Learning Outcomes (LO) of

**Certified PROFINET
Network Engineers
(CPNE)**

Version 2.0.0 – Date: 12th July 2017

Order No.: 4.812

Revision Log

Version	Originator	Date	Change Note / History / Reason
0.1.0	TC1 WG9 Training	06Jun05	Initial version
0.2.0	TC1 WG9 Training	26Aug05	add financial aspects
1.0.0	TC1 WG9 Training	01Dec08	Modify learning outcomes list. Modify syllabus. Modify course duration. Add troubleshooting to practical test. Other minor changes.
1.0.1	TC1 WG9 Training	28Sep10	Add fast start up and white papers as references. Reformatting.
d1.0.2	TC1 WG9 Training	25 Jan 11	Replace IRT Top by RT_CLASS_3, add reference to IRT Wireshark capture and update complete references with the sources, open the possibility to make a shorter practical test.
1.0.2	SU4/WG1	August 2016	Approved by PI Chairmen
2.0.0 (Draft A)	SU4/WG1	November 2016	Modify learning outcomes and partial implemented the syllabus.
2.00 (Draft B)	SU4/WG1	June 2017	A complete redesign of the learning outcomes and integrate the action verbs of Bloom.
2.0.0 (Draft C)	SU4/WG1	June 2017	Some changes based on comments and web meeting with some members. Some lexical and content changes. The content changes are: General: • PROFINET IO to PROFINET in case of application. Doesn't change PROFINET IO Controller and PROFINET IO device. • GSDXML to GSD • Only theoretical explanations about isochronous real time application. Specific L.O.: 2.2.2 : Added also the Gigabit and Fast Ethernet 2.2.3 : Added 4 and 8 wire variants 2.2.17: Show complete overview of PI profiles 2.6.1: Added Or. 2.2.16 : Added the MRP protocol. Added L.O.: 2.7.5: Added the use of PROFINET Guidelines. 2.8.5: Added the use of PROFINET Guidelines.

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| 2.0.0 (Draft D) | SU4/WG1 | | Some changes based on comments at the PI Meeting in Beijing. General: The course duration extended to a minimum of 3 Days and dimensioned in hours instead of days. GSDXML to GSD. Added reference to Bloom's taxonomy webpage. Specific L.O.: 2.1.3: y removed and u added. 2.2.17: Added the PA profile. 2.7.5: Added Design. 2.8.5: Commissioning. 2.9.1: Change to Hardware-based. 2.10: Operational Qualification |
| 2.0.0 | SU4/WG1 | 12th July 2017 | Issued to PI for approval following review at PICC/PITC meeting Beijing |

Course Title: **Certified PROFINET IO Network Engineer**

Course Code: **CPNE**

Course Duration: **Minimum 21 Hours (18 Hours + 3 Hours for examination)**

                      Advised 24 Hours (21 Hours + 3 Hours for examination)

Grading Type: **Normal**

Prerequisite: Industrial Automation Background.

Developed by PI SU4 "PI Training Center".

This Learning Outcome is one of a series of several courses:

4.712 Certified PROFIBUS Engineer
4.722 Certified PROFIBUS Installer
4.732 Certified PROFIBUS-PA Engineer
4.742 Certified PROFIBUS System Designer
4.812 Certified PROFINET IO Engineer
4.822 Certified PROFINET Installer

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1 Aims & Objectives

The objective of this course is to provide both hands-on and theoretical training on PROFINET IO. The training course will provide an opportunity for the participant to acquire the required skills to validate design, configure, commission, diagnose and troubleshoot PROFINET IO networks.

2 Learning Outcomes

The following learning outcomes specify what candidates will know or be able to do as a result of successfully completing the training course. The learning outcome consists of a reference number, description and assessment mode. There are three kind of assessment modes: theory (T), practical (P) and demonstration/class exercise (C).

The learning outcomes are grouped in two kind of outcomes; supporting and task-oriented. Every paragraph in this chapter contains a group of learning outcomes. The supporting learning outcomes support the task-oriented learning outcomes and are about concept discrimination, factual information and process explanation.

