



Lecture #2.4

Advance topics and
Machine interface

MAS418

Programming for Intelligent Robotics and Industrial systems

Part II: PLC Software Development

Spring 2024

Daniel Hagen, PhD

Previous Lecture

- **Object-oriented PLC programming**

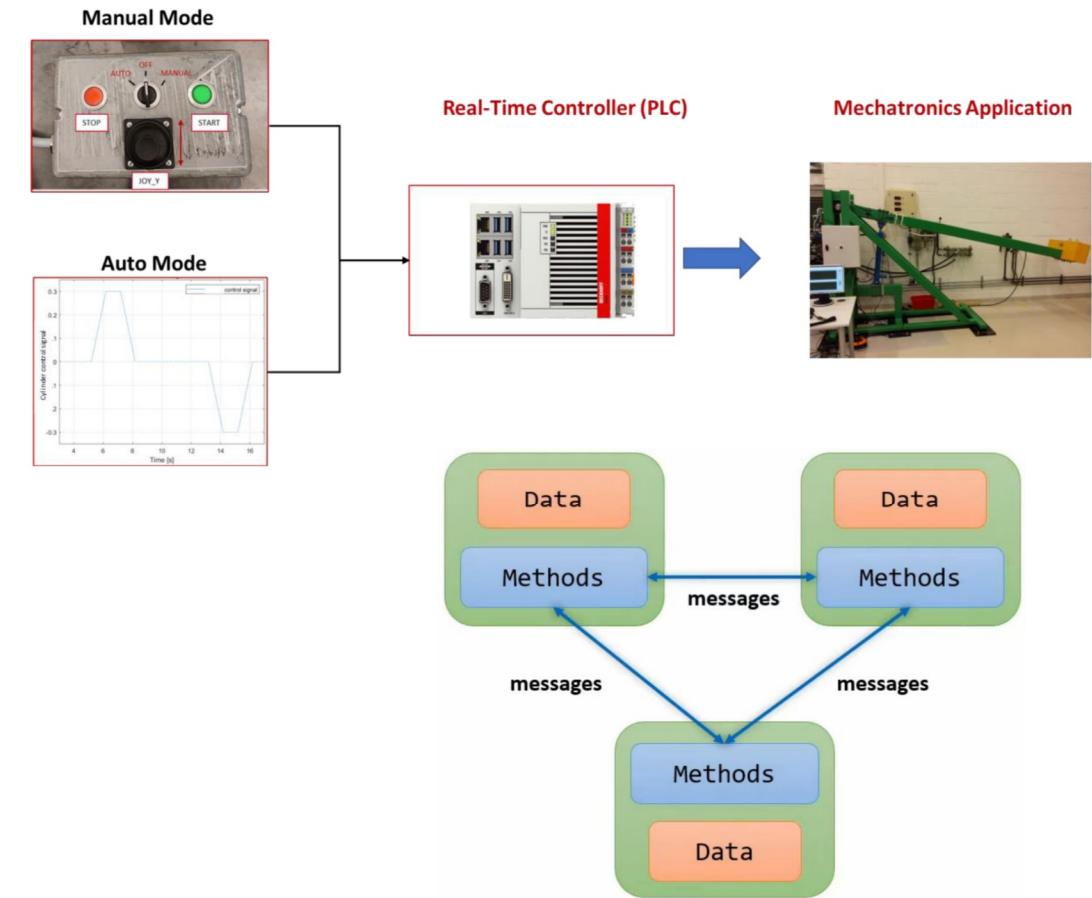
I. Presentation of application

- System overview
- Relevant IO
- Motion control
- Safety system
- Control input
- Programming task

II. Function Blocks

- Introduction
- Function blocks
- Methods
- Inheritance

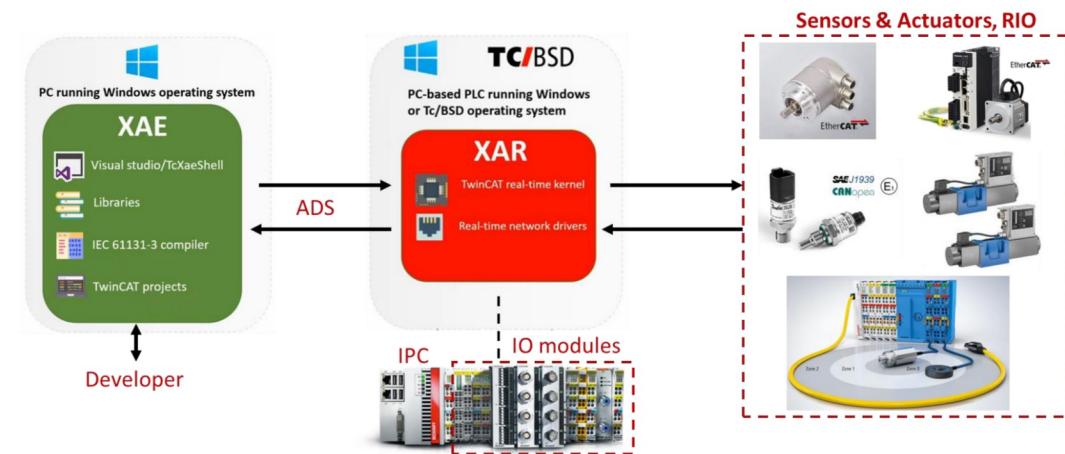
III. Interfaces



Key takeaways

- **Advance topics and Machine interface**

- TwinCAT Utilities library
- TwinCAT Libraries
- TwinCAT Functions
- TwinCAT HMI
- Handling of different TwinCAT versions
- TwinCAT Automation interface
- Test driven development
- Input & Outputs (I/O) configuration
- Fieldbus
- EtherCAT
- ADS
- IO mapping
- TwinCAT Measurement



Overview

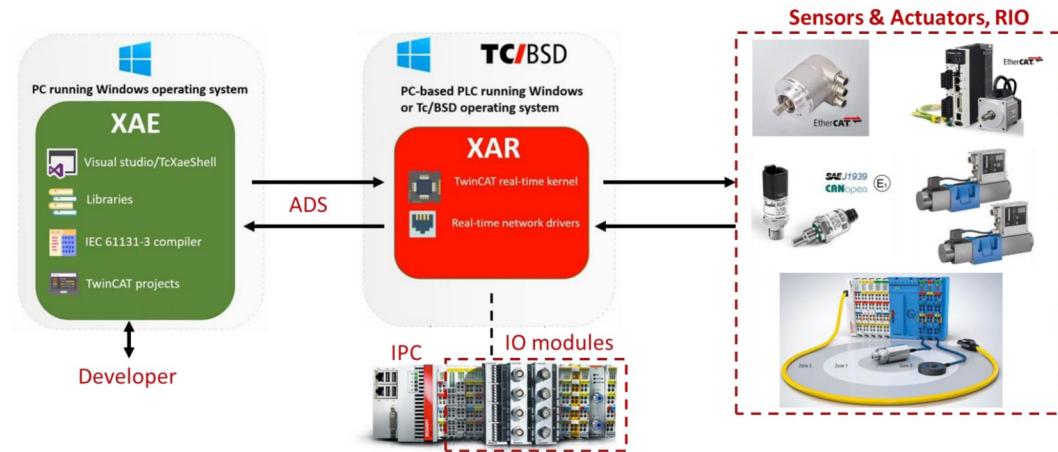
Introduction

Part I: TwinCAT advance (self-study)

