Certification and Development with the Automated Realtime Tester

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Agenda

1 Automated RT-Tester Basics

2 What to expect from a Testcase?

3 Demo

Agenda Part 1: Automated RT-Tester Basics

1 The Automated RT-Tester

2 PROFINET Device Certification

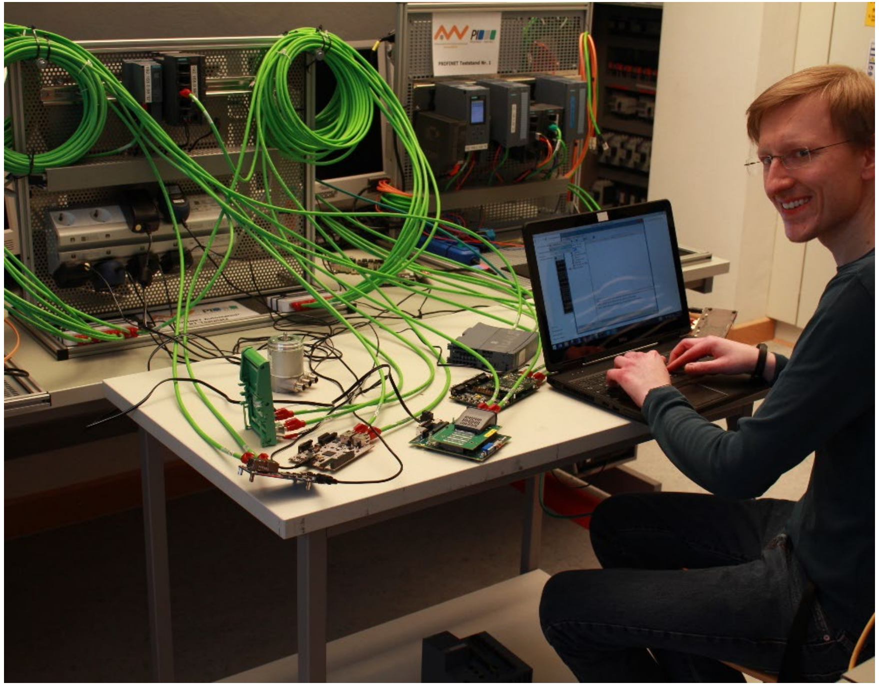
3 PROFINET Contoller Certification

4 PC System & Testsetups

5 Command Line Interface

The Automated RT-Tester

- Conformance testing and certification for PROFINET Devices and Controllers
- Fully automated testing in terms of
  - Test execution/processing
  - Result validation
- Designed for
  - Certification in PITLs
  - In-house (pre-certification) testing
  - Development and regression testing



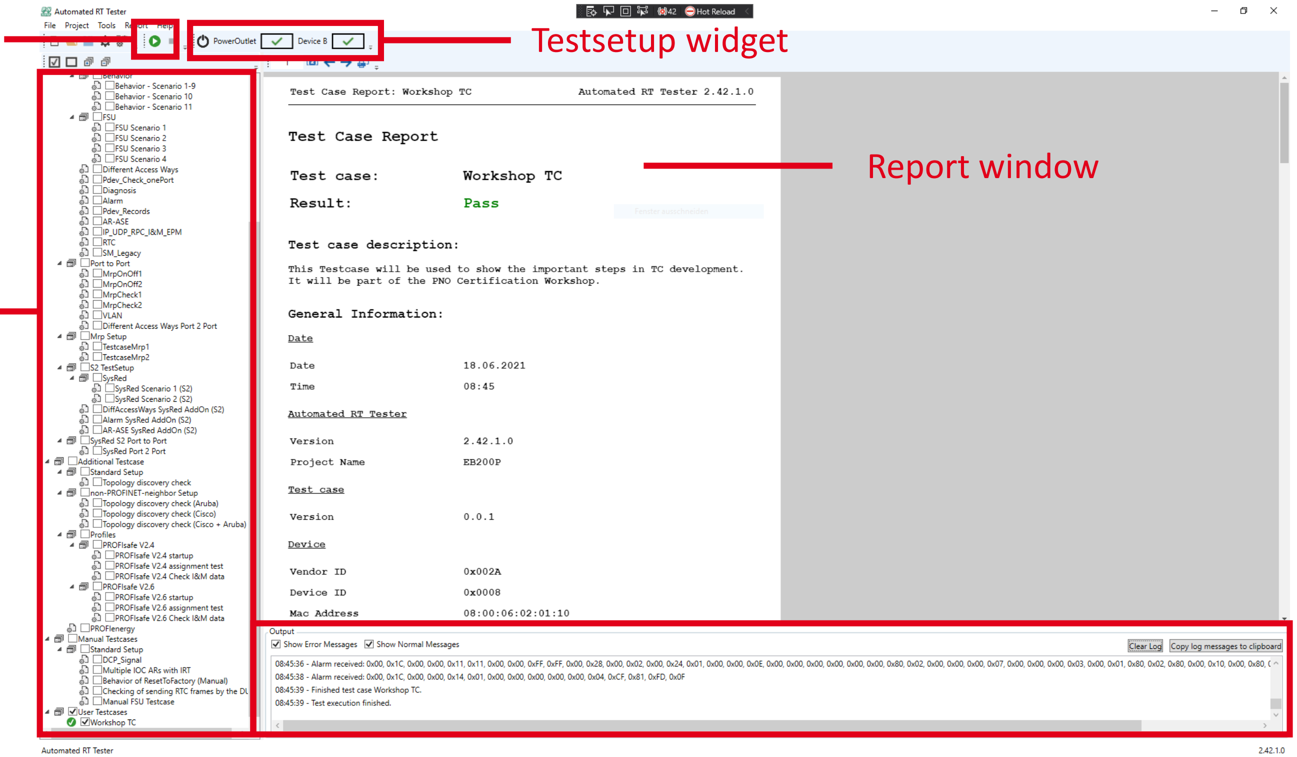
Testing with the Automated RT-Tester

The Automated RT-Tester

- Characteristics:
  - Easy handling
  - Max. test coverage and high coverage of PROFINET spec
  - Reliable and detailed results
  - Reproducibility
  - Full API access
- Developed at OTH Amberg-Weiden, WG AUT with support of aia – automations institute (PICC)
  - https://aut-oth.de/
  - https://aia-oth.de/

