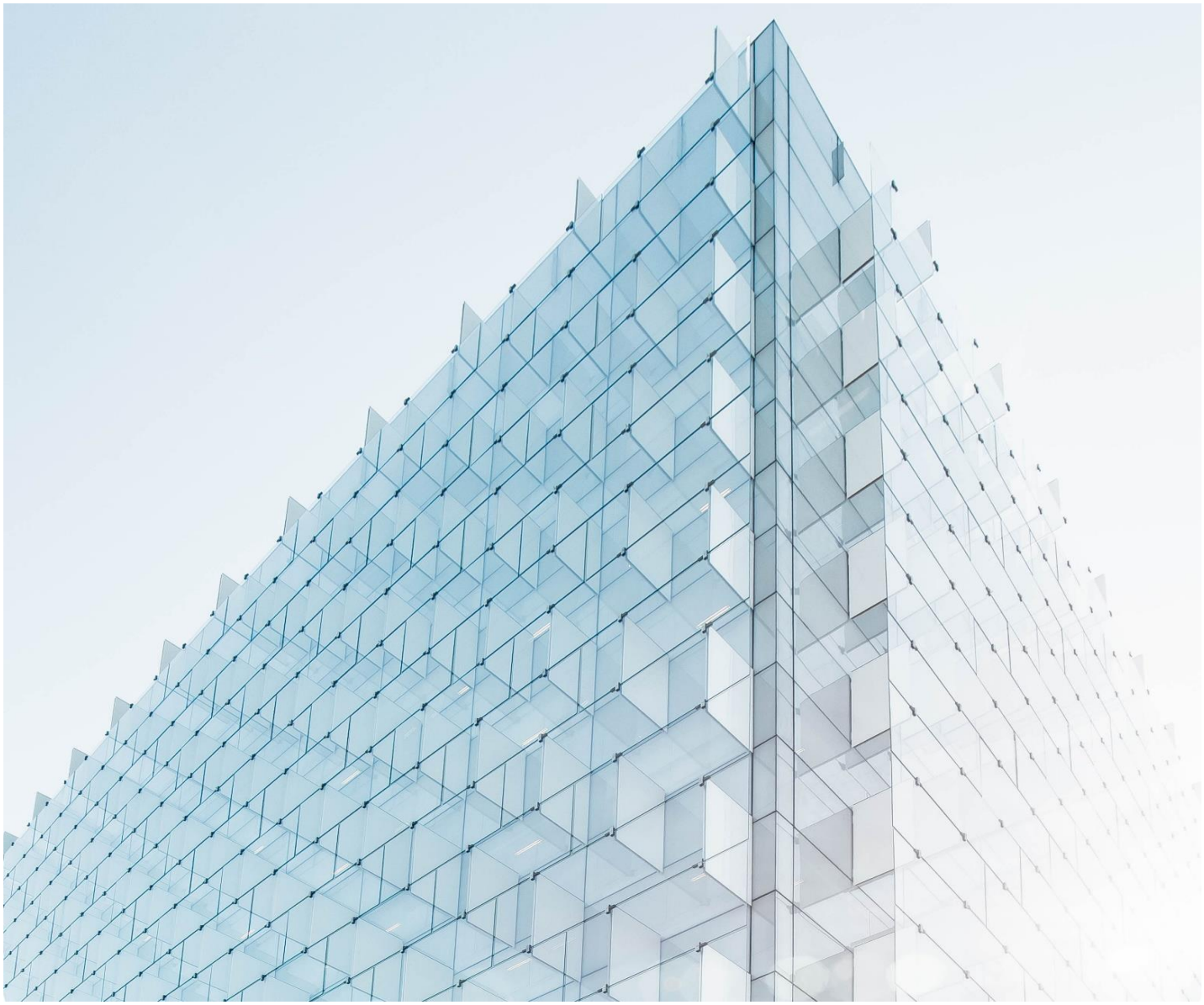
Automated Ethernet-APL
Power & Data Conformance Testing
Load/Sensor Devices

Whitepaper



ethernet-apl™
advanced physical layer

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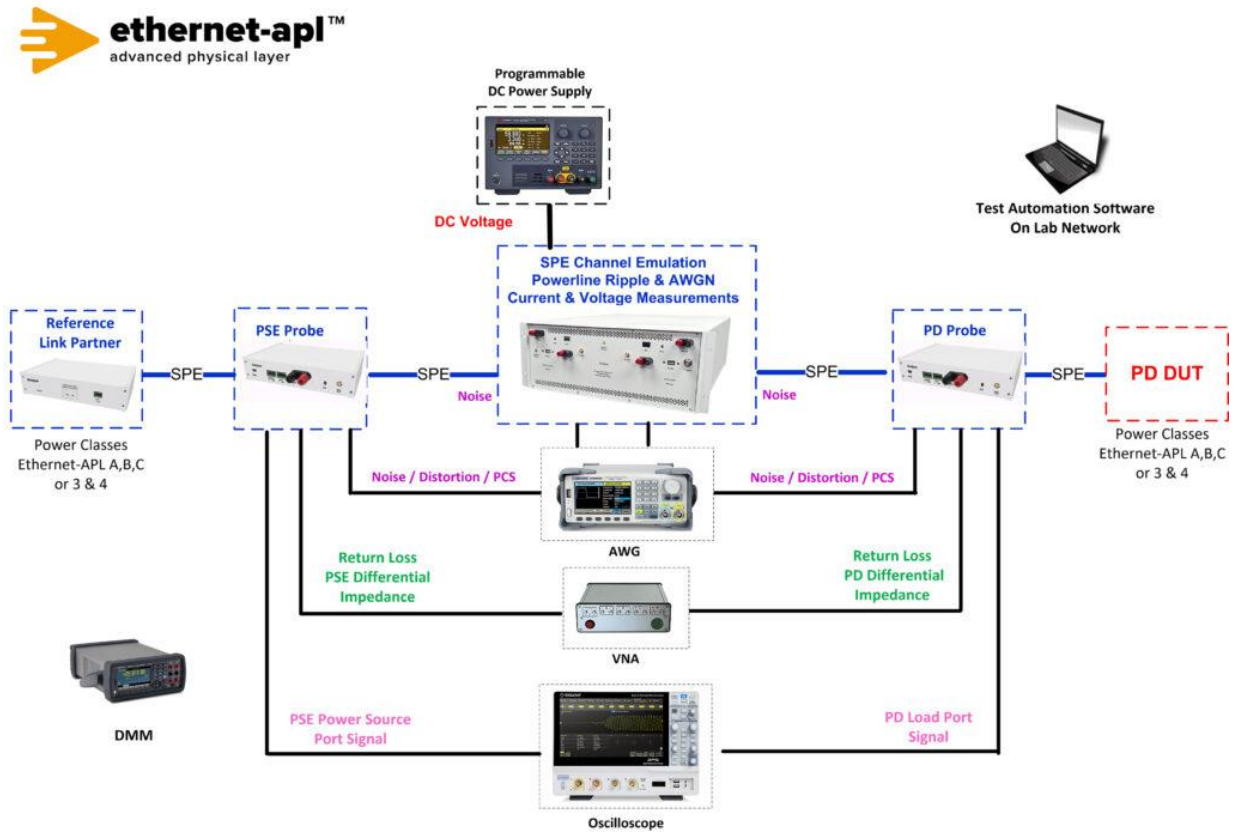
1 Benefits of the Automated Approach

Telebyte's Ethernet-APL Universal Test Setup supports PD Load ports with one setup for Ethernet-APL Conformance and Interoperability Data and Power testing. The small footprint saves valuable laboratory test space while the fully automated approach saves time and money and provides repeatable test results. The solution is easy to use, allowing tests to be performed by technicians with minimal training. There is no need to plug/unplug different instruments and fixtures in the test setup. Additional features include automated software for controlling DUTs and all test equipment. The software generates Pass / Fail Reports for Ethernet-APL Conformance Power and Data tests. A customer's PC with a serial and network connection is used to transfer data to the PC for post processing the captured Ethernet signal with Telebyte's Test Automation Software. Customers may purchase all integrated test setup instruments from Telebyte. Please note this same setup (with the addition of a DC programmable load) can be used for testing PSE switches. An optional switch matrix is available for switching in of multiple DUTs in a test bed.

2 Test Setup & Required Equipment



Required Equipment:

Telebyte 4950 10BASE-T1L Channel Emulator
Telebyte SPE Test Automation Software
Telebyte 4950-P01 Probe
10BASE-T1L Reference Link Partner
AEM MMVNA 8-Channel Vectored Network Analyzer
Keysight E36232A Programmable Power Supply
Siglent SDS2204X Digital Storage Oscilloscope
Siglent SDG6022X Arbitrary Waveform Generator (AWG)
Keysight KT-34465A Truevolt Digital Multimeter

Telebyte Product Information

Telebyte 4950 10BASE-T1L Channel Emulator

Telebyte's Model 4950 offers the world's first standard-based channel / cable emulator designed for testing Single Pair Ethernet (SPE) and supports a universal test setup with two Model 4950-P01 Multifunction Probes at the Power Source Port and Powered Device or Load Port.

This full duplex link supports power and communications over the same data line connected to devices at the edge of the "smart factory" network. The cost-effective technology provides data and analytics for industrial automation including control systems and cloud applications for remote operation as well as monitoring and management of the entire "intelligent building." Elevators, HVAC, power, security access, wireless access points, sensors, industrial controls, cameras, robotics, railway and transportation as well as lighting may all be integrated on the enterprise network.

Model 4950-P01 SPE Multifunction Probe

Single Pair Ethernet Testing Solution
For use with the Model 4950 Channel Emulator

The Telebyte 4950-P01 SPE Multifunction Probe test instrument is designed specifically for testing Single Pair Ethernet (SPE) 10BASE-T1L with Power over Dataline (PoDL) as defined in the Ethernet-APL Data Test Specification v1.5, Power Test Specification v1.2 and the IEEE 802.3-2022 standard.

This specialized instrument is used with the Model 4950 Channel Emulator to test a wide range of Power Source Ports (PSE) and Powered Device (PD or Load) ports in applications such as Auto-Negotiation Tests, Transmitter Tests, BER Receiver Test, Power coupling and decoupling, noise generation (including background and impulsive noise), noise capture to replicate field environments in the lab, Power Spectral Density (PSD) and power level measurements, Transmitter clock frequency, distortion and jitter measurements, Voltage Droop, MDI Return Loss, PoDL / SPoE measurements and more.

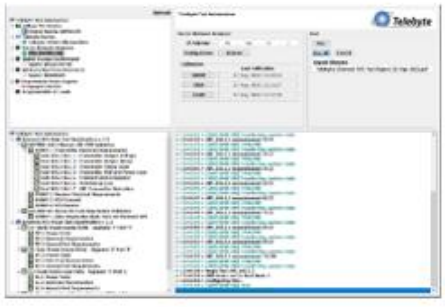
This physical layer compliance test solution ensures interoperability between different designs and applications offered by hardware vendors. It features a variety of functions designed to enable and simplify automation of a universal test setup with no manual changes of patch cables or test fixtures (e.g., jigs, baluns) in the test setup.

Telebyte Product Information continued

Model 4925
Reference Link Partner

Power Source (PSE)
or Power Load (PD) Emulator

The Telebyte 4925 Reference Link Partner is a specialized instrument used with Telebyte's Model 4950 Channel Emulator to provide engineers with a valuable test tool in the development of a PD load device or PSE switch device. The Emulator can serve as a reference link partner for power and data conformance testing of the IEEE 802.3-2022 and IEEE 802.3dd-2022 standards. In addition, it may be used to simulate an Ethernet-APL Power Source (PSE) device or as a PD Emulator simulating an Ethernet-APL Load (PD) device.



Telebyte SPE Test Automation Software

Automation of SPE
Standards-Based Testing

The Telebyte SPE Test Automation Software provides easy control and configuration of the devices in the test bed as well as data storage and reporting. This automates, unifies, standardizes and simplifies the testing process, thereby enabling repeatability across implementations, saving time and lowering costs. Designed for automated testing following the standards:

Ethernet-APL

- Ethernet-APL Port Profile Specification (FCG TS10186) Rev 1.2
- Ethernet-APL Data Test Specification (FCG TT10188) Rev 1.5.4
- Ethernet-APL Power Test Specification (FCG TT10189) Rev 1.3

IEEE 802.3 – 2022 / IEEE 802.3dd (Coming soon)

3 Required Tests

Ethernet-APL Data Test Specification
Group 1: Transmitter Electrical Measurements
Test APL.146.1.1 – Transmitter Output Voltage (Test Mode 1)
Test APL.146.1.2 – Transmitter Output Droop (Test Mode 2)
Test APL.146.1.3 – Transmitter Timing Jitter (Test Mode 1)
Test APL.146.1.4 – Transmitter Power Spectral Density (PSD) and Power Level (Test Mode 3)
Test APL.146.1.5 – Transmit Clock Frequency (Test Mode 1)
Test APL.146.1.6 – MDI Return Loss (Part A: Tx disabled: DUT in Slave, high Z state)
Test APL.146.1.6 – MDI Return Loss (Part B: Test Mode 3 VNA with narrowband IF of 100Hz)
Test APL.146.1.7 – Transmitter Distortion (Test Mode 2) with 1MHz Sinusoidal Disturber at 1.0Vpp and/or 2.4Vpp
Group 2: Receiver Electrical Measurements
Test APL.146.2.1 – Receiver Packet Error Rate Stress Test
Traffic Testing – Link Quality SNR better than 20dB, DUT Passing BER < 10^{-9}
Group 3: Transmit Packet Formation
Test APL.146.3.1 – Transmit Signaling
Group 4: Receive Error Handling
Test APL.146.4.1 – Automatic Polarity Detection and Correction
Test APL.146.4.2 – Handling of Received ESD_ERR4

Test APL.146.4.3 – Handling of Received CRC Errors

Section 98: Ethernet-APL Clause 98 Auto-Negotiation Validation

Group 1: Auto –Negotiation Basic Tests for Ethernet-APL

Test APL.98.1.1 – Advertisement and Auto-Negotiation Verification

Part A: DUT advertises valid capabilities

Part B: DUT links with compatible link partner

Part C: DUT spur port when LP advertises but does not request increased transmit level

Part D: DUT behavior with incompatible link partner (spur to trunk, trunk to spur)

Part E: DUT behaves properly with incompatible link partner (spur to trunk, trunk to spur)

Part F: DUT behavior when link partner prefers master or slave port role (M/S is always 0).

Part G: DUT behavior when link partner forces master or slave port role (M/S is always 1).

Test APL.98.1.2 – Management Restart of Auto-Negotiation

Test APL.98.1.3 – Link Status Fail

Test APL.98.1.4 – DME Voltage Envelope Test

Test APL.98.1.5 – Auto-Negotiated Link-Up Time

Ethernet-APL Power Test Specification

TL.1 Power Tests

TL.1.1 Minimum Current Draw Minimum Supply Voltage 28.8 V

TL.1.1 Minimum Current Draw Maximum Supply Voltage 50V

TL.1.2 Inrush Current

TL.2 Electrical Characteristics

TL.2.1 Differential In-Band Ripple and Noise

TL.2.2 Differential Out-Band Ripple and Noise

TL.2.3 Current Derivatives

TL.2.4 Current Events Maximum Supply Voltage 50V

TL.2.5 Under Voltage Current

TL.3 General Port Requirements

TL.3.1 Terminal and Connectors

TL.3.2 Shielding Options*

TL.3.3 Polarity Sensitivity Mode A + / –

TL.3.3 Polarity Sensitivity Mode B – / +

SL: Spur Power Load Ports – Segment 'S'; Port 'L'

SL.1 Power Tests

SL.1.1 Minimum Current Draw Minimum Supply Voltage UPL(min) Class A=9V ClassC =10.6V

SL.1.1 Minimum Current Draw Maximum Supply Voltage UPL(min) Class A and C = 15V

SL.1.2 Inrush Current

SL.2 Electrical Characteristics

SL.2.1 Differential In-Band Ripple and Noise Maximum Supply Voltage UPS(max) Class A and C = 15V

SL.2.1 Differential In-Band Ripple and Noise Minimum Load Voltage UPL(min) Class A=9V ClassC =10.6V

SL.2.2 Differential Out-Band Ripple and Noise Maximum Supply Voltage UPS(max) Class A and C = 15V

SL.2.2 Differential Out-Band Ripple and Noise Minimum Load Voltage UPL(min) Class A=9V ClassC =10.6V

SL.2.3 Current Derivatives Maximum Supply Voltage UPS(max) Class A and C = 15V

SL.2.3 Current Derivatives Minimum Load Voltage UPL(min) Class A=9V ClassC =10.6V

SL.2.4 Current Events Minimum Load Voltage UPL(min) Class A=9V ClassC =10.6V

SL.2.4 Current Events Maximum Supply Voltage UPS(max) Class A and C = 15V

SL.2.5 Under Voltage Current

SL.3 General Port Requirements

SL.3.1 Terminal and Connectors

SL.3.2 Shielding Options*

SL.3.3 Polarity Sensitivity Mode A + / –

SL.3.3 Polarity Sensitivity Mode B – / +

* External DMM required (KT-34465A direct measurement)

4 Appendix – Detailed Test Cases

This section provides detailed information about the required tests listed in the previous section including test name and type, purpose, required equipment, setup diagrams, and expected results.

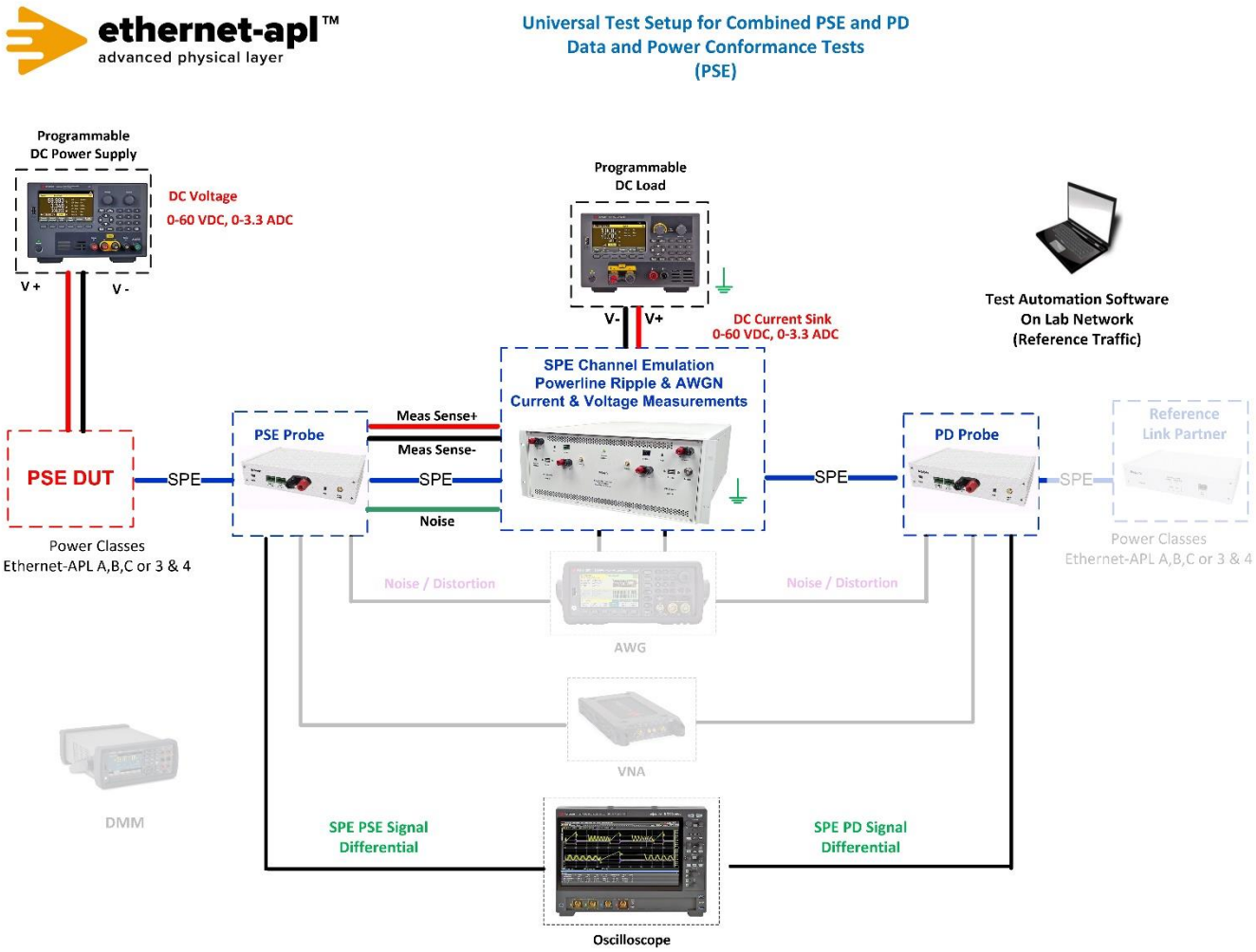
Test Type (Data or Power): Data
Test Name: 146.1.1 Transmitter Output Voltage

Purpose/Description: To verify that the transmitter output voltage does not exceed the maximum and minimum specified value for peak-to-peak voltage.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. Oscilloscope
7. Test Automation Software

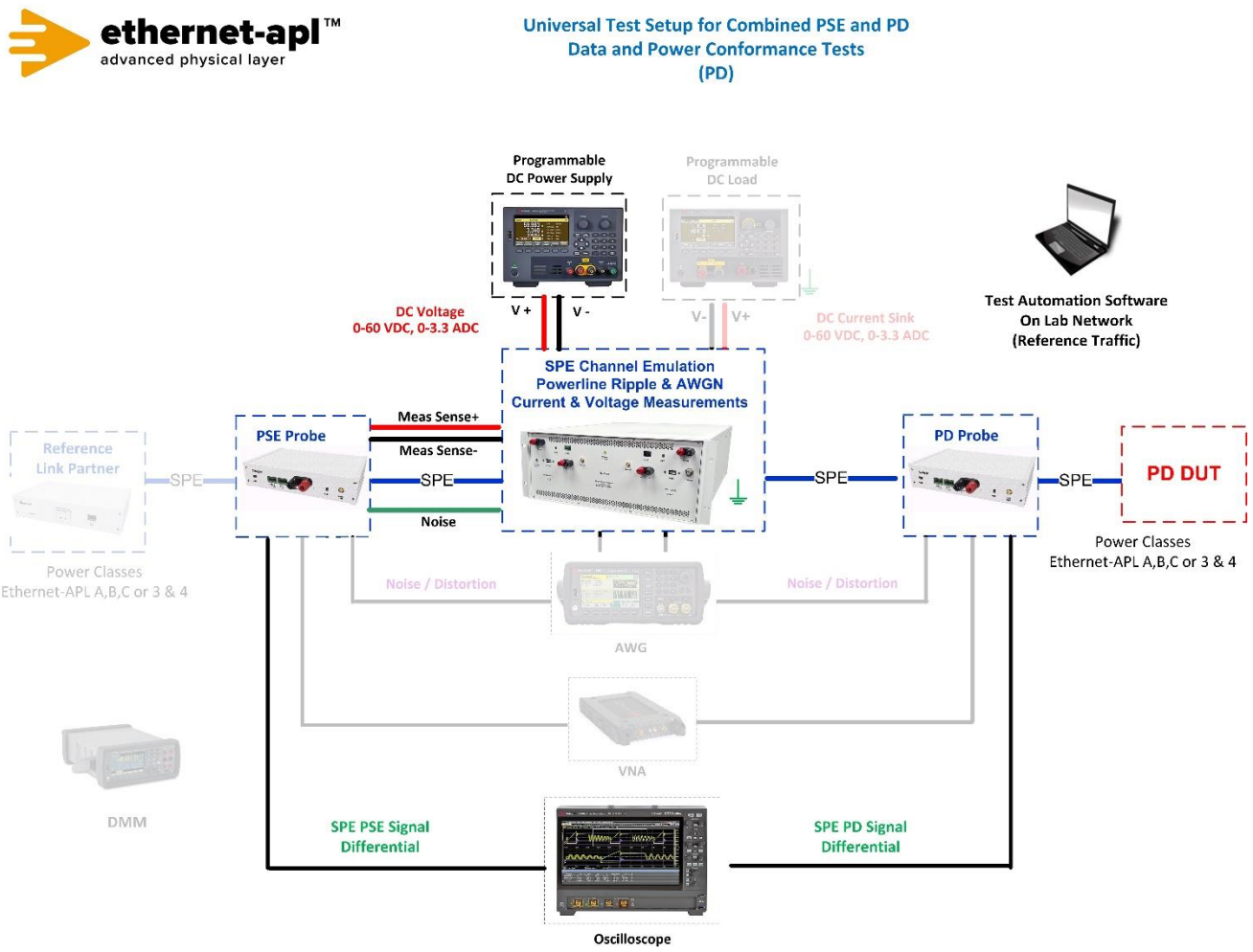
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. Oscilloscope
6. Test Automation Software

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Part A: Spur (1.0 Vpp operating mode) transmitter output voltage check

Step	Status	Description
A:10	PASS	In 1.0 Vpp operating mode, both of the Vpp_max and Vpp_min voltages are within 1.0V + 5% / - 15% for all of the ten 1 ms captures.
A:10	FAIL	In 1.0 Vpp operating mode, either of the Vpp_max and Vpp_min voltages are not within 1.0V + 5% / - 15% for any of the ten 1 ms captures.

Part B: Trunk (2.4 Vpp operating mode) transmitter output voltage check

Step	Status	Description
B:11	PASS	In 2.4 Vpp operating mode, both of the Vpp_max and Vpp_min voltages are within 2.4V + 5% / - 15% for all of the ten 1 ms captures.
B:11	FAIL	In 2.4 Vpp operating mode, either of the Vpp_max and Vpp_min voltages are not within 2.4V + 5% / - 15% for any of the ten 1 ms captures.