Part II: Machine Interface

Part III: Demo

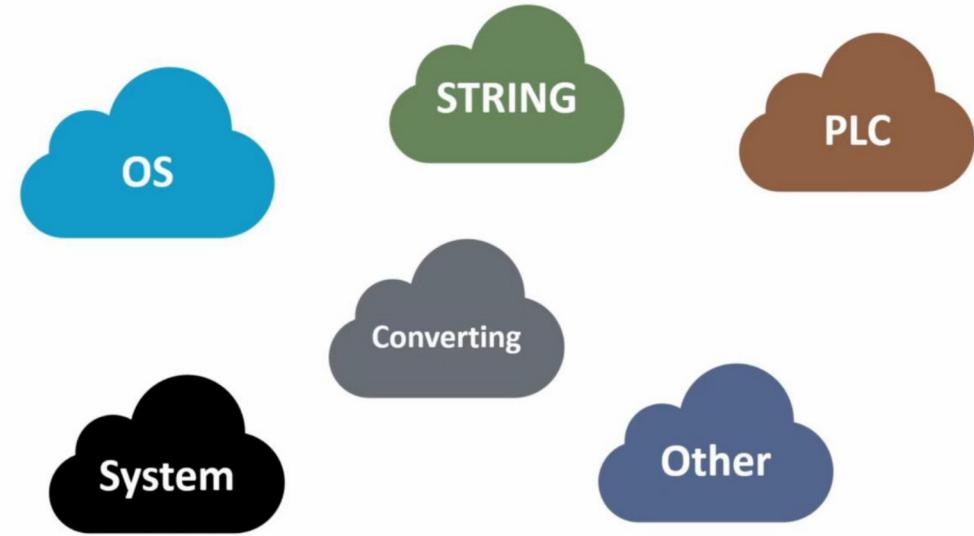
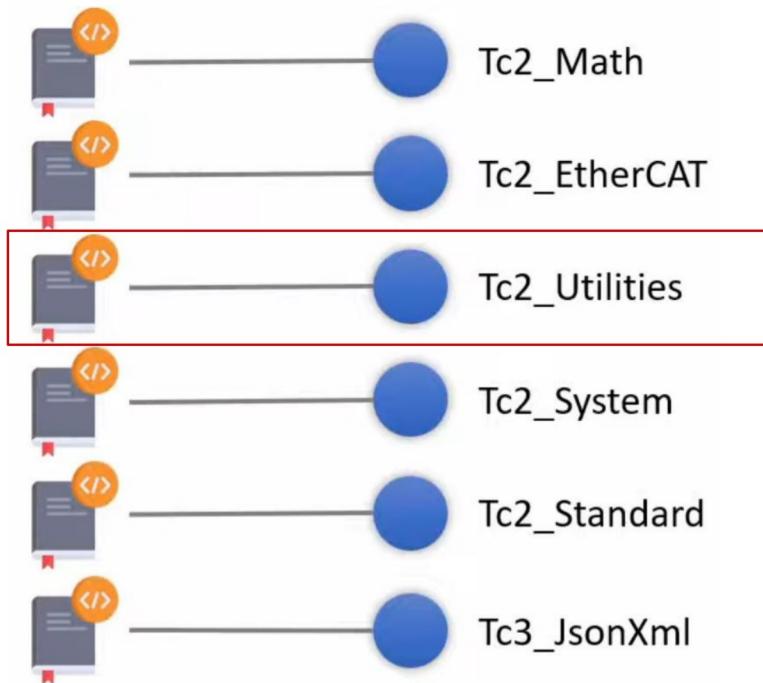
Summary



Part I: TwinCAT advance (self-study)

1. Libraries
2. Functions
3. HMI
4. Handling of different TwinCAT versions
5. Automation interface
6. Test driven development

Libraries



Libraries

 Tc2_Utility

A big box of tools

OS	STRING	System	Converting	PLC	Other
NT_Shutdown	FB_FormatString	TC_Restart	DT_TO_SYSTEMTIME	PLC_Reset	FB_BasicPID
NT_Reboot	F_ToUCase	TC_Stop	SYSTEMTIME_TO_STRING	PLC_Start	IsFinite
NT_GetTime	F_ToLCase	TC_Config	BYTEARR_TO_MAXSTRING	PLC_Stop	FB_MemRingBuffer
NT_StartProcess	FIND2	TC_CpuUsage	F_SwapRealEx	FB_WritePersistentData	RTC_EX2
FB_GetHostName	F_Ltrim	FB_GetSystemId	F_TranslateFileTimeBias	Profiler	F_GetWeekOfTheYear
FB_LocalSystemTime	CONCAT2	TC_SysLatency	GuidsEqualByVal	PLC_ReadSymInfoByName	FB_HashTableCtrl

Self-study:

FB_MemRingBuffer: allows data records of varying lengths to be written into a ring buffer.

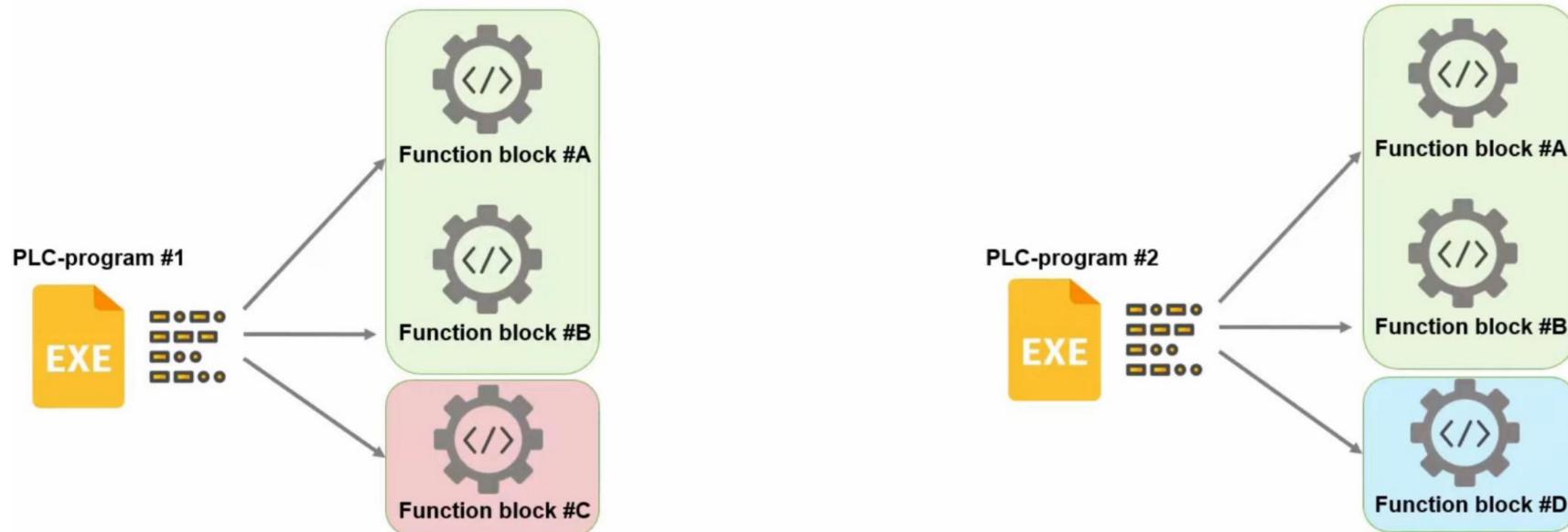
Profiler: can be used to measure the execution time of PLC code.

NT_StartProcess: can be used to start a windows application from the PLC.

[PLC programming using TwinCAT 3 - TwinCAT utilities](#)

Libraries

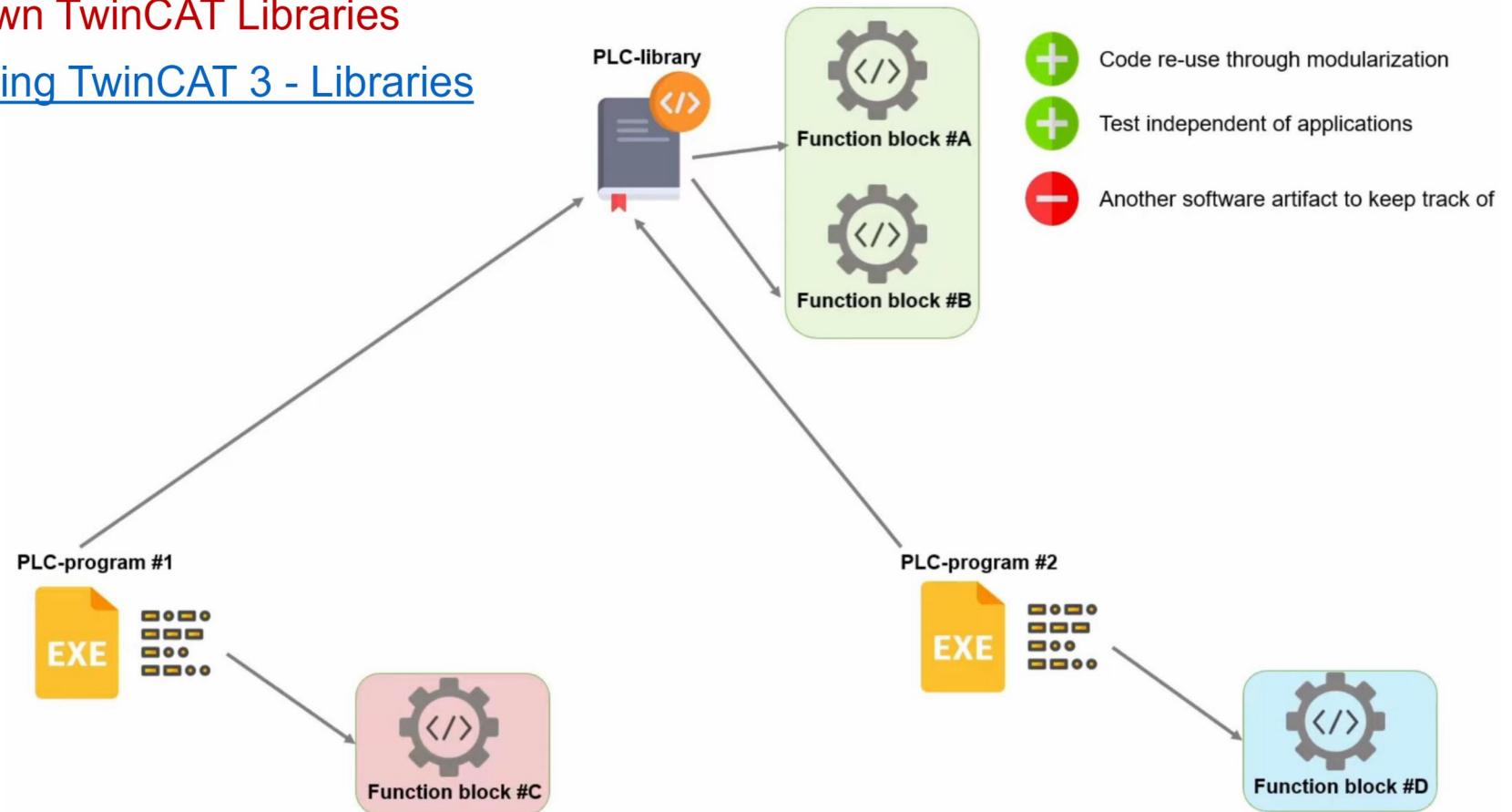
With libraries you can organize code and use it in multiple projects



