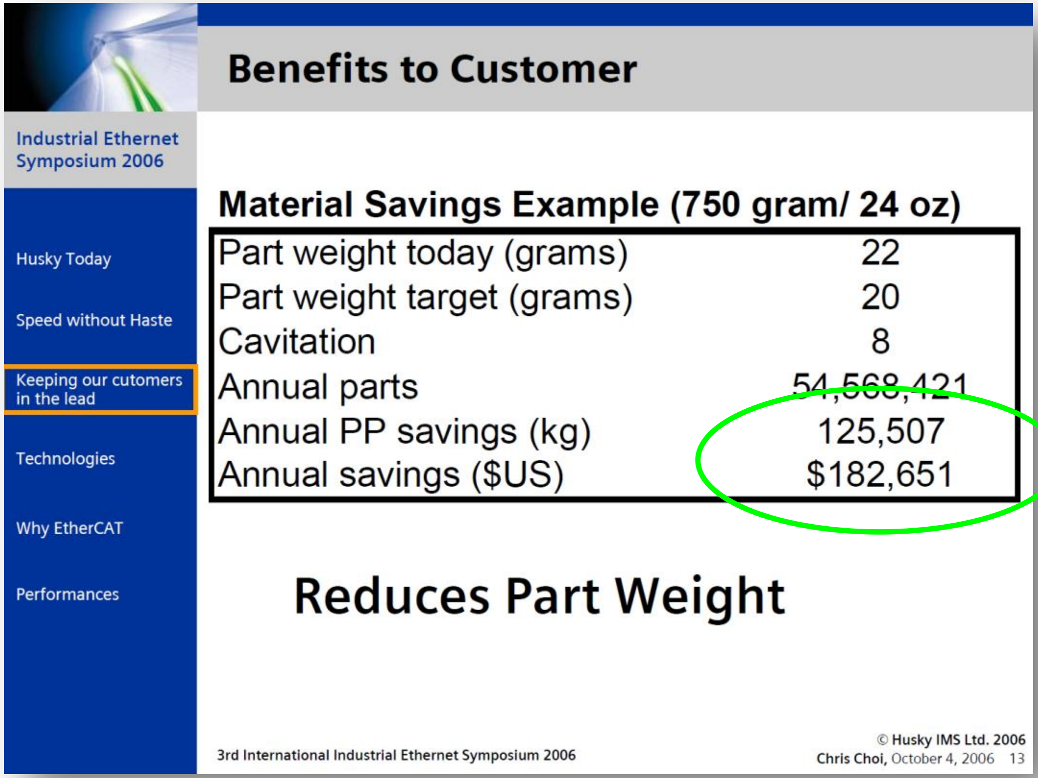
XFC Example: Raw Material Reduction @ Plastics Machine

Transition Pressure Control Plastics Machine



Source: Husky Injection Molding Systems Ltd.

XFC Example: Raw Material Reduction @ Plastics Machine



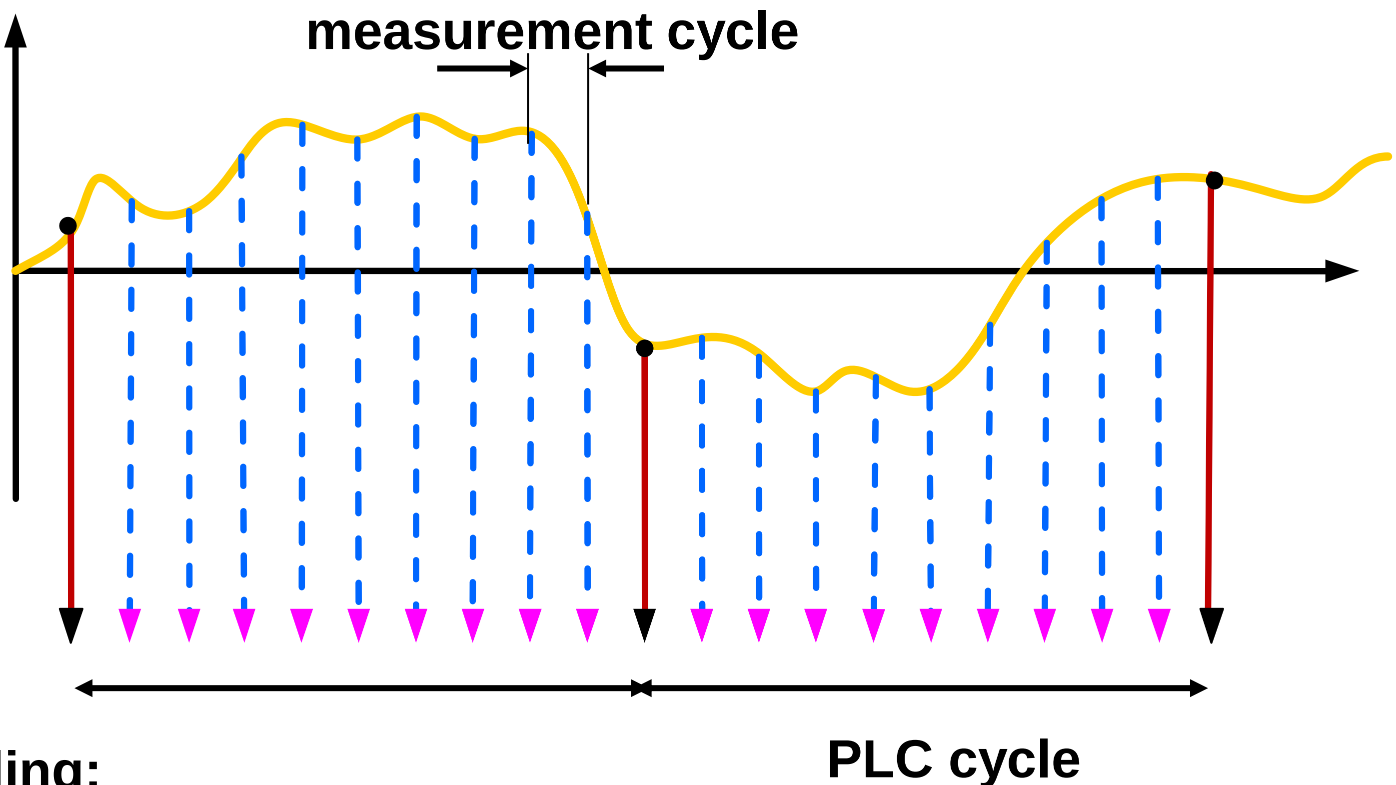
Due to EtherCAT >100t Material Saving / Year

