
UiA
University of Agder
Norway

Lecture #2.4

Advance topics and Machine interface

MAS418

Programming for Intelligent Robotics and Industrial systems

Part II: PLC Software Development

Spring 2024

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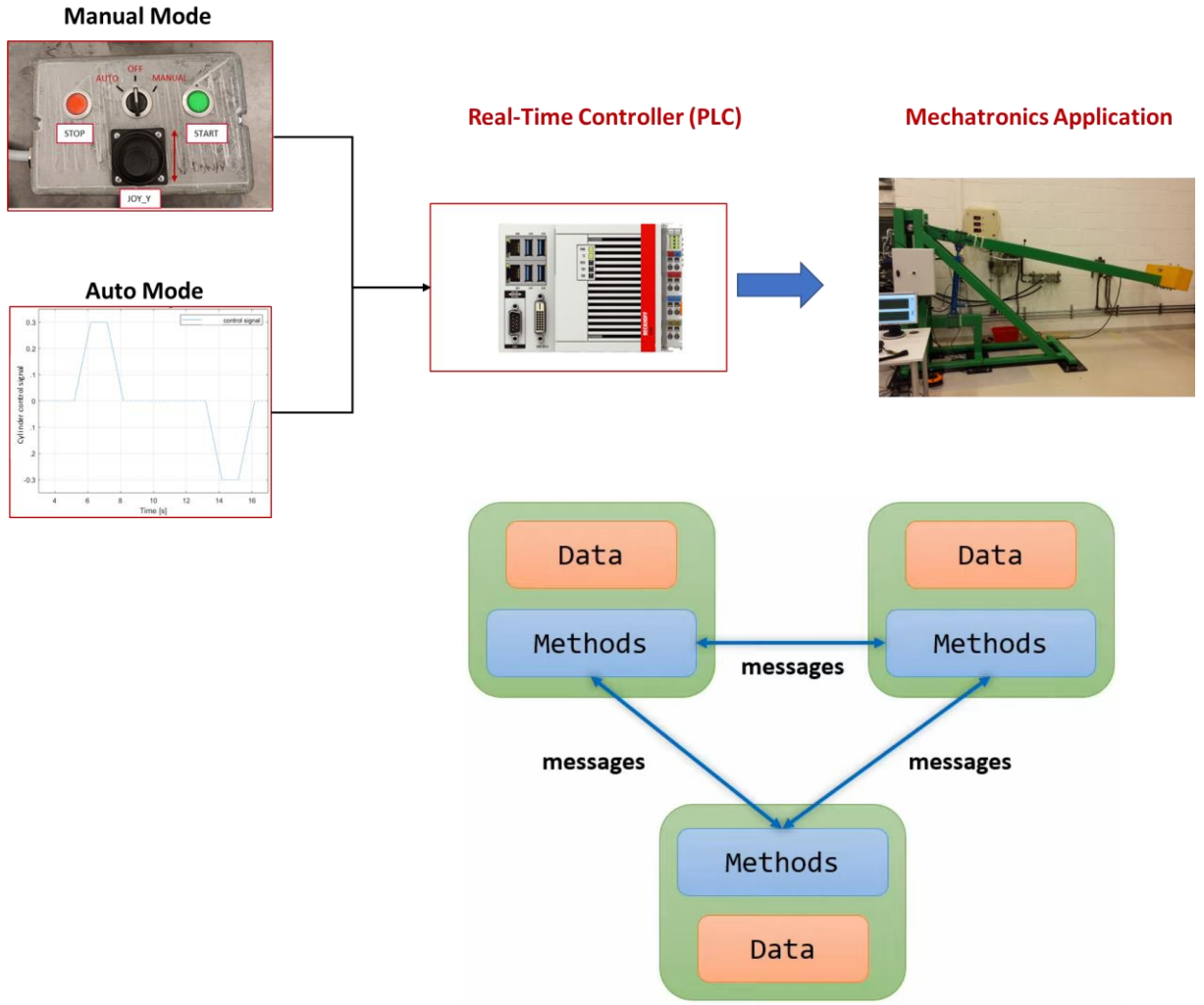
UiA