OTH Campus in Amberg

The Automated RT-Tester



```
Test Case Report: Workshop TC                    Automated RT Tester 2.42.1.0

Test Case Report

Test case:            Workshop TC
Result:               Pass

Test case description:
This Testcase will be used to show the important steps in TC development.
It will be part of the PNO Certification Workshop.

General Information:
Date

Date                  18.06.2021
Time                  08:45

Automated RT Tester

Version               2.42.1.0
Project Name          EB200P

Test case

Version               0.0.1

Device

Vendor ID             0x002A
Device ID             0x0008
Mac Address           08:00:06:02:01:10
```

```
08:45:36 - Alarm received: 0x00, 0x1C, 0x00, 0x00, 0x11, 0x11, 0x00, 0x00, 0xFF, 0xFF, 0x00, 0x28, 0x00, 0x02, 0x00, 0x24, 0x01, 0x00, 0x00, 0x0E, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x80, 0x02, 0x00, 0x00, 0x00, 0x07, 0x00, 0x00, 0x00, 0x03, 0x00, 0x01, 0x80, 0x02, 0x80, 0x00, 0x10, 0x00, 0x80, (
08:45:38 - Alarm received: 0x00, 0x1C, 0x00, 0x00, 0x14, 0x01, 0x00, 0x00, 0x00, 0x00, 0x00, 0x04, 0xCF, 0x81, 0xFD, 0x0F
08:45:39 - Finished test case Workshop TC.
08:45:39 - Test execution finished.
```

Starting the selected TCs

Testsetup widget

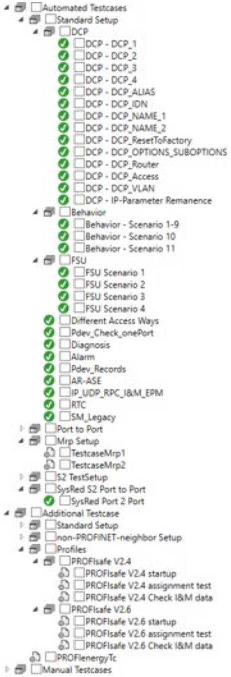
Report window

Testcase selection

Output window

The Automated RT-Tester

- PROFINET functionality is tested in different testcases, each with its own focus, e.g.
  - DCP
  - AR handling
  - Alarm statemachines
  - System Redundancy
  - PROFIsafe, PROFIenergy
  - …
- Specified sequence of operations
- Published and thoroughly reviewed
- Coverage: >80% of PROFINET base spec

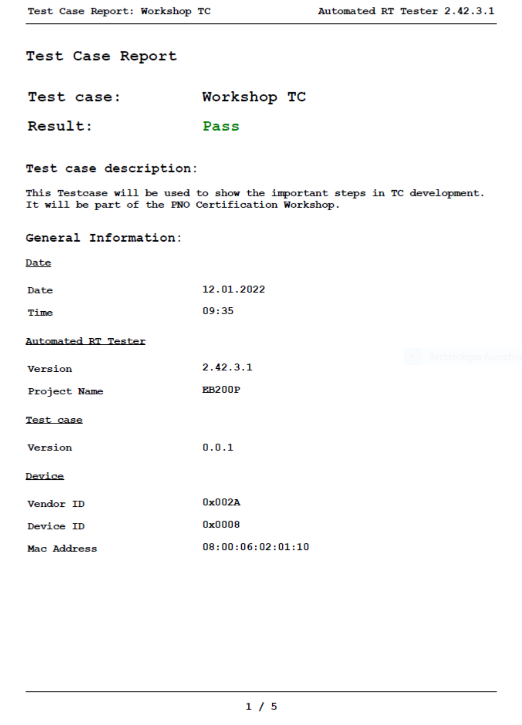


```
□ Automated Testcases
  □ Standard Setup
    □ DCP
      ✓ □ DCP - DCP_1
      ✓ □ DCP - DCP_2
      ✓ □ DCP - DCP_3
      ✓ □ DCP - DCP_4
      ✓ □ DCP - DCP_ALIAS
      ✓ □ DCP - DCP_IDN
      ✓ □ DCP - DCP_NAME_1
      ✓ □ DCP - DCP_NAME_2
      ✓ □ DCP - DCP_ResetToFactory
      ✓ □ DCP - DCP_OPTIONS_SUBOPTIONS
      ✓ □ DCP - DCP_Router
      ✓ □ DCP - DCP_Access
      ✓ □ DCP - DCP_VLAN
      ✓ □ DCP - IP-Parameter Remanence
    □ Behavior
      ✓ □ Behavior - Scenario 1-9
      ✓ □ Behavior - Scenario 10
      ✓ □ Behavior - Scenario 11
    □ FSU
      ✓ □ FSU Scenario 1
      ✓ □ FSU Scenario 2
      ✓ □ FSU Scenario 3
      ✓ □ FSU Scenario 4
    ✓ □ Different Access Ways
    ✓ □ Pdev_Check_onePort
    ✓ □ Diagnosis
    ✓ □ Alarm
    ✓ □ Pdev_Records
    ✓ □ AR-ASE
    ✓ □ IP_UDP_RPC_I&M_EPM
    ✓ □ RTC
    ✓ □ SM_Legacy
  □ Port to Port
  □ Mrp Setup
    □ TestcaseMrp1
    □ TestcaseMrp2
  □ S2 TestSetup
  □ SysRed S2 Port to Port
    ✓ □ SysRed Port 2 Port
□ Additional Testcase
  □ Standard Setup
  □ non-PROFINET-neighbor Setup
  □ Profiles
    □ PROFIsafe V2.4
      □ PROFIsafe V2.4 startup
      □ PROFIsafe V2.4 assignment test
      □ PROFIsafe V2.4 Check I&M data
    □ PROFIsafe V2.6
      □ PROFIsafe V2.6 startup
      □ PROFIsafe V2.6 assignment test
      □ PROFIsafe V2.6 Check I&M data
  □ PROFIenergyTc
□ Manual Testcases
```

Testcases for Device certification

The Automated RT-Tester

- Testcase reports
  - Each testcase produces a transparent report with a clear result
    - Pass
    - Fail
    - PassWithHint
    - Inconclusive
    - Skip
  - Detailed information and log regarding
    - DUT
    - Version of Automated RT-Tester and testcase
    - Testcase execution log
    - Hints and errors



Test Case Report: Workshop TC   Automated RT Tester 2.42.3.1

Test Case Report

Test case:	Workshop TC
Result:	Pass

Test case description:

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It will be part of the PNO Certification Workshop.