Libraries

How to create your own TwinCAT Libraries

PLC programming using TwinCAT 3 - Libraries



Functions

Additional functions not included in the base XAE installation



TF1xxx – TC3 System

[Controller Redundancy, Runtime for MATLAB/Simulink](#), [Runtime for FMI](#), [PLC HMI](#), [PLC HMI Web](#), [UML](#)



TF5xxx – TC3 Motion

[PTP Axis control](#), [Canting, Flying Saw, FIFO Axes](#), [Motion Control](#), [Interpolating, Kinematic Transformation](#), [Robotics mxAutomation, CNC...](#), etc.



TF2xxx – TC3 Human Machine Interface

[HMI server](#), [HMI Clients Packs](#), [HMI Target Packs](#), [HMI OPC UA](#), [HMI Extension SDK](#), [HMI Scope](#)



TF6xxx – Connectivity

[ADS Monitor](#), [JSON Data Interface](#), [OPC UA](#), [EtherCAT Redundancy](#), [External Sync](#), [Modbus TCP/RTU](#), [PROFINET](#), [EtherNet/IP](#), [FTP Client](#), [TCP/IP](#), [TCP/UDP Realtime](#), [Serial Communication](#), [SMS/SMTP](#), [Virtual Serial COM](#), [Database Server](#), [XML Server](#), etc.



TF3xxx – TC3 Measurement

[Scope Server](#), [Analytics...](#), [Condition Monitoring](#), [Power Monitoring](#), [Filter](#), [Interface for LabVIEW](#), [Machine Learning Inference Engine](#), [Neural Network Inference Engine](#), [Machine Learning Server](#), [Solar Position Algorithm](#)



TF7xxx – Vision

[GigE Vision Connector](#), [Vision Base](#), [Vision Matching 2D](#), [Vision Code Reading](#), [Vision Metrology 2D](#)



TF4xxx – TC3 Controller

[Controller Toolbox](#), [Temperature Controller](#), [Speech](#)



TF8xxx – Industry specific

[HVAC](#), [Building Automation](#), [BACnet](#), [Lighting Solution](#), [Wind Framework](#), [MTP Runtime](#), etc.

<https://youtu.be/FOC0rUeECDs>

Functions

TF6250 – TC3 Modbus TCP

PLC programming using TwinCAT 3 - TwinCAT functions



TF6xxx – Connectivity



TF6020 – TC3 JSON data interface



TF6100 – TC3 OPC-UA



TF6250 – TC3 Modbus TCP



TF6270 – TC3 PROFINET RT Device



TF6300 – TC3 FTP Client



HMI

Download:

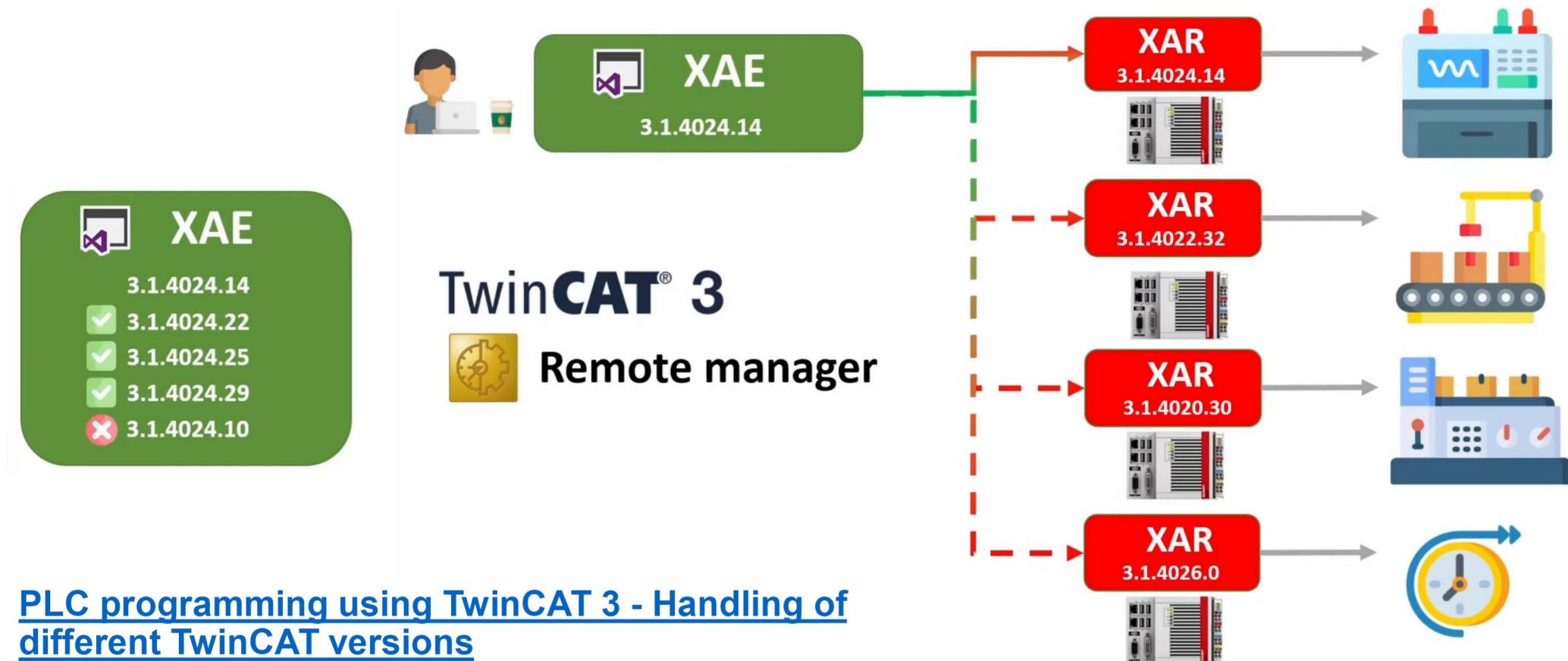
<https://www.beckhoff.com/en-en/products/automation/twincat-3-hmi/>

YouTube demo:

[TwinCAT 3 PLC HMI 1.8 project in 5 minutes](#)



Handling of different TwinCAT versions



PLC programming using TwinCAT 3 - Handling of different TwinCAT versions

Automation interface

Methods to automate tasks in order to save time and increase quality

Typical steps involved when developing TwinCAT software:

- Defining the **real-time properties**
- Writing **unit tests**
- Creation of POU^ss and business logic (**writing the software**)
- Defining the inputs and outputs (**I/O**) and linking them to the instances of the POU^ss
- Installing and referencing **libraries** both TwinCAT systems and own
- **Configuring the target** and installing any necessary software such as setting the IP addresses, etc.
- Creating an **AMS-route** to the target
- **Selecting the target** for deployment of the software
- **Activating configuration** on the target

Realtime properties

Unit tests

Writing the software

I/O

Library management

Target configuration

AMS-route to target

Selecting target

Activate configuration

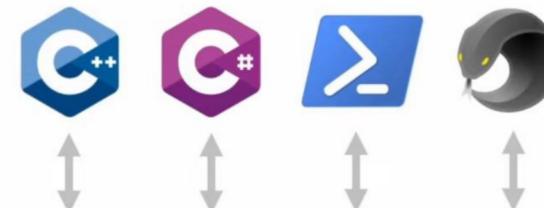
Automation interface

Help to automate the automation by enabling creation and manipulation of **TwinCAT XAE** configuration via programming or scripting code

- It is possible to **automate** most of the things you do manually in **TwinCAT**



TwinCAT® 3 Automation interface



- | | |
|----------------------------------|--------------------------------|
| ● Build/clean project | ● Adding/removing I/O |
| ● Activate configuration | ● Running static code analysis |
| ● Create AMS routes | ● Selecting target device |
| ● Do a broadcast search | ● Management of POU |
| ● Configuring real-time settings | ● Management of libraries |
| ● Adding/removing tasks | |