Notes:

References:

[1] IEEE Std. 802.3cg-2019, subclause 146.5.2 – Test modes
[2] Ibid., subclause 146.5.3 – Test Fixtures
[3] Ibid., section 146.5.4.1 – Transmitter Output Voltage
[4] Test plan Appendix E – 10BASE-T1L Test Fixtures

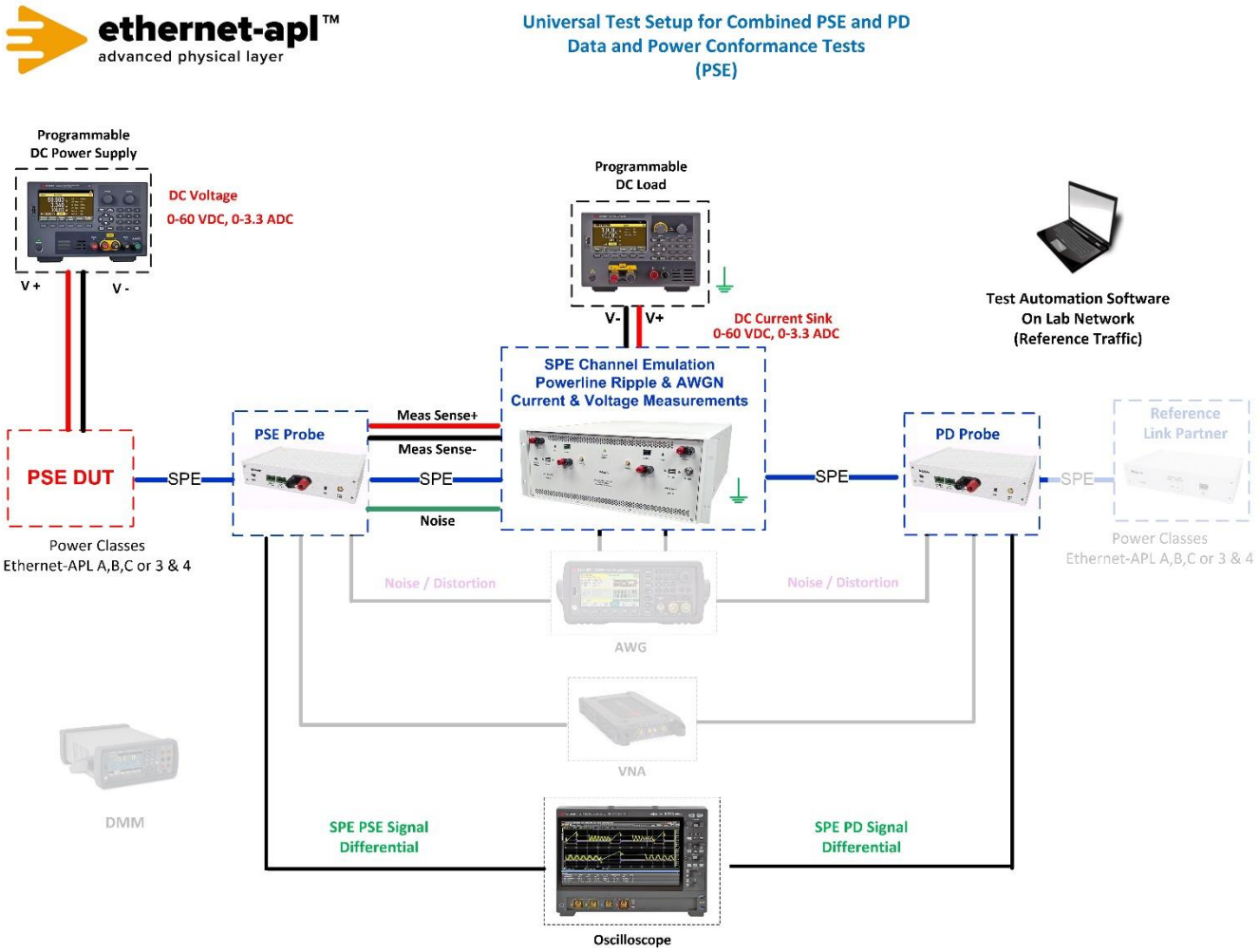
Test Type (Data or Power): Data
Test Name: 146.1.2 Transmitter Output Droop

Purpose/Description: To verify that the transmitter output level does not droop more than the maximum specified amount.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. Oscilloscope
7. Test Automation Software

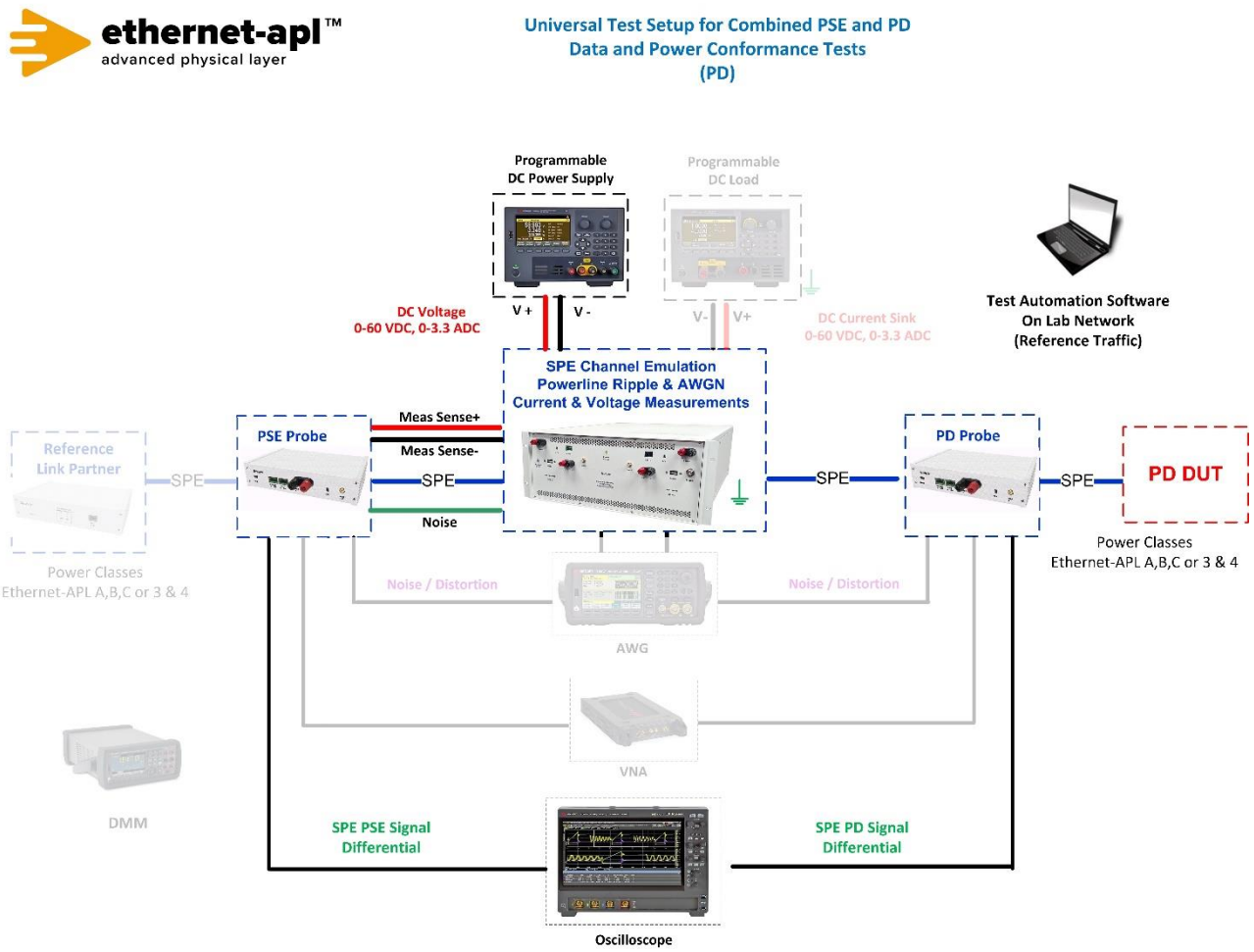
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. Oscilloscope
6. Test Automation Software with PCS Encoding and Decoding

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Part A: Spur Source (1.0 Vpp operating mode) transmitter output droop

Step	Status	Description
A	N/A	The DUT is not a Spur Source port.
A:8	Fail	The magnitude of any positive droop (Dpos) is more than 10.0% or 15.0% when a power coupling network is involved for any of the ten 1 ms captures.
A:8	Fail	The magnitude of any negative droop (Dneg) is more than 10.0% or 15.0% when a power coupling network is involved for any of the ten 1 ms captures.
A:8	Pass	The magnitude of all the observed positive and negative droop is observed to be less than 10.0% or 15.0% when a power coupling network is involved for all of the ten 1 ms captures.

Part B: Trunk Source (2.4Vpp operating mode) transmitter output droop

Step	Status	Description
B	N/A	The DUT is not a Trunk Source port.
B:9	Fail	The magnitude of the positive droop is more than 10.0% or 15.0% when a power coupling network is involved for any of the ten 1 ms captures.
B:9	Fail	The magnitude of the negative droop is more than 10.0% or 15.0% when a power coupling network is involved for any of the ten 1 ms captures.
B:9	Pass	The magnitude of the positive and negative droop is observed to be less than 10.0% or 15.0% when a power coupling network is involved for all of the ten 1 ms captures.

Part C: Spur Load (1.0 Vpp operating mode) transmitter output droop

Step	Status	Description
C:8	N/A	The DUT is not a Spur Load port.
C:8	Fail	The magnitude of any positive droop (Dpos) is more than 15.0% for any of the ten 1 ms captures.
C:8	Fail	The magnitude of any negative droop (Dneg) is more than 15.0% for any of the ten 1 ms captures.
C:8	Pass	The magnitude of all the observed positive and negative droop is observed to be less than 15.0% for all of the ten 1 ms captures.

Part D: Trunk Load (2.4Vpp operating mode) transmitter output droop

Step	Status	Description
D:8	N/A	The DUT is not a Trunk Load port.
D:8	Fail	The magnitude of any positive droop (Dpos) is more than 15.0% for any of the ten 1 ms captures.
D:8	Fail	The magnitude of any negative droop (Dneg) is more than 15.0% for any of the ten 1 ms captures.
D:8	Pass	The magnitude of all the observed positive and negative droop is observed to be less than 15.0% for all of the ten 1 ms captures.

Notes:

References:

[1] IEEE Std. 802.3cg-2019, subclause 146.5.2 – Test modes
[2] Ibid., subclause 146.5.3 – Test Fixtures
[3] Ibid., section 146.5.4.2 – Transmitter Output Droop
[4] Test plan Appendix E – 10BASE-T1L Test Fixtures
[5] Ethernet–APL Port Profile Specification v1.2 – clause 4.1

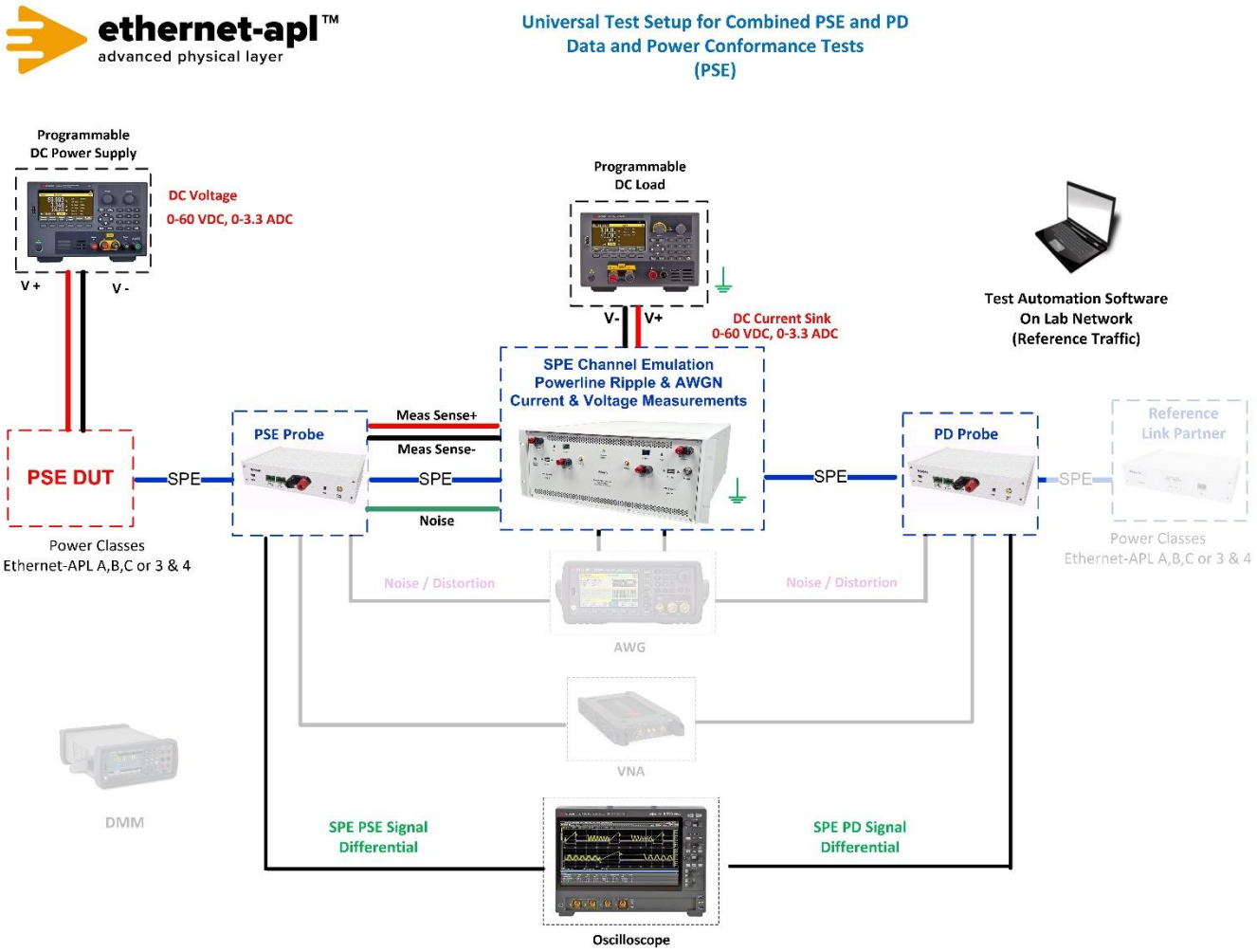
Test Type (Data or Power): Data
Test Name: 146.1.3 Transmitter Timing Jitter

Purpose/Description: To verify that the transmitter timing jitter of the PMA is within the conformance limits.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. Oscilloscope
7. Test Automation Software

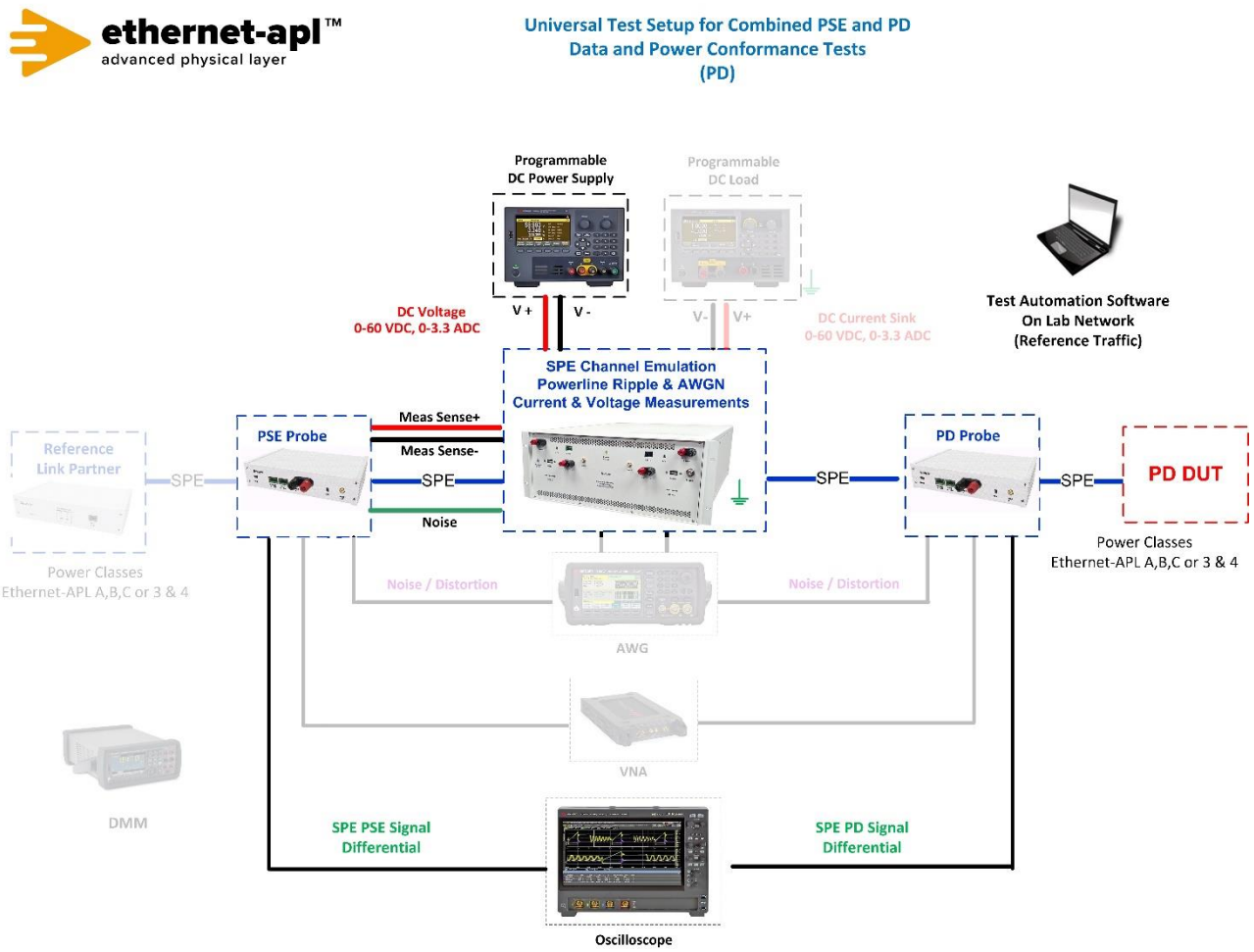
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. Oscilloscope
6. Test Automation Software

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Part A: Spur (1.0 Vpp operating mode) transmitter timing jitter

Step	Status	Description
A:7	Fail	The maximum jitter at the transmitter side is more than 10 ns symbol-to-symbol jitter for any of the ten 10 ms captures.
A:7	Pass	The maximum jitter at the transmitter side is observed to be less than 10 ns symbol-to-symbol jitter for all of the ten 1 ms captures.

Part B: Trunk (2.4 Vpp operating mode) transmitter timing jitter

Step	Status	Description
B:7	Fail	The maximum jitter at the transmitter side is more than 10 ns symbol-to-symbol jitter for any of the ten 10 ms captures.
B:7	Pass	The maximum jitter at the transmitter side is observed to be less than 10 ns symbol-to-symbol jitter for all of the ten 1 ms captures.

Notes:

References:

[1] IEEE Std. 802.3-2022, subclause 146.5.2 – Test modes
[2] Ibid., subclause 146.5.3 – Test Fixtures
[3] Ibid., section 146.5.4.3 – Transmitter Timing Jitter
[4] Test plan Appendix E – 10BASE-T1L Test Fixtures

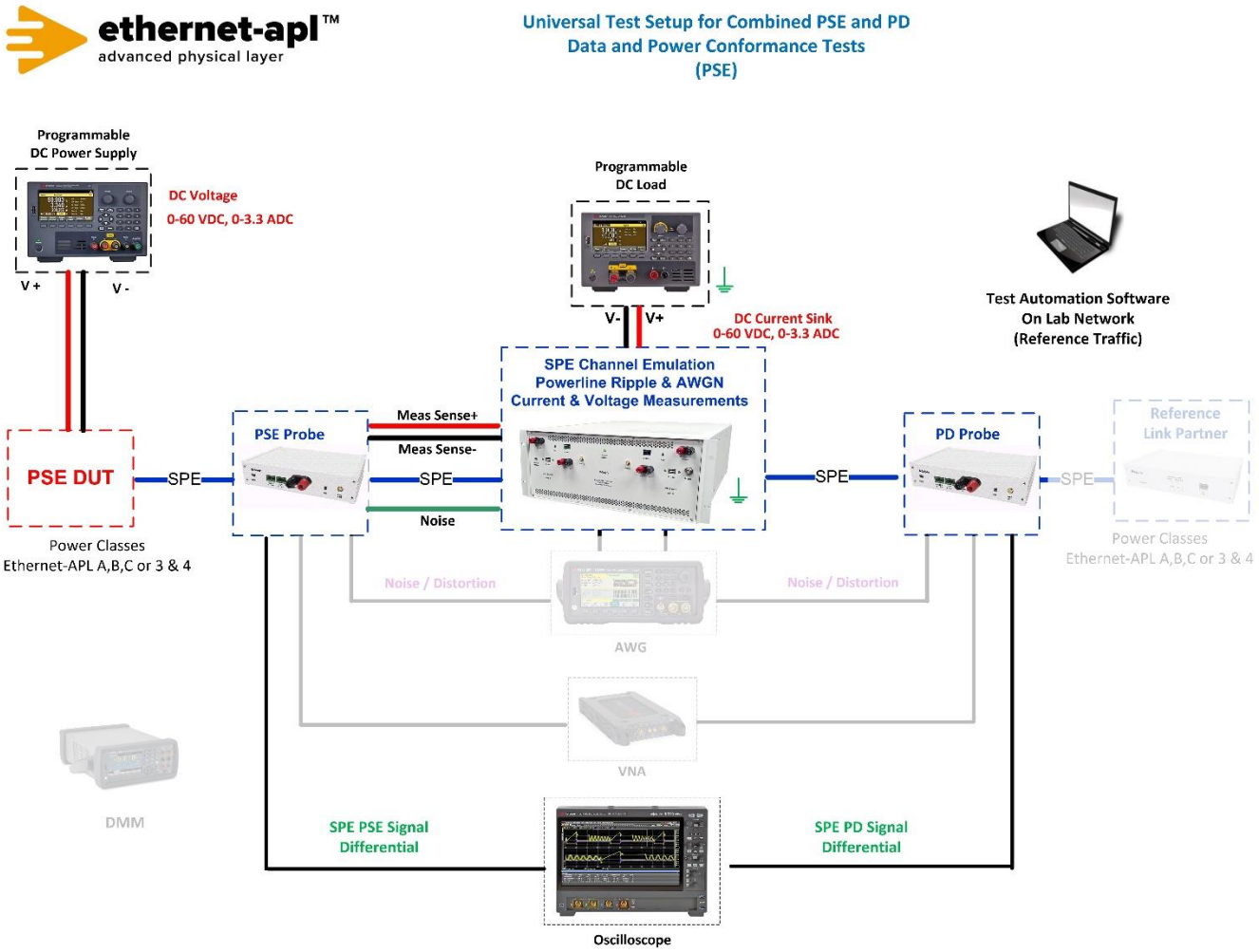
Test Type (Data or Power): Data
Test Name: 146.1.4 Transmitter Power Spectral Density and Power Level

Purpose/Description: To verify that the transmitter power spectral density and power level are within the conformance limits.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. Oscilloscope
7. Test Automation Software

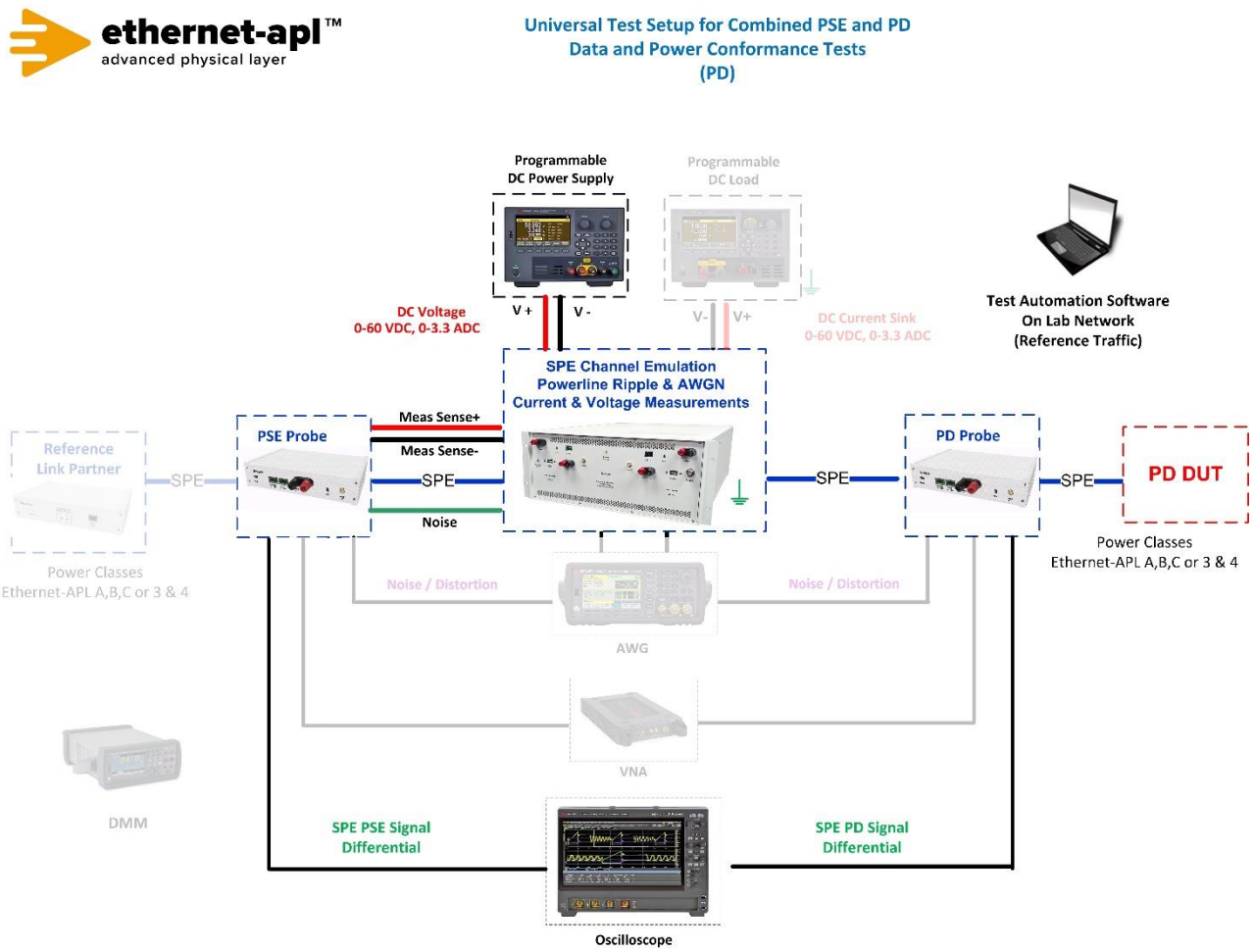
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. Oscilloscope
6. Test Automation Software

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Part A: Spur (1.0 Vpp operating mode) PSD and Power level

Step	Status	Description
A:7	Fail	The PSD of the transmitter output while operating in test mode 3 is not observed to fit within the transmitter 1.0 Vpp PSD mask defined in [3].
A:7	Fail	The power level of the transmitter output while operating in test mode 3 is not observed to be within 1.0 ± 1.2 dBm.
A:7	Pass	a. The PSD of the transmitter output while operating in test mode 3 is observed to fit within the transmitter 1.0 Vpp PSD mask defined in [3]. b. The power level of the transmitter output while operating in test mode 3 is observed to be within 1.0 ± 1.2 dBm.