Learning outcome	Kind of outcome	Hours(h)
General network basics	Supporting	0-1
PROFINET network basics	Supporting	2-3
PROFINET Cyclic data exchange	Supporting	2-3
PROFINET Acyclic data exchange	Supporting	2-3
Development of a PROFINET real time application	Supporting	2-3
Maintenance of a PROFINET real time application	Supporting	2-3
Development of a PROFINET real time application	Task-oriented	2-3
Maintenance of a PROFINET real time application	Task-oriented	2-3
PROFINET isochronous real time application	Supporting	2-3
PROFINET Operational Qualification	Supporting	0-1

The learning outcomes are specified according the rules of the Bloom's taxonomy (revised) and written with action verbs – see reference [13].

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2.1 General network basics

This learning outcomes are about the supporting skills/knowledge of general Ethernet technology.

On successful completion of this course students will be able to:

Ref.	Description	Assessment mode		
		T	P	C
2.1.1	Identify Network Addressing • MAC Address: Device & Port • IP Address • Subnet Mask	X		
2.1.2	Identify and explain: • A IEEE802.3 packet • TCP/UDP message • ARP packet.	X		
2.1.3	List the data rates of the IEE802.3u, x, and z.	X		
2.1.4	Compare a standard Ethernet frame with an Ethernet frame that has VLAN priority tagging and quality of service.	X		
2.1.5	Describe the behaviour of the following • Hub • Switch • Level-3 switch • Router • Firewall	X		X
2.1.6	Explain the following terminology: • Half/full duplex • auto crossover • auto negotiation • managed switches • Cut through vs. store and forward	X		

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| 2.1.7 | Label the wires of an Ethernet cable | X | | |
| 2.1.8 | Predict the effect of network changes to the content of a switch MAC-table. | X | | |

2.2 PROFINET Network basics

This learning outcomes are about the supporting skills/knowledge of the PROFINET network infrastructure and application in a general way.

On successful completion of this course students will be able to:

Ref.	Description	Assessment mode		
		T	P	C
2.2.1	List the cables and connector types of PROFINET.	X		
2.2.2	Compare the wires of general Ethernet cable with a PROFINET cable and Fast Ethernet and Gigabit.	X		
2.2.3	List the three cable classes A, B and C and explain the differences between these cable classes. Cover both 4 and 8 wire variants.	X		
2.2.4	Explain the roles of a PROFINET IO Controller, IO device and IO supervisor and the communication services.	X		
2.2.5	Classify an Ethernet switch based on the conformance classes A, B and C as a PROFINET-switch based on the PROFINET switch requirements.	X		
2.2.6	Identify the Ether types of PROFINET from of a list of Ethernet types.	X		
2.2.7	Relate the function of the Ether type in the Ethernet packet to the operation of a PROFINET application.	X		
2.2.8	Compare the mechanism of Application Relations and Communication Relations and FrameID with the connection mechanism of the TCP protocol.	X		
2.2.9	Describe the purposes of the following protocols and their role in a PROFINET Network: • Address Resolution Protocol (ARP) • Discovery and (basic) Configuration Protocol (DCP) • Link Layer Discovery protocol (LLDP) • Simple network management Protocol (SNMP)	X		

2.2.10	Download the PNIO device names and explain the function of the Discovery and configuration protocol (DCP).			X
2.2.11	Use the IO Device slots / subslot model to explain the structure of compact and modular field devices.	X		
2.2.12	Explain the role of a GSD file.	X		
2.2.13	Recognise the possible network topologies (Star,Tree and Line) and explain the scope of this topologies.	X		
2.2.14	Explain the function and differences of a coupler, proxy and gateway.	X		
2.2.15	Explain the function of proxy's and list three examples: PROFIBUS, PROFIBUS PA, IO-Link, AS-I bus.	X		
2.2.16	Describe the purpose and benefits of the following additional PROFINET technologies: • MRP • IPAR • FAST START-UP • I&M • System redundancy • Fast Forwarding	X		
2.2.17	Describe the purpose and benefits of the following PROFINET application profiles. • Encoder • PA • PROFIsafe • PROFIdrive • PROFIenergy • and the other profiles	X		X

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2.3   PROFINET Cyclic data exchange

This learning outcomes are about the supporting skills/knowledge of cyclic data exchange.