Automation interface

Two components are needed to fully **automate** the different tasks in **TwinCAT**

- With **TwinCAT automation interface** we get access to everything Beckhoff have added on top of **Visual Studio**



PLC programming using TwinCAT 3 - TwinCAT automation interface

Test driven development

Write tests before writing the implementation code

- **What you want to develop:**

- TDD starts with you **writing failing tests** for the behavior of the code

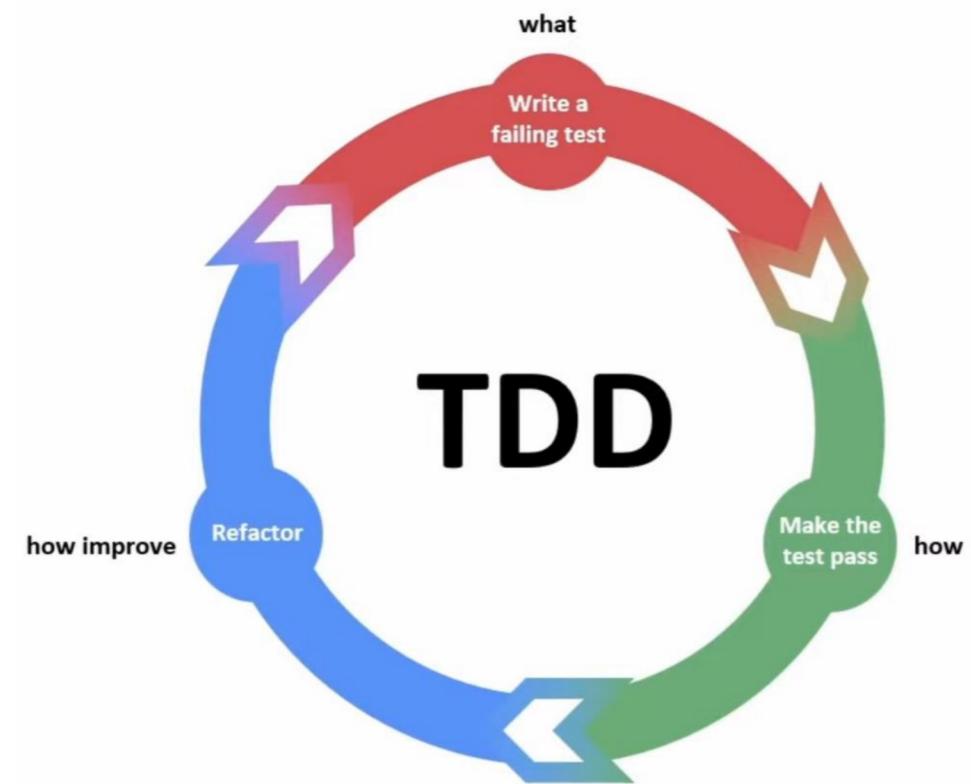
- **How you want to develop the code:**

- Only once written the failing test should you continue to the next step which is to **write code until the tests pass**

- **How to improve the code:**

- Once the two first steps are done you can go to the last and final step which is to **refactor** the code
- Then **repeat** the cycle for any additional functionality that you want to add to your code

Software development process

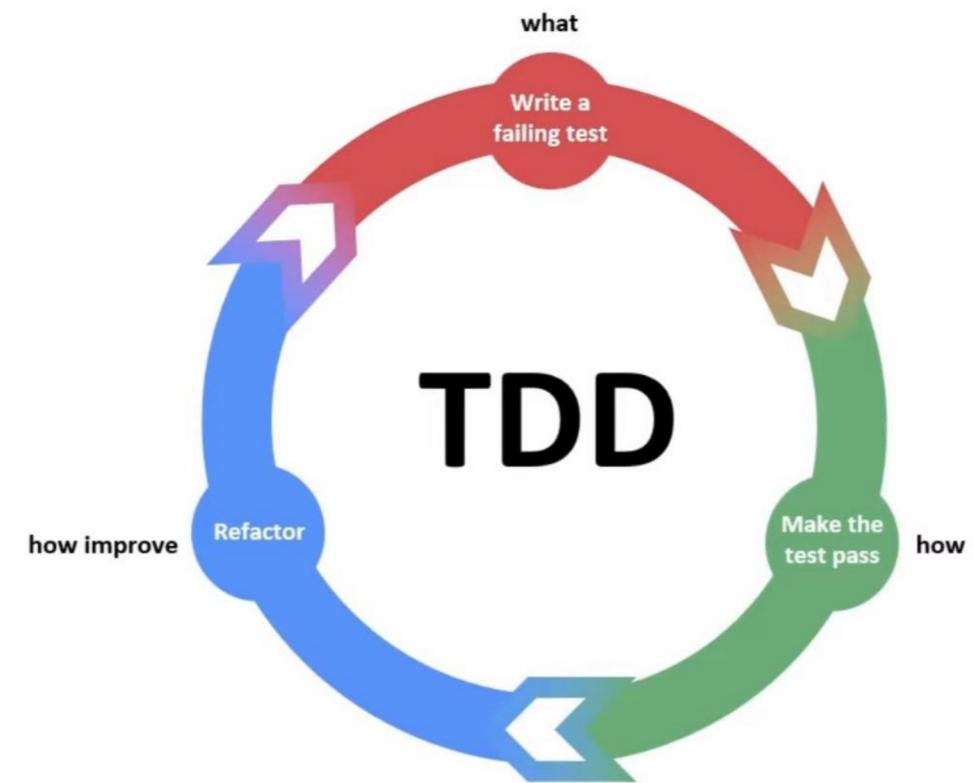


Test driven development

Why do we want to do TDD?

- Regression test-suite of your code
- Modularized, extensible, and flexible code
- Clearly defined interfaces
- Fewer bugs
- Documentation
- Acceptance criteria
- Tidier code

Software development process



Test driven development

Unit testing framework

- A type of software where individual units or components of a software is tested, with the purpose being to validate that each unit of the software code performs as expected
- **Open-source framework:**
 - Just download and install the **TcUnit** library and reference to it in the **TwinCAT** project

TcUnit

- [PLC programming using TwinCAT 3 - Test driven development \(Part 17a/18\)](#)
- [PLC programming using TwinCAT 3 - Test driven development \(Part 17b/18\)](#)