Part B: Trunk (2.4 Vpp operating mode) PSD and Power level

Step	Status	Description
B:7	Fail	The PSD of the transmitter output while operating in test mode 3 is not observed to fit within the transmitter 2.4 Vpp PSD mask defined in [3].
B:7	Fail	The power level of the transmitter output while operating in test mode 3 is not observed to be within 8.6 ± 1.2 dBm.
B:7	Pass	a. The PSD of the transmitter output while operating in test mode 3 shall fit within the transmitter 2.4 Vpp PSD mask defined in [3]. b. The power level of the transmitter output while operating in test mode 3 is observed to be within 8.6 ± 1.2 dBm.

Notes:

References:

[1] IEEE Std. 802.3cg-2019, subclause 146.5.2 – Test modes
[2] Ibid., subclause 146.5.3 – Test Fixtures
[3] Ibid., section 146.5.4.4 – Transmitter Power Spectral Density and Power Level
[4] Test plan Appendix E – 10BASE-T1L Test Fixtures

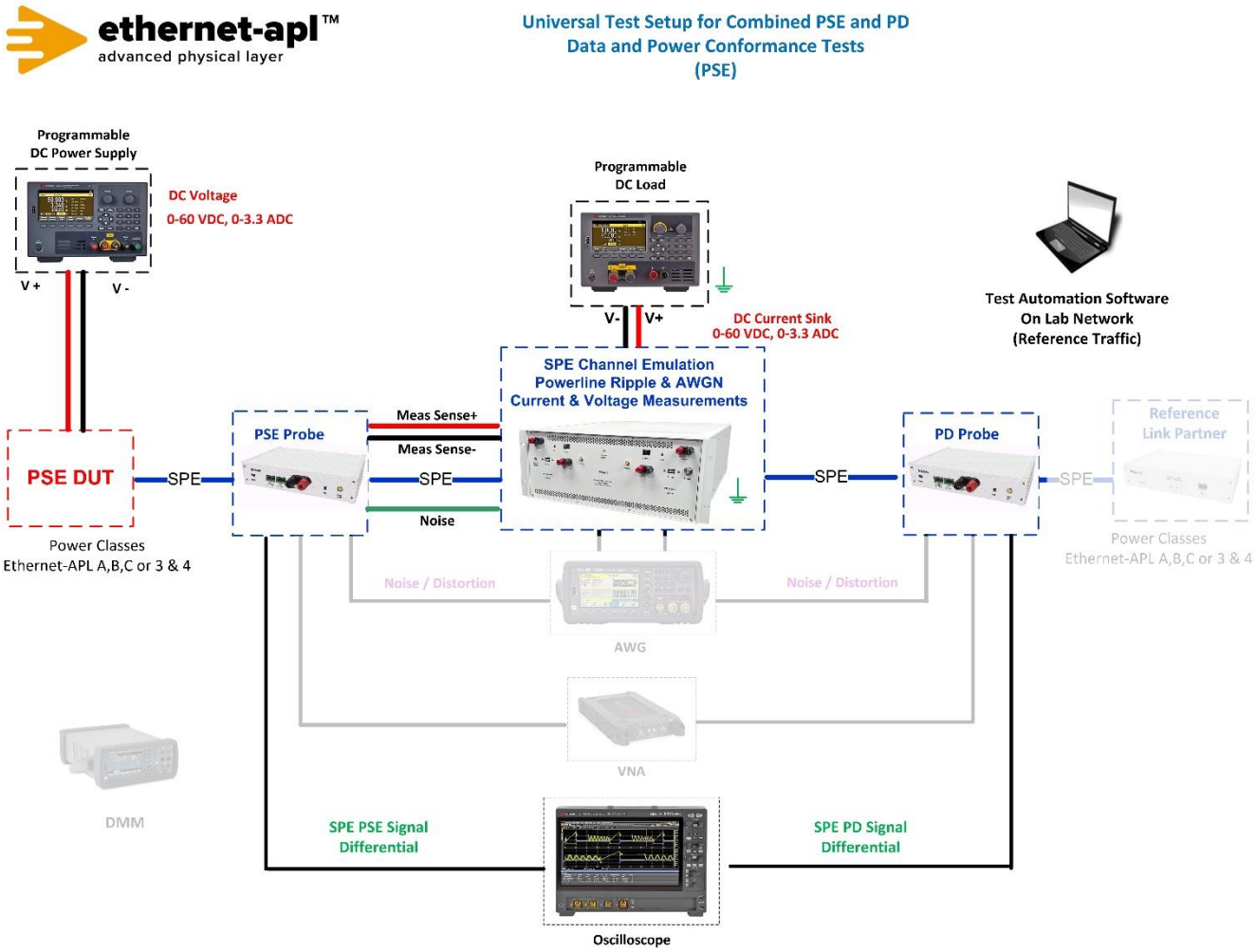
Test Type (Data or Power): Data
Test Name: 146.1.5 Transmit Clock Frequency

Purpose/Description: To verify that the frequency of the Transmit Clock is within the conformance limits.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. Oscilloscope
7. Test Automation Software

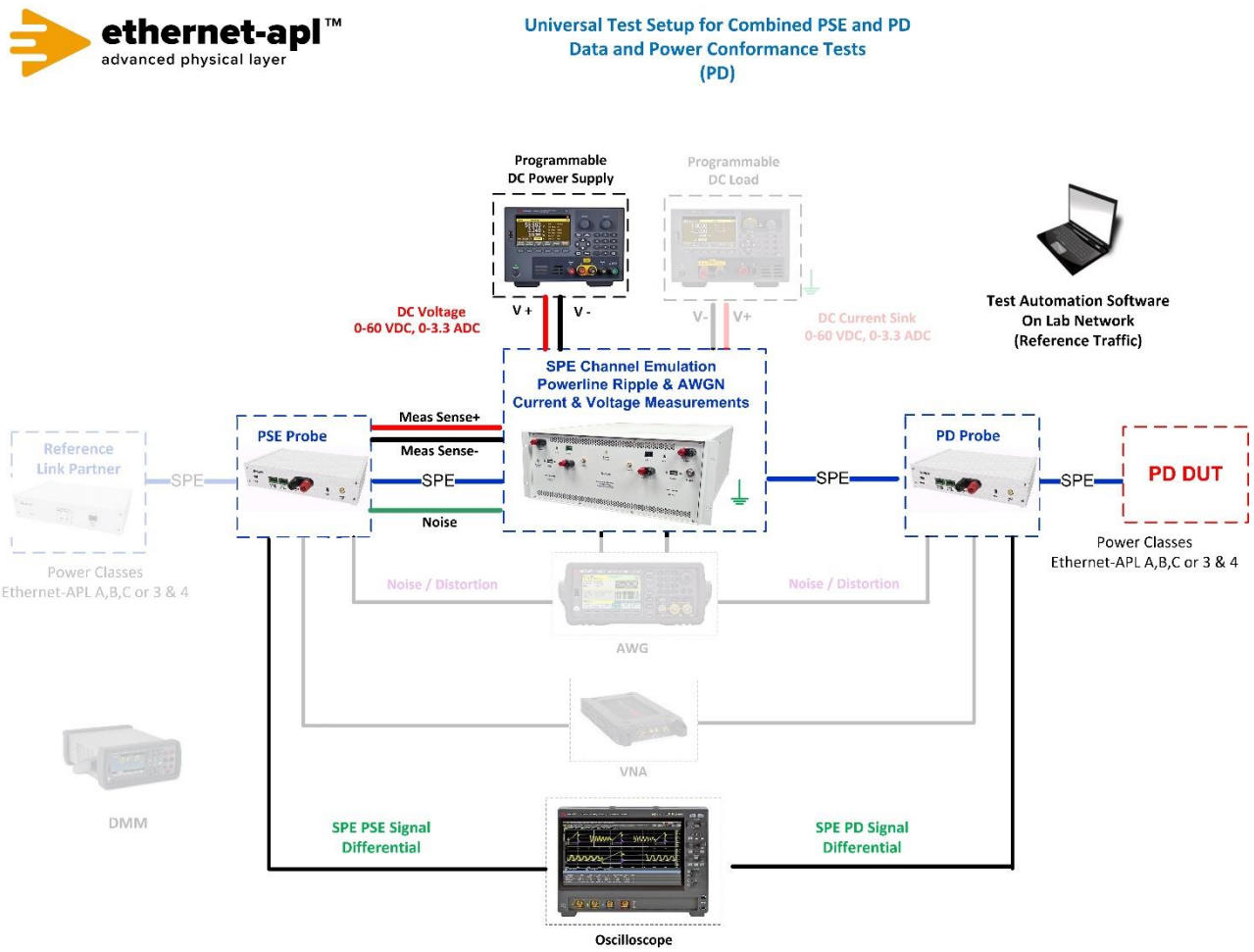
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. Oscilloscope
6. Test Automation Software

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Part A: Spur (1.0 Vpp operating mode) transmitter clock frequency

Step	Status	Description
A:7	Fail	The transmit clock generated by the DUT is not observed to have a frequency between 7.499625 MBd and 7.500375 MBd.
A:7	Pass	The transmit clock generated by the DUT is observed to have a frequency between 7.499625 MBd and 7.500375 MBd.

Part B: Trunk (2.4 Vpp operating mode) transmitter clock frequency

Step	Status	Description
B:6	Fail	In any observed capture, the transmit clock generated by the DUT is not observed to have a frequency between 7.499625 MBd and 7.500375 MBd.
B:6	Pass	The transmit clock generated by the DUT is observed to have a frequency between 7.499625 MBd and 7.500375 MBd.

Notes:

References:

[1] IEEE Std. 802.3-2022, subclause 146.5.4.5 – Transmit Clock Frequency.
[2] Test plan Appendix E – 10BASE-T1L Test Fixtures

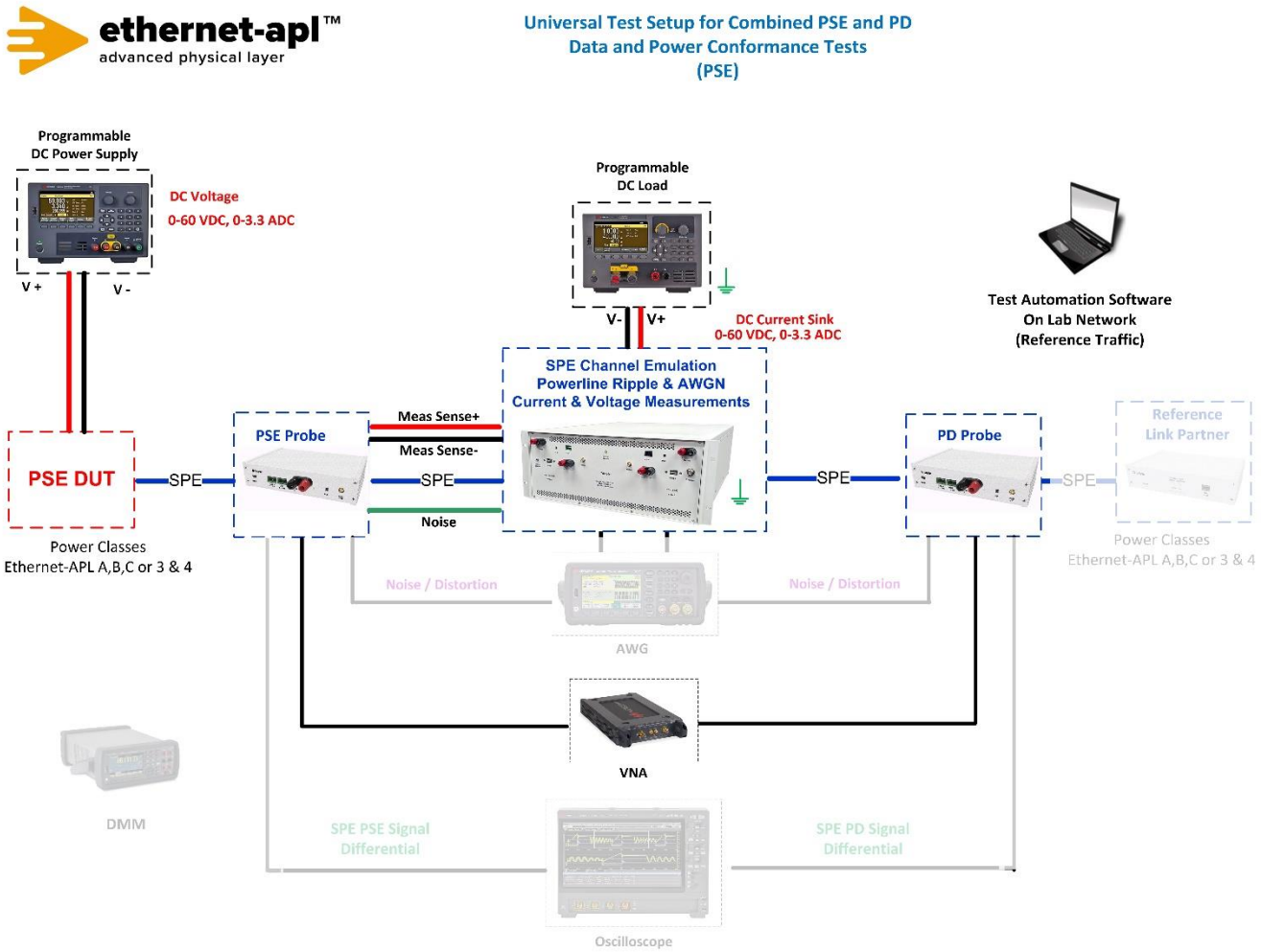
Test Type (Data or Power): Data
Test Name: 146.1.6 MDI Return Loss

Purpose/Description: To measure the return loss at the MDI.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. VNA
7. Test Automation Software

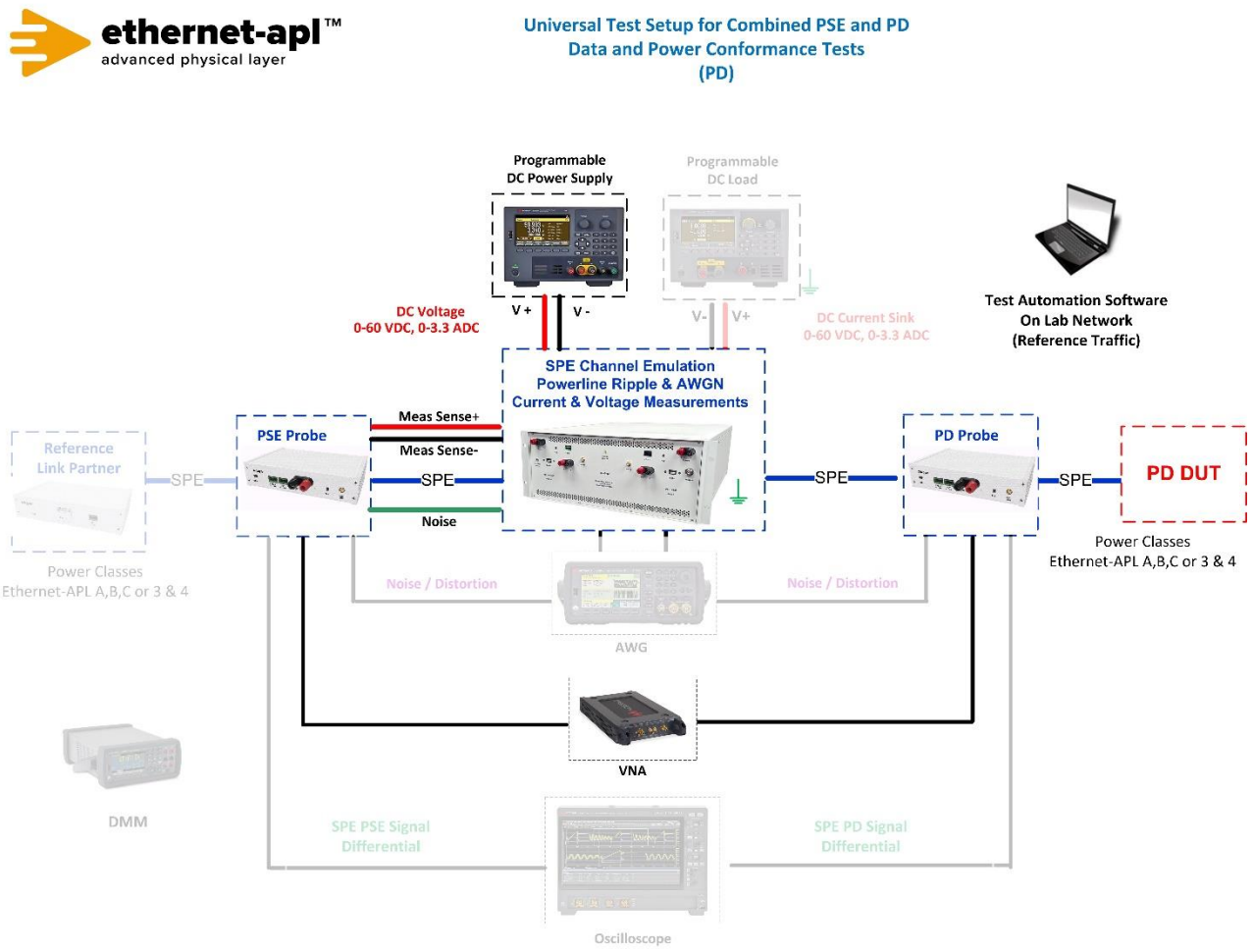
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. VNA
6. Test Automation Software

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Part A: Spur (1.0 Vpp operating mode) MDI return loss in SEND_Z

Step	Status	Description
A:6	Fail	The return loss measured at the MDI is not observed to be at least 20 – 18*log(0.2/f) dB from 100 to 200 kHz, 20 dB from 200 kHz to 1 MHz, 20 – 16.7*log(f) dB from 1 to 10 MHz, and 3.3 – 7.6*log(f/10) dB from 10 to 20 MHz.
A:6	Pass	The return loss measured at the MDI is observed to be at least 20 – 18*log(0.2/f) dB from 100 to 200 kHz, 20 dB from 200 kHz to 1 MHz, 20 – 16.7*log(f) dB from 1 to 10 MHz, and 3.3 – 7.6*log(f/10) dB from 10 to 20 MHz.

Part B: Spur (1.0 Vpp operating mode) MDI return loss in Test Mode 3.

Step	Status	Description
B:6	Fail	The return loss measured at the MDI is not observed to be at least 20 – 18*log(0.2/f) dB from 100 to 200 kHz, 20 dB from 200 kHz to 1 MHz, 20 – 16.7*log(f) dB from 1 to 10 MHz, and 3.3 – 7.6*log(f/10) dB from 10 to 20 MHz.
B:6	Pass	The return loss measured at the MDI is observed to be at least 20 – 18*log(0.2/f) dB from 100 to 200 kHz, 20 dB from 200 kHz to 1 MHz, 20 – 16.7*log(f) dB from 1 to 10 MHz, and 3.3 – 7.6*log(f/10) dB from 10 to 20 MHz.

Part C: Trunk (2.4 Vpp operating mode) MDI return loss in SEND_Z.

Step	Status	Description
C:6	Fail	The return loss measured at the MDI is not observed to be at least 20 – 18*log(0.2/f) dB from 100 to 200 kHz, 20 dB from 200 kHz to 1 MHz, 20 – 16.7*log(f) dB from 1 to 10 MHz, and 3.3 – 7.6*log(f/10) dB from 10 to 20 MHz.
C:6	Pass	The return loss measured at the MDI is observed to be at least 20 – 18*log(0.2/f) dB from 100 to 200 kHz, 20 dB from 200 kHz to 1 MHz, 20 – 16.7*log(f) dB from 1 to 10 MHz, and 3.3 – 7.6*log(f/10) dB from 10 to 20 MHz.

Part D: Trunk (2.4 Vpp operating mode) MDI return loss.

Step	Status	Description
D:6	Fail	The return loss measured at the MDI is not observed to be at least 20 – 18*log(0.2/f) dB from 100 to 200 kHz, 20 dB from 200 kHz to 1 MHz, 20 – 16.7*log(f) dB from 1 to 10 MHz, and 3.3 – 7.6*log(f/10) dB from 10 to 20 MHz.
D:6	Pass	The return loss measured at the MDI is observed to be at least 20 – 18*log(0.2/f) dB from 100 to 200 kHz, 20 dB from 200 kHz to 1 MHz, 20 – 16.7*log(f) dB from 1 to 10 MHz, and 3.3 – 7.6*log(f/10) dB from 10 to 20 MHz.

Notes:

References:

[1] IEEE Std. 802.3-2022, section 146.8.3 – MDI Return Loss
[2] Test plan Appendix E – 10BASE-T1L Test Fixtures

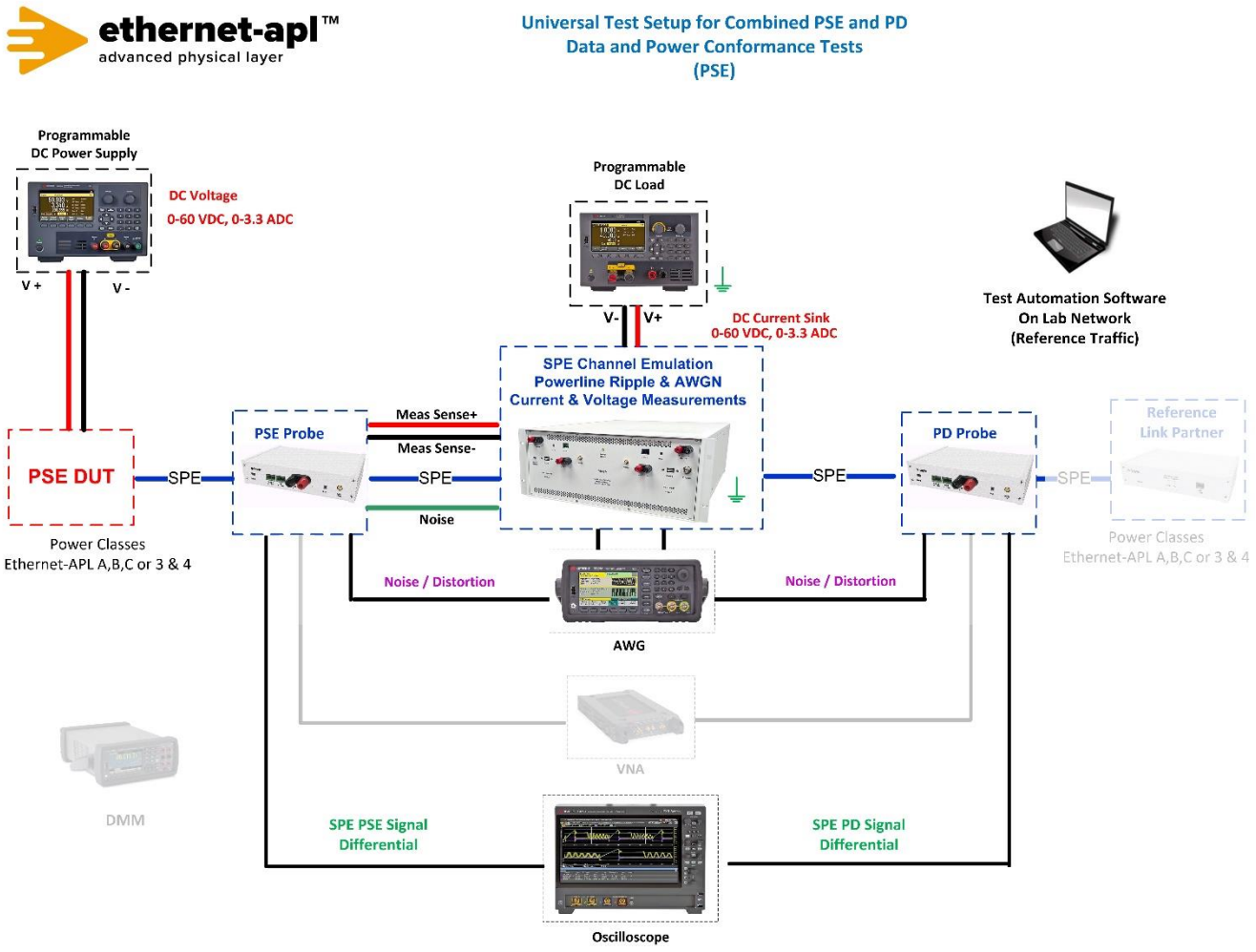
Test Type (Data or Power): Data
Test Name: 146.1.7 APL Transmitter Distortion

Purpose/Description: APL Transmitter Distortion.