And Energy Saving accordingly…

I/O Oversampling: Improving Timing, Resolution and Reaction

Signal Analysis with up to 500 kSamples

Analog Input with Oversampling

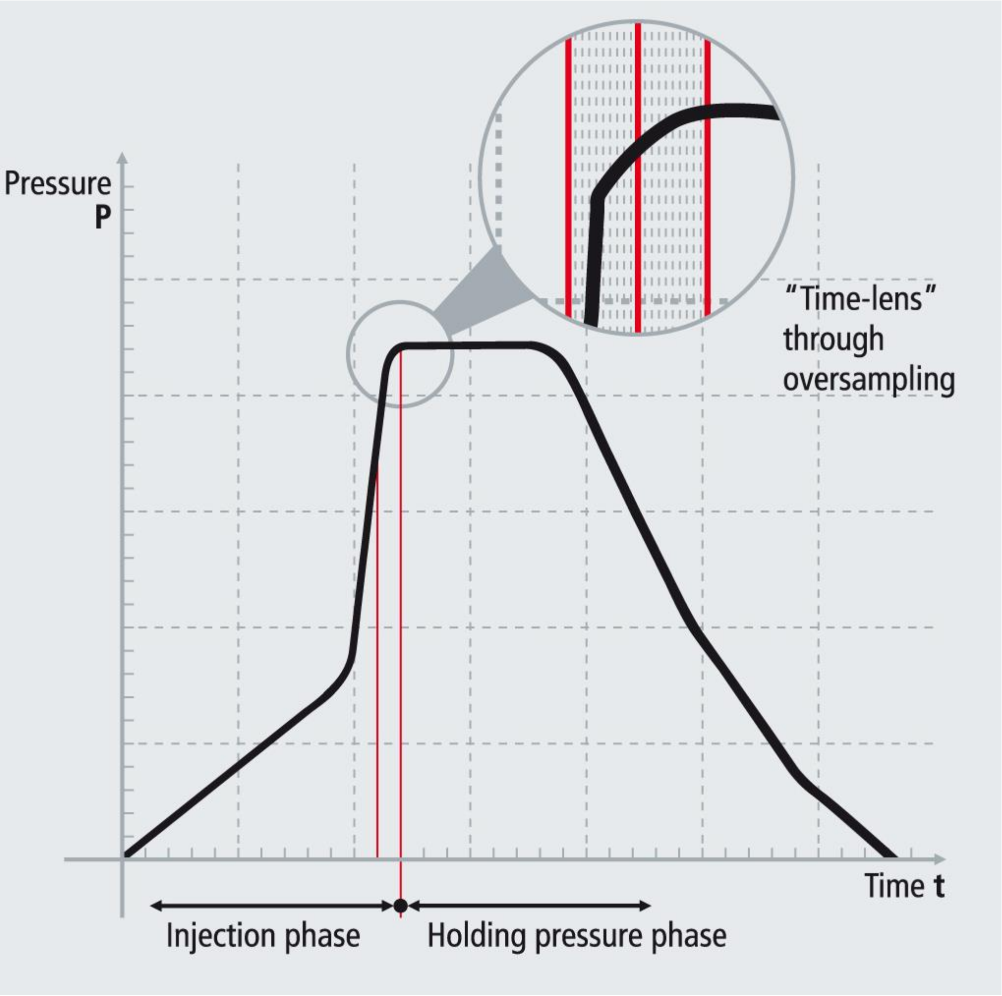


Oversampling:

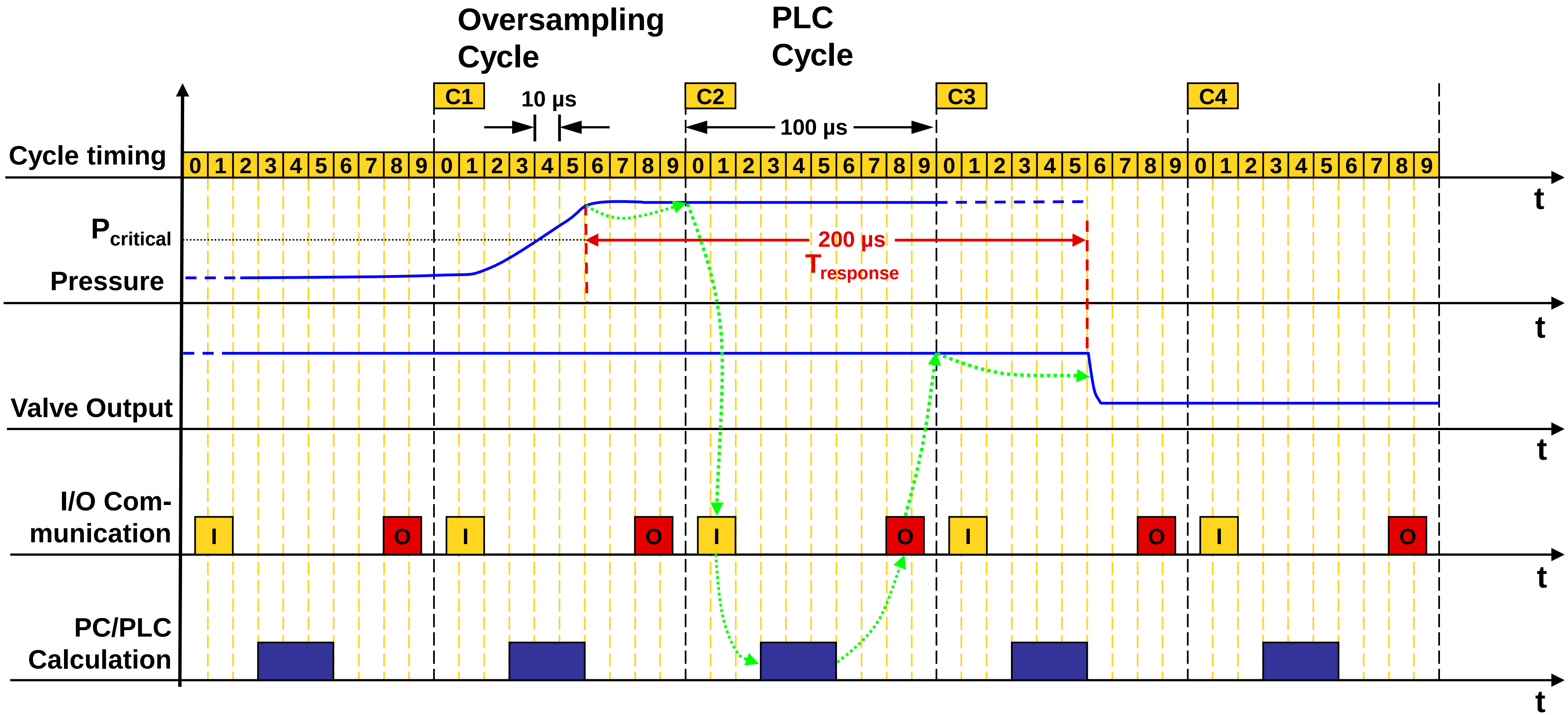
- **Up to 500kSamples/sec**
- **Oversampling Factor from 2 - 100**

Oversampling:
Usage for Critical Treshold Detection

Simplified pressure curve during filling phase of injection molding machines



Oversampling for Critical Threshold Detection and Reaction



Exact threshold detection with 10us timing resolution!
Intelligent signal algorithms (filtering, …) freely programmable on the PC!
Very short and exact reaction with 200us delay and 100ns jitter

XFC: Summary

- XFC provides a new class of control performance
- It de-couples the process from the control cycle time
- Required Ingredients:
  - EtherCAT
  - XFC I/O Terminals from Beckhoff
  - PC based Control Performance
  - TwinCAT, the Automation Software Suite
- XFC accelerates your Application!