tcunit.org



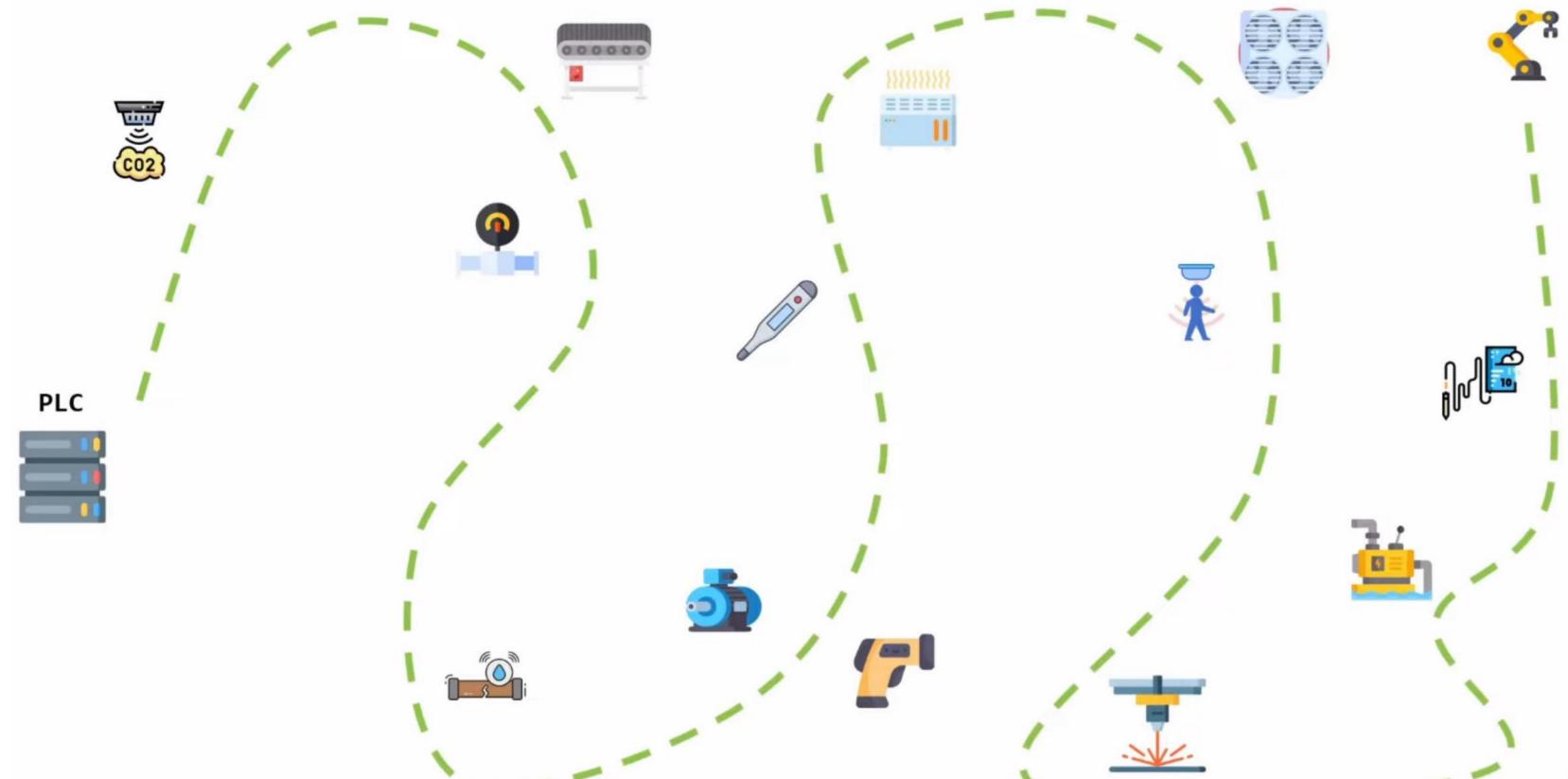
github.com/tcunit

Part II: Machine Interface

1. Input & Outputs (I/O)
2. Fieldbus
3. EtherCAT
4. ADS
5. I/O mapping

Input & Outputs (I/O)

- **What is I/O?**
 - Sensors
 - Actuators
- Fieldbus



<https://youtu.be/zQwiBeDbDcM>

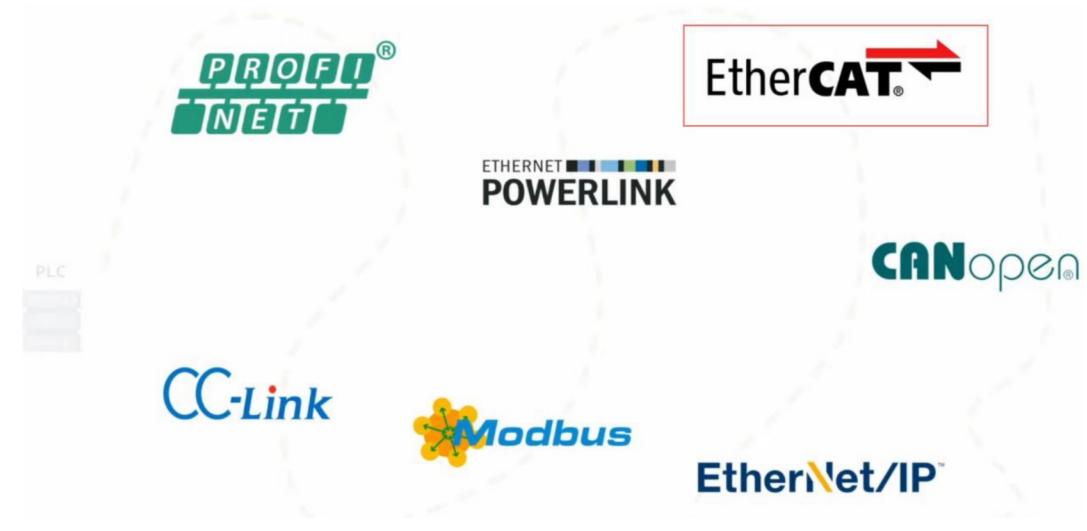
Fieldbus

- Fieldbus is an interface that connects the PLC to all these sensors and actuators
- It's a name for an industrial computer network used for real-time distributed control
- It can be implemented in a wide variety of ways and there are many different ones
 - Profinet
 - CC-Link
 - Modbus
 - Powerlink
 - EtherCAT
 - EtherNet/IP
 - CanOpen

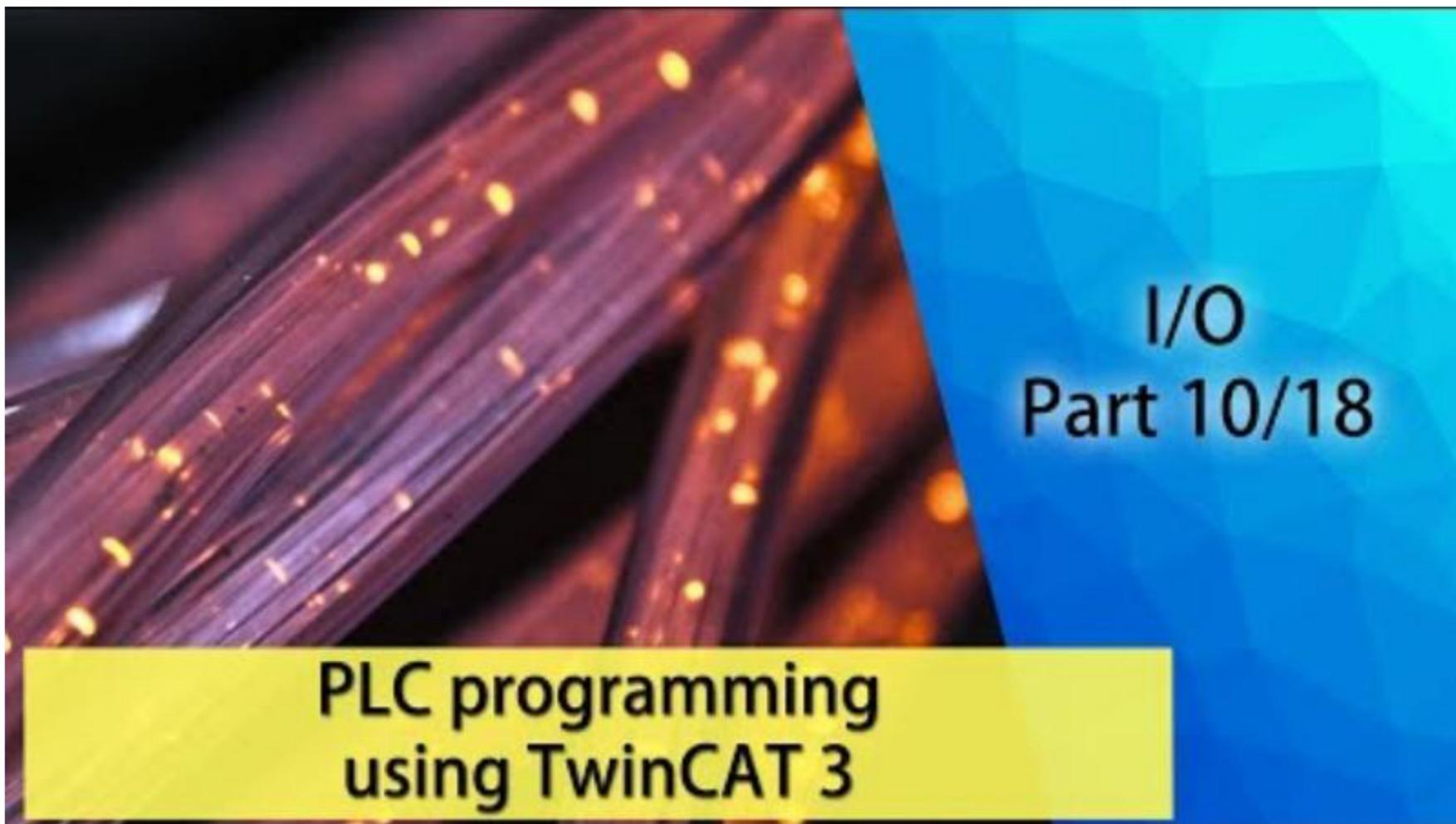


EtherCAT

- EtherCAT is the fieldbus in Beckhoff PLCs
- It was invented by Beckhoff, and the real-time drivers for it are per default included in every Beckhoff PLC
- However, Beckhoff PLCs support most other Fieldbuses