General Information:

Date

Date	12.01.2022
Time	09:35

Automated RT Tester

Version	2.42.3.1
Project Name	EB200P

Test case

Version	0.0.1

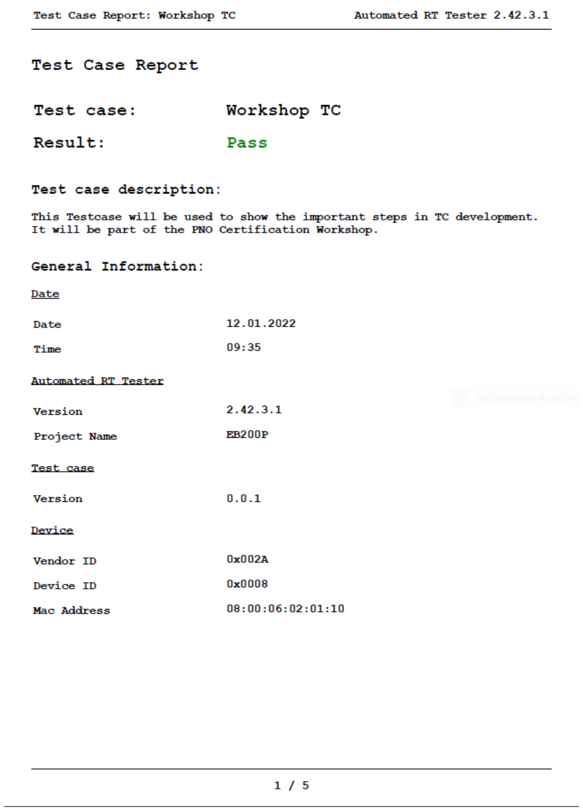
Device

Vendor ID	0x002A
Device ID	0x0008
Mac Address	08:00:06:02:01:10

1 / 5

Example report

The Automated RT-Tester



Test Case Report: Workshop TC — Automated RT Tester 2.42.3.1

Test Case Report

Test case:	**Workshop TC**
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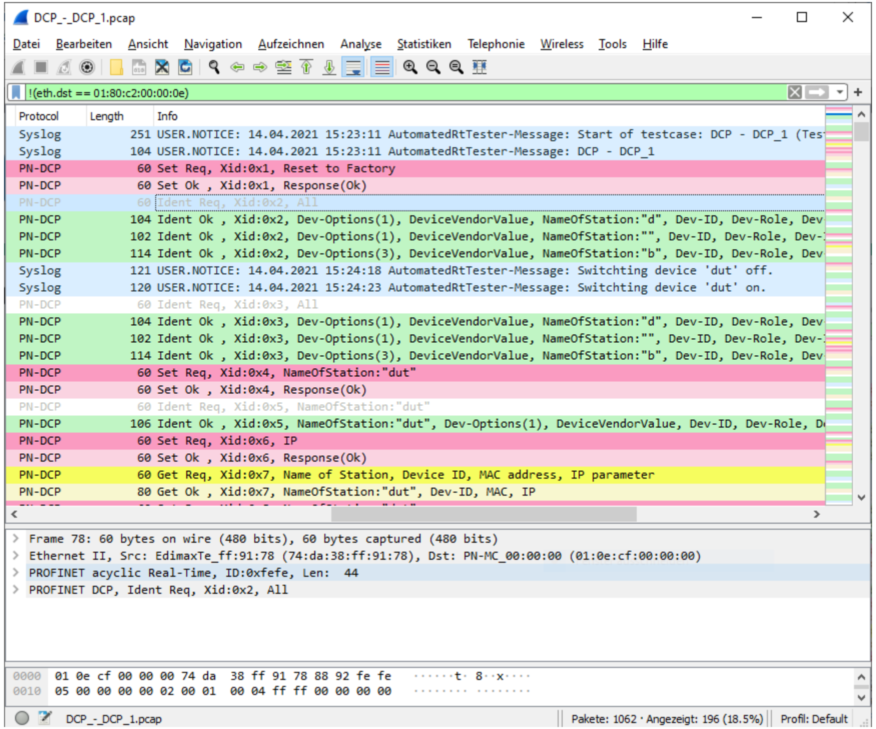
1 / 5

The Automated RT-Tester

- PCAPs
  - Each testcase produces a PCAP file
  - Dumps of all network traffic of the NICs connected with the test setup
  - Injection of Syslogs for easy navigation and highlighting
  - Detailed analysis
  - Archiving
  - Transparency



```
!(eth.dst == 01:80:c2:00:00:0e)
```

```
Protocol  Length Info
Syslog       251 USER.NOTICE: 14.04.2021 15:23:11 AutomatedRtTester-Message: Start of testcase: DCP - DCP_1 (Tes
Syslog       104 USER.NOTICE: 14.04.2021 15:23:11 AutomatedRtTester-Message: DCP - DCP_1
PN-DCP        60 Set Req, Xid:0x1, Reset to Factory
PN-DCP        60 Set Ok , Xid:0x1, Response(Ok)
PN-DCP        60 Ident Req, Xid:0x2, All
PN-DCP       104 Ident Ok , Xid:0x2, Dev-Options(1), DeviceVendorValue, NameOfStation:"d", Dev-ID, Dev-Role, Dev
PN-DCP       102 Ident Ok , Xid:0x2, Dev-Options(1), DeviceVendorValue, NameOfStation:"", Dev-ID, Dev-Role, Dev-
PN-DCP       114 Ident Ok , Xid:0x2, Dev-Options(3), DeviceVendorValue, NameOfStation:"b", Dev-ID, Dev-Role, Dev
Syslog       121 USER.NOTICE: 14.04.2021 15:24:18 AutomatedRtTester-Message: Switchting device 'dut' off.
Syslog       120 USER.NOTICE: 14.04.2021 15:24:23 AutomatedRtTester-Message: Switchting device 'dut' on.
PN-DCP        60 Ident Req, Xid:0x3, All
PN-DCP       104 Ident Ok , Xid:0x3, Dev-Options(1), DeviceVendorValue, NameOfStation:"d", Dev-ID, Dev-Role, Dev
PN-DCP       102 Ident Ok , Xid:0x3, Dev-Options(1), DeviceVendorValue, NameOfStation:"", Dev-ID, Dev-Role, Dev-
PN-DCP       114 Ident Ok , Xid:0x3, Dev-Options(3), DeviceVendorValue, NameOfStation:"b", Dev-ID, Dev-Role, Dev
PN-DCP        60 Set Req, Xid:0x4, NameOfStation:"dut"
PN-DCP        60 Set Ok , Xid:0x4, Response(Ok)
PN-DCP        60 Ident Req, Xid:0x5, NameOfStation:"dut"
PN-DCP       106 Ident Ok , Xid:0x5, NameOfStation:"dut", Dev-Options(1), DeviceVendorValue, Dev-ID, Dev-Role, De
PN-DCP        60 Set Req, Xid:0x6, IP
PN-DCP        60 Set Ok , Xid:0x6, Response(Ok)
PN-DCP        60 Get Req, Xid:0x7, Name of Station, Device ID, MAC address, IP parameter
PN-DCP        80 Get Ok , Xid:0x7, NameOfStation:"dut", Dev-ID, MAC, IP
```

```
> Frame 78: 60 bytes on wire (480 bits), 60 bytes captured (480 bits)
> Ethernet II, Src: EdimaxTe_ff:91:78 (74:da:38:ff:91:78), Dst: PN-MC_00:00:00 (01:0e:cf:00:00:00)
> PROFINET acyclic Real-Time, ID:0xfefe, Len:  44
> PROFINET DCP, Ident Req, Xid:0x2, All
```