On successful completion of this course students will be able to:

Ref.	Description	T	P	C
2.3.1	Identify the following types of PROFINET frames • Connect Request and Response • Write Records for parameterization • End of Parameterization • Application Ready for Data Exchange • Cyclic I/O frames.	X		
2.3.2	Explain the encapsulation / decapsulation process of a PROFINET frame and show the location of the following: • Ether type • Frame ID • Protocol • Port (TCP/UDP)	X		
2.3.3	Order the PNIO frame structure elements, respectively: IO data, IOPS (Provider status), IOCS (Consumer status), of cyclic data exchange in the right order for the situations: controller to device and device to controller.	X		
2.3.4	Relate the Watchdog function to the cyclic data exchange process.	X		

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2.4   PROFINET Acyclic data exchange

This learning outcomes are about the supporting skills/knowledge of acyclic data exchange.

On successful completion of this course students will be able to:

Ref.	Description	Assessment mode		
		T	**P**	**C**
2.4.1	Give four examples of useful use cases for acyclic data exchange.	X		
2.4.2	Identify two devices – controller, supervisor - that can run an acyclic data exchange.	X		
2.4.3	Apply the addressing of the record data services.	X		
2.4.4	Explain the basic sequence of acyclic data communication including the Read/Write REQ and Read/Write RES.	X		
2.4.5	Explain the differences between acyclic data and real time acyclic data exchange (Alarms)	X		

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2.5   Development of a PROFINET application

This learning outcomes are about the general skills and knowledge of a PROFINET frame and the operation of PROFINET functions.

On successful completion of this course students will be able to:

Ref.	Description	Assessment mode		
		T	P	C
2.5.1	Explain the relation between a GSD file and a PROFINET IO device.	X		
2.5.2	Interpret the GSD file naming according the naming convention and check the graphic file name.	X		
2.5.3	Check a GSD file with the PROFINET GSD Checker and explain possible problems of this file.	X		X
2.5.4	Connect GSD file content to the programming and support environment (PSE). The content parts are: DAP, Module, Parameters, Value lists, Channel Diagnostics text, Icon Bitmap file, Module Categories and Multiple language support.	X		X
2.5.5	Set the update times of PROFINET IO Device according the available rules.			X
2.5.6	List the limit values of the network load of PROFINET application.	X		
2.5.7	List the maximum line depth in relation to update time of 'store and forward' and 'Cut through' switches.	X		
2.5.8	List all of the options that solve possible real-time network load problems.	X		
2.5.9	Prove the relation between the update times of PROFINET IO Devices and the actual phase shifts and network (port) load. Underpin this with a packet analyser to show the effects of the update time changes.			X

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2.6   Maintenance of a PROFINET application

This learning outcomes are about the general skills and knowledge of a PROFINET frame and the operation of PROFINET functions.

On successful completion of this course students will be able to:

Ref.	Description	Assessment mode		
		T	P	C
2.6.1	Make a packet log of switch port with a packet analyser and use a port mirror and/or a tap and explain the differences between these two approaches.			X
2.6.2	Demonstrate the added value of switch featured with SNMP (managed switch) by showing the content of the MIBII management information base.			X
2.6.3	Demonstrate the added value of a PROFINET device (switch) featured with LLDP by showing the simple device replacement (non-configured) of a PROFINET IO Device.			X
2.6.4	Demonstrate the PROFINET diagnostic model and explain the related alarm messages.			X

2.7   Development of a PROFINET Real time application

This learning outcome is about the task of engineer.

On successful completion of this course students will be able to:

Ref.	Description	Assessment mode		
		T	P	C
2.7.1	Identify the possible performance problems of a given design of a PROFINET Real time application according the performance indicators; network load, latency and jitter. The design consists of several PROFINET IO devices and may contain non-real time hosts with given bandwidth.	X		
2.7.2	Modify the design parameters line depth, update time, topology of a given design of a PROFINET IO Real time application according to the performance problems.	X		
2.7.3	Setup a PROFINET Real time application, according to the design, with three PROFINET IO Devices in cyclic data exchange. One of the PROFINET IO Device is a switch.		X	

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		T	P	C
2.7.4	Setup a PROFINET Real time application, according to the design, with two PROFINET IO Devices in cyclic data exchange and minimum one additional PROFINET IO Device is in acyclic data exchange. The acyclic data exchange solution is based on given example. One of the PROFINET IO Device is a switch.		X	
2.7.5	Use the PROFINET Design Guidelines to develop a PROFINET application.		X	

2.8   Maintenance of a PROFINET Real time application

This learning outcome is about the task of engineer.