Required Test Equipment for PSE:

1. PD Probe (Probe Mode 3)
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe (Probe Mode 3)
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. Oscilloscope
7. Arbitrary Waveform Generator (AWG)
8. Test Automation Software

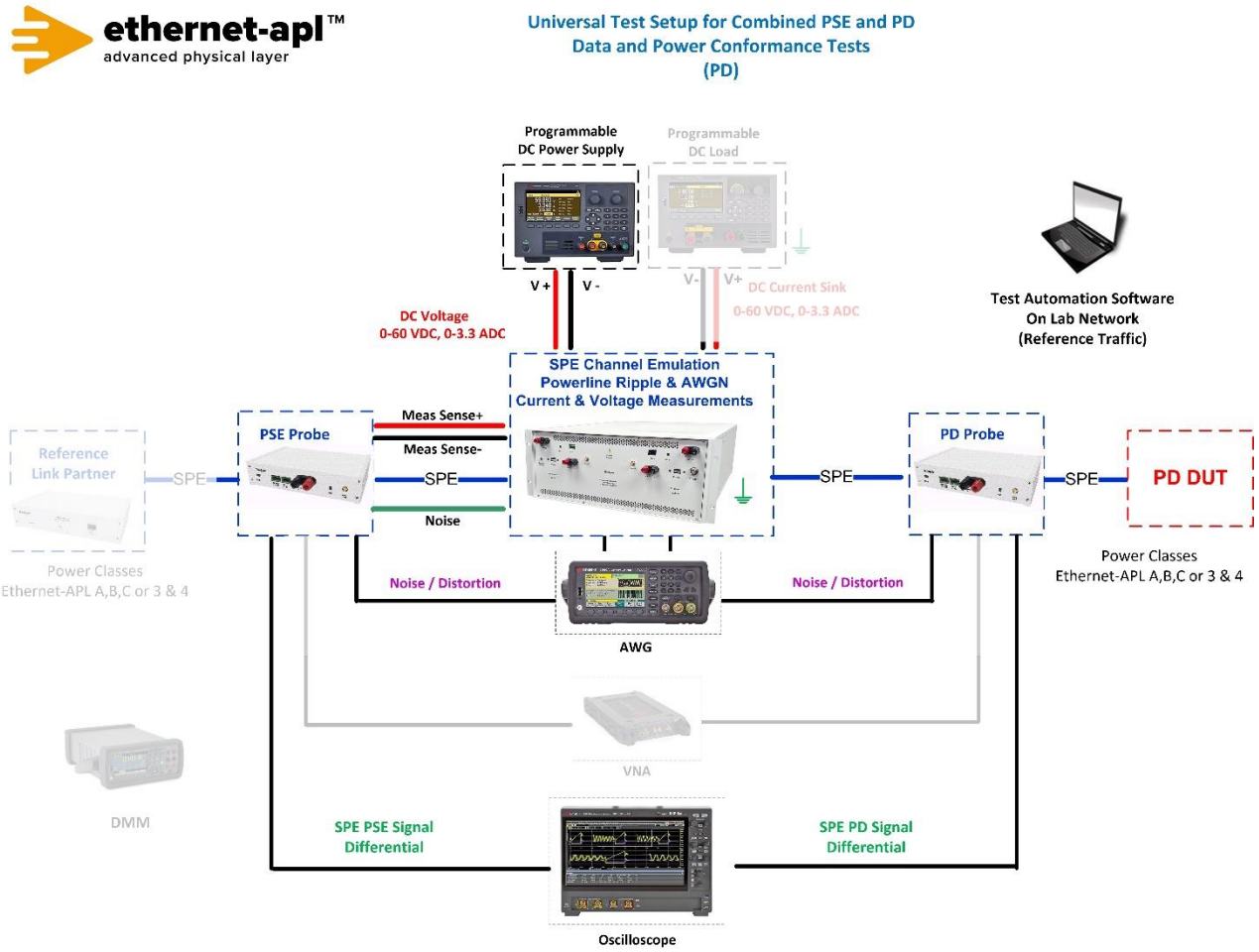
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe (Probe Mode 3)
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe (Probe Mode 3)
4. Programmable DC Power Supply (to power the PD Load DUT)
5. Oscilloscope
6. Arbitrary Waveform Generator (AWG)
7. Test Automation Software

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Part A: Spur (1.0 Vpp operating mode) Power Class A, B or C transmitter distortion check.

Step	Status	Description
A	N/A	The DUT is not a spur port.
A:11	Fail	VDiff is greater than 50 mV for any of the ten 10 ms captures.
A:11	Pass	VDiff is equal to or less than 50 mV for all ten 10 ms captures.

Part B: Trunk (2.4 Vpp operating mode) Power Class 3 or 4 transmitter distortion check

Step	Status	Description
B	N/A	The DUT is not a trunk port.
B:11	Fail	VDiff is greater than 50 mV for any of the ten 10 ms captures.
B:11	Pass	VDiff is equal to or less than 50 mV for all ten 10 ms captures.

Notes:

References:

[1] IEEE Std. 802.3-2022, subclause 146.5.2 – Test modes
[2] Ibid., subclause 146.5.3 – Test Fixtures 478 [3] Test plan Appendix E – 10BASE-T1L Test Fixtures
[4] IEEE Std. 802.3-2018, subclause 96.5.2 – Test modes
[5] Ethernet–APL Port Profile Specification v1.1 – clause 4.1

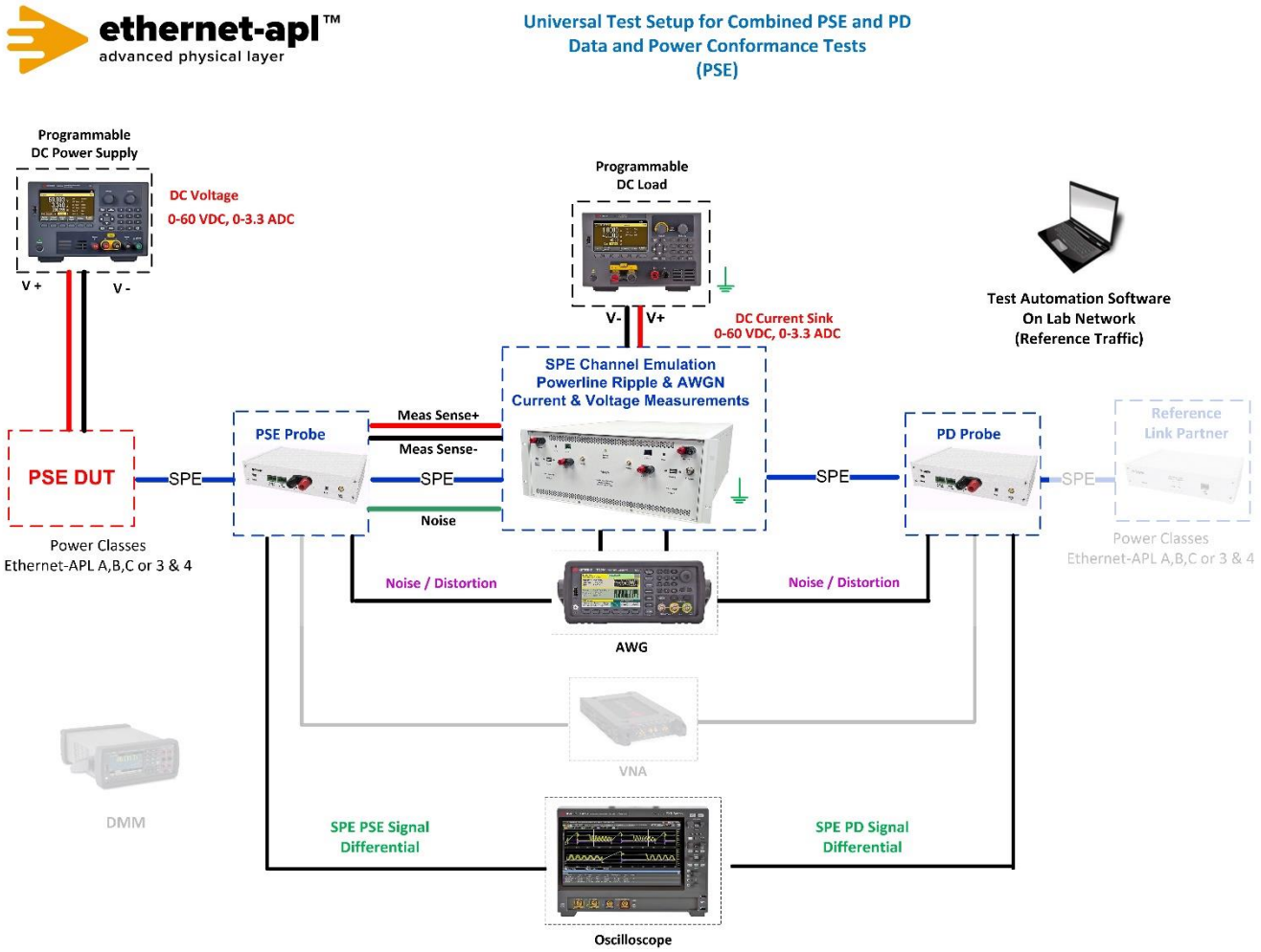
Test Type (Data or Power): Data
Test Name: 146.2.1 Receive Packet Error Rate Stress Test

Purpose/Description: To verify that the DUT can maintain a bit error rate of less than 10^{-9} in the presence of a noise source, power ripple (if applicable), and worst case (IL) test channel from remote PHY.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements, AWGN and Ripple Noise)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. Oscilloscope
7. AWG (Optional if you want to add Impulsive Noise or Alien Crosstalk for Interoperability Test)
8. Test Automation Software

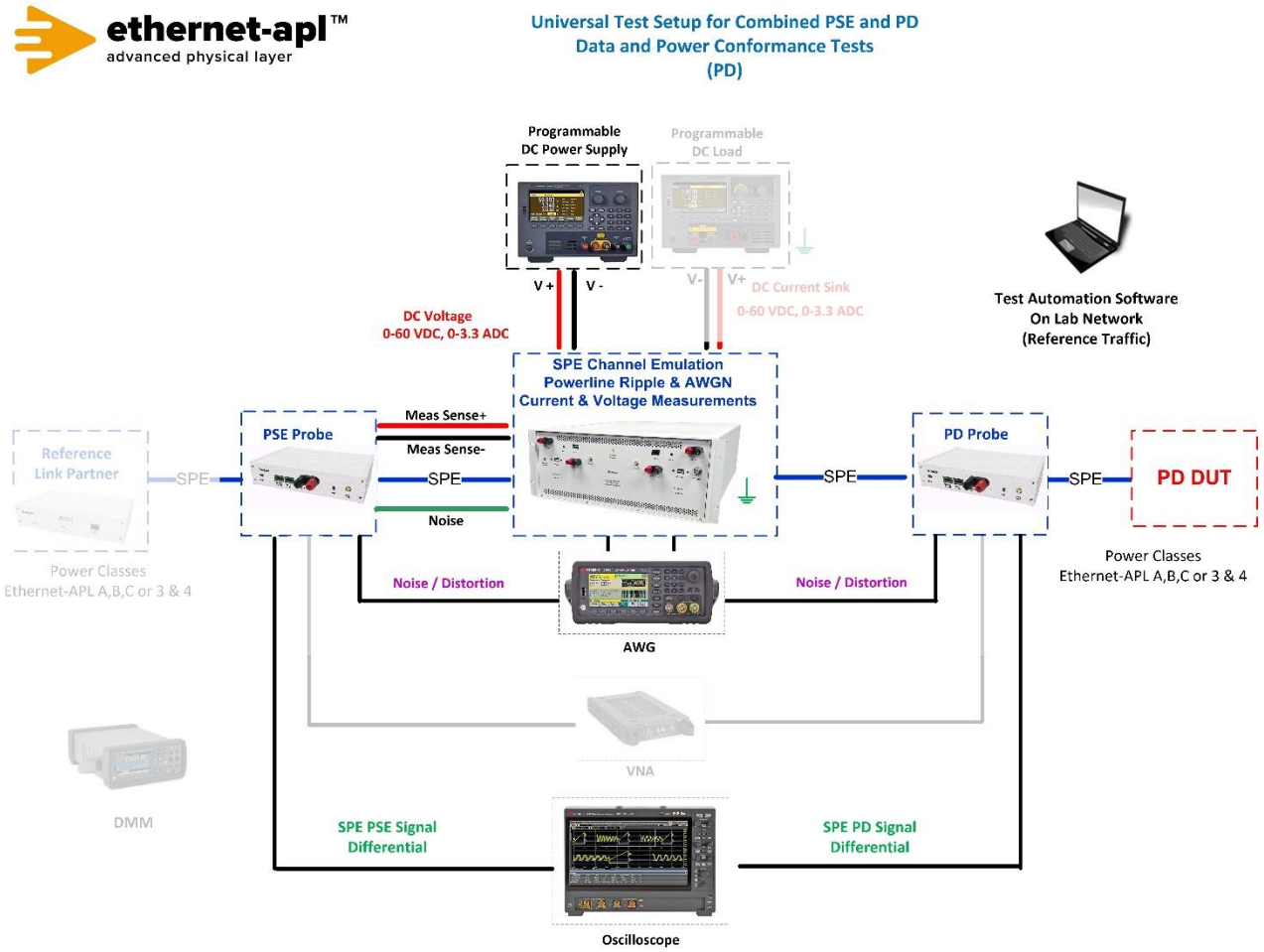
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements, AWGN and Ripple Noise))
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. Oscilloscope
6. AWG (Optional if you want to add Impulsive Noise or Alien Crosstalk for Interoperability Test)
7. Test Automation Software

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Enter the Type of Device: Trunk Source, Trunk Load, Spur Source or Spur Load and Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software DUT Information.

Expected Results (Pass/Fail Criteria):

Part A: Spur (1.0 Vpp): SLAVE DUT tolerance to worst-cast alien crosstalk noise and high IL channel.

Step	Status	Description
A:7,8	Fail	The DUT's BER is observed to exceed 10^{-9} observed by seeing 7 or more Test Packets sent without responses received by the monitor.
A:7,9	Warn	1 to 6 Test Packets were sent without responses received by the monitor. As bit errors are allowed, no definitive statement can be made that the BER has been violated; however, as greater than zero Test Packets were lost, we cannot state that the target BER was met with 95% confidence. As bit errors are allowed, we cannot conclude this to be a failure, but it may be an indication that the target BER is not being met.
A:7,8	Pass	The DUT maintained a BER of less than 10^{-9}

Part B: Trunk (2.4 Vpp): SLAVE DUT tolerance to worst-cast alien crosstalk noise and high IL channel.

Step	Status	Description
B: 7,8	Fail	The DUT's BER is observed to exceed 10^{-9} observed by seeing 7 or more Test Packets sent without responses received by the monitor.
B: 7,8	Warn	1 to 6 Test Packets were sent without responses received by the monitor. As bit errors are allowed, no definitive statement can be made that the BER has been violated; however, as greater than zero Test Packets were lost, we cannot state that the target BER was met with 95% confidence. As bit errors are allowed, we cannot conclude this to be a failure, but it may be an indication that the target BER is not being met.
B: 7,8	Pass	The DUT maintained a BER of less than 10^{-9}.

Notes:

References:

[1] IEEE Std. 802.3cg-2019, subclause 146.5.5.1 – Receiver Differential Input Signals
[2] Ibid., subclause 146.5.5.3 – Alien Crosstalk Noise Rejection
[3] Ibid., subclause 146.7 – Link segment characteristics
[4] IOL TP-PMD Test Plan Appendix 25.D
[5] Test plan Appendix E – 10BASE-T1L Test Fixtures
[6] Test plan Appendix F – 10BASE-T1L Cabling for Receiver Testing

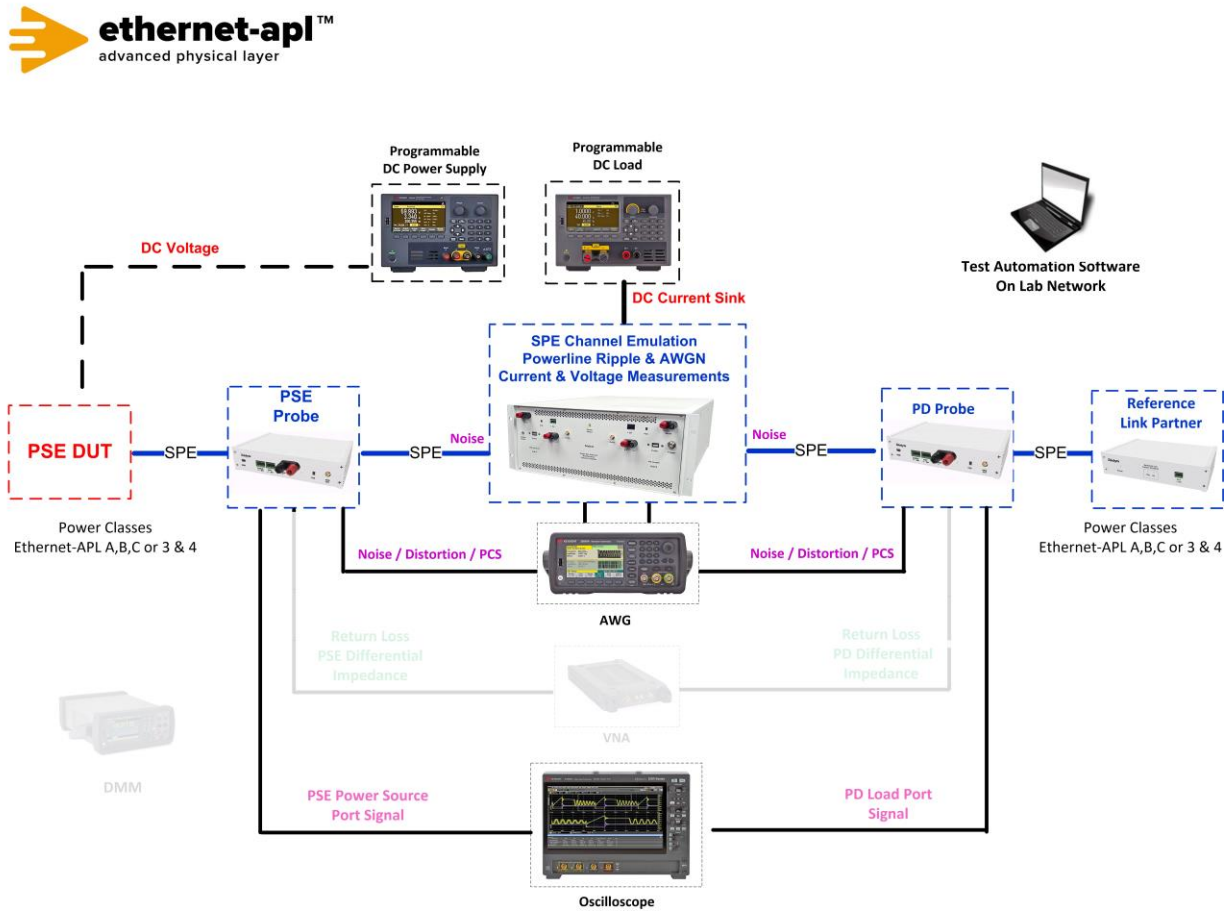
Test Type (Data or Power): Data
Test Name: 146.3.1 Transmit Packet Formation

Purpose/Description: To verify that the PCS properly performs the side-stream scrambling and code-group generation (4B3T) and can receive three packets at line-rate.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. AWG
7. Oscilloscope
8. Test Automation Software
9. Model 4925 Telebyte Link Partner

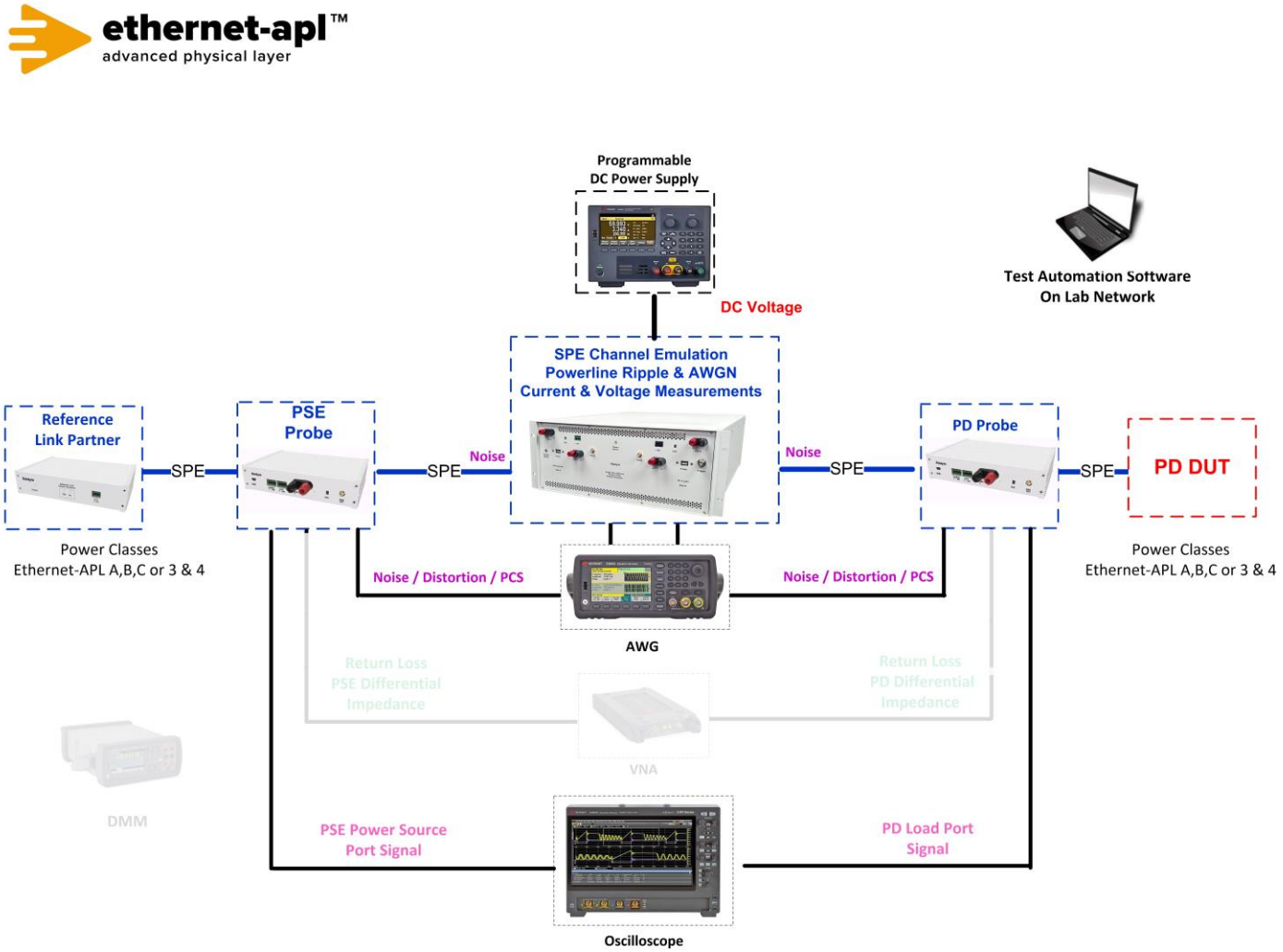
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. Oscilloscope
6. AWG
7. Test Automation Software
8. Model 4925 Telebyte Link Partner

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Part A: DUT as 10BASE-T1L SLAVE, Tx Enabled, Auto-Negotiation Disabled, Forced Slave
- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.
- The Device Under Test (DUT) must have the ability to send and receive Test Packets
- A test station capable of Auto-Negotiation, 10BASE-T1L link signaling, arbitrary packet generation and capturing; OR A test station capable of transmitting arbitrary ternary symbols (allowing explicit control of tx_disparity) and receiving valid ethernet packets. Note that if an Option 1A test station is in use, Auto-negotiation must be disabled. If an Option 2 test station is in use, the test station will be capable of DME page exchange as well.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
A:3	PASS	The DUT, as SLAVE, is observed to establish a link and properly encode idle and data packets.
A:1	FAIL	The DUT does not link.
A:2	FAIL	The transmissions did not follow: the side-stream scrambler polynomial specified in [1] for SLAVE; the generation of Sdn[3:0] specified in [3] for idle transmissions; or, mapping of Sdn[3:0] to any column of the respective Sdn[3:0] row of [5] during idle transmissions.
A:3	FAIL	Three response packets are not captured from the DUT.
A:3	FAIL	Coding Check: The data transmissions did not follow: the side-stream scrambler polynomial specified in [1] for SLAVE; the generation of Sdn[3:0] specified in [3] for data transmissions; or, the 4B3T symbol mapping as defined in [5] during data transmissions. During data transmissions any incorrect disparity events that would cause a receiver to set RX_ER = TRUE, as shown in [8], were observed.
A:3	FAIL	SSD Check: The DUT did not transmit {0, 0, 0}, {0, 0, 0}, {-1, TBx, TCx}, {TAz, TBz, TCz} or {0 ,0 ,0}, {0, 0, 0}, {1, TBy, TCy}, {TAz, TBz, TCz} at the beginning of the packet. Where TBx, TCx can take on the values {0, 1}, {0, 0}, {0, -1}, or {-1, -1}; TBy, TCy can take on the values {0, 1}, {0, 0}, {0, -1}, or {1, 1}; and TAz, TBz, TCz can take on the values {1, 1, -1} or {-1, -1, 1}.
A:3	FAIL	ESD Check: The DUT did not transmit {0, 0, 0}, {0, 0, 0}, {-1, TBx, TCx}, {TAz, TBz, TCz} or {0, 0, 0}, {0, 0, 0}, {1, TBy, TBy}, {TAz, TBz, TCz} at the end of the packet. Where TBx, TCx can take on the values {0, 1}, {0, 0}, {0, -1}, or {-1, -1}; TBy, TCy can take on the values {0, 1}, {0, 0}, {0, -1}, or {1, 1}; and TAz, TBz, TCz can take on the values {1, -1, 1} or {-1, 1, -1}.
A:3	FAIL	Preamble Check: The DUT transmitted less than seven (7) bytes of Preamble, accounting for the two SSD bytes as part of Preamble.
A:3	WARNING	Preamble Warn: The DUT transmitted more than seven (7) bytes of Preamble, accounting for the two SSD bytes as part of Preamble. [Only 7 bytes are necessary, but excess preamble is unlikely to cause an interoperability issue.]
A:3	FAIL	SFD Check: The DUT did not transmit one (1) byte of start of frame delimiter (SFD) immediately after the Preamble.
A:3	WARNING	Disparity Check: At any time the transmissions did not follow the 4B3T symbol mapping defined in [5]. (This includes following the tx_disparity encoding rules).