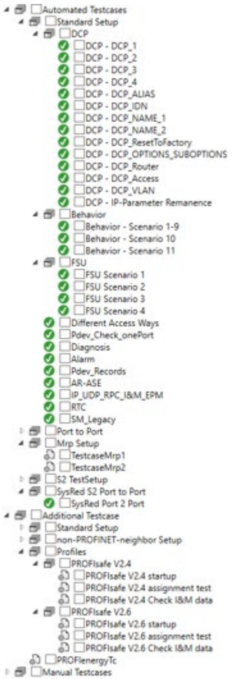
```
0000  01 0e cf 00 00 00 74 da  38 ff 91 78 88 92 fe fe   ······t· 8··x····
0010  05 00 00 00 00 02 00 01  00 04 ff ff 00 00 00 00   ········ ········
```

DCP_-_DCP_1.pcap | Pakete: 1062 · Angezeigt: 196 (18.5%) | Profil: Default

PCAP recorded with the ART

PROFINET Device Certification

- DUT is Device
- Automated RT-Tester simulates a PROFINET Controller
- GSD as base for PROFINET configuration
- Current status:
  - 40 main device testcases
  - Split into 64 single excecutable testcases



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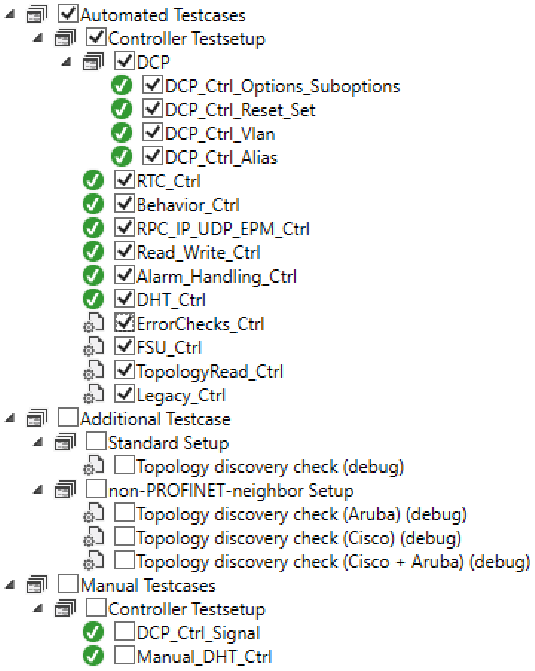
  □ PROFIenergyTc
□ Manual Testcases
```

Testcases for Device Certification

PROFINET Controller Certification



- ☑ Automated Testcases
  - ☑ Controller Testsetup
    - ☑ DCP
      - ✓ ☑ DCP_Ctrl_Options_Suboptions
      - ✓ ☑ DCP_Ctrl_Reset_Set
      - ✓ ☑ DCP_Ctrl_Vlan
      - ✓ ☑ DCP_Ctrl_Alias
    - ✓ ☑ RTC_Ctrl
    - ✓ ☑ Behavior_Ctrl
    - ✓ ☑ RPC_IP_UDP_EPM_Ctrl
    - ✓ ☑ Read_Write_Ctrl
    - ✓ ☑ Alarm_Handling_Ctrl
    - ✓ ☑ DHT_Ctrl
    - ☑ ErrorChecks_Ctrl
    - ☑ FSU_Ctrl
    - ☑ TopologyRead_Ctrl
    - ☑ Legacy_Ctrl
- ☐ Additional Testcase
  - ☐ Standard Setup
    - ☐ Topology discovery check (debug)
  - ☐ non-PROFINET-neighbor Setup
    - ☐ Topology discovery check (Aruba) (debug)
    - ☐ Topology discovery check (Cisco) (debug)
    - ☐ Topology discovery check (Cisco + Aruba) (debug)
- ☐ Manual Testcases
  - ☐ Controller Testsetup
    - ✓ ☐ DCP_Ctrl_Signal
    - ✓ ☐ Manual_DHT_Ctrl

Testcases for Controller Certification

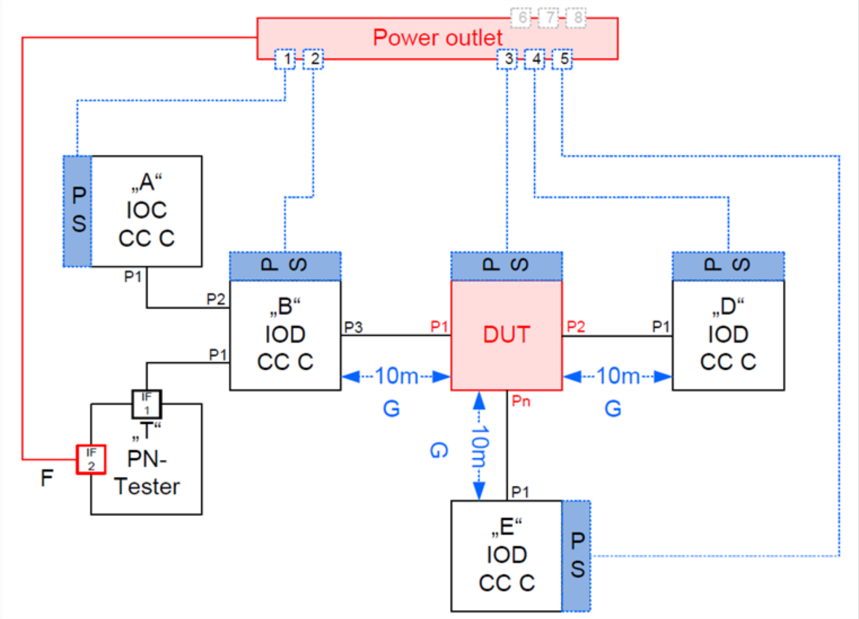
- DUT is Controller
- Automated RT-Tester simulates a PROFINET Device
- TFPC (Test Flow Protocol for Controllers) for Device → Controller test commands
- Controller applications necessary (examples provided with every bundle)
- CDML (Controller Description ML)
- Current status:
  - 17 main controller testcases
  - Split into 21 single executable testcases

Hardware for testing – PC system

- Specified PC system with following requirements:
  - Windows 10® 64 Bit Professional, Version 20H2 (21H2 from next release on)
  - I350-T2/T4: 100BaseTX network card(s) with possibility to disable striping of VLAN-Tag for connection with the testsetup
  - Additional network card for connection with the power outlet
- Motivation: Reliable results and guaranteed reproducibility
- See test specification for full details

Test development at OTH Amberg

Hardware for testing – Testsetups



Standard testsetup

- Testsetups are specified in detail
  - PSU (Power Supply Unit)
  - Device B
  - Neighbor Devices
  - Cabling and ports
  - …
- Testsetups vary based on the testcases, e.g.
  - Standard Testsetup
  - S2 System Redundancy Testsetup
  - Port-to-Port Testsetup
  - …

Hardware for testing – Testsetups

- Specified in test specification
  - Different testsetups
  - Dedicated testsetup for each testcase
  - Additional devices, e.g.
    - Converters for FO devices
    - Non-PROFINET-Neighbor devices for TedCheck

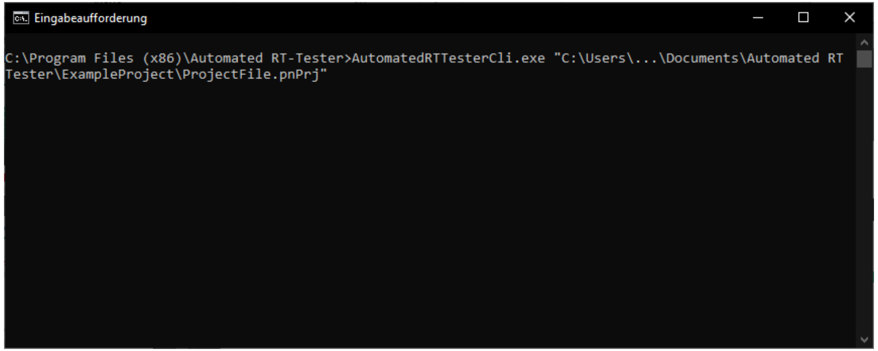
One of the PROFINET test stands at OTH

Standard Testsetup

Demo

Command Line Interface

- Motivation:
  - CLI for further test automation
  - Regression testing
  - Automated comparison of test results
- AutomatedRTTesterCli.exe is provided with each installer of the ART
  - Default location: installation folder (C:\Program Files (x86)\Automated RT-Tester)
- Use:
  - Setup ART project
  - Pass path to project(s) as parameter