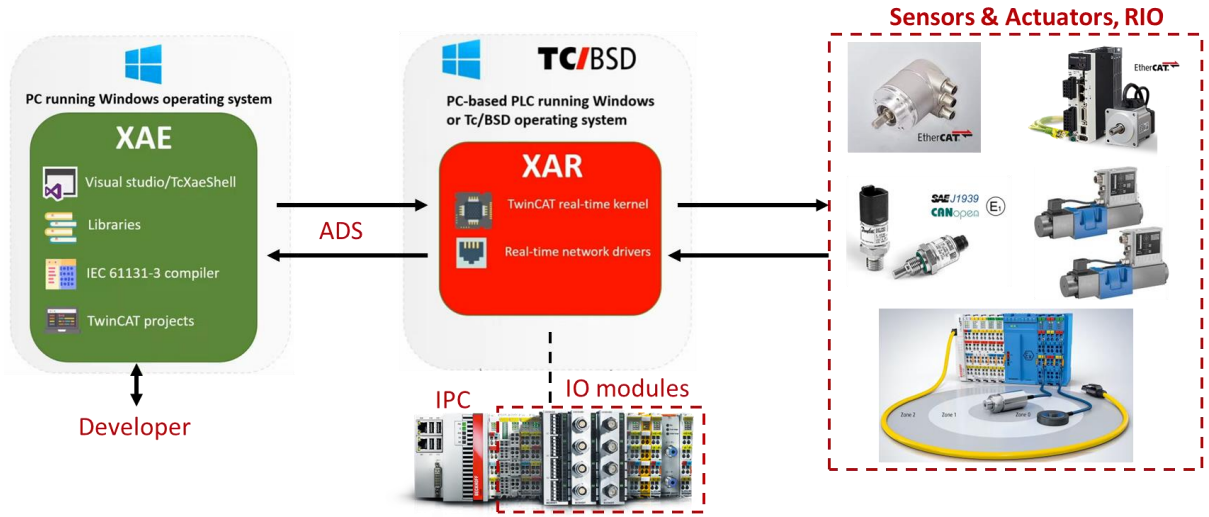
Previous Lecture

- **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

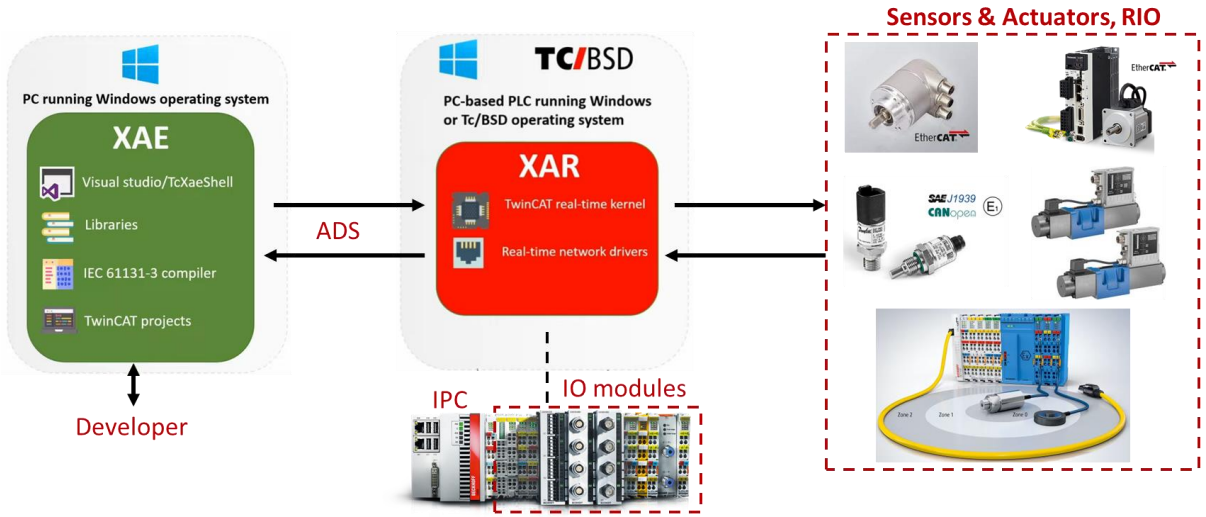
Introduction

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

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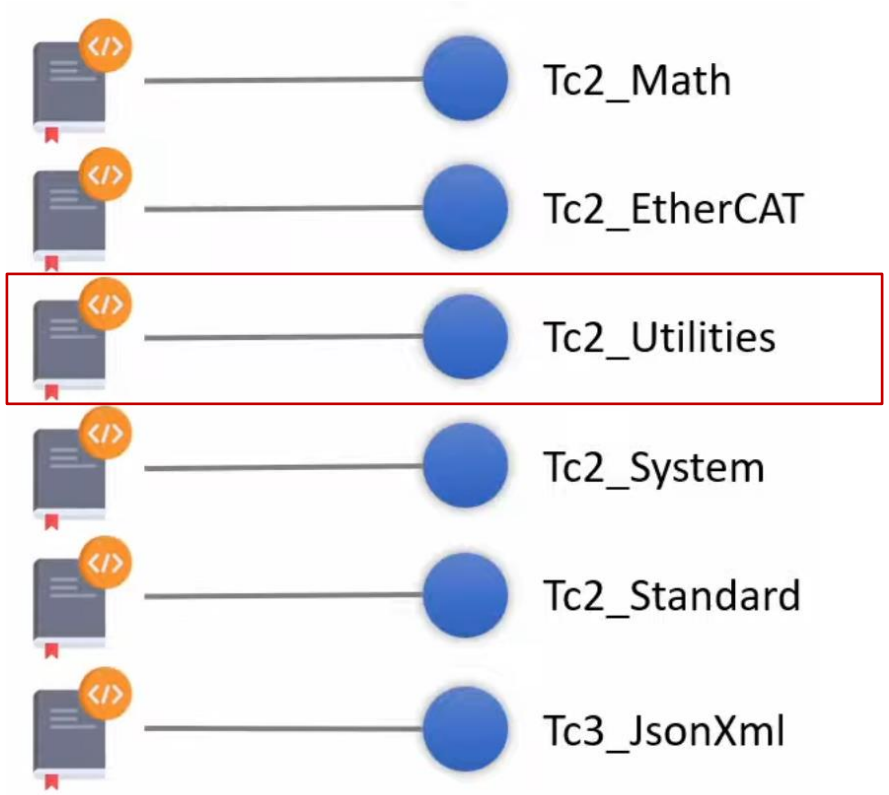
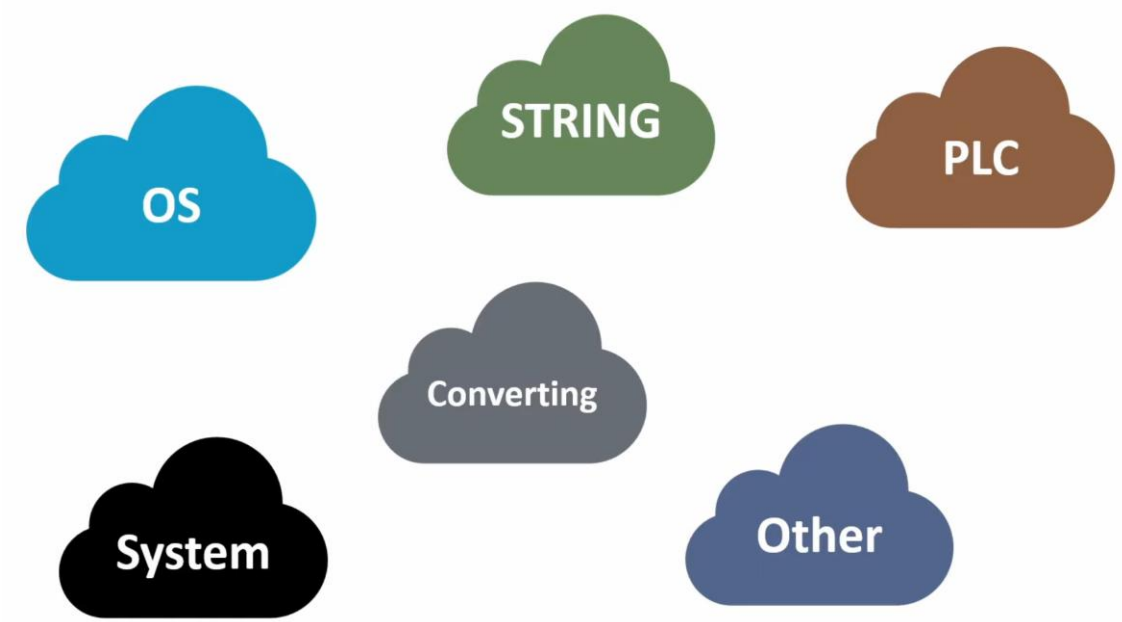
Libraries





https://youtu.be/1s5O8srtDTM

Libraries

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.

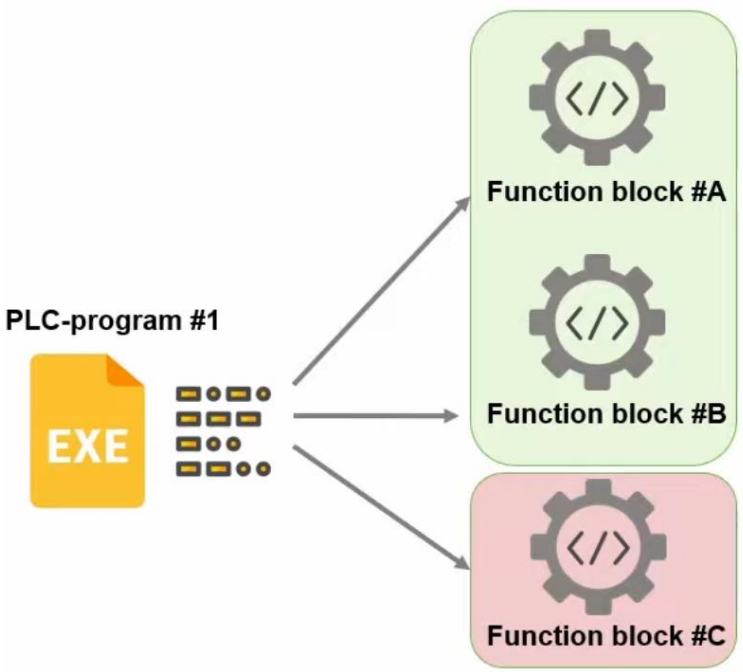
NT_StartProcess: can be used to start a windows application from the PLC.

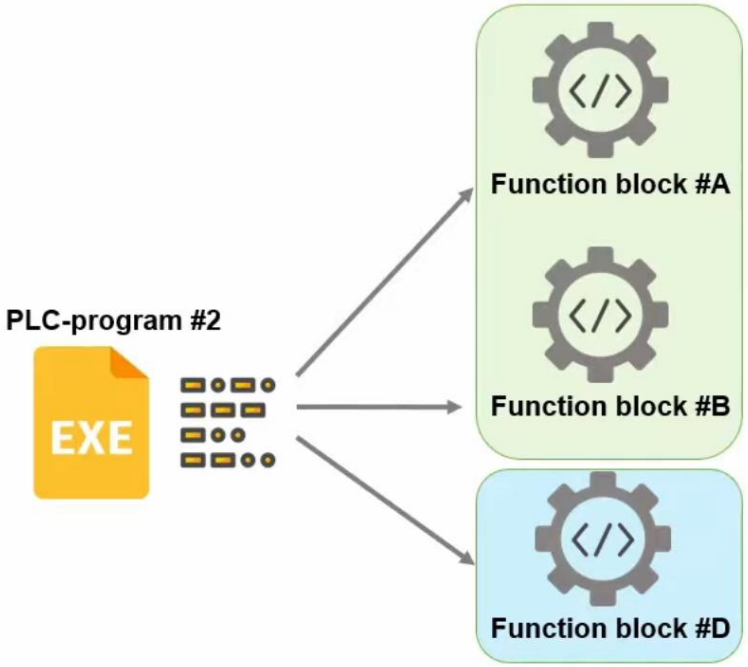
PLC programming using TwinCAT 3 - TwinCAT utilities

https://youtu.be/1s5O8srtDTM

Libraries

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



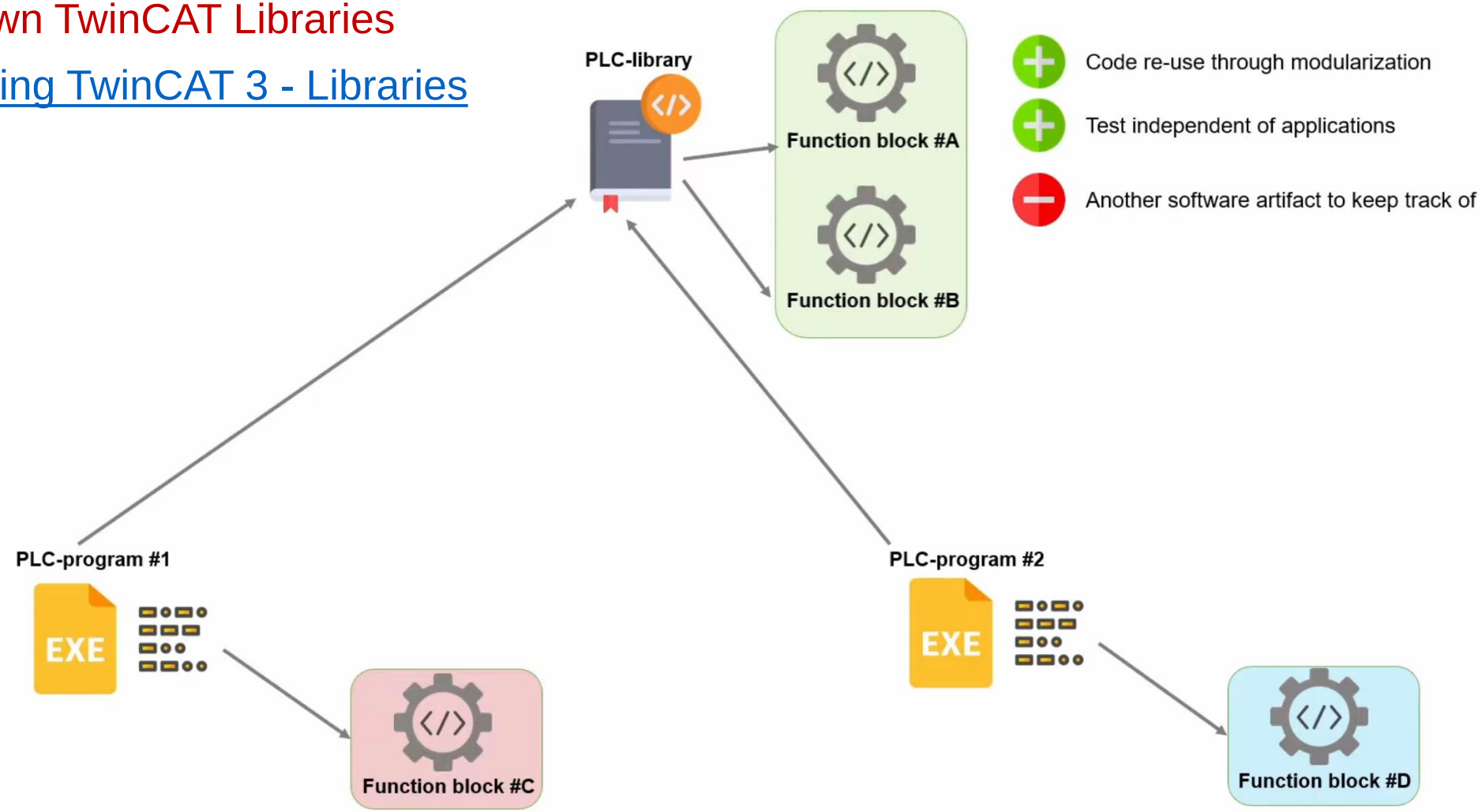


https://youtu.be/rWWPWuUYFbg

Libraries

How to create your own TwinCAT Libraries

PLC programming using TwinCAT 3 - Libraries



https://youtu.be/rWWPWuUYFbg

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

TF2xxx – TC3 Human Machine Interface

HMI server, HMI Clients Packs, HMI Target Packs, HMI OPC UA, HMI Extension SDK, HMI Scope