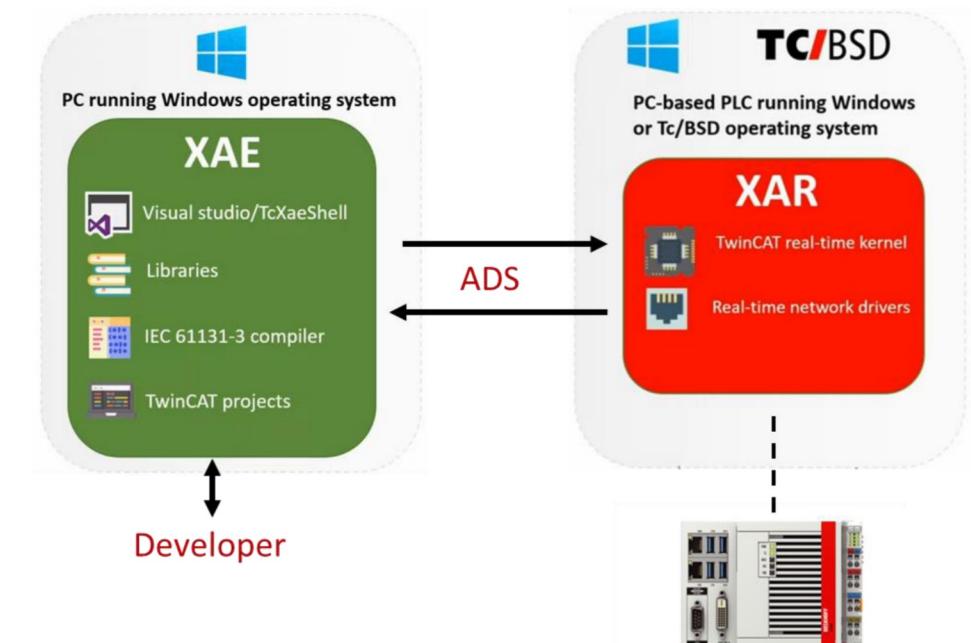
EtherCAT

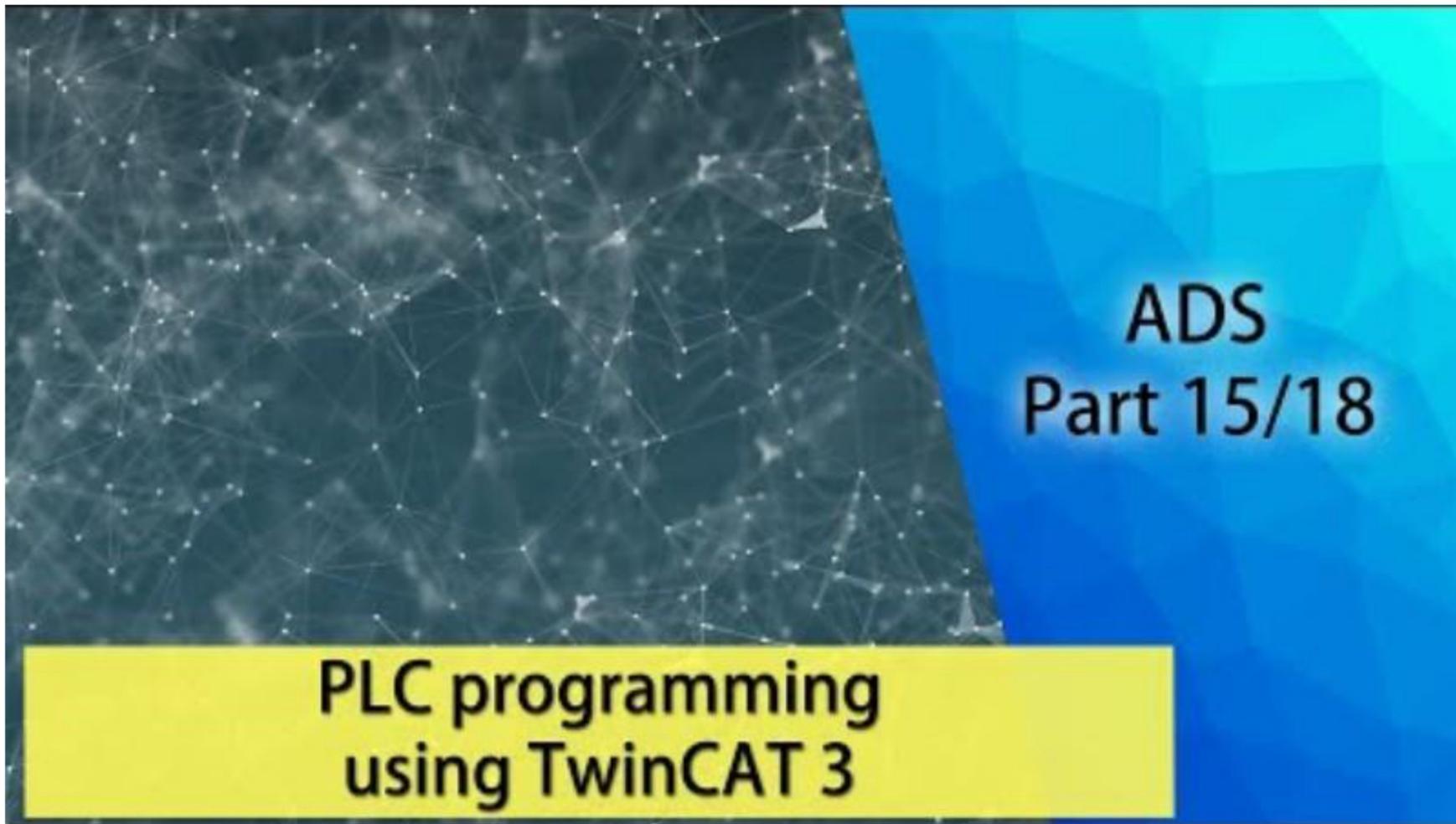


ADS

Automation Device Specification (ADS)

- Beckhoff's interface between software modules in TwinCAT based on a client and server architecture





ADS

Self-study:

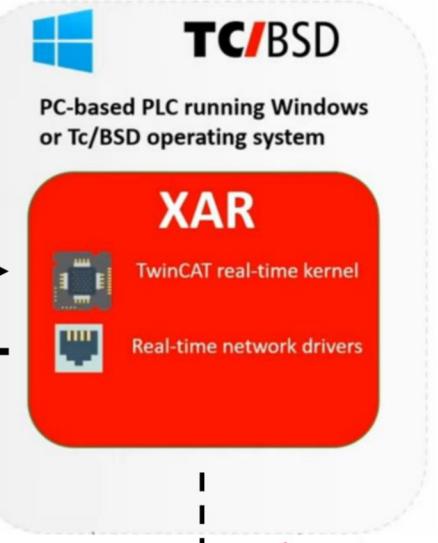
ADS practice and interface with Linux

PLC programming using TwinCAT 3 - ADS

PC (Ubuntu)

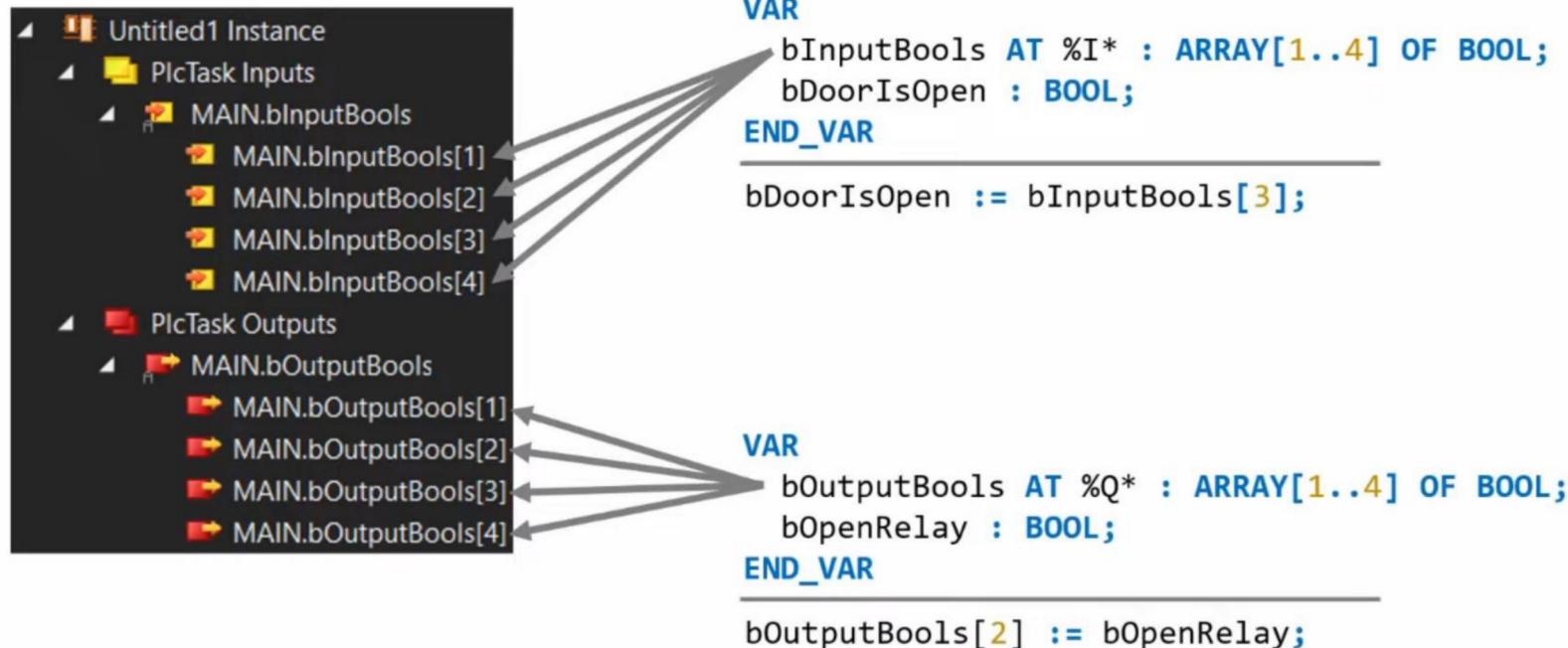


ADS



<https://youtu.be/JZChSdU2LMc>

I/O mapping



```
VAR  
    bInputBools AT %I* : ARRAY[1..4] OF BOOL;  
    bDoorIsOpen : BOOL;  
END_VAR
```

```
bDoorIsOpen := bInputBools[3];
```