```
C:\Program Files (x86)\Automated RT-Tester>AutomatedRTTesterCli.exe "C:\Users\...\Documents\Automated RT
Tester\ExampleProject\ProjectFile.pnPrj"
```

Using the CLI

End of part 1

Upcoming: What to expect from a testcase?

Agenda part 2: What to expect from a testcase?

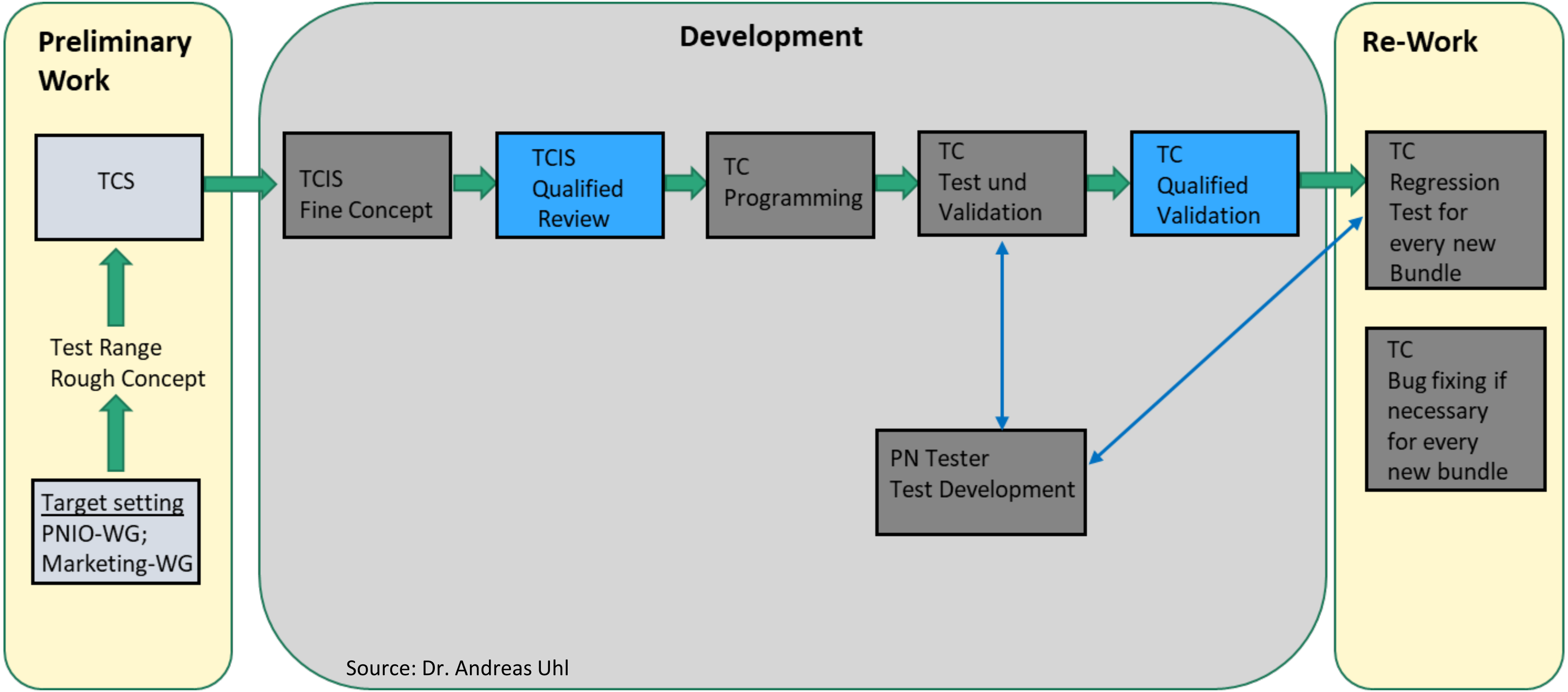
1 Process

2 Resources (Testspec, TCS, TCIS, Code)

3 Testcase IP_UDP_RPC_EPM_I&M in detail

4 Writing your own testcases

Process



Source: Dr. Andreas Uhl

Resources

- Testspec
  - General test concept
  - Basics and coverage of scope of certification process
  - Information to provide to your PITL
  - Overview on all test systems (Automated RT-Tester, Spirta, Security Level 1, …)
  - All testsetups
    - Devices with order numbers and settings (NameOfStation, IpParameters, …)
    - Media converters
    - PSU
    - Cabling

Resources

- TCS – Test Case Specification
  - Specific to a certain testcase
  - What to test? What to consider when testing?
  - General part:
    - Referenced versions of base specifications
    - GSD versions valid for certification testing (loading)
    - GSD attributes used in this testcase
    - Testsetup
    - Possible results with explanation
  - Testcase details:
    - Description of the testcase
    - Focus points for test development

Resources

- TCIS – Test Case Implementation Specification
  - Specific to a certain testcase, based on the corresponding TCS
  - Exception: TCIS General containing details valid for all TCIS
    - e.g. AR-Establishment, AlarmHandling, DCP check / set NameOfStation / IpParameters, …
  - How to test? Detailed explanation of the implementation
  - General part:
    - Additions to TCS, e.g. deviations
  - Implementation part:
    - Flow charts for all scenarios
    - Detailed description of every test step
    - Protocol tables for all tested PDUs

Resources

- Testcase code
  - Plain source code for all testcases is included in every installer of the Automated RT-Tester
  - Default location: C:\Program Files (x86)\Automated RT-Tester\Documentation\Testcases_NO_SUPPORT.zip
  - Better understanding of testcase
  - Hints and examples for development of user testcases

Scenarios of IP_UDP_RPC_I&M_EPM

Scenario I: Checking of RPC, IP, UDP, Part 1

1. ICMP Ping request and validation of response
2. IOC-AR (little endian RPC)
   1. Check ModuleDiffBlock and IOPS (good)
   2. Read I&M0 Data and validate response
3. IOC-AR (big endian RPC)
   1. Check ModuleDiffBlock and IOPS (good)
   2. Read I&M0 Data
      1. Validate response