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

TF4xxx – TC3 Controller

Controller Toolbox, Temperature Controller, Speech

TF5xxx – TC3 Motion

PTP Axis control, Camming, Flying Saw, FIFO Axes, Motion Control, Interpolating, Kinematic Transformation, Robotics mxAutomation, CNC…, etc.

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.

TF7xxx – Vision

GigE Vision Connector, Vision Base, Vision Matching 2D, Vision Code Reading, Vision Metrology 2D

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

https://youtu.be/FOC0rUeECDs

HMI

Download:

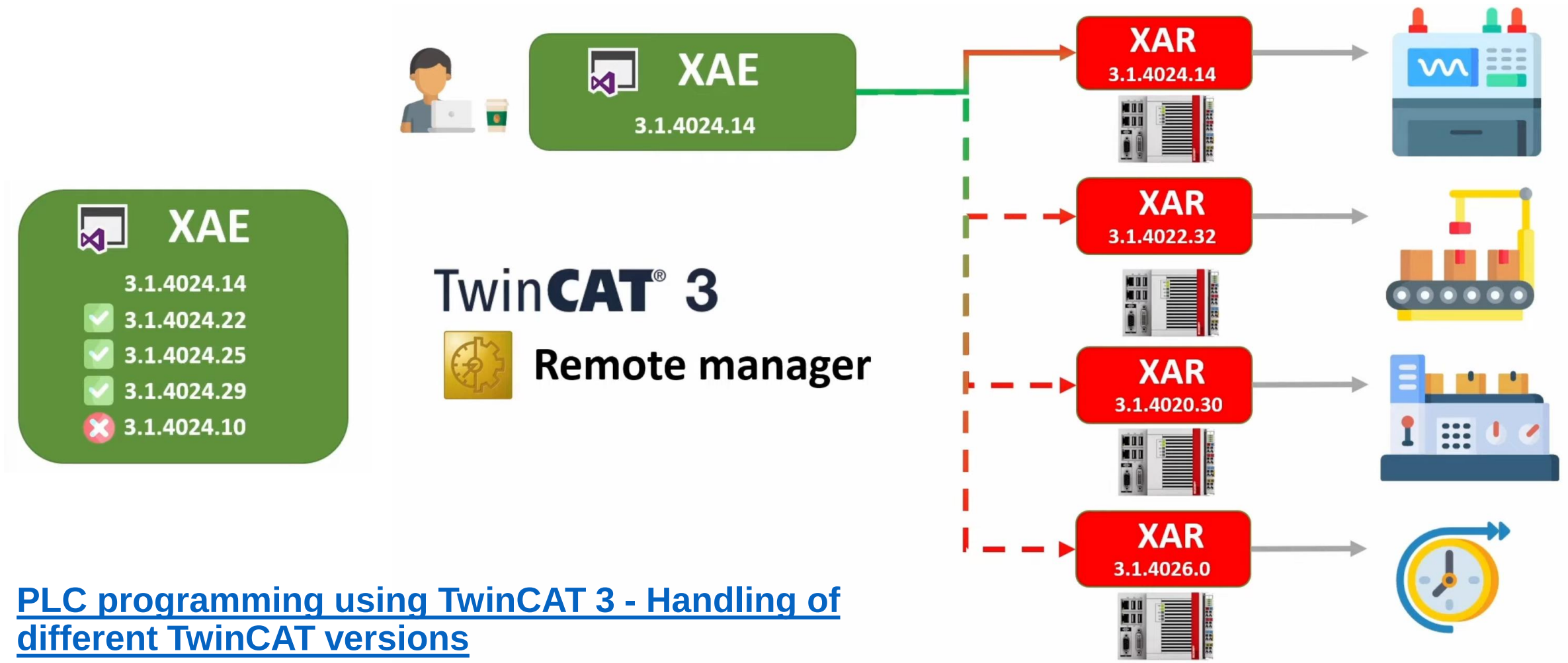
https://www.beckhoff.com/en-en/products/automation/twincat-3-hmi/

YouTube demo:

TwinCAT 3 PLC HMI 1.8 project in 5 minutes

https://youtu.be/wsYMoKRlh74

Handling of different TwinCAT versions



[PLC programming using TwinCAT 3 - Handling of different TwinCAT versions]

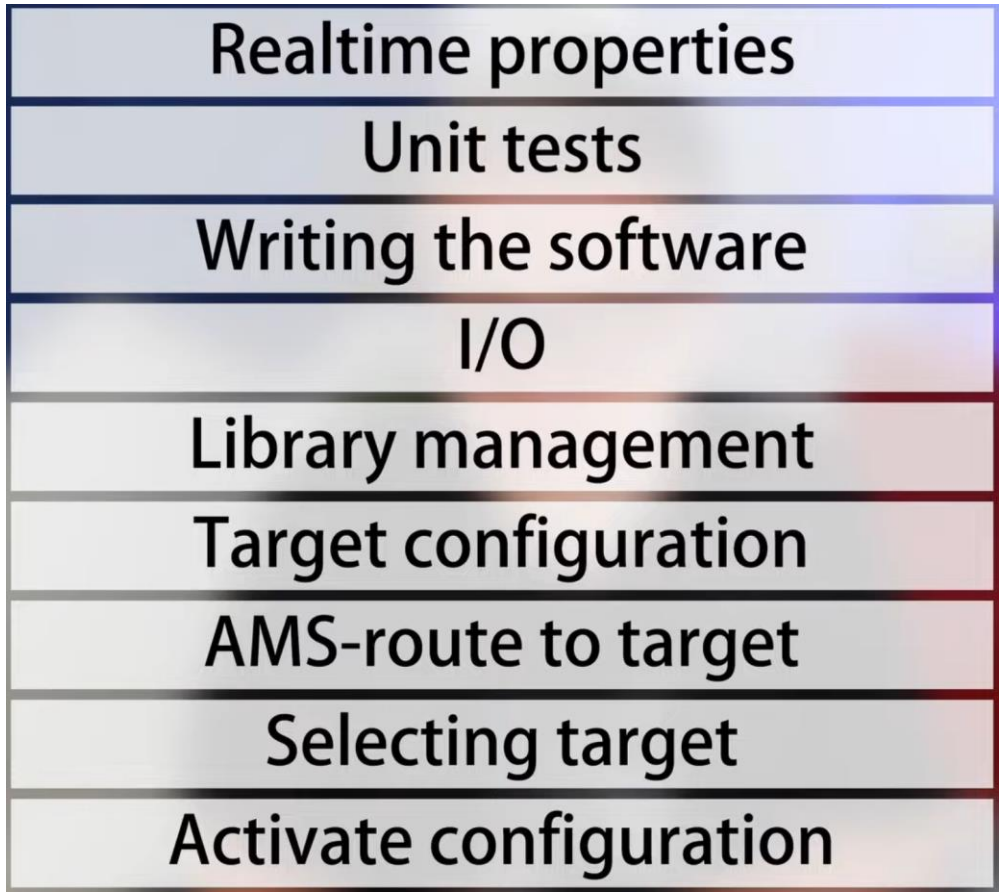
https://youtu.be/RxWEi21mDjM

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 POUs and business logic (writing the software)
- Defining the inputs and outputs (I/O) and linking them to the instances of the POUs
- 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