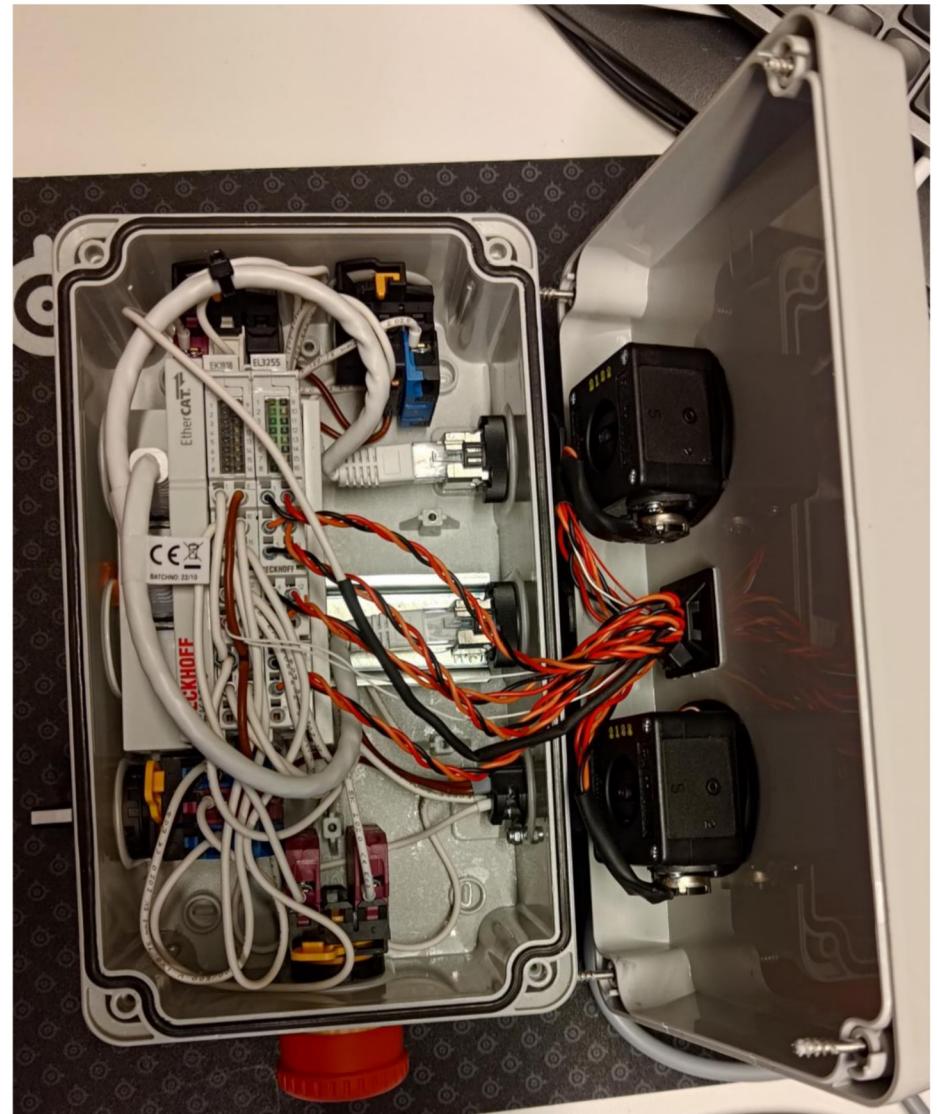
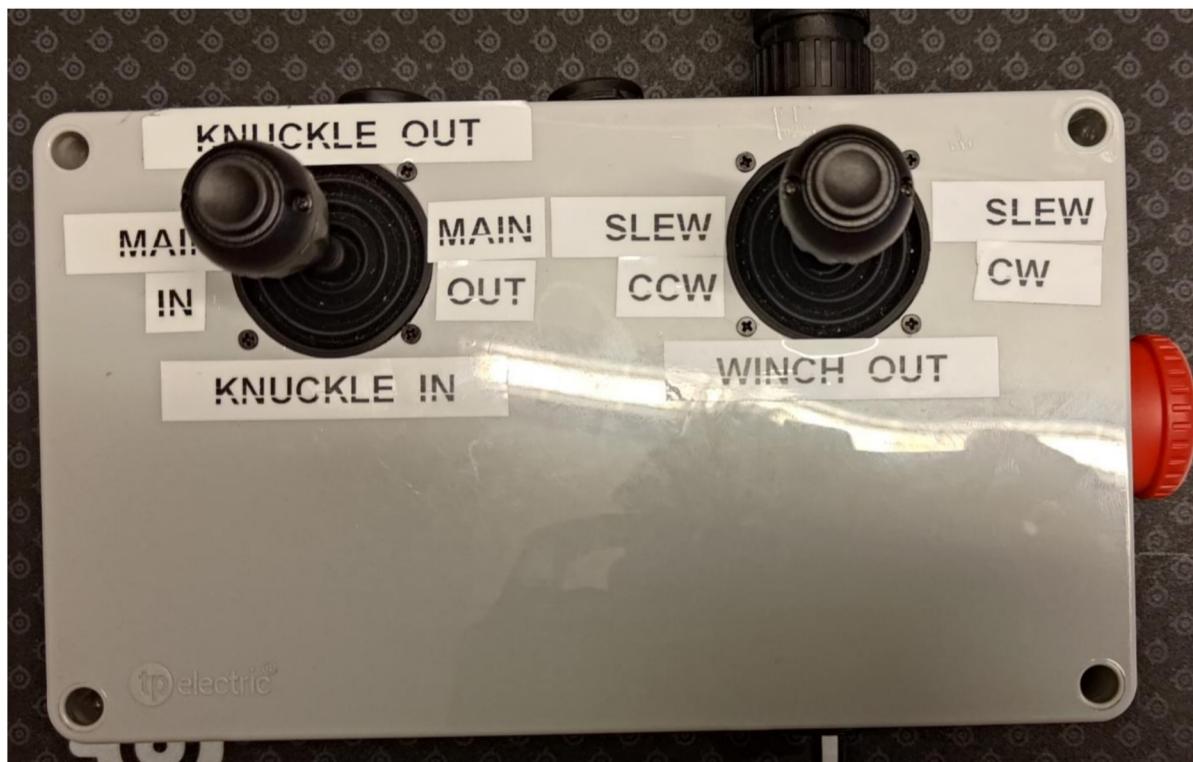
```
VAR  
    bOutputBools AT %Q* : ARRAY[1..4] OF BOOL;  
    bOpenRelay : BOOL;  
END_VAR
```

```
bOutputBools[2] := bOpenRelay;
```