Notes:

References:

[1] IEEE Std. 802.3-2022 subclause 146.3.3.4.1 – Side-stream scrambler polynomial
[2] IEEE Std. 802.3-2022 subclause 146.3.3.4.2 – Generation of Syn[3:0]
[3] IEEE Std. 802.3-2022 subclause 146.3.3.4.3 – Generation of scrambled bits Sdn[3:0]
[4] IEEE Std. 802.3-2022 subclause 146.3.3.5 – Generation of code-groups
[5] IEEE Std. 802.3-2022 Table 146-1 – 4B3T encoding
[6] IEEE Std. 802.3-2022 Table 146-2 – Disparity reset
[7] IEEE Std. 802.3-2022 Table 146-3 – Delimiters
[8] IEEE Std. 802.3-2022 Figure 146-9 – PCS receive state diagram (part a)

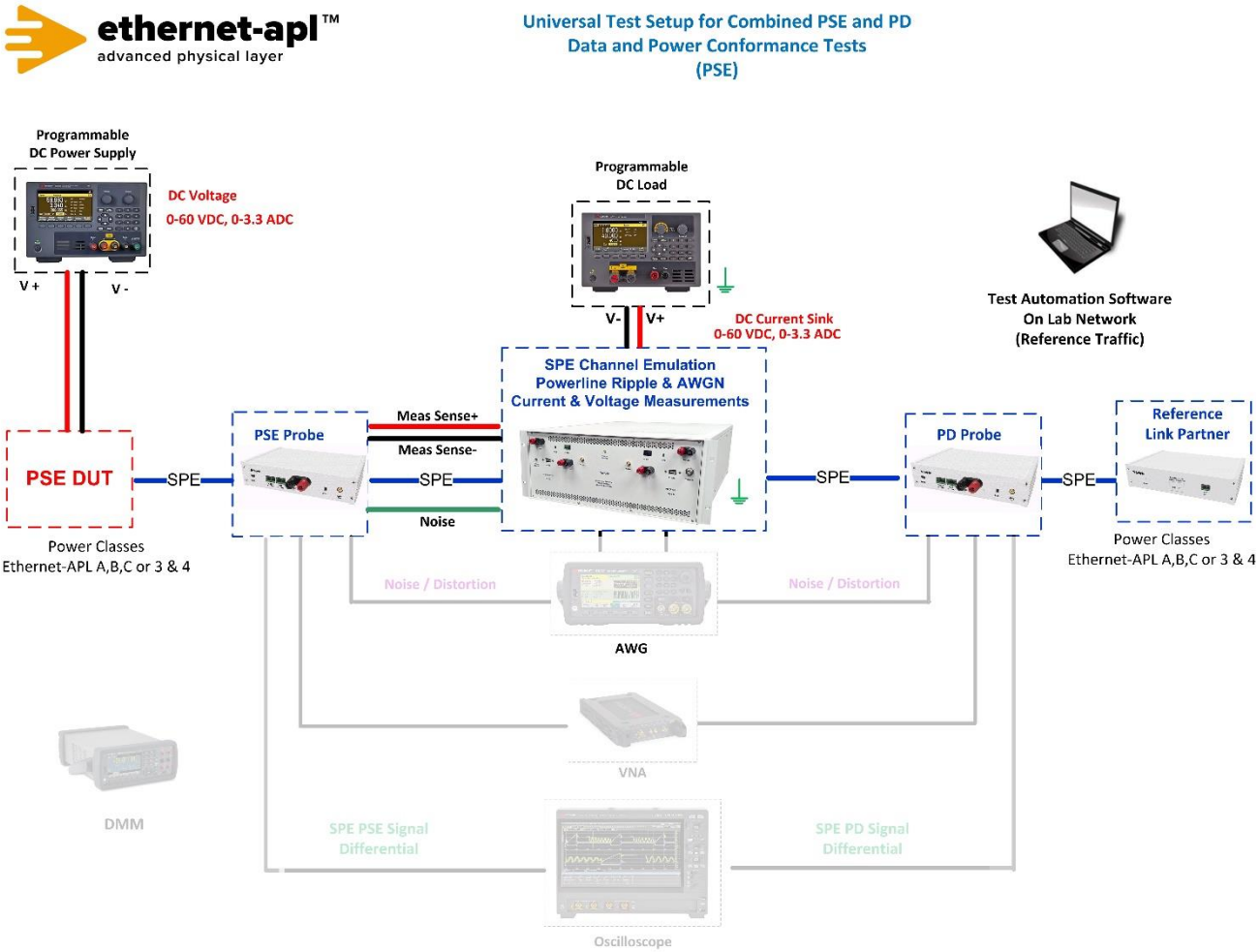
Test Type (Data or Power): Data
Test Name: 146.4.1 Automatic Polarity Detection and Correction

Purpose/Description: To verify that the Ethernet–APL Device properly corrects incorrect channel polarity per the PCS detection and correction mechanism.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. Reference Link Partner
7. Test Automation Software
8. Telebyte Model 4925 Link Partner

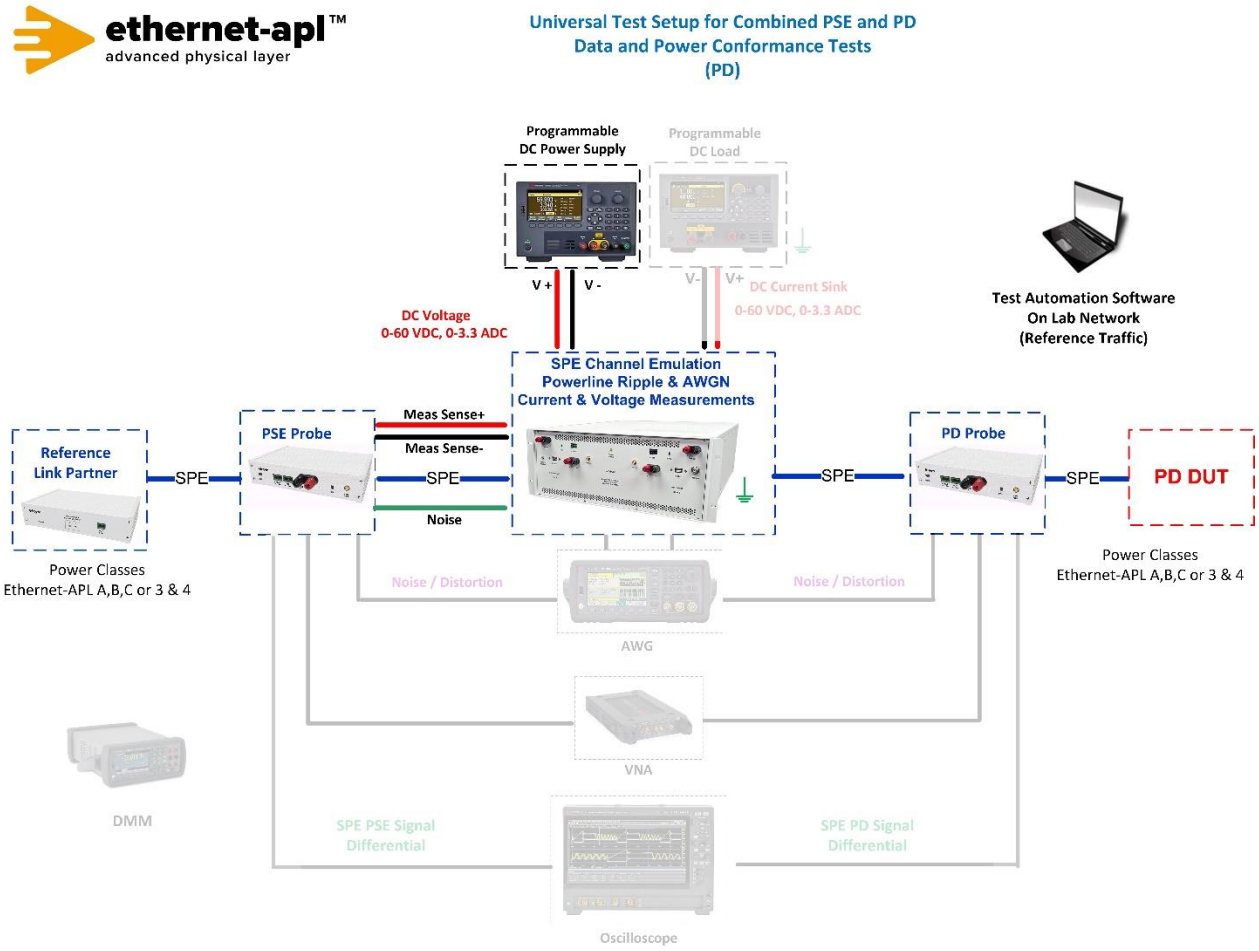
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. Reference Link Partner
6. Test Automation Software
7. Telebyte Model 4925 Link Partner

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Part A: Configure the DUT as 10BASE-T1L SLAVE with Auto-Negotiation Enabled
- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.
- The Device Under Test (DUT) must have the ability to send and receive Test Packets
- A test station capable of Auto-Negotiation, 10BASE-T1L link signaling, arbitrary packet generation and capturing; OR A test station capable of transmitting arbitrary ternary symbols (allowing explicit control of tx_disparity) and receiving valid ethernet packets. Note that if an Option 1A test station is in use, Auto-negotiation must be disabled. If an Option 2 test station is in use, the test station will be capable of DME page exchange as well.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
A:4	PASS	The DUT establishes a link regardless of the received polarity, as indicated by responding to the test packet in both cases.
A:1	FAIL	The DUT does not link. Note the polarity tested.
A:3	FAIL	The DUT does not respond to all test packets. Note the polarity tested.

Notes:

References:

[1] IEEE Std. 802.3cg-2019 subclause 146.3.4.4 (PCS Receive automatic polarity detection)

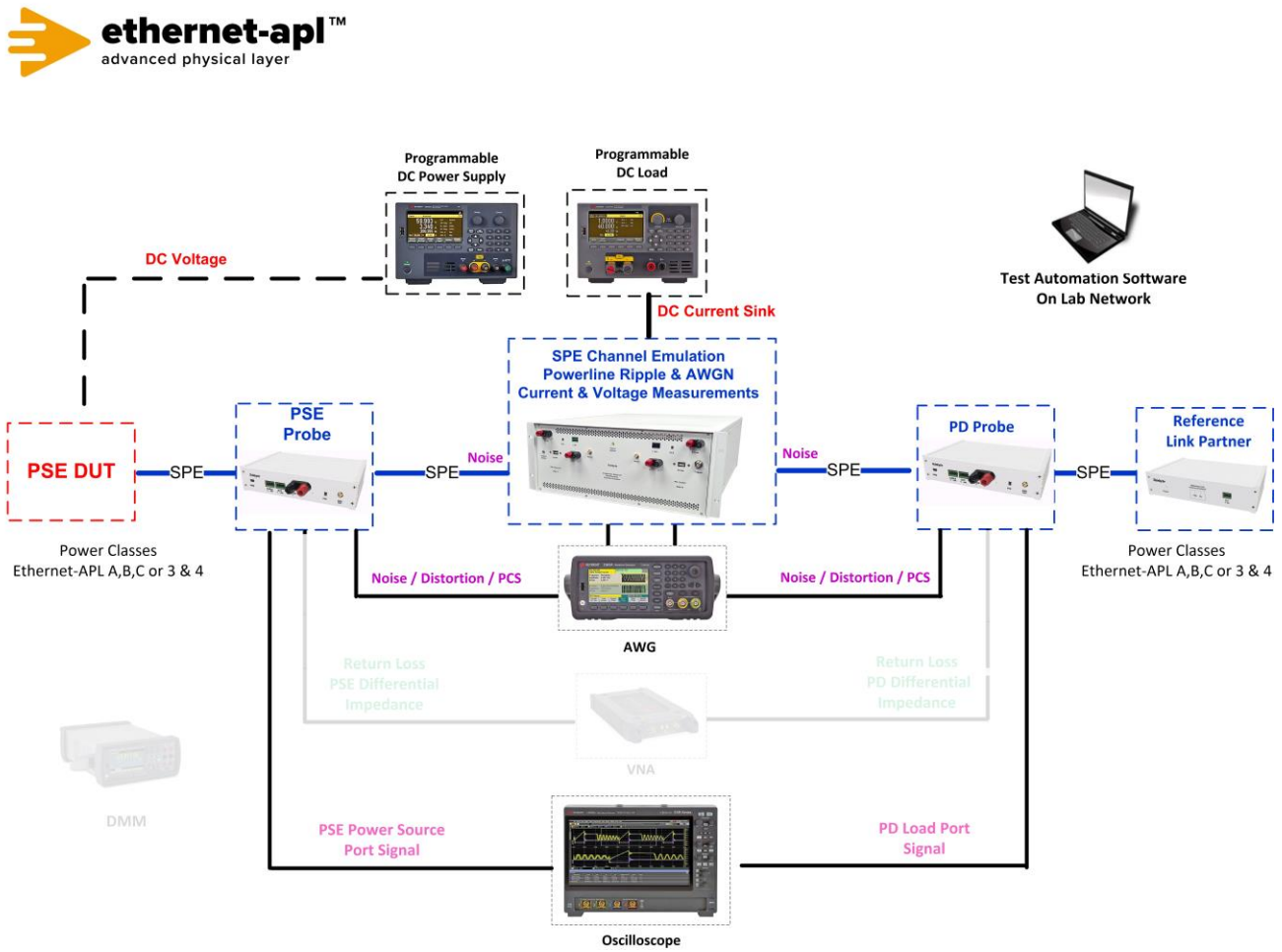
Test Type (Data or Power): Data
Test Name: 146.4.2 Handling of Received ESD_ERR4

Purpose/Description: To verify that the PCS properly indicates reception of an error upon reception of 709 ESD_ERR4, as observed by the handling of test packets.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. AWG
7. Oscilloscope
8. Test Automation Software
9. Telebyte Model 4925 Link Partner

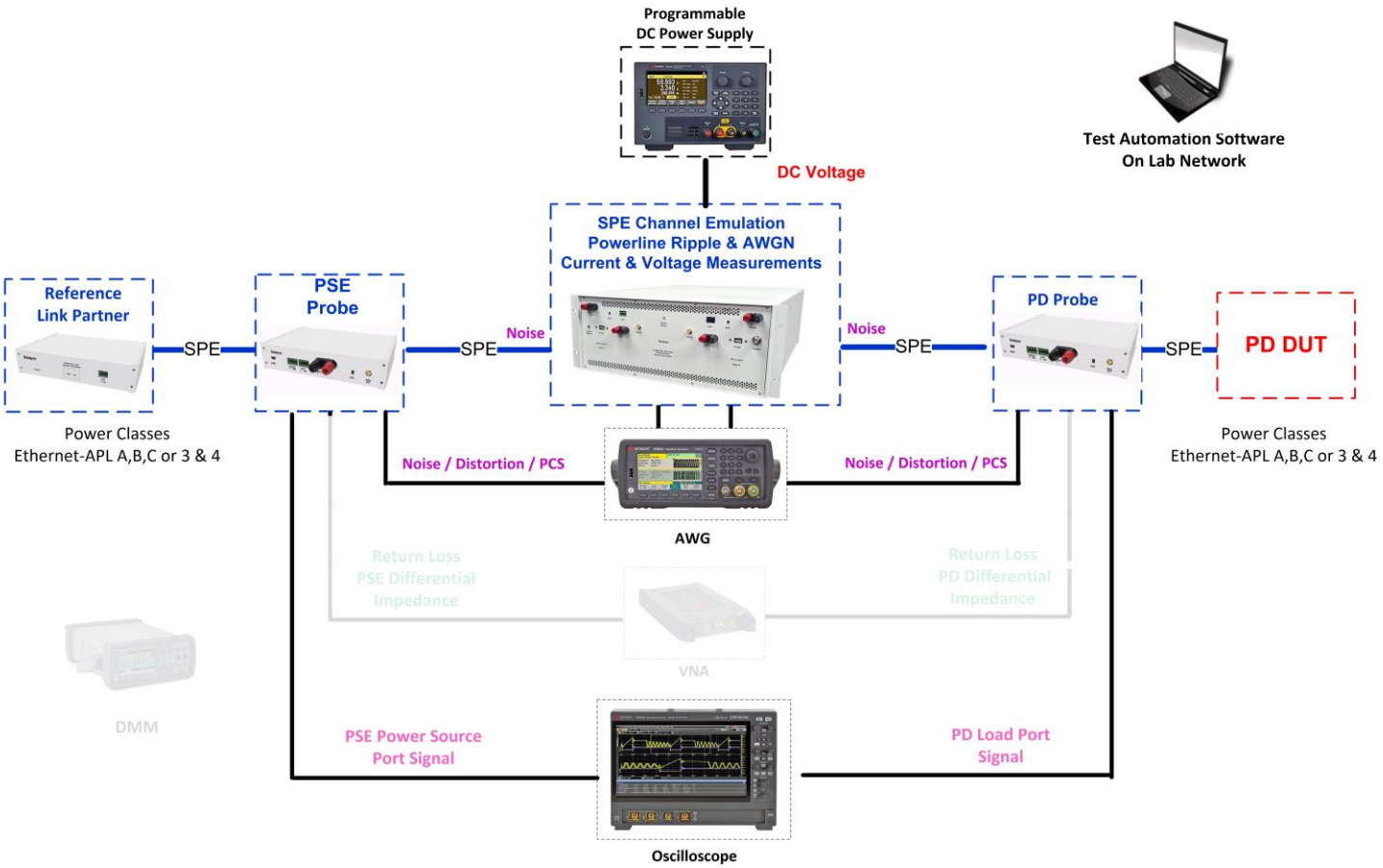
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. AWG
6. Oscilloscope
7. Test Automation Software
8. Telebyte Model 4925 Link Partner

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Part A: DUT as 10BASE-T1L SLAVE, Tx Enabled and disable auto-negotiation
- Set DUT's IP address is 192.168.1.107
- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.
- The Device Under Test (DUT) must have the ability to send and receive Test Packets
- A test station capable of Auto-Negotiation, 10BASE-T1L link signaling, arbitrary packet generation and capturing; OR A test station capable of transmitting arbitrary ternary symbols (allowing explicit control of tx_disparity) and receiving valid ethernet packets. Note that if an Option 1A test station is in use, Auto-negotiation must be disabled. If an Option 2 test station is in use, the test station will be capable of DME page exchange as well.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
A:3	PASS	The DUT properly discards packets received with ESD_ERR4 indicated. Receipt of valid packets is not impacted when received immediately before and after the invalid packet.
A:1	FAIL	The DUT does not link.
A:3	FAIL	Responses to the first (“A”) and third (“C”) Test Packet are not captured from the DUT. Responses to the first (“A”) and third (“C”) If the first and third (no ARP required) or second and fourth (ARP required) ICMP Echo Request sequence numbers sent by the test tool do not match the sequence numbers of the ICMP Echo Responses sent by the DUT this test is a FAIL.
A:3	FAIL	A response to the second Test Packet (“B”) is captured from the DUT. If the second (no ARP required) or third (ARP required) ICMP Echo Request sequence number sent by the test tool matches the sequence number of any ICMP Echo Response sent by the DUT this test is a FAIL.

Notes:

References:

[1] IEEE Std. 802.3cg-2019 subclause 146.3.4 – PCS Receive
[2] IEEE Std. 802.3cg-2019 subclause 146.3.4.2 – PCS Receive symbol decoding
[3] IEEE Std. 802.3cg-2019 Table 146-2 – Disparity reset
[4] IEEE Std. 802.3cg-2019 Table 146-3 – Delimiters

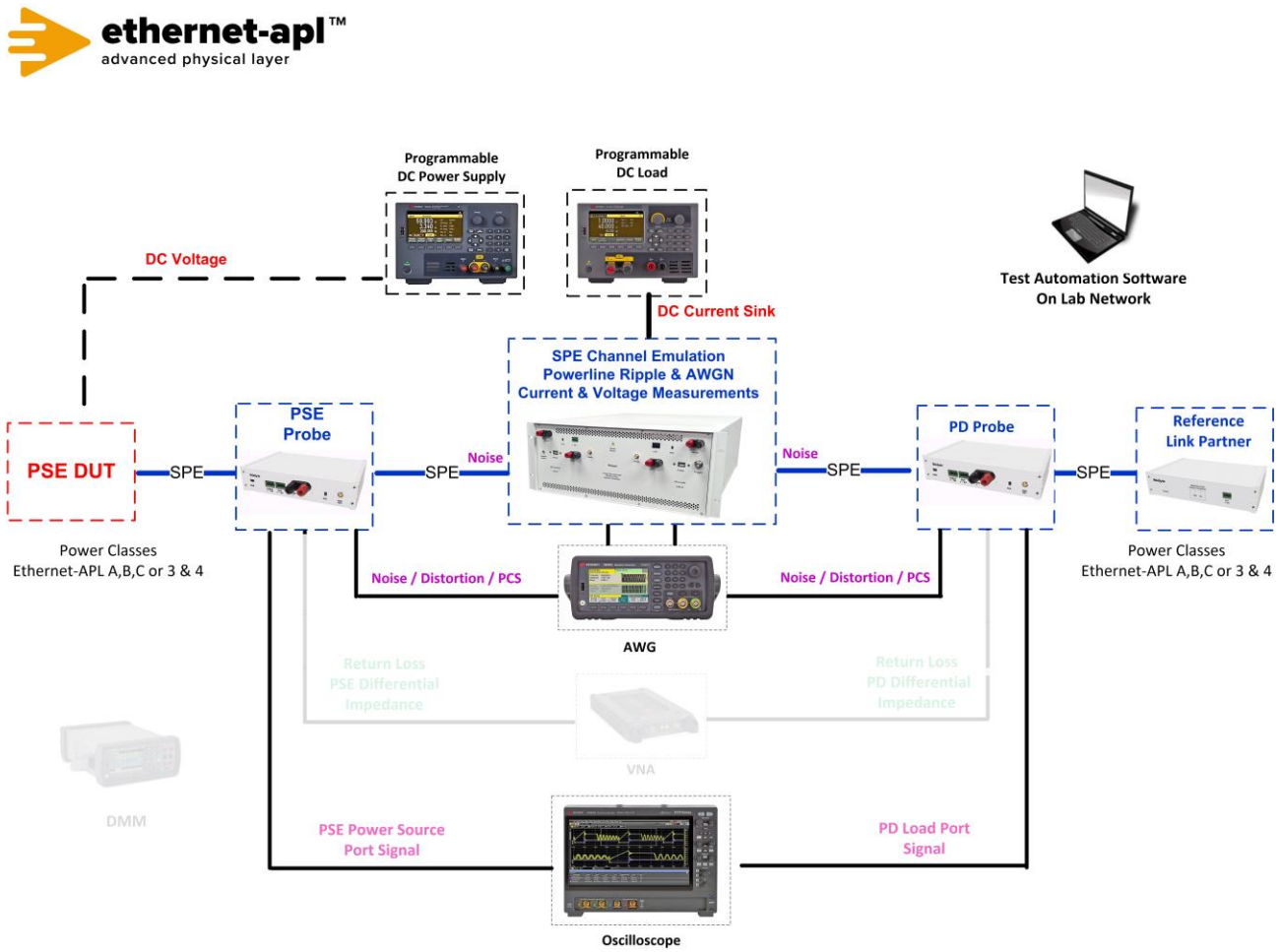
Test Type (Data or Power): Data
Test Name: 146.4.3 Handling of Received FCS Errors

Purpose/Description: To verify that the DUT properly sets disparity_error based on the values of Rxn-4 and rx_disparity, as observed by the handling of test packets.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. AWG
7. Oscilloscope
8. Test Automation Software
9. Telebyte Model 4925 Link Partner