On successful completion of this course students will be able to:

Ref.	Description	Assessment mode		
		T	P	C
2.8.1	Find the root cause of a PROFINET (start up) problem with a packet analyser to show the correlated packets to underpin the explanation.		X	
2.8.2	Create a network load base line with a packet analyser and a port mirror/TAP to identify possible problems with the comparisons of a given network load base line of a PROFINET IO controller. The network base line consists of ARP, Multicast, Unicast and PROFINET packets.		X	
2.8.3	Document the hardware and firmware versions of a PROFINET Real time with three PROFINET IO devices. Use the programming environment or a SNMP-based tool.		X	
2.8.4	Check the status of an individual Ethernet port of a PROFINET device based on duplex type, send and receive frames, error frames and multi/single cast with webpage.		X	
2.8.5	Use the PROFINET Commissioning Guidelines to maintain a PROFINET application.		X	

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2.9 PROFINET Isochronous real time application

This learning outcomes are about the general skills and knowledge of a PROFINET Isochronous real time application.

On successful completion of this course students will be able to:

Ref.	Description	Assessment mode		
		T	P	C
2.9.1	Explain the differences between best-effort Ethernet and hardware-based Ethernet.	X		
2.9.2	List the two features that Isochronous real time enables.	X		
2.9.3	Explain the differences between RT_Class_1 and RT_Class_3	X		
2.9.4	Show the requirements for IRT Control	X		
2.9.5	Explain the differences between RT communication and IRT communication configuring	X		

2.10 PROFINET Operational Qualification

This section of the learning outcomes is about the need to formally qualify a PROFINET installation on completion of the installation qualification but prior to application-specific testing.

On successful completion of this course students will be able to:

Ref.	Description	Assessment mode		
		T	P	C
2.10.1	Explain the purpose of Operational Qualification and the need to perform it prior to application-specific testing.	X		
2.10.2	Explain the scope of Operational Qualification	X		
2.10.3	Explain the need to incorporate Test Access Points			
2.10.4	Explain the role of permanent monitors in the qualification of a PROFINET network, where they should be located in a network and the two types available, i.e. Active (using regular SNMP polling) and Passive.	X		X

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3 Syllabus

The syllabus contains the specification of the course content.

3.1 Text Books and References

Ref	Number	Book	Version	Year
[1]	4.182f	Book: Industrial communication with PROFINET		2014
[2]	8.062	PROFINET Design	1.14	2014
[3]	8.072	PROFINET Cabling and Assembly	1.00	2009
[4]	2.252	PROFINET Cabling and Interconnection technology	4.00	2017
[5]	8.082	PROFINET Commissioning	1.36	2014
[6]	2.352	GSDML Specification for PROFINET IO	2.33	2016
[7]	7.092	PROFINET IO Media Redundancy in Process Automation systems	1.02	2012
[8]	7.112	PROFINET IO Configure in Run	1.10	2015
[9]	7.122	PROFINET IO System Redundancy	1.11	2016
[10]	7.142	Diagnosis for PROFINET IO	1.13	2016
[11]	7.172	PROFINET IRT Engineering	1.35	2017
[12]	7.182	Topology Engineering and Discovery for PROFINET IO	2.00	2016
[13]	N/A	https://www.cte.cornell.edu/documents/Assessment%20-%20Blooms%20Taxonomy%20Action%20Verbs.pdf		

3.2 General network basics

This specification depends on the prior knowledge of a participant.

3.3 PROFINET Network basics

Subject	L.O.	Reference
Copper cables	2.2.1	8.062, § 9.3, p.155-166
Optical fibres	2.2.1	8.062, § 9.4, p.167-171
Connectors and transitions points	2.2.1	8.062, § 9.5, p.172-185
Ethernet Cable and PROFINET Cable	2.2.2	Sheet
Cable classes	2.2.3	2.252, § 9.5, p. 31
The basic components and functions of a PROFINET.	2.2.4	4.182f, p.16-19 4.182f, § 6.4