      2. Compare response to block received above
4. IOC-AR, ConnectRequest fragmented on RPC layer

Scenarios of IP_UDP_RPC_I&M_EPM

Scenario I: Checking of RPC, IP, UDP, Part 2

5. IOC-AR (with errors)
   - Record Data Read with:
     - Wrong checksum in IP part
     - Wrong checksum in UDP part
     - Wrong checksums in IP and UDP part
     - Data length in IP part is set too big
     - Data length in UDP part is set to the same value as in IP part
     - Data length in IP part is set too small
     - Data length in UDP part is set too small
   - None of those frames shall be forwarded to the DCE RPC layer
   - DCE RPC pings are used to ensure functionality of DCE RPC service

Scenarios of IP_UDP_RPC_I&M_EPM

Scenario II: Consistency check of EPM, I&M and DCP

1. NDR Endpoint Mapper Lookup Requests (rpc_c_ep_all_elts)
2. Read I&M0Data of device representative
3. Send DCP IdentifyAllReq
4. Compare for consistency:
    - VendorId
    - DeviceVendorValue
    - OrderId
    - HardwareRevision
    - SoftwareRevisionPrefix
    - SoftwareRevision
    - …

Scenarios of IP_UDP_RPC_I&M_EPM

Scenario III: I&M Write

1. IOC-AR
   - For all Submodules in I&M0FilterData.FilterDataSubmodules:
     - Read I&M0 Data
     - Write I&M0 Data and validate error code
     - Read I&M0 Data
     - For I&M1 – 4: If supported (I&M.IM_Supported, GSD):
       - Write IM, validate success/error code
     - Read I&M5, validate success (if supported) or error code
     - Write I&M5 and validate error code
2. Release IOC-AR
3. Power cycle DUT

Scenarios of IP_UDP_RPC_I&M_EPM

Scenario III: I&M Write

4. IOC-AR
   - Read I&0 Data and compare to previously written data
   - If supported: ResetToFactory Mode 1, 4, 8 or 9
     - Read writable I&M Data, check if successfully reset to factory settings.
5. Release IOC-AR

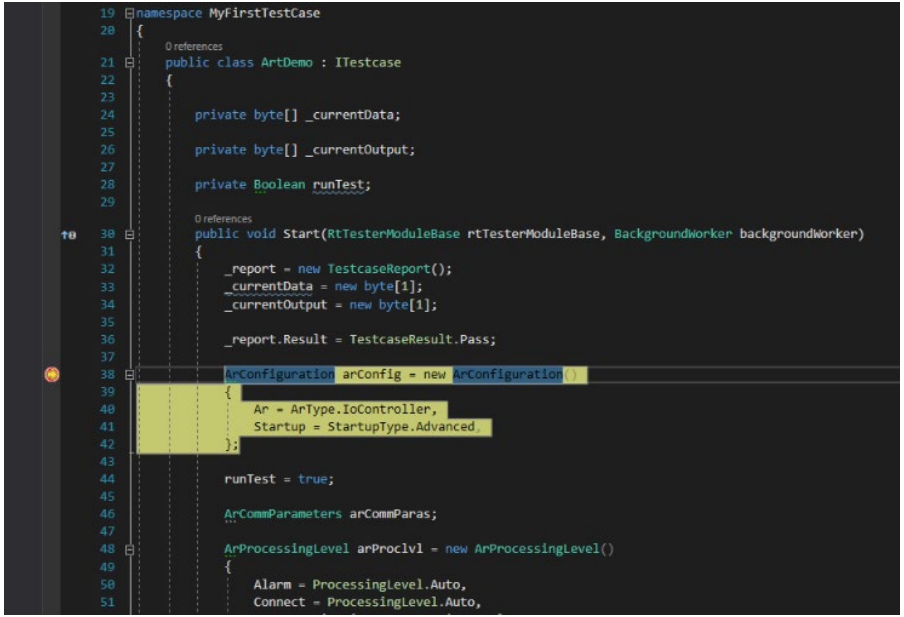
Scenarios of IP_UDP_RPC_I&M_EPM

Scenario IV: Check of ActivityUUID

1. IOC-AR, save RPCActivityUUID from ApplicationReadyReq
2. Release IOC-AR
3. IOC-AR, save RPCActivityUUID from ApplicationReadyReq
4. Release IOC-AR
5. Compare ActivityUUIDs
    - Subsequent ActivityUUIDs shall not be equal
    - Last 6 bytes of AcitvityUUIDs shall match the MAC address of the device

User testcase development

- Users of the Automated RT-Tester can develop and run their own testcases
- Motivation:
  - Debugging of stack
  - Regression tests
  - Development of new features
  - …
- API of Automated RT-Tester framework is available
- CLI support
- Detailed description of setup is included in every installer.