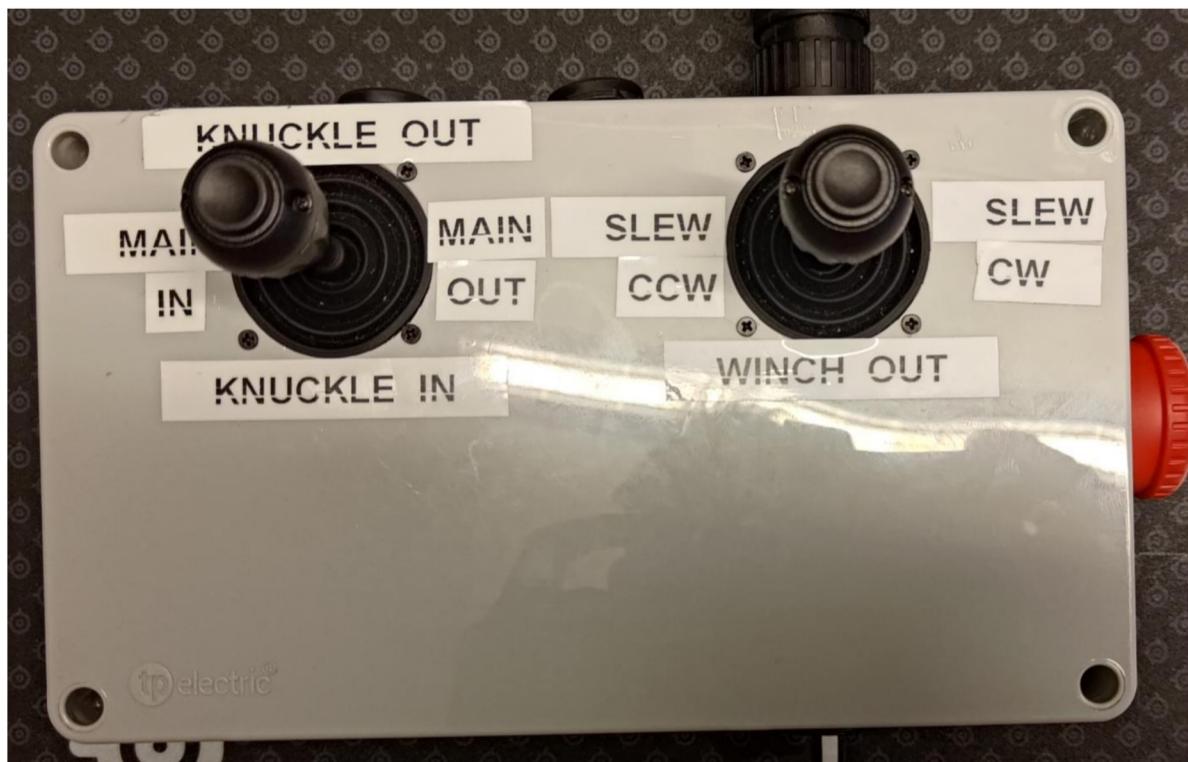
Part III: Demo

1. I/O configuration
2. I/O mapping
3. Measurement (YT Scope)

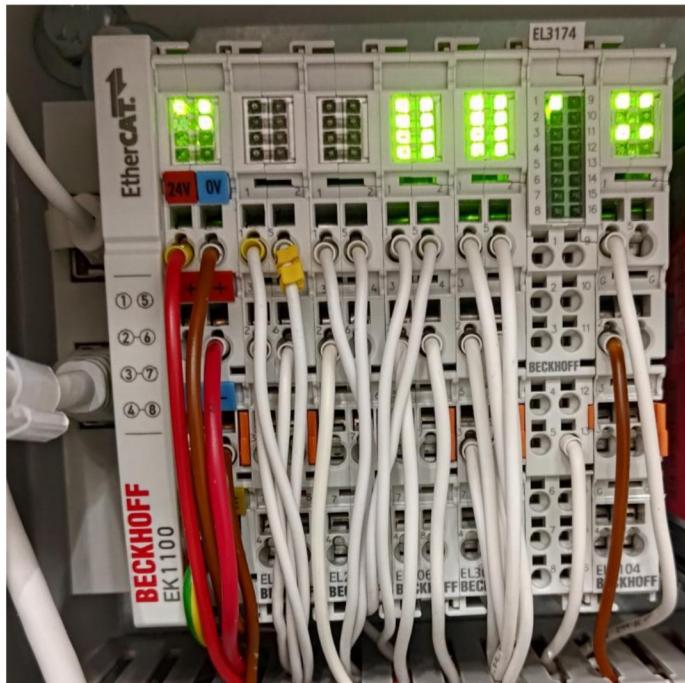
Demo



Demo



I/O



Model	Description
EL1008	8-channel digital input
EL2008	8-channel digital output
EL3068	8-channel analog input, voltage, 0...10 V
EL3068	8-channel analog input, voltage, 0...10 V
EL3174	4-channel analog input, multi- function, ±10 V, ±20 mA
EL4104	4-channel analog output, voltage, 0...10 V
EL9011	Bus end cover

I/O

Function	I/O	Function	I/O	Function	I/O	Function	I/O	Function	I/O	Function	I/O
Auto	DI1:1	Green LED	DO1:1	JoyX	AI1:1	pS	AI2:1	Qr	AI3:1	ValveOut	AO1:1
Manual	DI1:2	Red LED	DO1:2	JoyY	AI1:2	pR	AI2:2				
Start	DI1:3	Enable Valve	DO1:3	Xc	AI1:3	pC	AI2:3				
Stop	DI1:4			Xspool	AI1:4	pp	AI2:4				
						pA	AI2:5				
						pr	AI2:6				

Summary

Summary

I. TwinCAT advance (self-study)

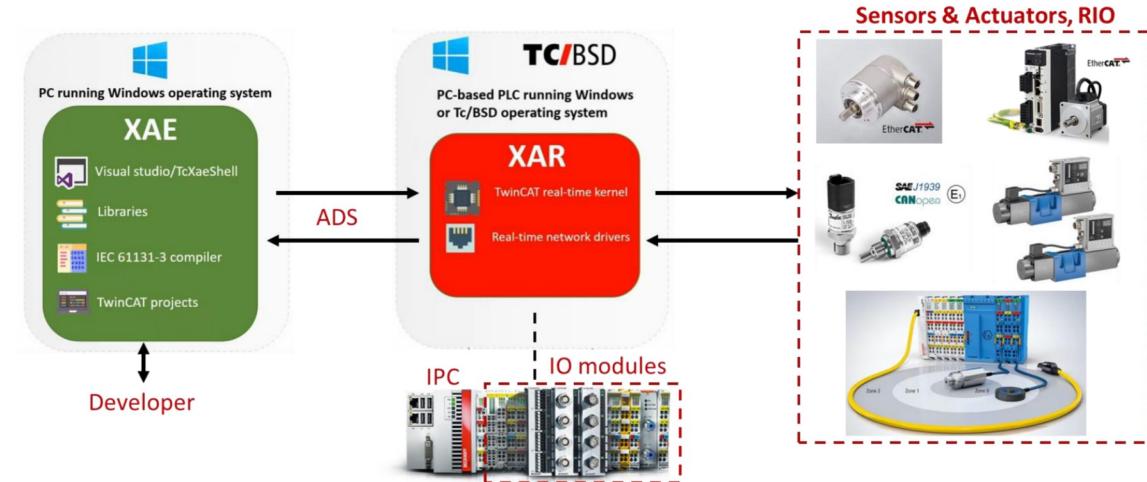
- Libraries
- Functions
- HMI
- Handling of different TwinCAT versions
- Automation interface
- Test driven development

II. Machine Interface

- Input & Outputs (I/O)
- Fieldbus
- EtherCAT
- ADS
- I/O mapping

III. Demo

- I/O configuration
- I/O mapping
- Measurement (YT Scope)



Next Lecture

Project Introduction

- Homework:**

- Work with the exercise.**
- Look at earlier exams (will be shared in Canvas) with respect to the grading method presented in [Lecture #2.1 slide 11](#).**

Januar 2024							Februar 2024							Mars 2024									
Uke	Ma	Ti	On	To	Fr	Lø	Sø	Uke	Ma	Ti	On	To	Fr	Lø	Sø	Uke	Ma	Ti	On	To	Fr	Lø	Sø
1	1	2	3	4	5	6	7	5				1	2	3	4	9				1	2	3	
2	8	9	10	11	12	13	14	6	5	6	7	8	9	10	11	10	4	5	6	7	8	9	10
3	15	16	17	18	19	20	21	7	12	13	14	15	16	17	18	11	11	12	13	14	15	16	17
4	22	23	24	25	26	27	28	8	19	20	21	22	23	24	25	12	18	19	20	21	22	23	24
5	29	30	31					9	26	27	28	29				13	25	26	27	28	29	30	31

1.1: 1. nyttårsdag

24.3: Palmesendag, 28.3: Skjærvorsdag, 29.3: Langfredag,
31.3: 1. påskedag

April 2024							Mai 2024							Juni 2024									
Uke	Ma	Ti	On	To	Fr	Lø	Sø	Uke	Ma	Ti	On	To	Fr	Lø	Sø	Uke	Ma	Ti	On	To	Fr	Lø	Sø
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15	8	9	10	11	12	13	14	19	6	7	8	9	10	11	12	23	3	4	5	6	7	8	9
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18	29	30						22	27	28	29	30	31			26	24	25	26	27	28	29	30

1.4: 2. påskedag

1.5: Offentlig høytidssdag, 9.5: Kristi Himmelfartsdag, 17.5:
Grunnlovsdag, 19.5: 1. pinsedag, 20.5: 2. pinsedag

Self-study Part #1 Part #2 Part #3 Exam

Lab exercise

#2.4 - Machine Interface

Lab exercises

 #2.0 - TwinCAT setup

 #2.1 - Basic PLC programming

 MAS418-LabExercise#2.1-SolutionProposal_Task1.tnzip

 MAS418-LabExercise#2.1-SolutionProposal_Task2.tnzip

 #2.2 - Procedural-oriented PLC programming

 MAS418-LabExercise#2.2-SolutionProposal.tnzip

 #2.3 - Object-oriented PLC programming

 MAS418-LabExercise#2.3-SolutionProposal.tnzip

 #2.4 - Machine Interface