PROFINET switch requirements	2.2.5	4.182f, § 6.2 p. 24
Ether types and Frame ID	2.2.6 2.2.7 2.2.8	4.182f, § 6.5 p. 33
ARP	2.2.9	4.182f, § 9.3 p. 88
DCP	2.2.9 2.2.10	4.182f, § 9.1-5 p. 86-89
LLDP	2.2.9	4.182f, § 9.3 p. 88
PROFINET name and address resolution	2.2.10	4.182f, § 5.1 p. 20
Device Model	2.2.11	4.182f, § 6.3 p. 26-31
GSD file	2.2.12	4.182f, § 15.1-5 p. 180-183
Topologies	2.2.13	8.062, § 3.1 p. 51-54
Coupler	2.2.14	-
Proxy	2.2.14 2.2.15	4.182f, § 21.1-5 p. 226
Gateway	2.2.14	4.182f, § 21.1-5 p. 226
iPar	2.2.16	4.182f, § 14.1 p. 172-174
Fast Start-up	2.2.16	4.182f, § 9.1 p.101
I&M	2.2.16	4.182f, § 16 p.191
System redundancy	2.2.16	4.182f, § 17.3 p. 201
Fast Forwarding	2.2.16	4.182f, § 13.1 p.163
Encoder profile	2.2.17	-

PROFIsafe	2.2.17	4.182f, § 19.3 p. 213
PROFIdrive	2.2.17	4.182f, § 13.2 p. 212
PROFIenergy	2.2.17	4.182f, § 19.1 p. 210

3.4   PROFINET Cyclic data exchange

Subject	L.O.	Reference
Connect Request	2.3.1	4.182f, § 9.6.1 p. 92
Connect Response	2.3.1	4.182f, § 9.6.2 p. 95
Write Request	2.3.1	4.182f, § 9.6.3 p. 96
Write Response	2.3.1	4.182f, § 9.6.4 p. 98
DControl Request (End of Parameterization)	2.3.1	4.182f, § 9.6.5 p. 98
DControl Response	2.3.1	4.182f, § 9.6.6 p. 98
CControl Request (Ready for data exchange)	2.3.1	4.182f, § 9.6.7 p. 98
CControl Response	2.3.1	4.182f, § 9.6.8 p. 99
Cyclic I/O Frame (Device to controller)	2.3.1 2.3.3	4.182f, § 10.1.1 p. 108
Cyclic I/O Frame (Controller to Device)	2.3.1 2.3.3	4.182f, § 10.1.2 p. 109
Encapsulation/ De-encapsulation	2.3.2	-

| Watchdog | 2.3.4 | 4.182f, § 11.4 p. 133 |
| | | 8.062, § 5.2.2 p. 108 |

3.5   PROFINET Acyclic data exchange

Subject	L.O.	Reference
Examples Acyclic data exchange	2.4.1	4.182f, § 10.2 p. 111
Acyclic services initiators	2.4.2	4.182f, § 10.2 p. 110
Addressing rules	2.4.3	4.182f, § 10.2 p. 110

3.6   Development of a PROFINET application

Subject	L.O.	Reference
GSD File	2.5.1	4.182f, § 15.8 p. 186
Naming convention GSD file	2.5.2	4.182f, § 15.3 p. 180
Structure of GSD file	2.5.3 2.5.4	4.182f, § 15.5 p. 182
Creation of GSD file	2.5.3	4.182f, § 15.6 p. 184
Validation of GSD file	2.5.3	4.182f, § 15.7 p. 185
Transmission intervals	2.5.5	4.182f, § 7.2.4 p. 56
		8.062, § 5.1.2 p. 97
		8.062, § 5.2 p. 106

Limit values of network load	2.5.6	8.062, § 5.3.2 p. 115
	2.5.8	
Maximum Line depth	2.5.7	8.062, § 5.3.1 p. 111

3.7   Maintenance of a PROFINET application

Subject	L.O.	Reference
Analysis tool	2.6.1	8.082, § 2.3.4.1 p. 38 4.182f, § 22.2.1 p. 231
Port mirroring	2.6.1	8.082, § 2.3.4.1 p. 40
Tap (Test Access Point)	2.6.1	8.082, § 2.3.4.1 p. 40
Diagnose PROFINET Device with Webserver and/or SNMP	2.6.2	8.082, § 2.3.3 p. 37 4.182f, § 11.2.2 p. 130
LLDP	2.6.3	4.182f, § 8.5 p. 73
Device replacement without programming device	2.6.3	4.182f, § 7.2.5 p. 61
Diagnose concepts of PROFINET	2.6.4	4.182f, § 11 p. 117
Alarm handling from the user perspective	2.6.4	4.182f, § 11.1.2 p. 124