```
namespace MyFirstTestCase
{
    0 references
    public class ArtDemo : ITestcase
    {

        private byte[] _currentData;

        private byte[] _currentOutput;

        private Boolean runTest;

        0 references
        public void Start(RtTesterModuleBase rtTesterModuleBase, BackgroundWorker backgroundWorker)
        {
            _report = new TestcaseReport();
            _currentData = new byte[1];
            _currentOutput = new byte[1];

            _report.Result = TestcaseResult.Pass;

            ArConfiguration arConfig = new ArConfiguration()
            {
                Ar = ArType.IoController,
                Startup = StartupType.Advanced,
            };

            runTest = true;

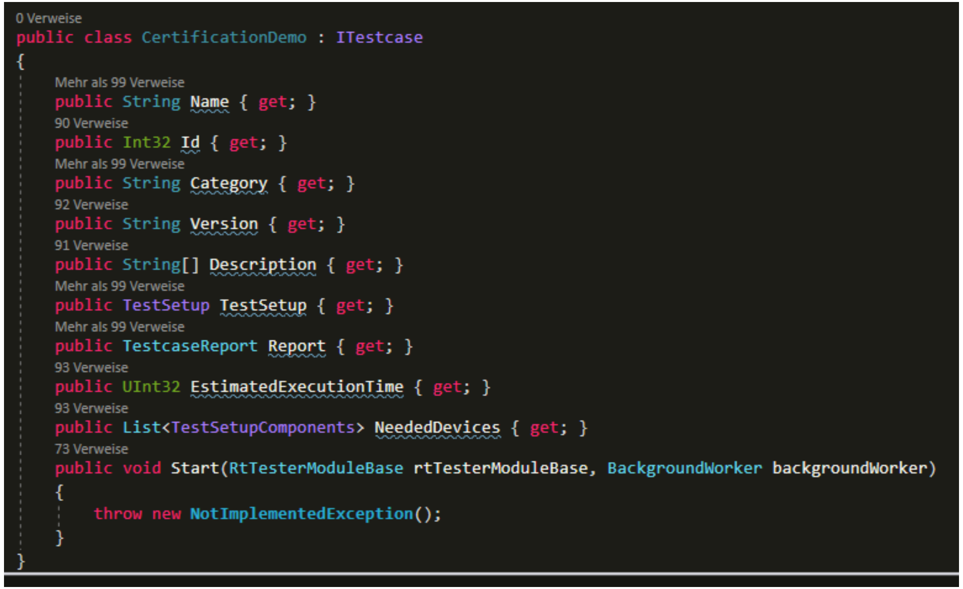
            ArCommParameters arCommParas;

            ArProcessingLevel arProclvl = new ArProcessingLevel()
            {
                Alarm = ProcessingLevel.Auto,
                Connect = ProcessingLevel.Auto,
```

Development of user testcases

Implementing the ITestcase interface

- Testcases have to implement the ITestcase interface
- Members:
  - Name: Name of the Testcase
  - Id: Id of the Testcase as shown in the report.
  - Category: Location in TC tree
  - TestSetup (Standard, P2P, SystemRedundancy, …)
  - NeededDevices: Will be checked while TC preparation.

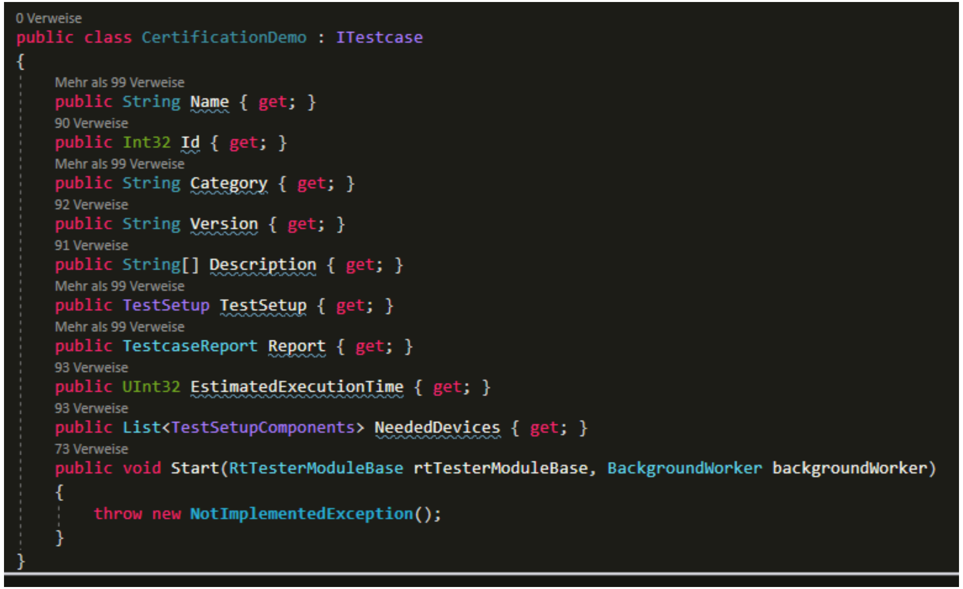