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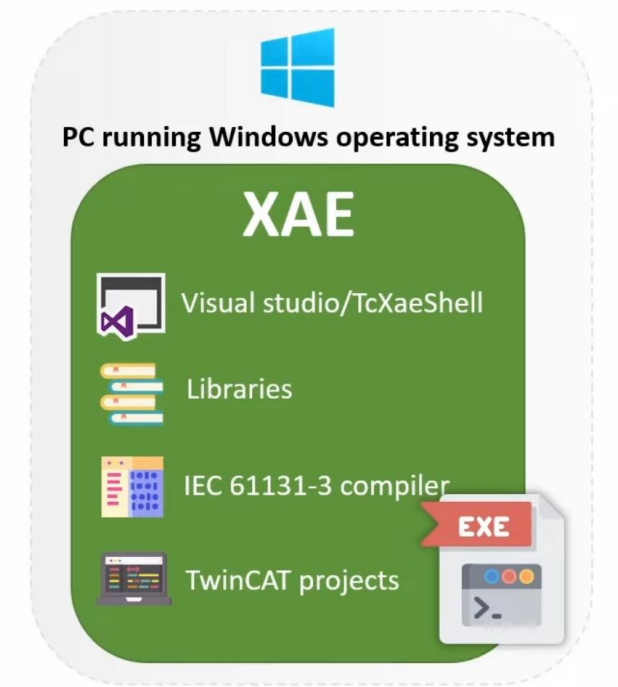
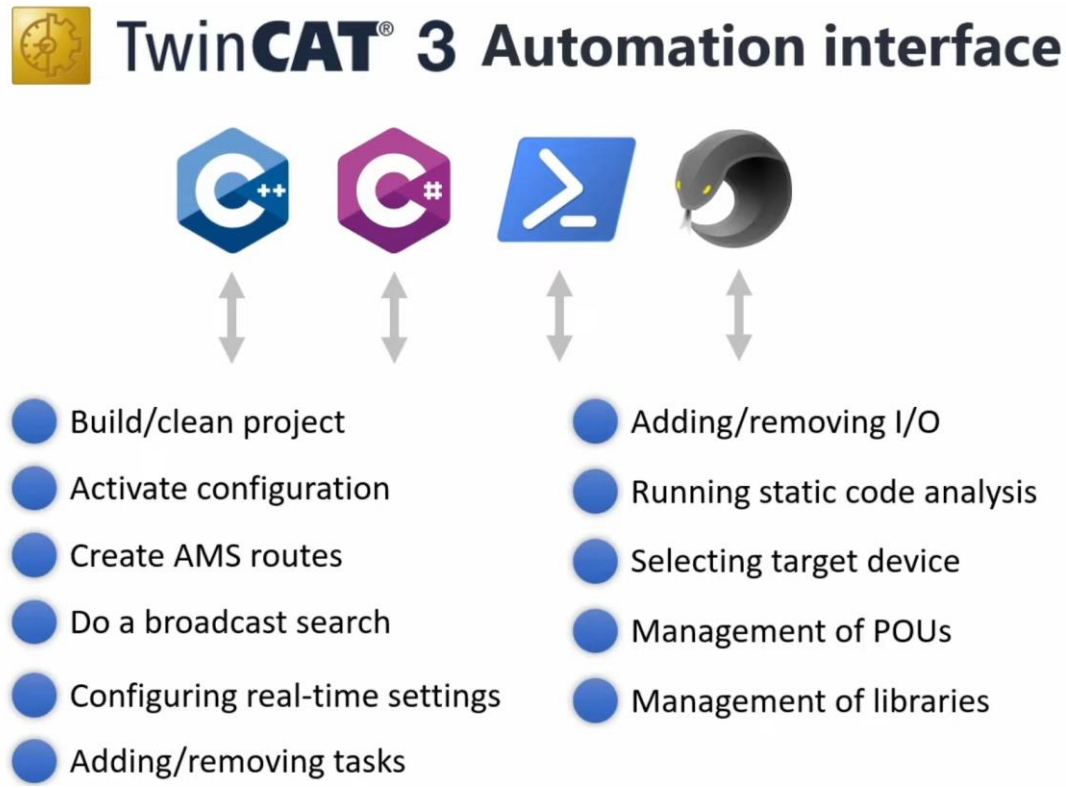
Automation interface

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





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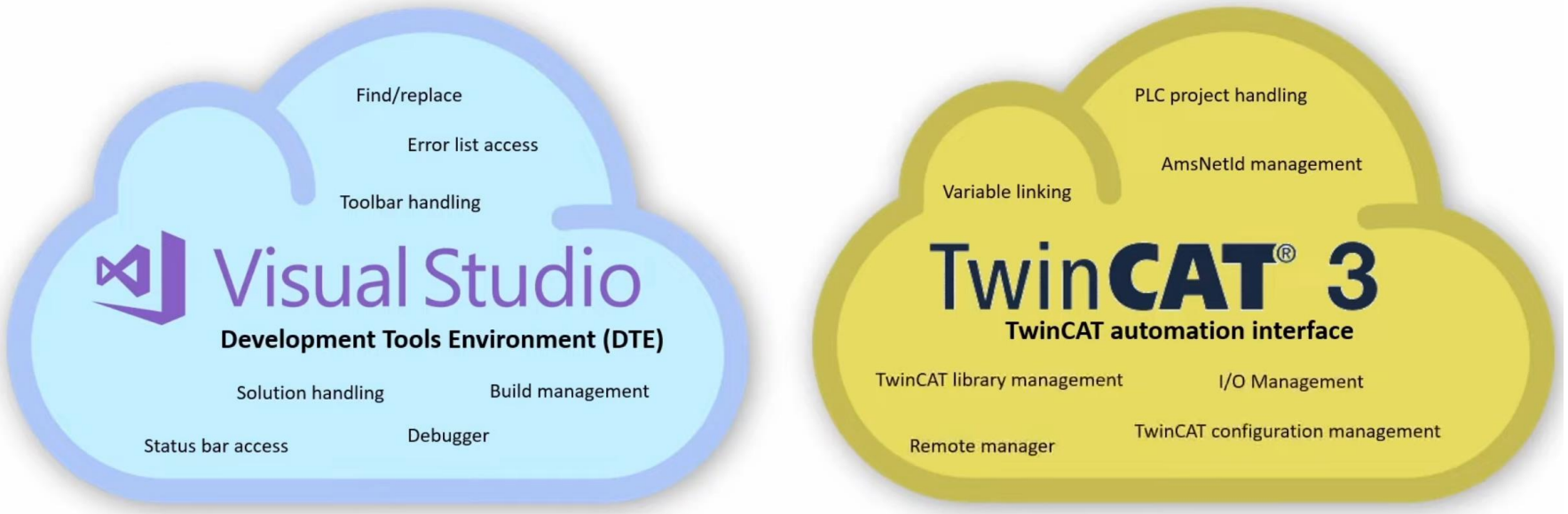
Automation interface