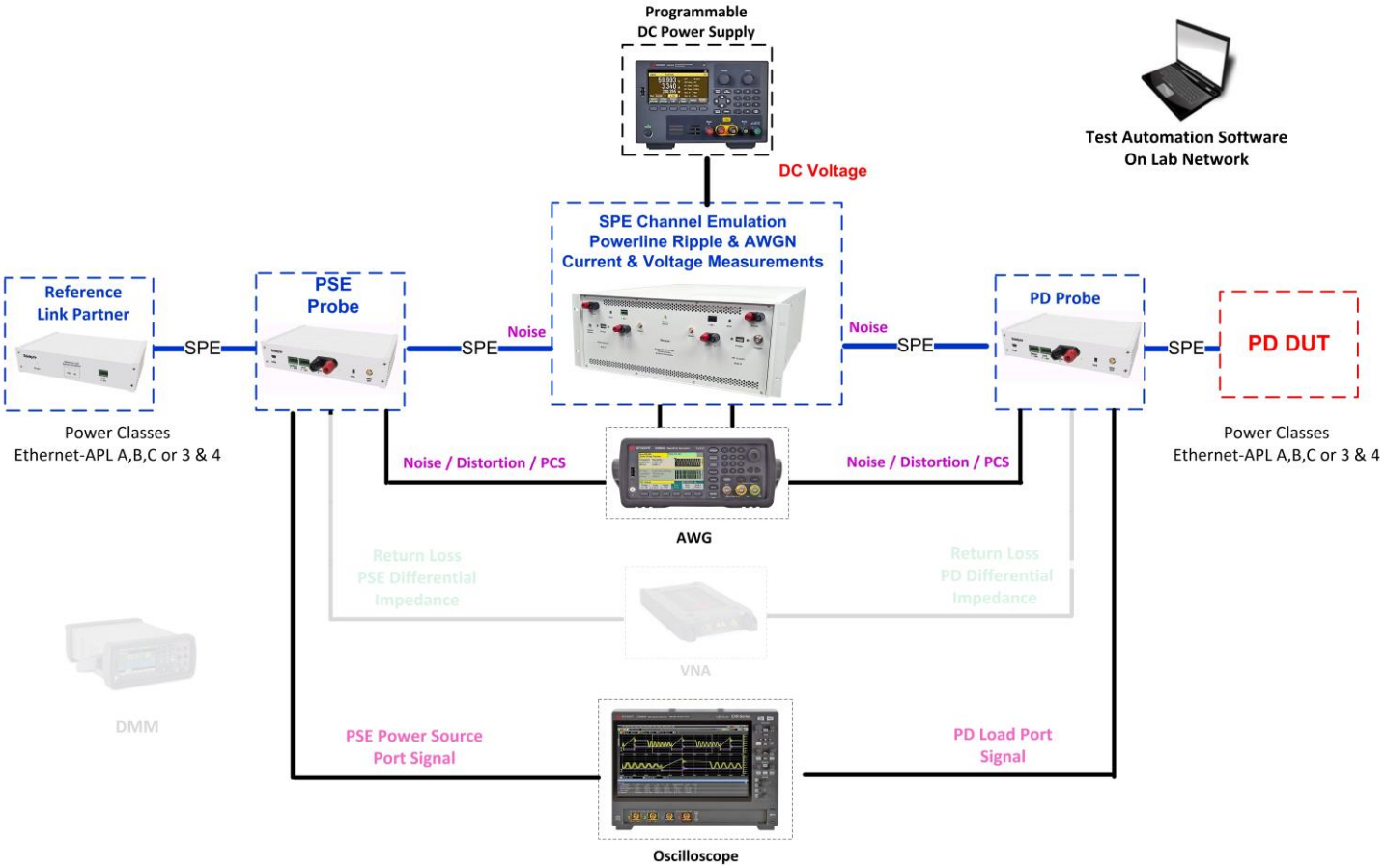
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. AWG
6. Oscilloscope
7. Test Automation Software
8. Telebyte Model 4925 Link Partner

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- Part A: DUT as 10BASE-T1L SLAVE, Tx Enabled and disable auto-negotiation
- Set DUT's IP address is 192.168.1.107
- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.
- The Device Under Test (DUT) must have the ability to send and receive Test Packets
- A test station capable of Auto-Negotiation, 10BASE-T1L link signaling, arbitrary packet generation and capturing; OR A test station capable of transmitting arbitrary ternary symbols (allowing explicit control of tx_disparity) and receiving valid ethernet packets. Note that if an Option 1A test station is in use, Auto-negotiation must be disabled. If an Option 2 test station is in use, the test station will be capable of DME page exchange as well.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
A:3	PASS	The DUT properly discards packets received with ESD_ERR4 indicated. Receipt of valid packets is not impacted when received immediately before and after the invalid packet.
A:1	FAIL	The DUT does not link.
A:3	FAIL	Responses to the first (“A”) and third (“C”) Test Packet are not captured from the DUT. Responses to the first (“A”) and third (“C”) If the first and third (no ARP required) or second and fourth (ARP required) ICMP Echo Request sequence numbers sent by the test tool do not match the sequence numbers of the ICMP Echo Responses sent by the DUT this test is a FAIL.
A:3	FAIL	A response to the second Test Packet (“B”) is captured from the DUT. If the second (no ARP required) or third (ARP required) ICMP Echo Request sequence number sent by the test tool matches the sequence number of any ICMP Echo Response sent by the DUT this test is a FAIL.

Notes:

References:

[1] IEEE Std. 802.3cg-2019 subclause 146.3.4 – PCS Receive
[2] IEEE Std. 802.3cg-2019 subclause 146.3.4.2 – PCS Receive symbol decoding
[3] IEEE Std. 802.3cg-2019 Table 146-2 – Disparity reset
[4] IEEE Std. 802.3cg-2019 Table 146-3 – Delimiters

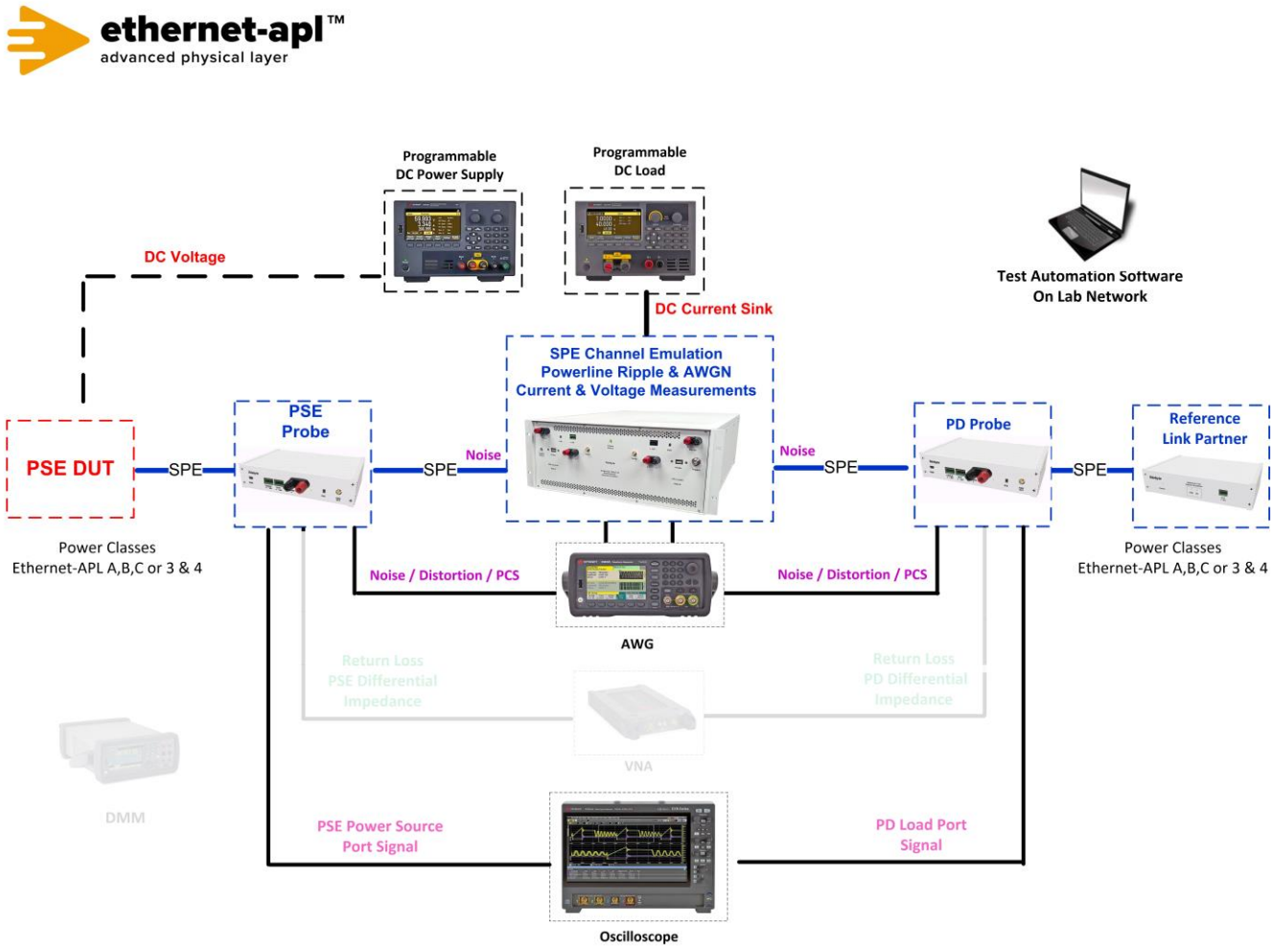
Test Type (Data or Power): Data
Test Name: 98.1.1 Advertisement and Auto-Negotiation Verification

Purpose/Description: To verify that the Ethernet–APL Device properly encodes valid operating modes in its advertised abilities via Auto-Negotiation and links properly based on link-partner advertised abilities.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. AWG
7. Oscilloscope
8. Test Automation Software
9. Telebyte Model 4925 Link Partner

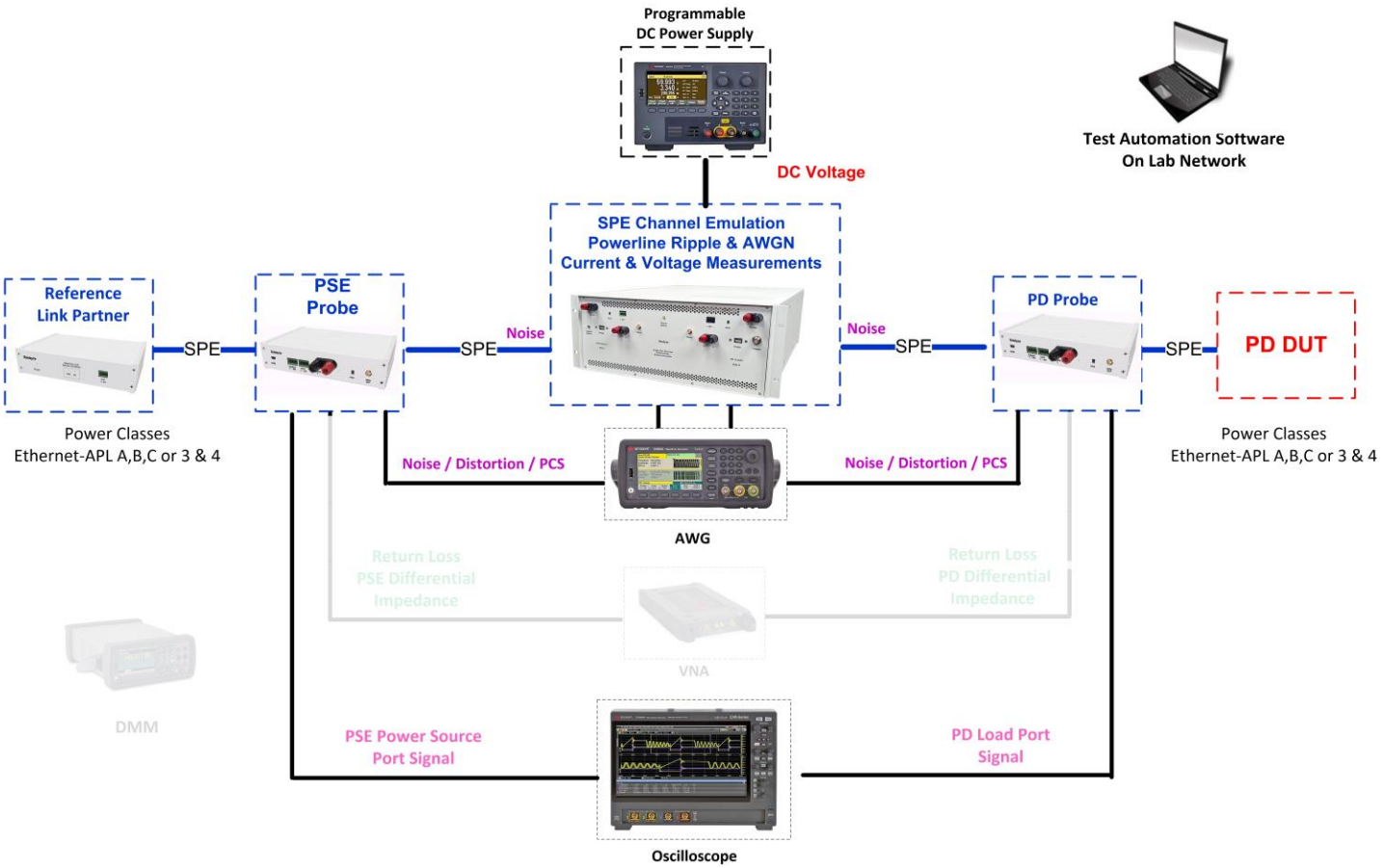
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. AWG
6. Oscilloscope
7. Test Automation Software
8. Telebyte Model 4925 Link Partner

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- DUT as 10BASE-T1L and enable auto-negotiation
- Note if the DUT is a Trunk or a Spur Port
- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software
- A test station capable of Auto-Negotiation, 10BASE-T1L link signaling, and arbitrary packet generation and capturing and decoding ternary symbols.
- A line-monitoring system capable of decoding Auto-Negotiation DME pages.
- Link Partner will be a Slave M/S bit = 0 DUT will be in default configuration

Expected Results (Pass/Fail Criteria):

Part A: DUT advertises valid capabilities.

Step	Status	Description
A:1	PASS	The DUT advertises capabilities that match the expected values per the vendor claimed APL segment type (Spur or Trunk).
A:1	FAIL	The DUT does not advertise capabilities matching its APL segment type (Spur or Trunk).
A:1	WARN	If the DUT sets M/S to 1, the possibility exists that a link would not occur with link partners that also have M/S set to 1 and a matching T[4] value.

Part B: DUT links with compatible link partner.

Step	Status	Description
B:3	PASS	The DUT properly links at the expected operating mode.
B:3	FAIL	The DUT does not link at the expected operating mode.

Part C: DUT spur port when LP advertises but does not request increased transmit level.

Step	Status	Description
C:2	PASS	The DUT properly links at the spur (1.0 Vpp) operating mode.
C:2	FAIL	The DUT does not link at the spur (1.0 Vpp) operating mode.
	N/A	The DUT is not a spur port.

Part D: DUT behavior with incompatible link partner (spur to trunk, trunk to spur).

Step	Status	Description
D:3	INFO	D:3 INFO Report if spur (1.0 Vpp) or trunk (2.4 Vpp) link signaling is attempted by the DUT when link_control_[10BASE-T1L] = ENABLE. Note if link signaling is observed and what voltage. (APL expects Spurs connected to Trunks to disable communications).

Part E DUT behaves properly with incompatible link partner (spur to trunk, trunk to spur).

Step	Status	Description
E:5	PASS	If no link is seen in E:4, then the DUT's management prevents link when a spur is connected to a trunk, or vice versa. If a link is seen in E:4, then the DUT properly does not enable communication when a spur is connected to a trunk, or vice versa.
E:5	FAIL	If a link is established but communication support is enabled when it should not be (per [6] IEEE802.3cg-2019 Annex 98.B).
	INFO	Report if a link is indicated.

Part F: DUT behavior when link partner prefers master or slave port role (M/S is always 0).

Step	Status	Description
F:5	PASS	The DUT behaves properly when the link partner prefers Master or Slave operation, and the transmitted nonce value is either higher or lower than that from the DUT.
F:4	FAIL	If the DUT is a trunk, and spur (1.0 Vpp) link signaling is attempted by the DUT when link_control_[10BASE-T1L] = ENABLE. If Trunk, is 2.4 Vpp signaling observed from DUT?
F:4	FAIL	If the DUT is a spur, and trunk (2.4 Vpp) link signaling is attempted by the DUT when link_control_[10BASE-T1L] = ENABLE. If Spur is 1.0 Vpp signaling observed from DUT?
F:4	FAIL	If the DUT should be MASTER, but no signaling is seen from the DUT when link_control_[10BASE-T1L] = ENABLE. If Master, is there no >1ms gap between DME & link signaling
F:4	FAIL	If the DUT should be SLAVE, but signaling is seen from the DUT when link_control_[10BASE-T1L] = ENABLE instead of SEND_Z. If Slave, is there a >1ms gap between DME & link signaling

Part G: DUT behavior when link partner forces master or slave port role (M/S is always 1).

Step	Status	Description
G:3	PASS	The DUT behaves properly when the link partner is forced to Master or Slave operation.
G:3	FAIL	If the DUT is a trunk, and should be MASTER and spur (1.0 Vpp) link signaling is attempted by the DUT when link_control_[10BASE-T1L] = ENABLE. If Trunk, is 2.4 Vpp signaling observed from DUT?
G:3	FAIL	If the DUT is a spur, and should be MASTER and trunk (2.4 Vpp) link signaling is attempted by the DUT when link_control_[10BASE-T1L] = ENABLE. If Spur is 1.0 Vpp signaling observed from DUT?
G:3	FAIL	If the DUT should be MASTER, but no signaling is seen from the DUT when link_control_[10BASE-T1L] = ENABLE. If Master, is there no >1ms gap between DME & link signaling
G:3	FAIL	If the DUT should be SLAVE, but signaling is seen from the DUT when link_control_[10BASE-T1L] = ENABLE instead of SEND_Z. If Slave, is there a >1ms gap between DME & link signaling
G:3	INFO	If the DUT advertises with M/S = 1, report the behavior when a Configuration Fault occurs (for example, if the DUT sets T[4] to 0 and the test station also sets T[4] to 0). If DUT sets M/S =1 by default, note as INFO when Config faults occur.

Notes:

References:

[1] IEEE Std. 802.3-2022 subclause 45.2.7.22 (AN LP Base Page ability register)
[2] IEEE Std. 802.3-2022 subclause 45.2.7.24 (AN LP Next Page ability register)
[3] IEEE Std. 802.3-2022 subclause 98.3 (State diagram variable to AN register mapping)
[4] IEEE Std. 802.3-2022 subclause 45.2.7 (Auto-Negotiation registers)
[5] IEEE Std. 802.3-2022 subclause 45.2.7.26 (10BASE-T1L capability advertisement)
[6] IEEE Std. 802.3-2022 Annex 98B.3
[7] Ethernet–APL Port Profile Specification v1.1 – clause 4.1

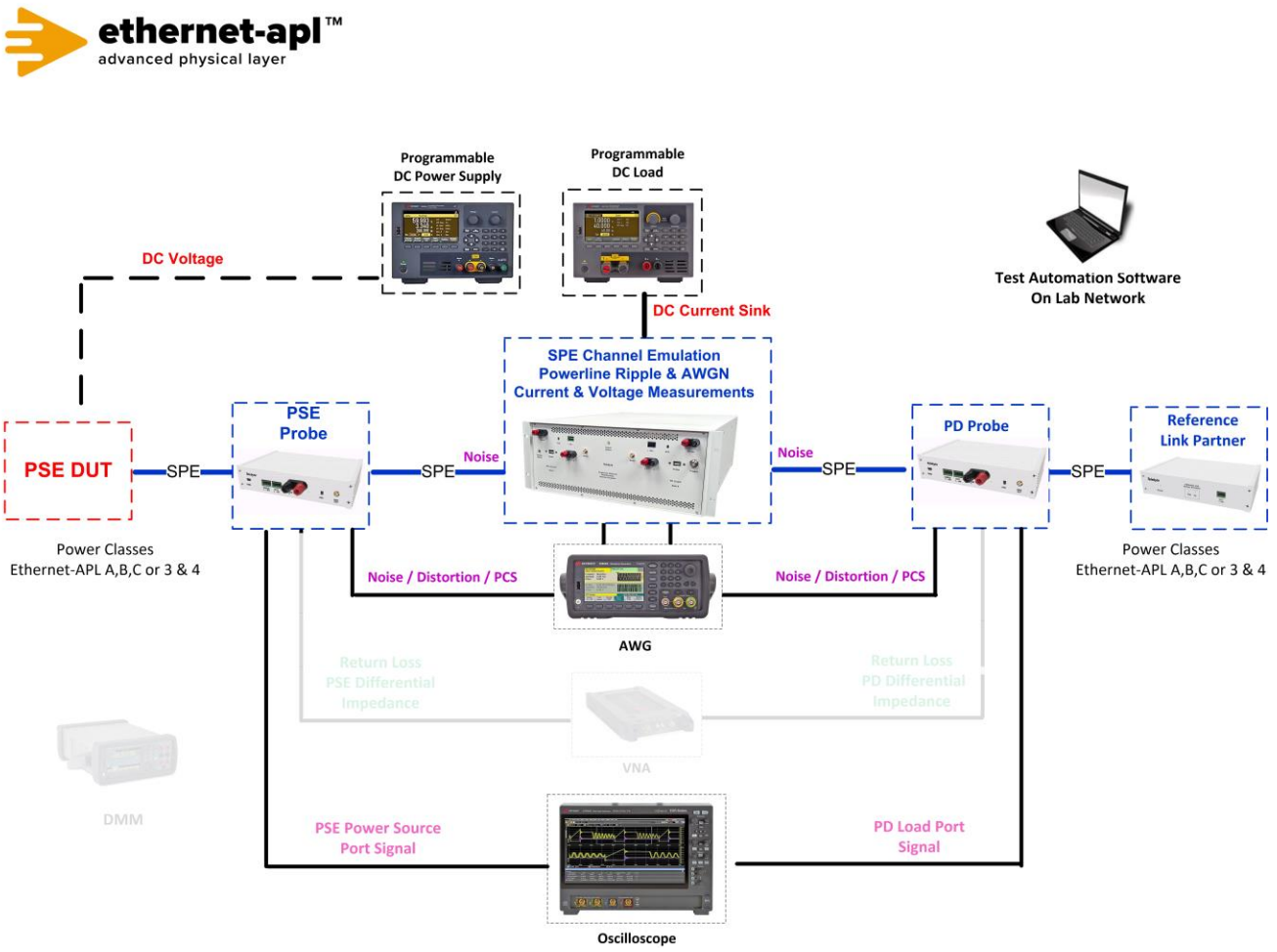
Test Type (Data or Power): Data
Test Name: 98.1.2 Management Restart of Auto-Negotiation

Purpose/Description: To verify that the Ethernet–APL Device can initiate a restart of Auto-Negotiation via the standard defined management register.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. AWG
7. Oscilloscope
8. Test Automation Software
9. Telebyte Model 4925 Link Partner

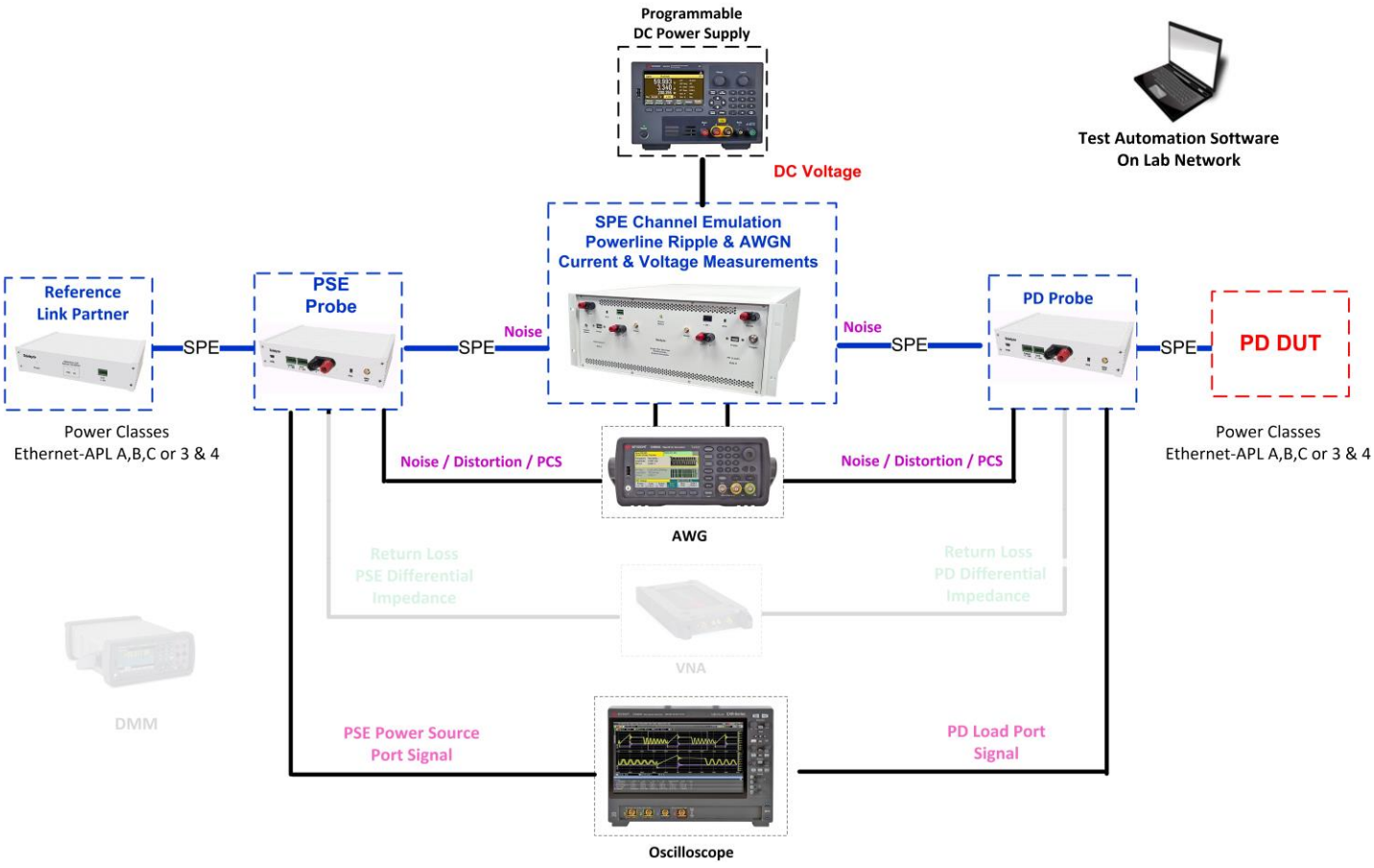
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. AWG
6. Oscilloscope
7. Test Automation Software
8. Telebyte Model 4925 Link Partner

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- DUT as 10BASE-T1L and enable auto-negotiation.
- Note if the DUT is a Trunk or a Spur Port.
- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.
- A test station capable of Auto-Negotiation, 10BASE-T1L link signaling, and arbitrary packet generation and capturing and decoding ternary symbols.
- A line-monitoring system capable of decoding Auto-Negotiation DME pages.
- Link Partner will be a Slave M/S bit = 0 DUT will be in default configuration.