```
0 Verweise
public class CertificationDemo : ITestcase
{
    Mehr als 99 Verweise
    public String Name { get; }
    90 Verweise
    public Int32 Id { get; }
    Mehr als 99 Verweise
    public String Category { get; }
    92 Verweise
    public String Version { get; }
    91 Verweise
    public String[] Description { get; }
    Mehr als 99 Verweise
    public TestSetup TestSetup { get; }
    Mehr als 99 Verweise
    public TestcaseReport Report { get; }
    93 Verweise
    public UInt32 EstimatedExecutionTime { get; }
    93 Verweise
    public List<TestSetupComponents> NeededDevices { get; }
    73 Verweise
    public void Start(RtTesterModuleBase rtTesterModuleBase, BackgroundWorker backgroundWorker)
    {
        throw new NotImplementedException();
    }
}
```

Development of user testcases

Implementing the ITestcase interface

- Start()-Method
  - Will be executed on TC start
  - Holds or manages the TC logic
  - rtTesterModuleBase
    - Provides access to all data regarding configuration of DUT, network communication and PowerOutlet of the test setup
  - backgroundWorker
    - Cancellation of running TC by the user



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```
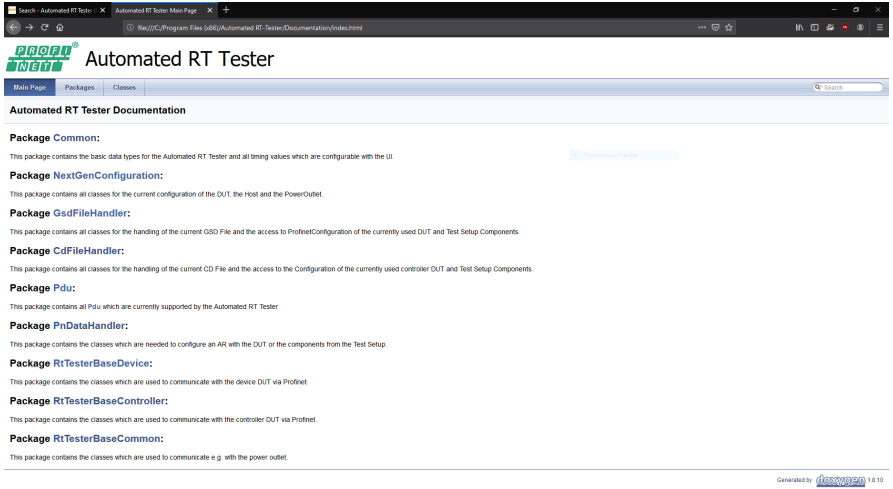

Development of user testcases

Docs and API

- Docs for developers:
  - The latest version of the documentation is always part of a bundle.



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Automated RT Tester Documentation

Package Common:

This package contains the basic data types for the Automated RT Tester and all timing values which are configurable with the UI.

Package NextGenConfiguration:

This package contains all classes for the current configuration of the DUT, the Host and the PowerOutlet.

Package GsdFileHandler:

This package contains all classes for the handling of the current GSD File and the access to ProfinetConfiguration of the currently used DUT and Test Setup Components.

Package CdFileHandler:

This package contains all classes for the handling of the current CD File and the access to the Configuration of the currently used controller DUT and Test Setup Components.

Package Pdu:

This package contains all Pdu which are currently supported by the Automated RT Tester

Package PnDataHandler:

This package contains the classes which are needed to configure an AR with the DUT or the components from the Test Setup.

Package RtTesterBaseDevice:

This package contains the classes which are used to communicate with the device DUT via Profinet.

Package RtTesterBaseController:

This package contains the classes which are used to communicate with the controller DUT via Profinet.

Package RtTesterBaseCommon:

This package contains the classes which are used to communicate e.g. with the power outlet.

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Documentation for developers

Possibilities of the ART-Framework

- MSF-Vathauer: SME with a broad product spectrum for frequency converters, drives etc. for automation.
  - Latest project: Frequency converters and soft-starter with PROFINET connection.
- Complete test tool for development, pre-certification and testing within assembly based on the Automated RT-Tester Framework.
- Complete independency from other software or IO-Controllers.

MSF VATHAUER

ANTRIEBSTECHNIK

End of part 2

Upcoming: Live demo (structure and contents of the bundle, project setup, test execution)

Part 3: Live demo

Structure and contents of the Test Bundle

Project Setup for Device & Controller Certification

Test execution

OTH Testbed: Guarantee of Quality

- 10 Standard Testsetups
- 5 Unified Testsetups
- More than 40 PROFINET Devices of a wide range of manufacturers
- PROFINET Controllers of major manufacturers

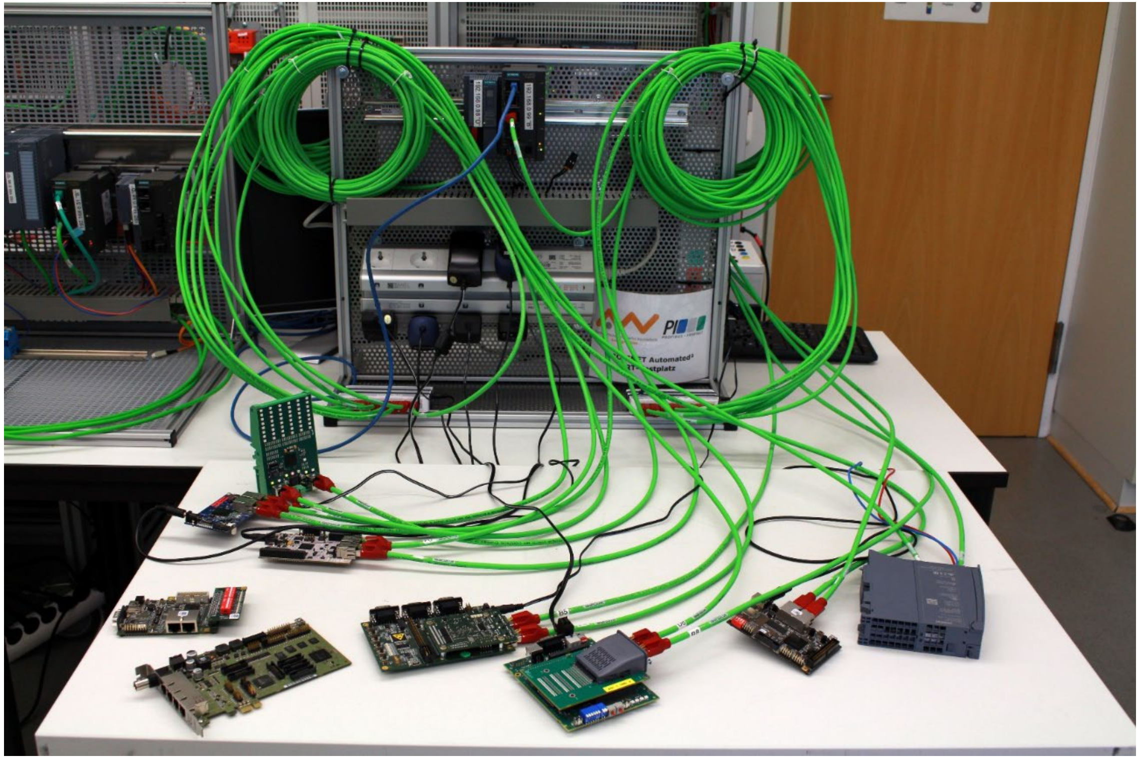
OTH Testbed

Close collaboration with manufacturers

PHOENIX CONTACT

hilscher
COMPETENCE IN COMMUNICATION

molex®



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- Software solutions for small and medium-sized enterprises and industry in the field of automation.

aia offices at OTH campus in Amberg

Thank you!

Do you have any questions?

b.etzold@oth-aw.de | pn-ts-support@oth-aw.de

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Amberg-Weiden