3.8   Maintenance of a PROFINET Real time application

Subject	L.O.	Reference
Introduction to troubleshooting	2.8.1	8.082, § 6.1 p. 105
Network load	2.8.2	8.082, § 5.4.3 p. 95
Broadcasts and multicasts	2.8.2	8.082, § 5.4.4 p. 98
Jitter	2.8.2	8.082, § 5.5 p. 98
Discarded packets	2.8.4	8.082, § 5.4.2 p. 94

3.9   PROFINET isochronous real time application

Subject	L.O.	Reference
Different types of Ethernet	2.9.1	4.182f, § 12.1 p. 135
Synchronization types	2.9.2	4.182f, § 12.1 p. 135
RT_Class_3	2.9.3	4.182f, § 6.6 p. 36 4.182f, § 12.2.3 p. 146
Requirement for IRT Control	2.9.4	4.182f, § 12.1.1 p. 138
Configuring of RT_Class_3 communication	2.9.5	4.182f, § 12.3 p. 147

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3.10 PROFINET Operational Qualification

Subject	L.O.	Reference
Purpose of Operational Qualification.	2.10.1	8.082 Section 5.4
Scope of Operational Qualification	2.10.2	8.082 Section 5.4
Explain the need to incorporate Test Access Points	2.10.3	8.062 Section 4.5
Permanent Monitoring	2.10.4	8.062 Section 5.2.2 / 5.3

4 Instructors

The instructor(s) must have passed the Certified PROFINET Network Engineer Course as a minimum and must be registered with PI.

5 Training and assessment methods

The training should cover the topics listed in the content specification below and must cover the learning outcomes. An example slide-set in English is provided by PI as a guideline. The delivery may be customized and formatted to suit the desires of the instructor and the needs of the candidates. The training must include a significant practical element in which the candidates can apply the theory concepts by testing a small network and debugging pre-made scenarios.

It is a good idea to include a short tutorial session in which revision/practice questions are answered and checked with the aid of the instructor. The tutorial questions should generally be open-ended to promote discussion and explore any weaknesses or misunderstandings the candidate(s) may have.

6 Typical Practical Work

- Commissioning of the given plant with the Engineering tool of the given IO Controller, includes: importing of GSD files of IO Devices, assigning names to the devices, downloading the configuration
- Recording of the Ethernet Frames with a packet analyzer during start-up phase and normal operation, interpretation of the frames
- Causing errors/alarms, recording of the transferred Ethernet frames with a packet analyzer, interpretation of the frames
- Setup of a faulty system by the trainer (wrong IO configuration, wrong device name, wrong cable or not 100 Mb/s Full-duplex), finding of the error by trainee and correction of the error
- Reading I&M functionality if supported by IO Controller application or Engineering tool

7 Training Equipment

The typical training equipment is given as a guide. Each PITC can decide on the configuration of the equipment so long as the syllabus for the course is covered and the learning outcomes achievable.

Example set-up:
Engineering tool, GSD Viewer, (IO Supervisor), IO Controller, 2 IO Devices, 1 monitoring switch, packet analyzer, cables and connectors, stripping tool, devices from at least 2 different manufacturers shall be included.

Devices and components from any supplier can be used (connectors, cables, passive devices). Recommendation: at least 2 different suppliers should be included in the equipment.

No more than two students should share a training kit.

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8 Assessment Scheme

The assessment is a combination of practical and theory examinations. Candidates must pass both components to pass the course. A candidate must score 70% in each component to pass the course.

Practical Test (Duration 1½ - 2 hours)

The candidate will be examined according to the learning outcomes specified in sections 2.7 and 2.8 of this document.

Theory Test: (Duration 2 Hours)

The candidate will be examined according to the learning outcomes specified in sections 2.1 - 2.6 and 2.9 – 2.10 of this document.

The exam questions must be picked from a central database of questions; this database is set up and administered by PI. This task may also be delegated to a member of the SU4/WG1. Each question in the database is given a weight in points. Each PITC should select appropriate number of questions from each section to achieve the breakdown given above.