Expected Results (Pass/Fail Criteria):

Part A: DUT can properly perform a restart of the Auto-Negotiation process.

Step	Status	Description
A:5	PASS	The DUT can properly restart Auto-Negotiation and receive packets before and after such events.
A:1	FAIL	The DUT does not link.
A:3	FAIL	The DUT does not respond to all test packets.
A:4	FAIL	The DUT does not send signaling for at least 7ms as a result of the mr_restart_negotiation signal. (break_link_timer requires at least 8ms this test ensures that the large gap is observed properly from the DUT without repeating stricter tests performed as part of silicon validation) Was a gap of at least 7ms observed on the scope?
A:4	FAIL	The DUT does not link.
A:5	FAIL	The DUT does not respond to all test packets.

Notes:

References:

[1] IEEE Std. 802.3-2018 subclause 45.2.7.19 (BASE-T1 AN control register)
[2] IEEE Std. 802.3-2018 subclause 98.3 (State diagram variable to AN register mapping)

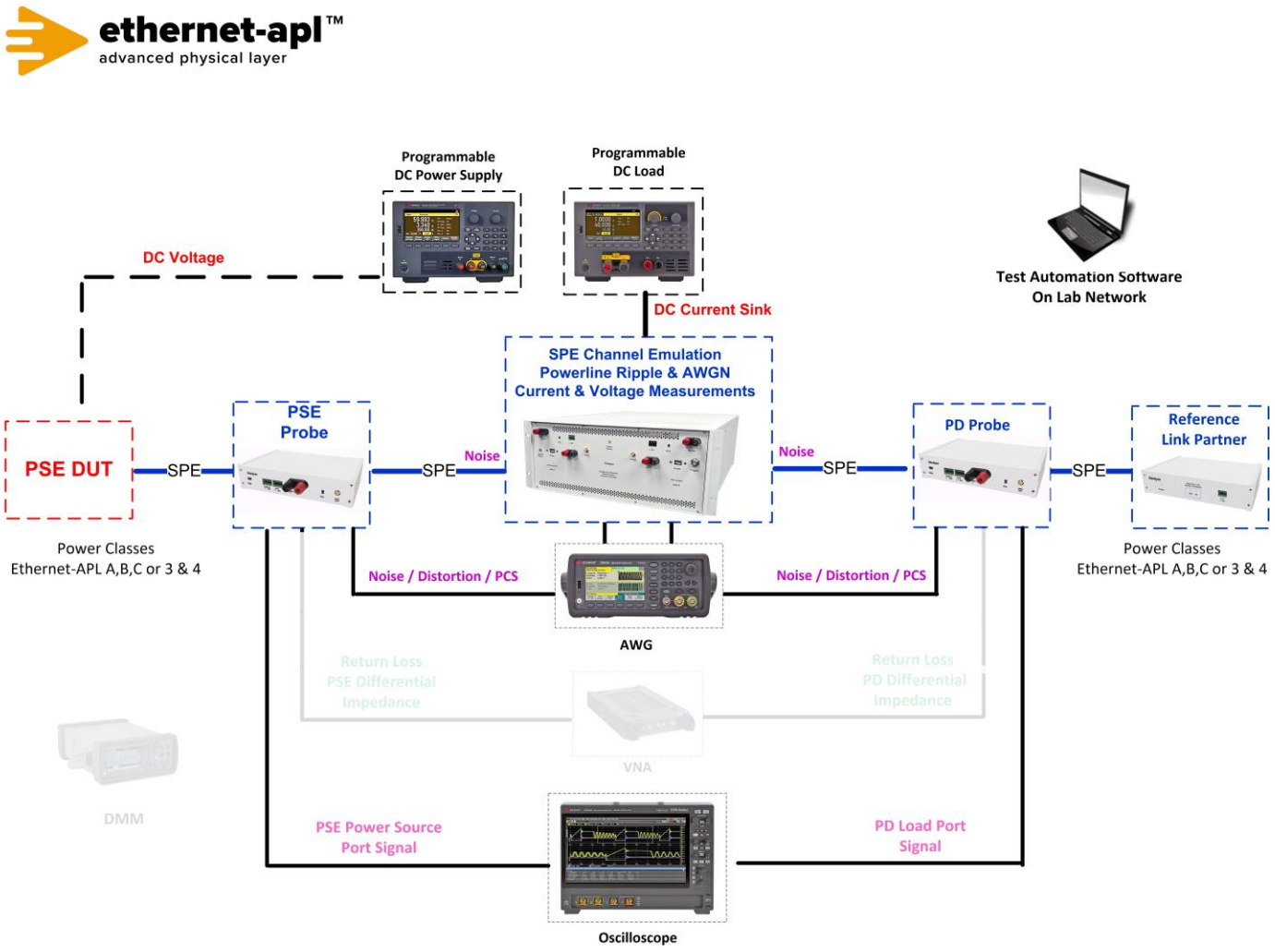
Test Type (Data or Power): Data
Test Name: 98.1.3 Link Status Fail

Purpose/Description: To verify that the Ethernet–APL Device detects link_status [10BASE-T1L] = FAIL.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. AWG
7. Oscilloscope
8. Test Automation Software
9. Telebyte Model 4925 Link Partner

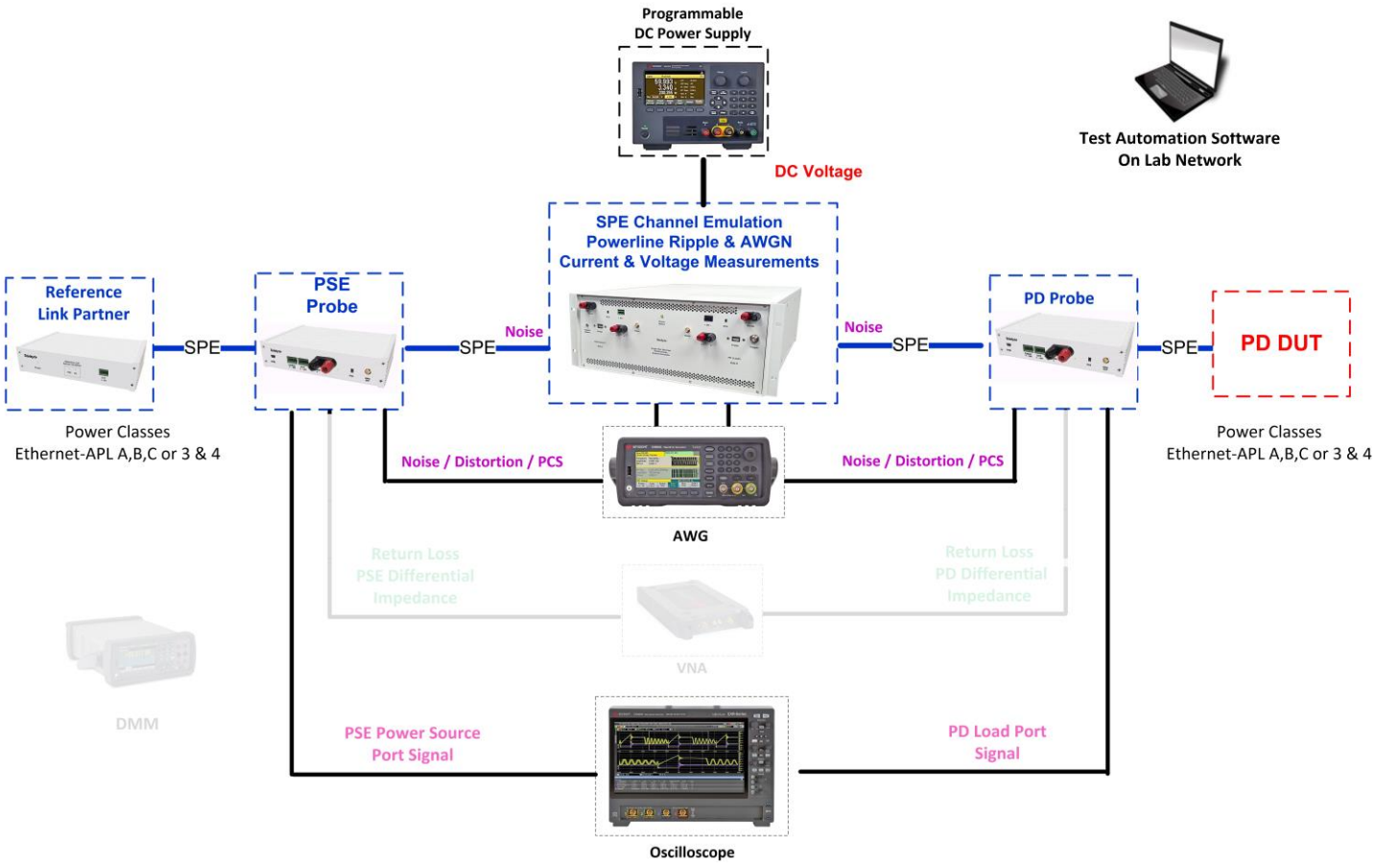
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. AWG
6. Oscilloscope
7. Test Automation Software
8. Telebyte Model 4925 Link Partner

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- DUT as 10BASE-T1L default configuration and enable auto-negotiation.
- Note if the DUT is a Trunk or a Spur Port.
- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.
- A test station capable of Auto-Negotiation, 10BASE-T1L link signaling, and arbitrary packet generation and capturing and decoding ternary symbols. Test stations must be either Option 1B (Figure C.2) or Option 2 (Figure C.3) with test setup as noted below.
- A line-monitoring system capable of decoding Auto-Negotiation DME pages.
- Link Partner test station with controllable 1.2249.14 bit (10BASE-T1L Transmit Disable).

Expected Results (Pass/Fail Criteria):

Part A: DUT receives no valid 10BASE-T1L signaling in Auto-Negotiation (AN) GOOD CHECK state.

Step	Status	Description
A:2	PASS	Following detection of link_status[10BASE-T1L] = FAIL, the DUT properly resumes DME transmissions, and can properly link. No detectable violations of link_fail_inhibit_timer[10BASE-T1L] or break_link_timer[LSM] were observed.
A:1	FAIL	The DUT is not observed to restart Auto-Negotiation after it detects link_status[10BASE-T1L] = FAIL.
A:1	FAIL	If the DUT is MASTER and does not transmit 10BASE-T1L link signaling (MASTER training signaling).
A:1	WARN	If the DUT is MASTER and does not send MASTER training signaling for at least 2430.4 ms. This time is 80% of the minimum value of link_fail_inhibit_timer[10BASE-T1L] {3030 ms} (an arbitrary accuracy limit selected for this test). Issued as a WARN as the DUT may issue a PHY Reset (eg: mr_main_reset) at any time.
A:1	FAIL	If the DUT is MASTER and sends MASTER training signaling for more than 3090 ms.
A:1	FAIL	If the DUT is MASTER, and after ceasing MASTER training signaling, the DUT resumes sending DME pages within 6.4 ms, violating break_link_timer[LSM], which is nominally 8 ms to 8.133 ms. 6.4 ms is 80% of the minimum value of break_link_timer[LSM] (an arbitrary accuracy limit selected for this test). Note that the idle gap between MASTER training signaling cessation and DME page transmission may exceed the maximum of one break_link_timer[LSM] as many events (e.g., mr_main_reset) may cause the timer to restart.

Notes:

References:

[1] IEEE Std. 802.3-2022 subclause 98 (Auto-Negotiation for single differential-pair media)
[2] IEEE Std. 802.3-2022 Figure 98-7 (Arbitration state diagram)
[3] IEEE Std. 802.3-2022 subclause 98.5.2 (break_link_timer_[LSM])
[4] IEEE Std. 802.3-2022 subclause 98.5.2 (link_fail_inhibit_timer_[HCD])

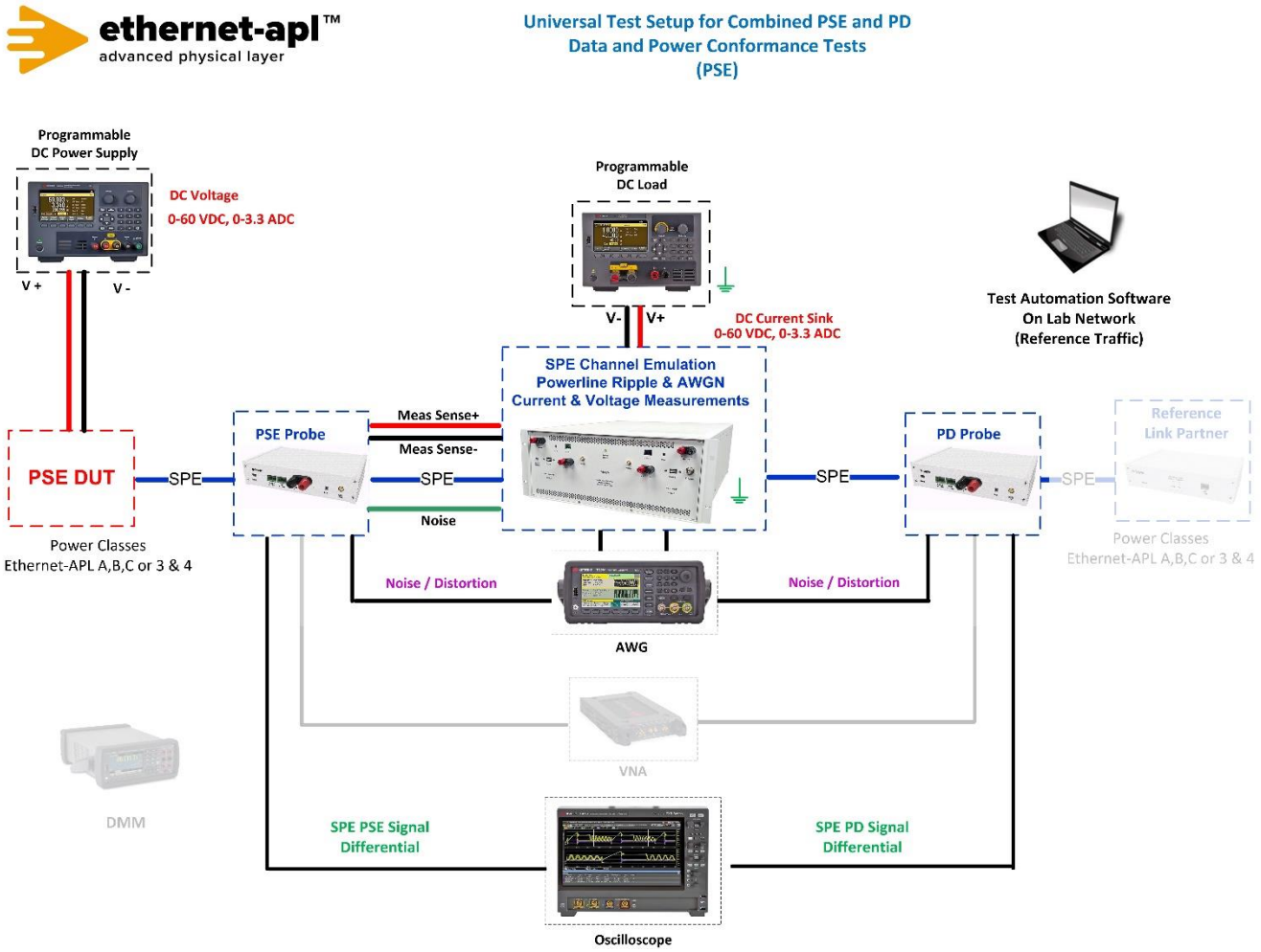
Test Type (Data or Power): Data
Test Name: 98.1.4 DME Voltage Envelope Test

Purpose/Description: To verify that the Ethernet–APL Device's DME signaling never exceeds the allowed voltage amplitude.

Required Test Equipment for PSE:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PSE DUT)
5. Programmable DC Load (to draw current from PSE DUT)
6. AWG
7. Oscilloscope
8. Test Automation Software

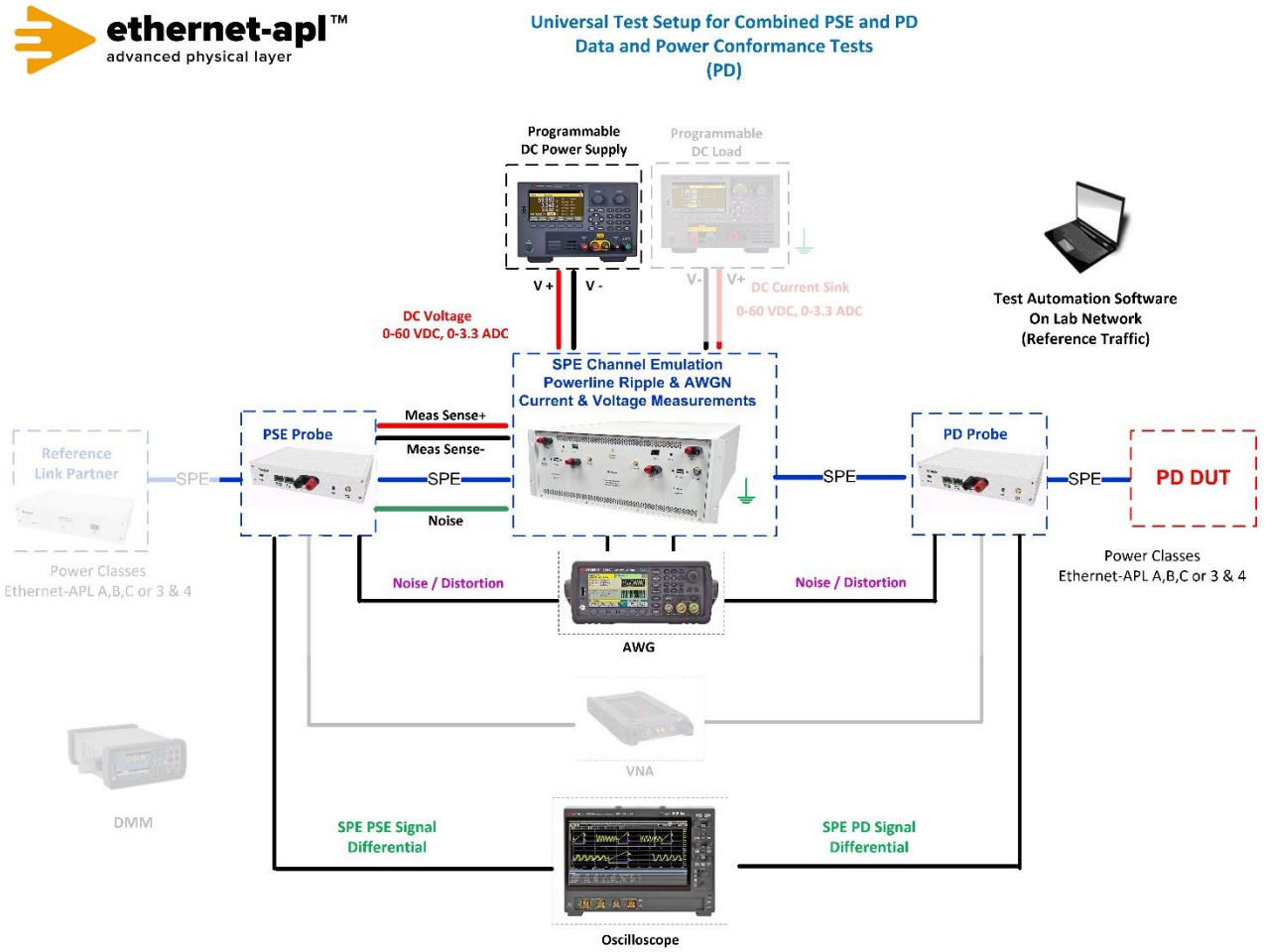
Test Setup / Connection Diagram (PSE):



Required Test Equipment for PD:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. PSE Probe
4. Programmable DC Power Supply (to power the PD Load DUT)
5. AWG
6. Oscilloscope
7. Test Automation Software

Test Setup / Connection Diagram (PD):



Device Under Test Setup:

- DUT as 10BASE-T1L default configuration and enable auto-negotiation
- Note if the DUT is a Trunk or a Spur Port
- Enter the Power Class for the Device Under Test (Trunk: Class 3 or 4, Spur: Class A, B or C) into the test automation software.
- A test station capable of Auto-Negotiation, 10BASE-T1L link signaling, and arbitrary packet generation and capturing and decoding ternary symbols. Test stations must be either Option 1B (Figure C.2) or Option 2 (Figure C.3) with test setup as noted below.
- A line-monitoring system capable of decoding Auto-Negotiation DME pages.
- Link Partner test station with controllable 1.2249.14 bit (10BASE-T1L Transmit Disable)

Expected Results (Pass/Fail Criteria):

Part A: DUT transmits within a valid voltage range while sending DME pages.

Step	Status	Description
A:6	PASS	The DUT is not observed to send DME pages exceeding the voltage requirements.
A:4	FAIL	Any observed voltage level Vpp_max exceeds 1.3 V (1.0 V + 30%).
A:5	FAIL	Any observed voltage level Vpp_min is below 0.7 V (1.0–V - 30%).

Notes:

References:

[1] IEEE Std. 802.3-2018 subclause 98.2.1.1.4 (Transmitter peak differential output)

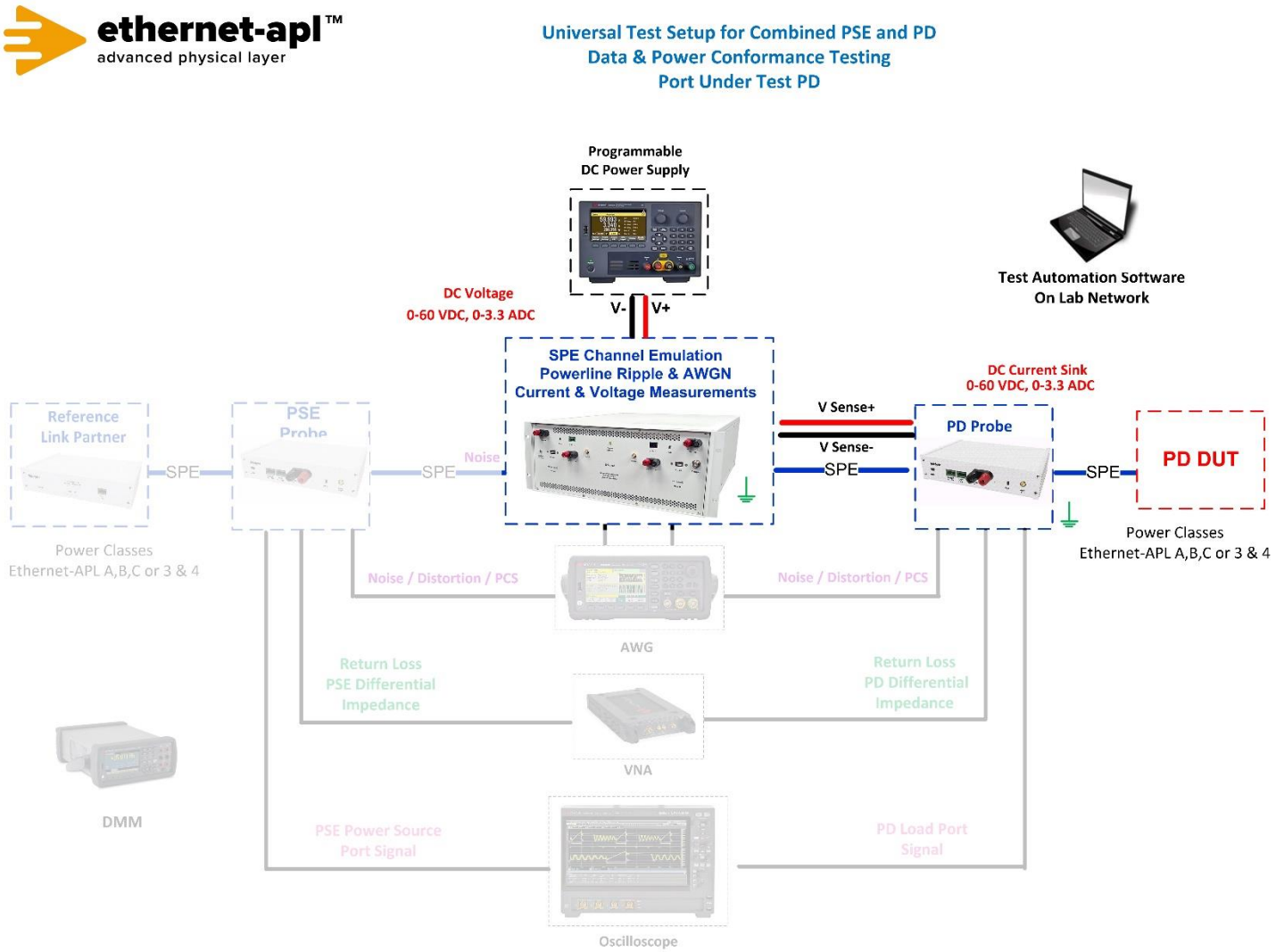
Test Type (Data or Power): Power
Test Name: SL.1.1 Shielding Options

Purpose/Description: To verify that a Spur Power Load port will continuously draw the minimum specified value of current during steady state operation. Minimum and Maximum current draw.