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

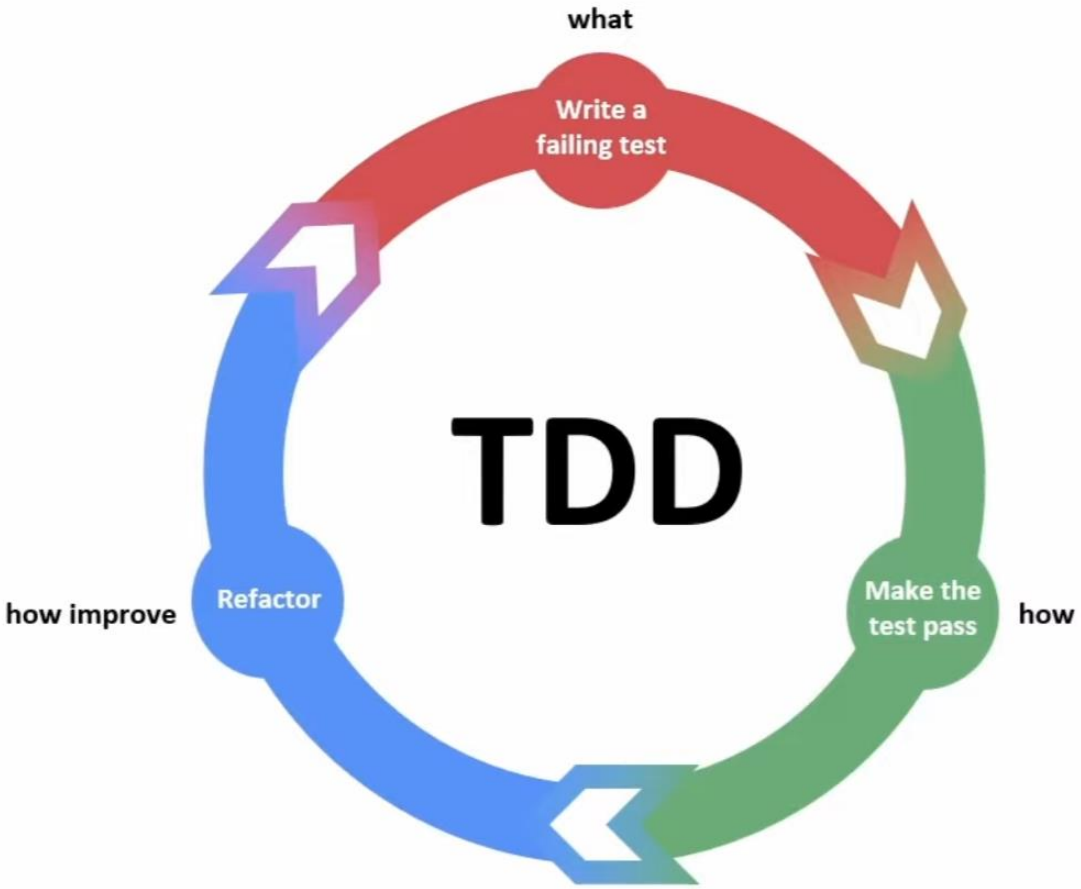
https://youtu.be/7Z6K7uf6qIY

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



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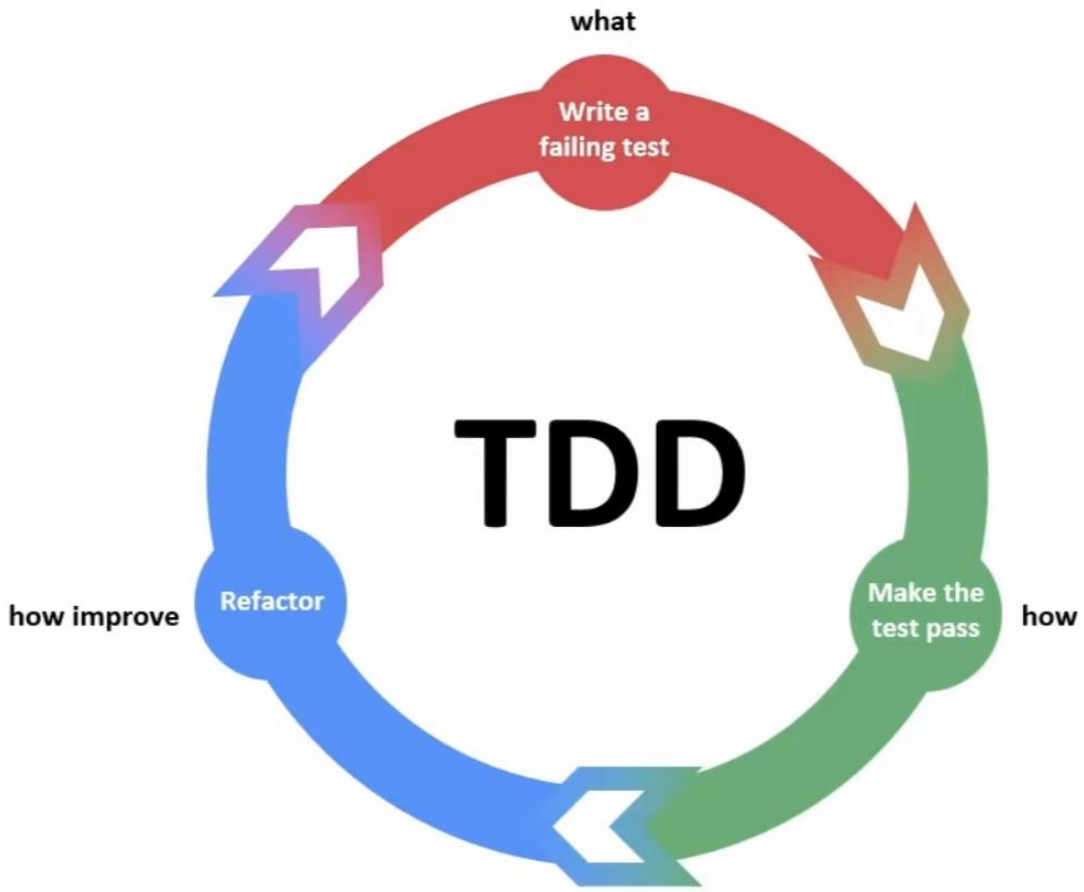
Test driven development

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



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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

https://youtu.be/FnXY6MA3axw

Part II: Machine Interface

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

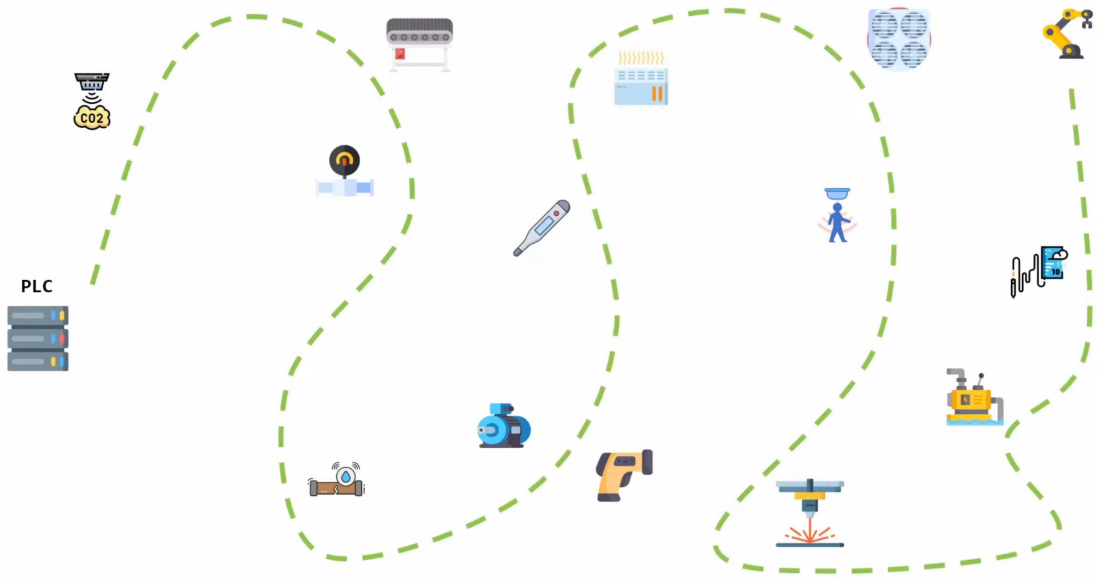
Input & Outputs (I/O)

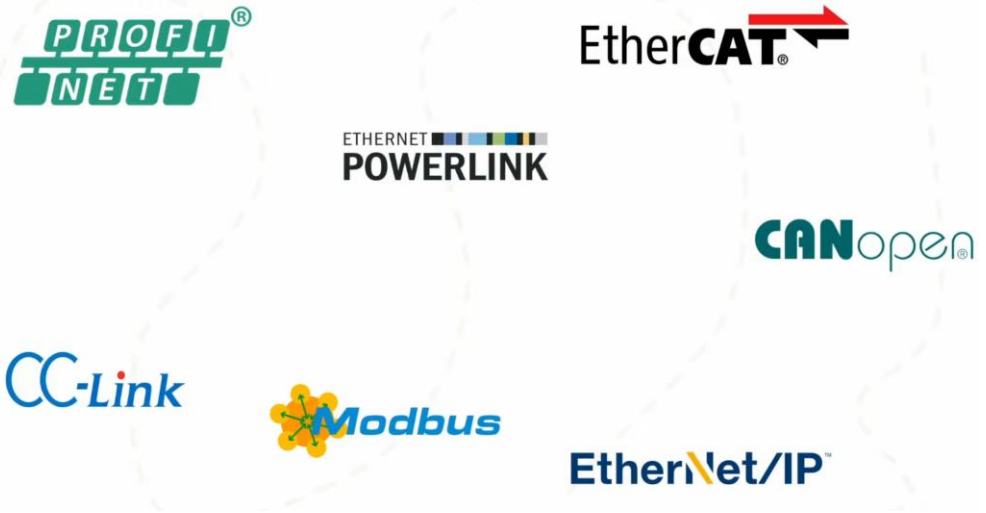
- **What is I/O?**
  - Sensors
  - Actuators
- Fieldbus

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

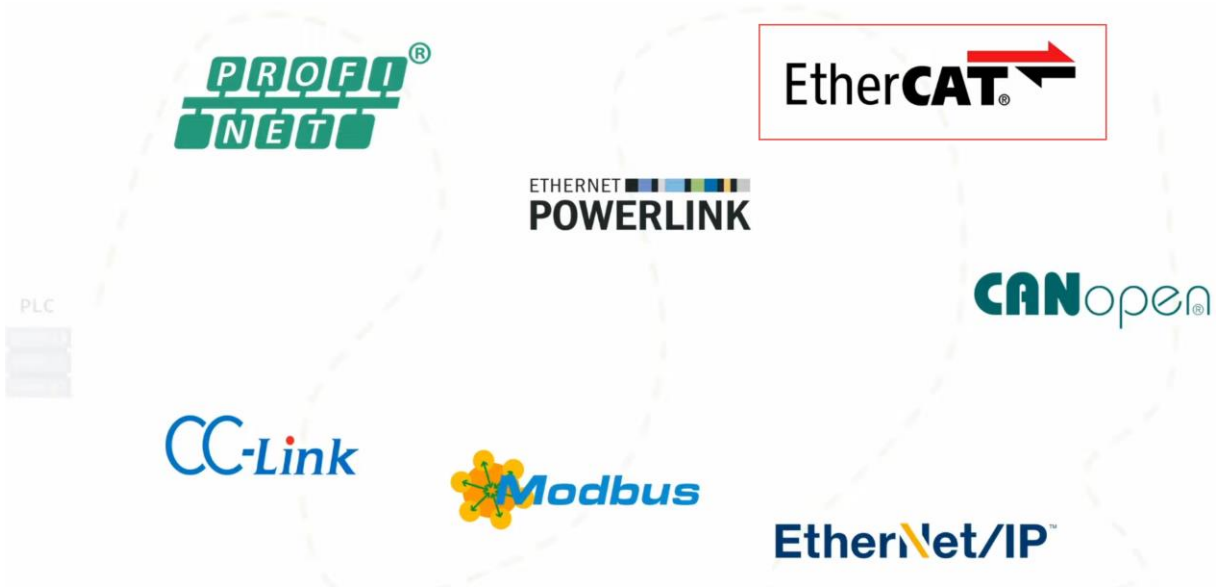




https://youtu.be/zQwiBeDbDcM

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



https://youtu.be/zQwiBeDbDcM

EtherCAT

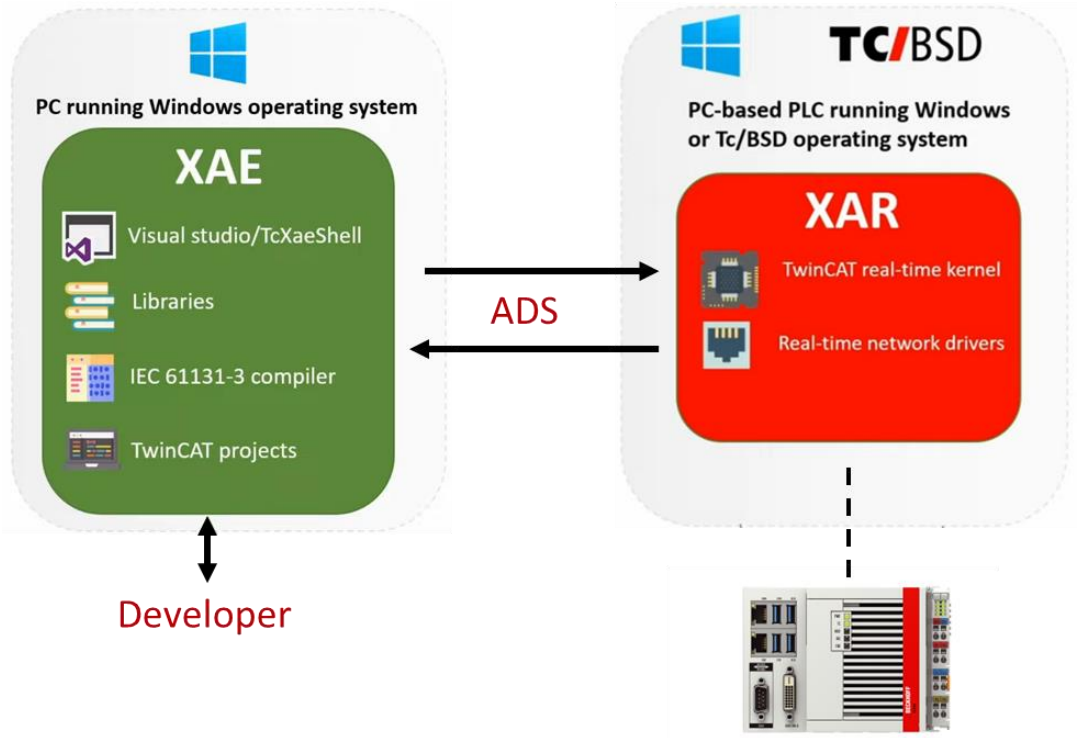
From 4.37

https://youtu.be/zQwiBeDbDcM

ADS

Automation Device Specification (ADS)

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



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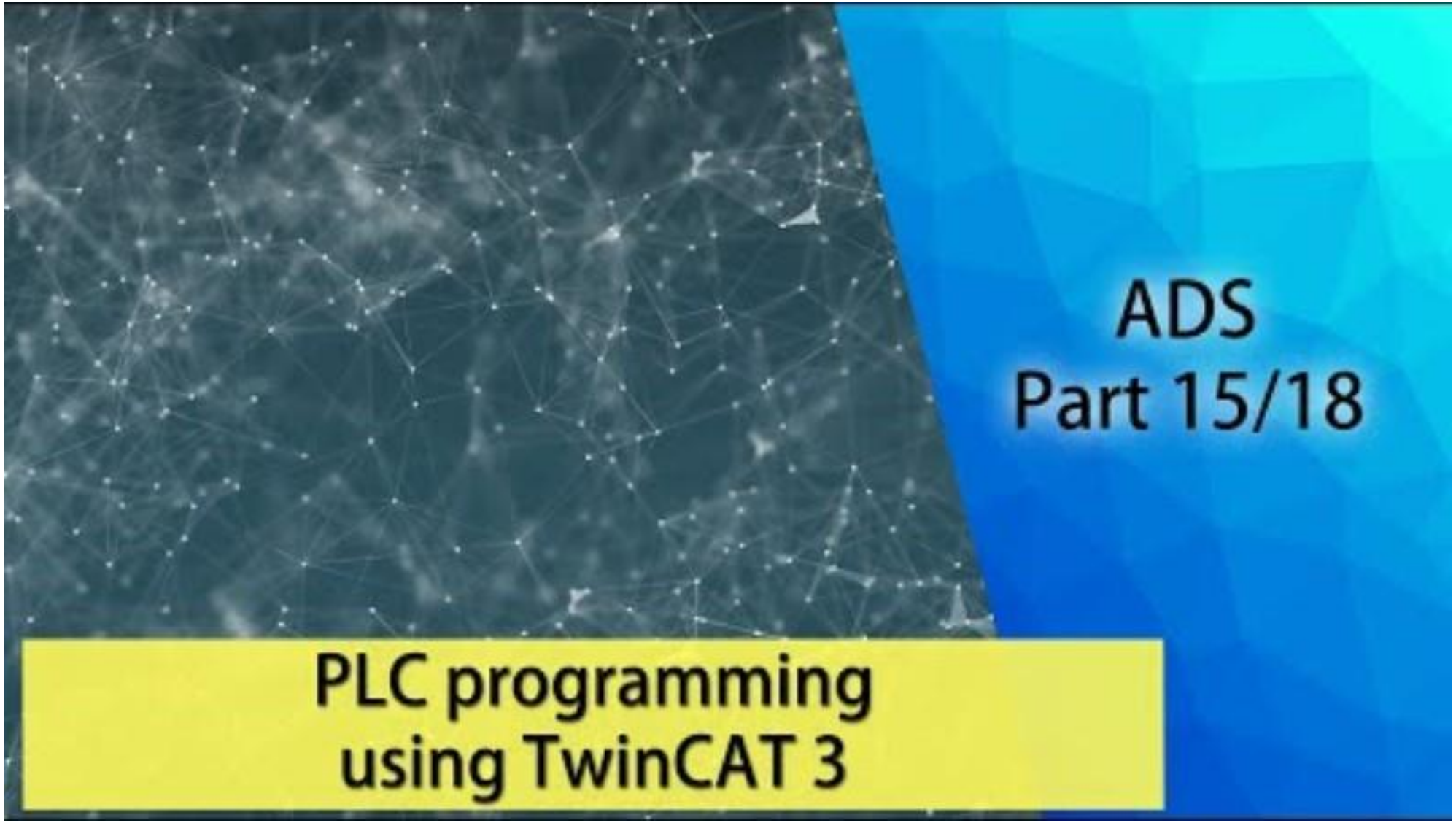
ADS



From 1.36

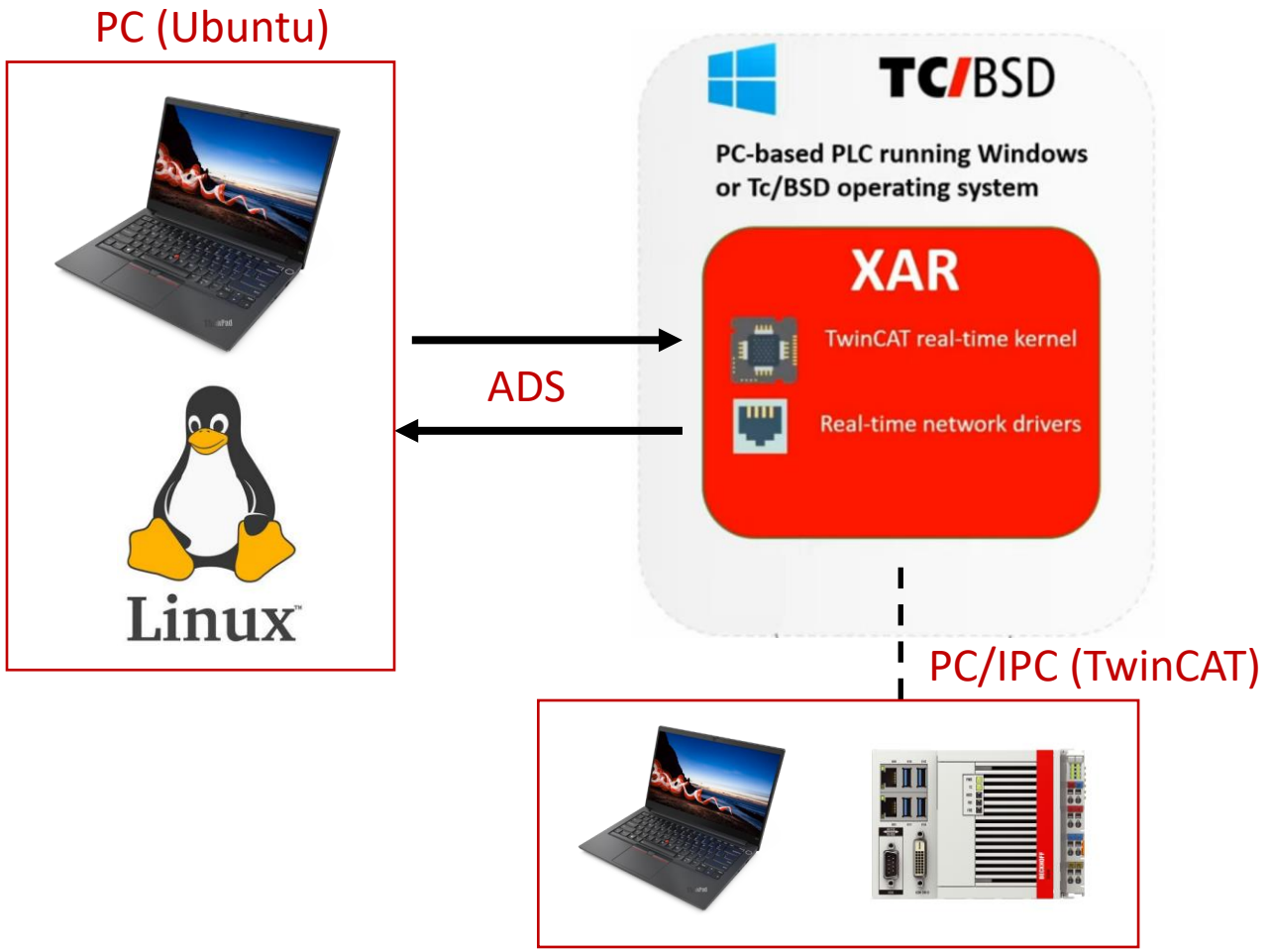
https://youtu.be/JZChSdU2LMc

ADS

Self-study:

ADS practice and interface with Linux

PLC programming using TwinCAT 3 - ADS



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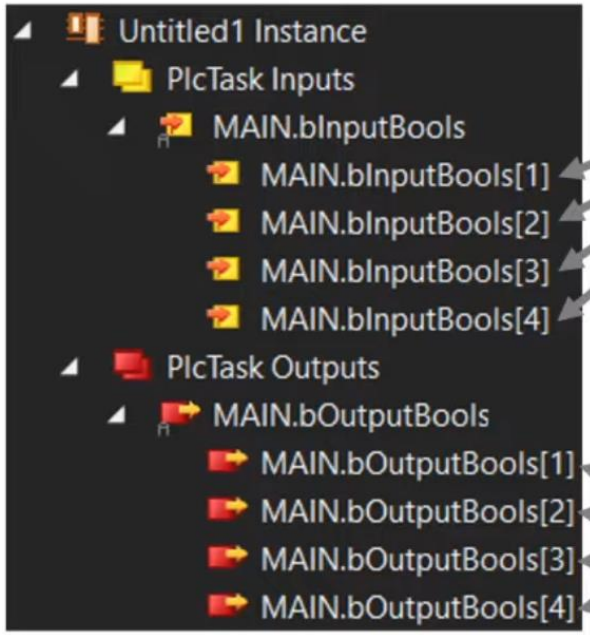
I/O mapping




```
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
```

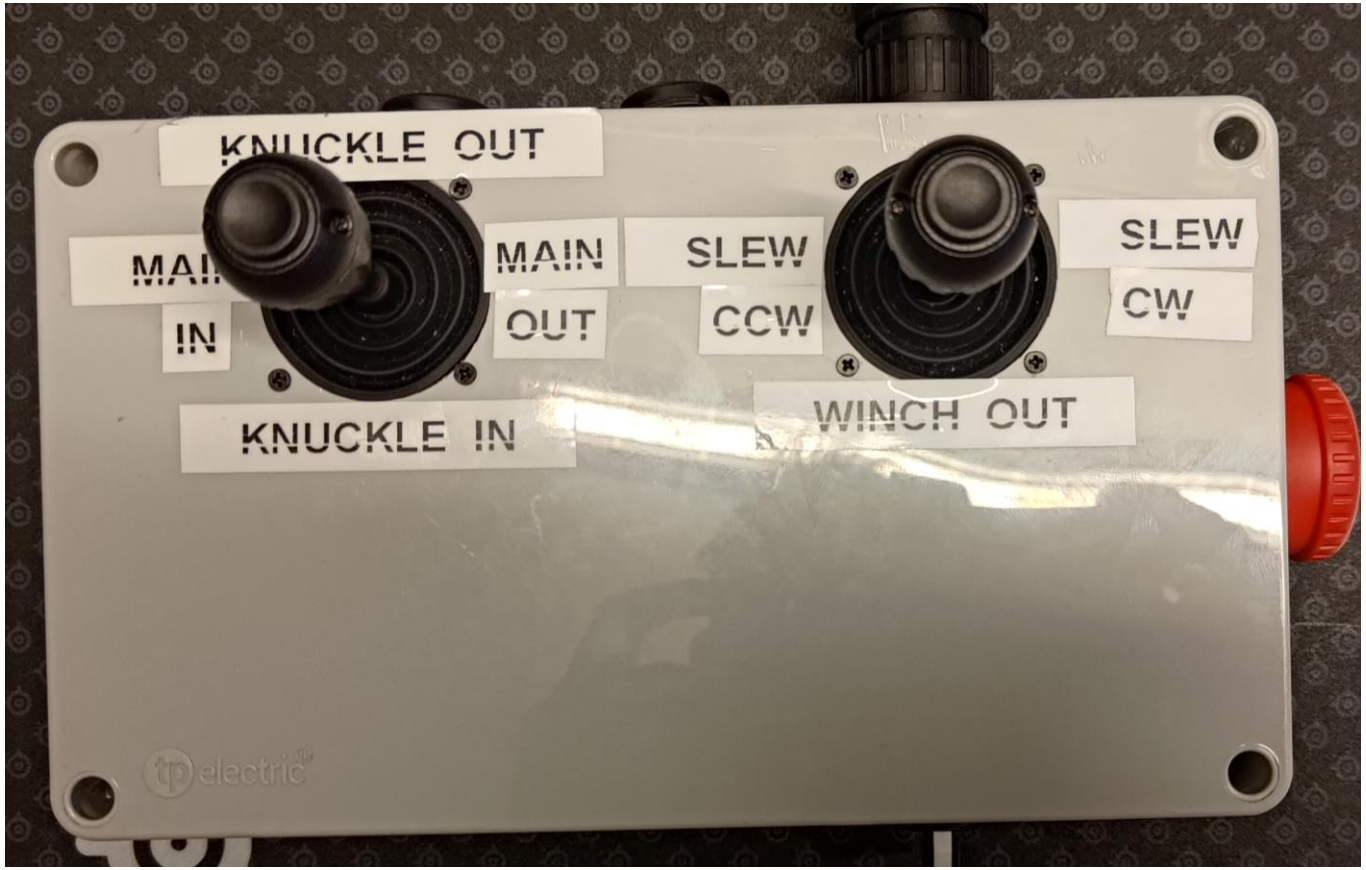
```
bOutputBools[2] := bOpenRelay;
```

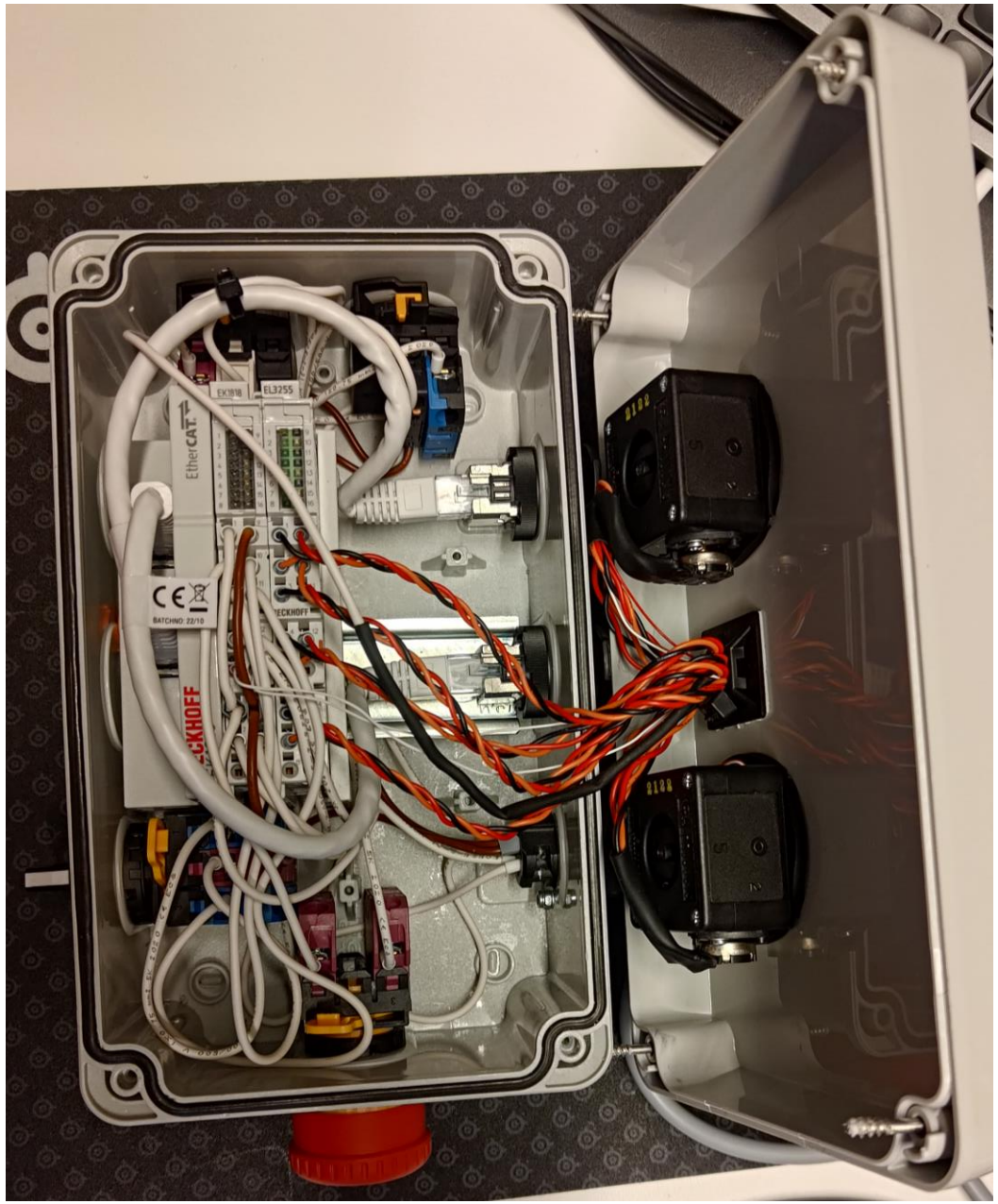
https://youtu.be/zQwiBeDbDcM

Part III: Demo

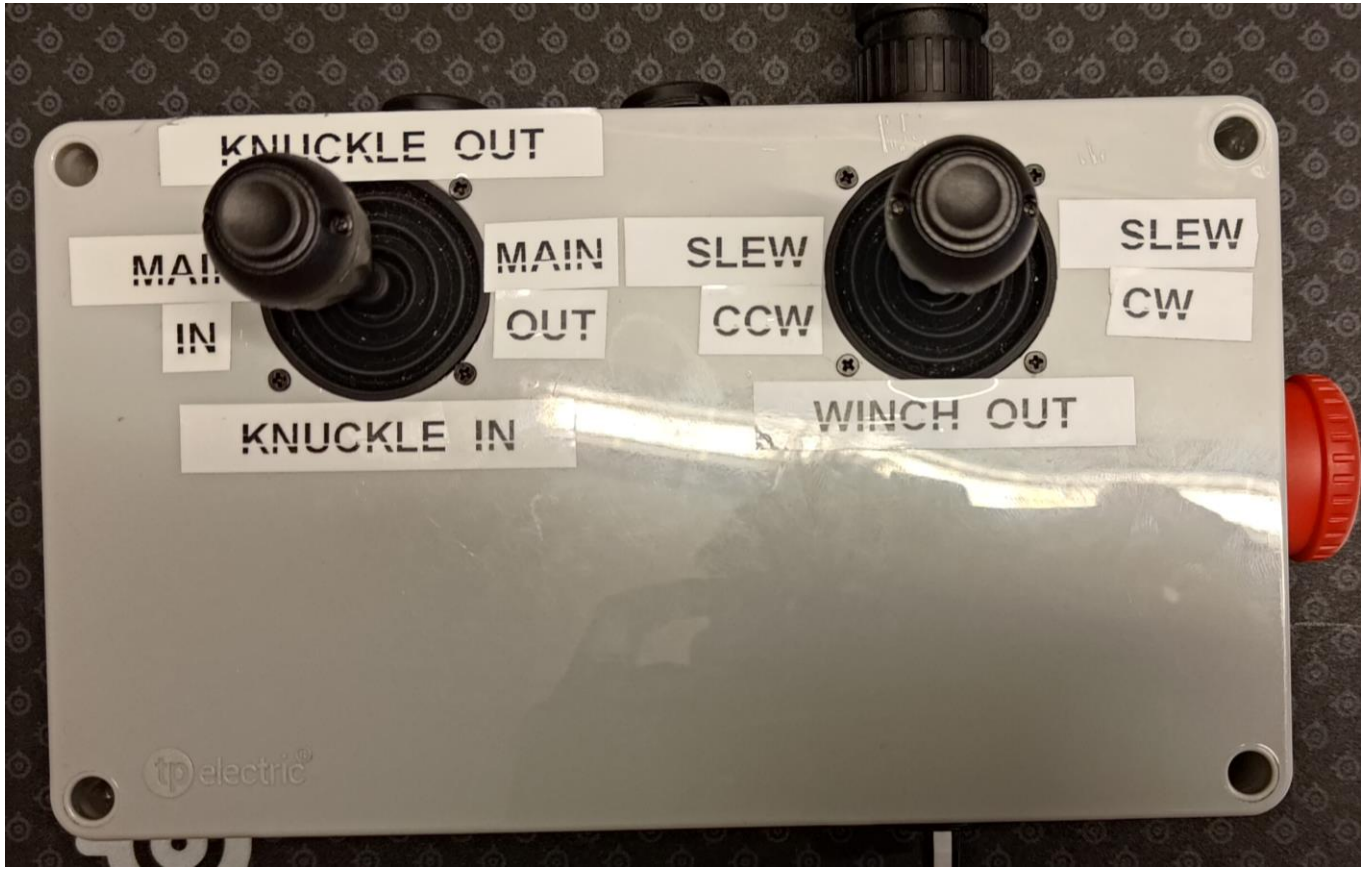
1. I/O configuration
2. I/O mapping
3. Measurement (YT Scope)

Demo


KNUCKLE OUT
MAIN
IN
MAIN
OUT
SLEW
CCW
SLEW
CW
KNUCKLE IN
WINCH OUT
tp electric


EtherCAT
BECKHOFF

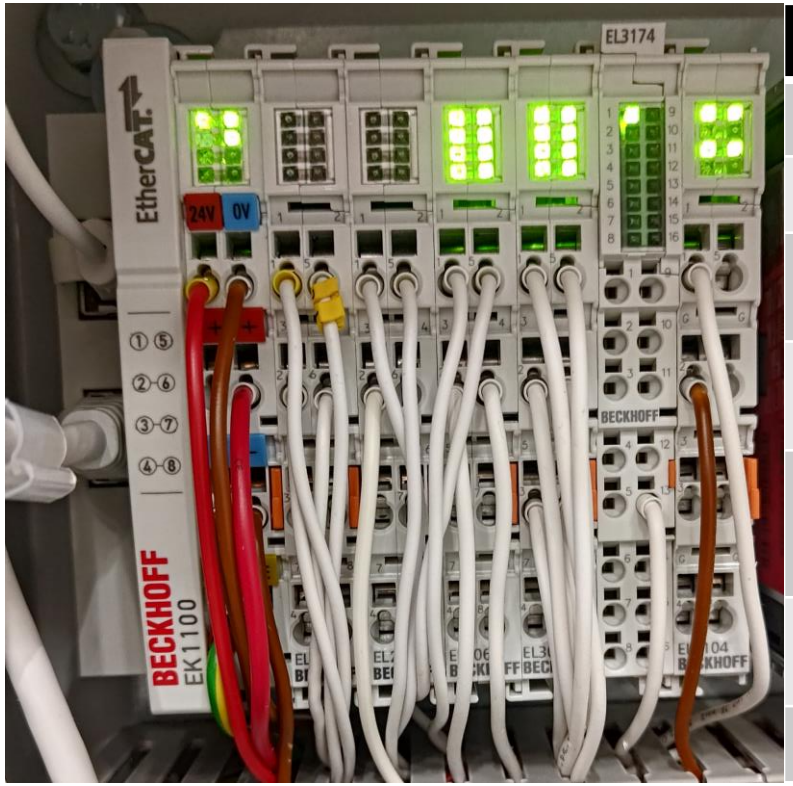
Demo


KNUCKLE OUT
MAIN
IN
MAIN
OUT
SLEW
CCW
SLEW
CW
KNUCKLE IN
WINCH OUT
tp electric


OUT
NNi


OUT

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
Auto	**DI1:1**
Manual	**DI1:2**
Start	**DI1:3**
Stop	**DI1:4**

Function	I/O
Green LED	**DO1:1**
Red LED	**DO1:2**
Enable Valve	**DO1:3**

Function	I/O
JoyX	**AI1:1**
JoyY	**AI1:2**
Xc	**AI1:3**
Xspool	**AI1:4**

Function	I/O
pS	**AI2:1**
pR	**AI2:2**
pC	**AI2:3**
pp	**AI2:4**
pA	**AI2:5**
pr	**AI2:6**

Function	I/O
Qr	**AI3:1**

Function	I/O
ValveOut	**AO1:1**

Summary

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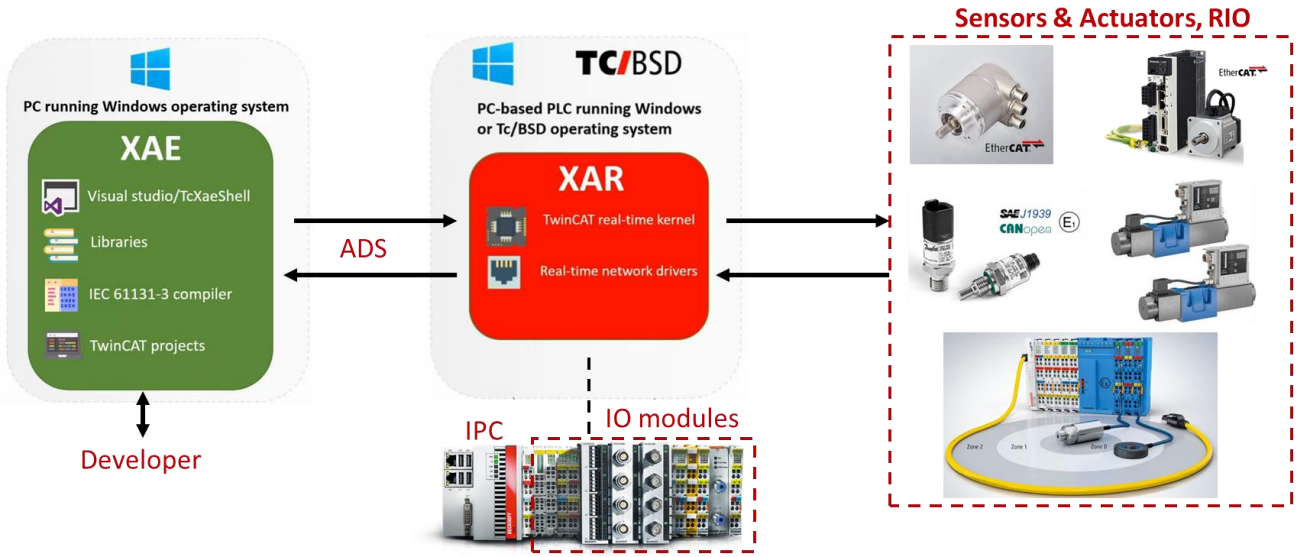
Summary

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.**

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

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Course Modules: MAS418-G 24V Programmering for intelligent robotikk og industrielle systemer (instructure.com)