Required Test Equipment:

1. **PD Probe**
2. **4950 Channel Emulator (for current measurements)**
3. **Programmable DC Power Supply (to power the PD Load DUT)**

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Spur Power Load Port will continuously draw the specified value of current during steady state. Class A and C $I_{PL(MIN)}$ = 20mA

Step	Status	Description
4	PASS	The recorded value of I_{PL} is greater than or equal to $I_{PL(MIN)}$ for the port power class with a minimum supply voltage
4	FAIL	The recorded value of I_{PL} is less than $I_{PL(MIN)}$ for the port power class with a minimum supply voltage
5	PASS	The recorded value of I_{PL} is greater than or equal to $I_{PL(MIN)}$ for the port power class with a maximum supply voltage
5	FAIL	The recorded value of I_{PL} is less than $I_{PL(MIN))}$ for the port power class with a maximum supply voltage

Notes:

References:

[1] APL Port Profile 1.1 Section 5.4
[2] Methods Annex – Sampling with Digital Multimeter
[3] Methods Annex – Disabling PHY
[4] Methods Annex – Power Supply Voltage Sensing

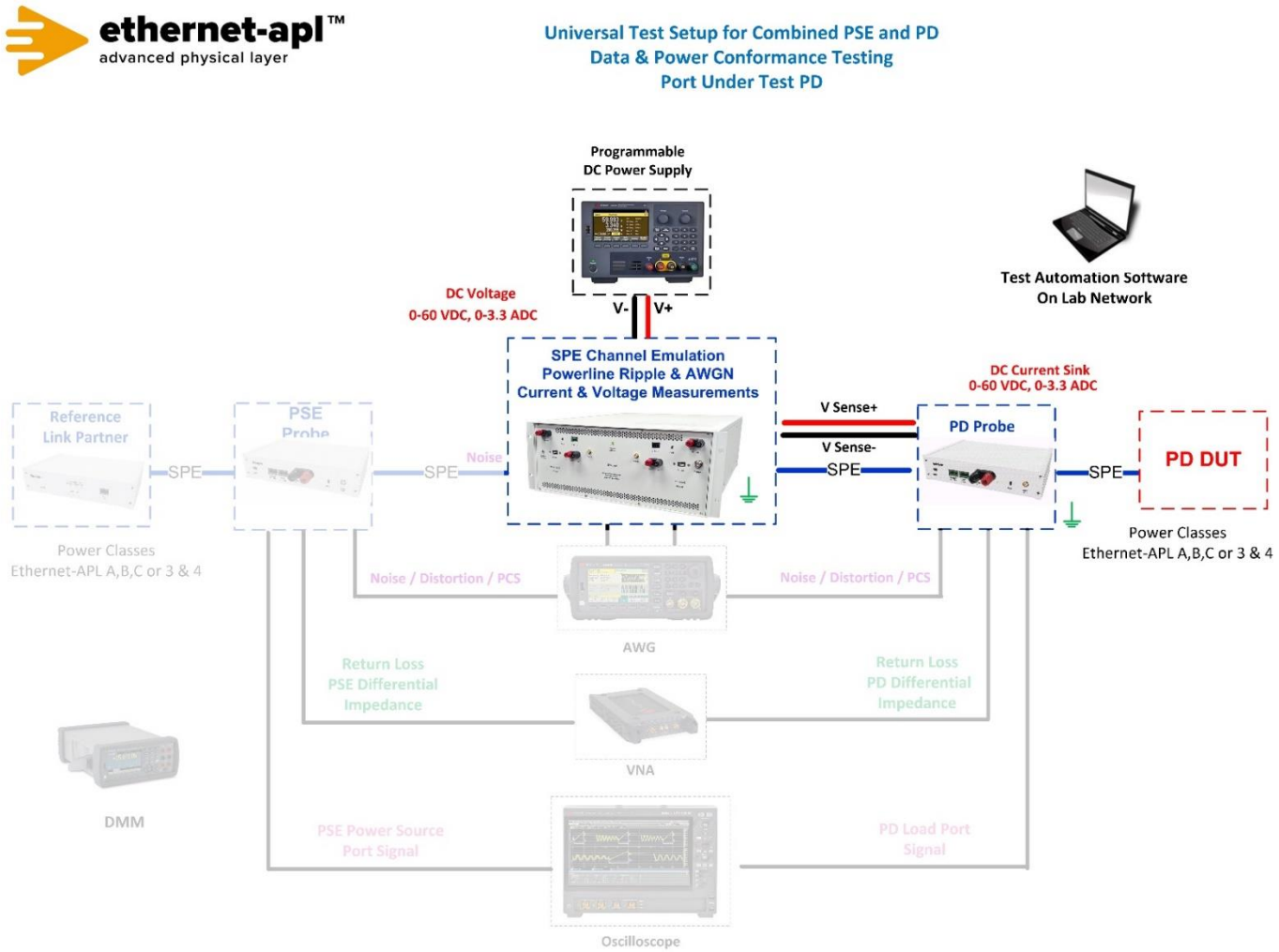
Test Type (Data or Power): Power
Test Name: SL.1.2 Inrush Current

Purpose/Description: To verify that a Spur Power Load port operates within the bounds of inrush energy limits.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.
- Enter if the Device Under Test is Intrinsically Safe or Non-Intrinsically Safe.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
5, 6	PASS	a. The port is intrinsically safe, and Ein does not exceed 200 µJ ; and b. The value of tinrush_end is less than or equal to 1 ms or a. The port is non-intrinsically safe, and Ein does not exceed 500 µJ ; and b. The value of tinrush_end is less than or equal to 1ms or a. The inrush current does not exceed IPS(MIN) (Class A =55.56mA, Class B = 115mA and Class C = 95mA)
5	FAIL	The value of tinrush_end is greater than 1ms
6	FAIL	The port is intrinsically safe, and Ein exceeds 200 µJ
6	FAIL	The port is non-intrinsically safe, and Ein exceeds 500 µJ

Notes:

References:

[1] APL Port Profile 1.2 Section 5.4
[2] Methods Annex – Sampling with Digital Multimeter
[3] Methods Annex – Inrush Energy Definition and Calculation
[4] Methods Annex – Disabling PHY
[5] Methods Annex – Power Supply Voltage Sensing

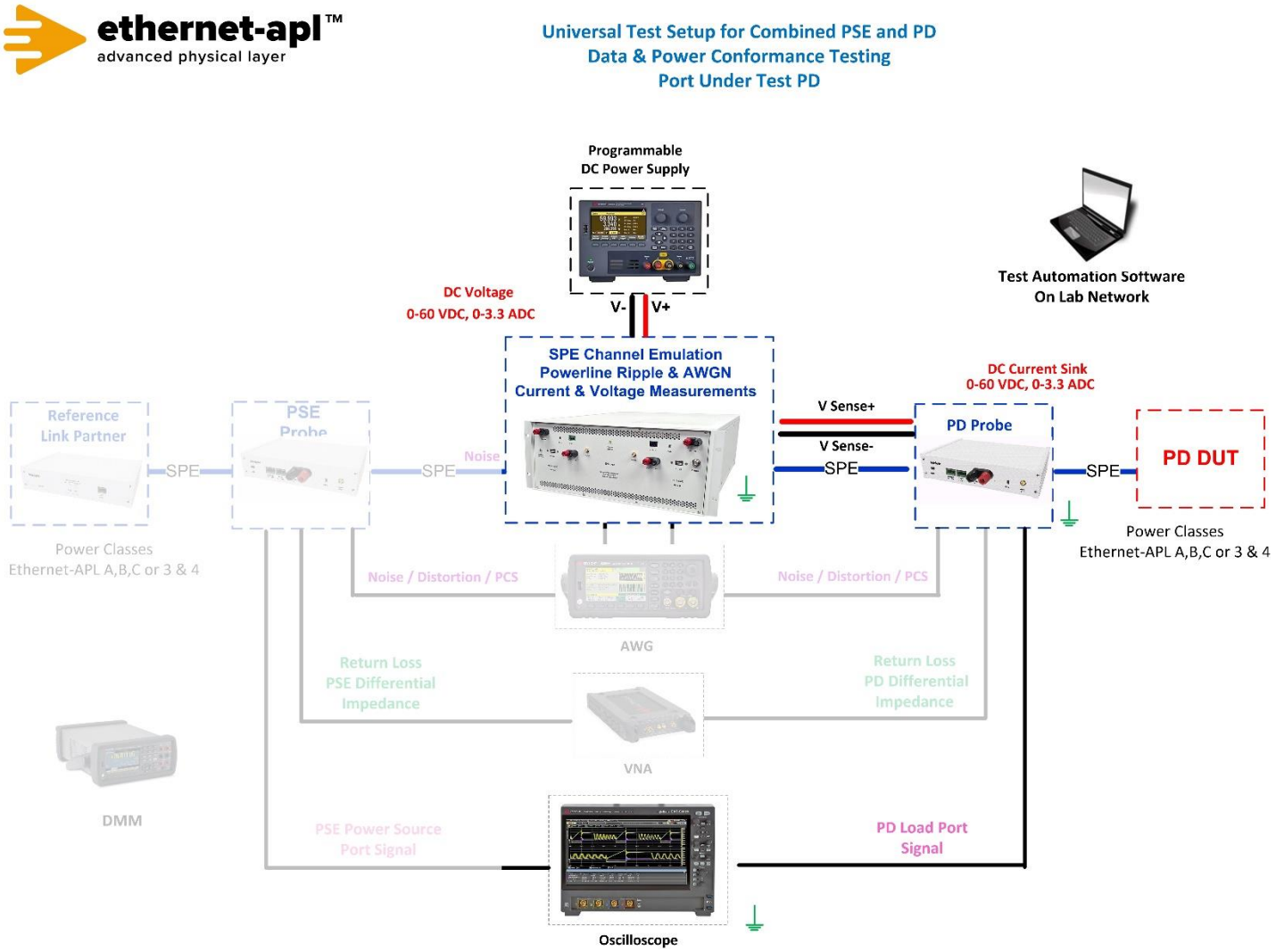
Test Type (Data or Power): Power
Test Name: SL.2.1 Differential In-Band Ripple and Noise

Purpose/Description: To verify that a Spur Power Load port introduces a level of ripple and noise below the required level in the normal operating band. Maximum Supply Voltage and Minimum Load Voltage.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Oscilloscope
5. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
6	PASS	All filtered measurements of U_{Noise} are less than or equal to 10 mV_{PP} with a maximum supply voltage
6	FAIL	At least one filtered measurement of U_{Noise} is greater than 10 mV_{PP} with a maximum supply voltage
7	PASS	All filtered measurements of U_{Noise} are less than or equal to 10 mV_{PP} with a minimum supply voltage
7	FAIL	At least one filtered measurement of U_{Noise} is greater than 10 mV_{PP} with a minimum supply voltage

Notes:

References:

[1] APL Port Profile 1.2 Section 5.4
[2] Methods Annex – Bandpass Filter
[3] Methods Annex – Disabling PHY
[4] Methods Annex – Power Supply Voltage Sensing

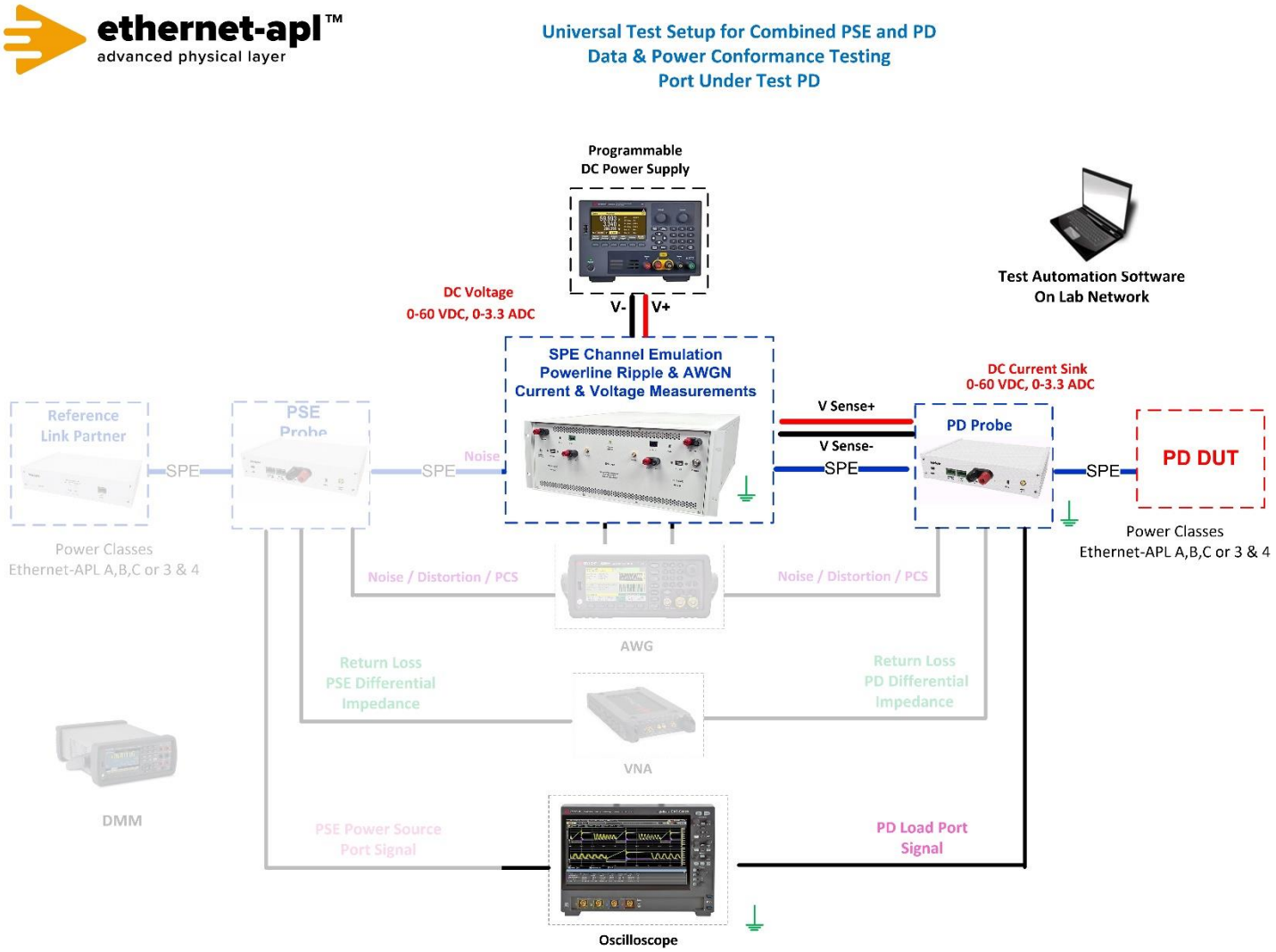
Test Type (Data or Power): Power
Test Name: SL.2.2 Differential Out-Band Ripple and Noise

Purpose/Description: To verify that a Spur Power Load port introduces a level of ripple and noise below the required level outside the normal operating band. Maximum Supply Voltage and Minimum Load Voltage.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Oscilloscope
5. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
7	PASS	All filtered measurements of U_{Noise} are less than or equal to 100 mV_{PP} with a maximum supply voltage
7	FAIL	At least one filtered measurement of U_{Noise} is greater than 100 mV_{PP} with a maximum supply voltage
8	PASS	All filtered measurements of U_{Noise} are less than or equal to 100 mV_{PP} with a minimum supply voltage
8	FAIL	At least one filtered measurement of U_{Noise} is greater than 100 mV_{PP} with a minimum supply voltage

Notes:

References:

[1] APL Port Profile 1.2 Section 5.4
[2] Methods Annex – Disabling PHY
[3] Methods Annex – Power Supply Voltage Sensing

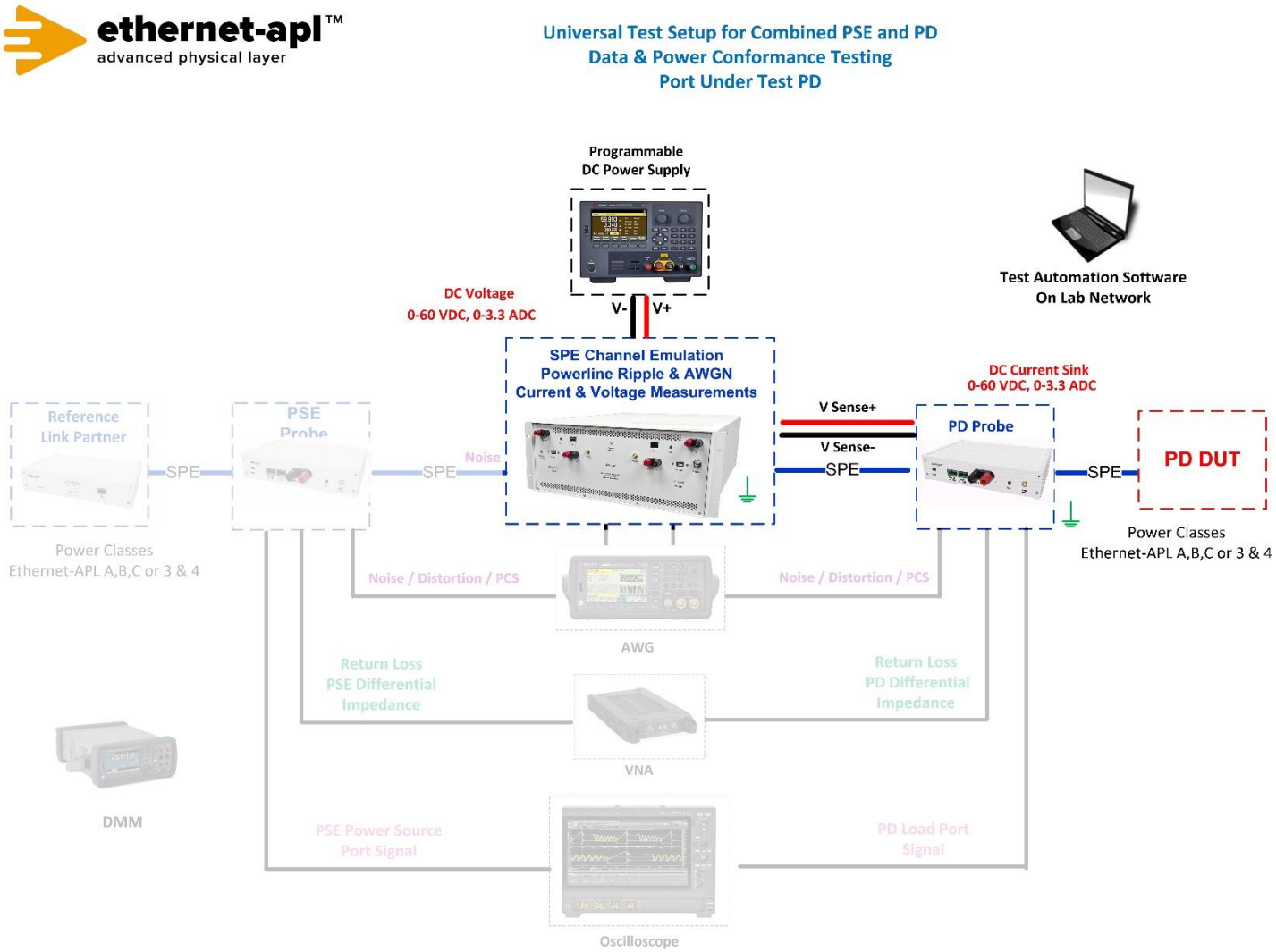
Test Type (Data or Power): Power
Test Name: SL.2.3 Current Derivatives

Purpose/Description: To verify that a Spur Power Load port limits the load current slew rate during steady-state operation. Maximum Supply Voltage and Minimum Load Voltage.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.

- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
6	PASS	All measurements of dI_{CR} /dt less than or equal to 10 mA/ms
6	FAIL	At least one measurement of dI_{CR} /dt is greater than 10 mA/ms
8	PASS	All measurements of dI_{CR} /dt less than or equal to 10 mA/ms
8	FAIL	At least one measurement of dI_{CR} /dt is greater than 10 mA/ms

Notes:

References:

[1] APL Port Profile 1.2 Section 5.4
[2] Methods Annex – Sampling with Digital Multimeter
[3] Methods Annex – Disabling PHY
[4] Methods Annex – Power Supply Voltage Sensing

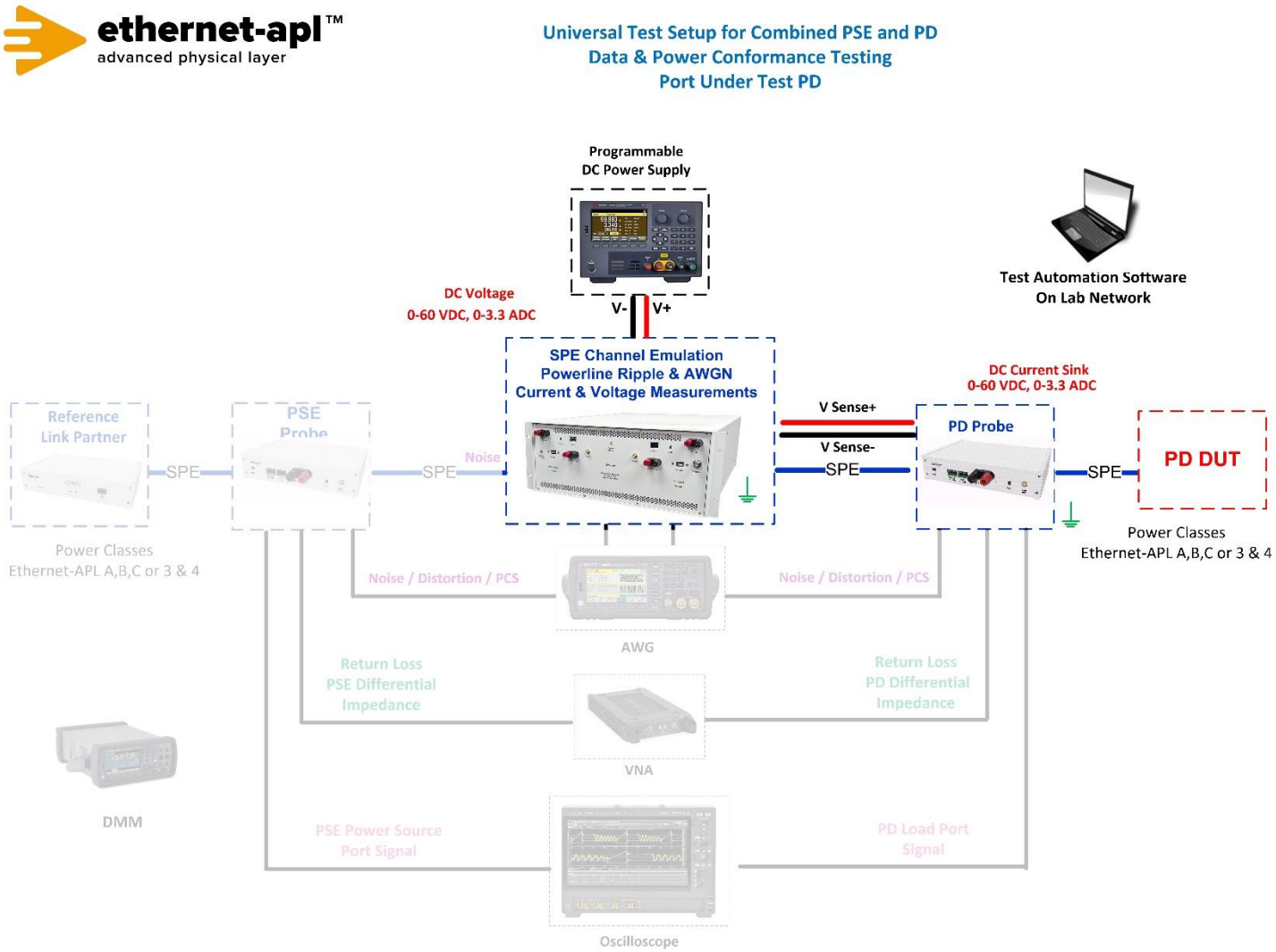
Test Type (Data or Power): Power
Test Name: SL.2.4 Current Events

Purpose/Description: To verify that a Spur Power Load port properly regulates its usage of current steps and spikes during operational start up. Maximum Supply Voltage and Minimum Load Voltage.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
5,7	PASS	a. All current steps have a maximum magnitude of 50 mA; **and** b. All current spikes have a maximum charge of 20 µC; **and** c. No current spike causes the current consumption of the port under test to exceed $I_{PS(MIN)}$ for the port power class; **and** d. There are no more than six current events in the first 1000 ms after applying port power; **and** e. There are no current events after the first 1000 ms after applying port power
5	FAIL	At least one current step has a magnitude greater than 50 mA
7	FAIL	At least one current spike has a charge greater than 20 µC
5	FAIL	At least one current spike causes the current consumption of the port under test to exceed $I_{PS(MIN)}$ for the port power class
5	FAIL	There are more than six current events in the first 1000 ms after applying port power
5	FAIL	There is at least one current event that occurs after the first 1000 ms after applying port power

Notes:

References:

[1] APL Port Profile 1.2 Section 5.4
[2] Methods Annex – Sampling with Digital Multimeter
[3] Methods Annex – Inrush Energy Definition and Calculation
[4] Methods Annex – Disabling PHY
[5] Methods Annex – Power Supply Voltage Sensing

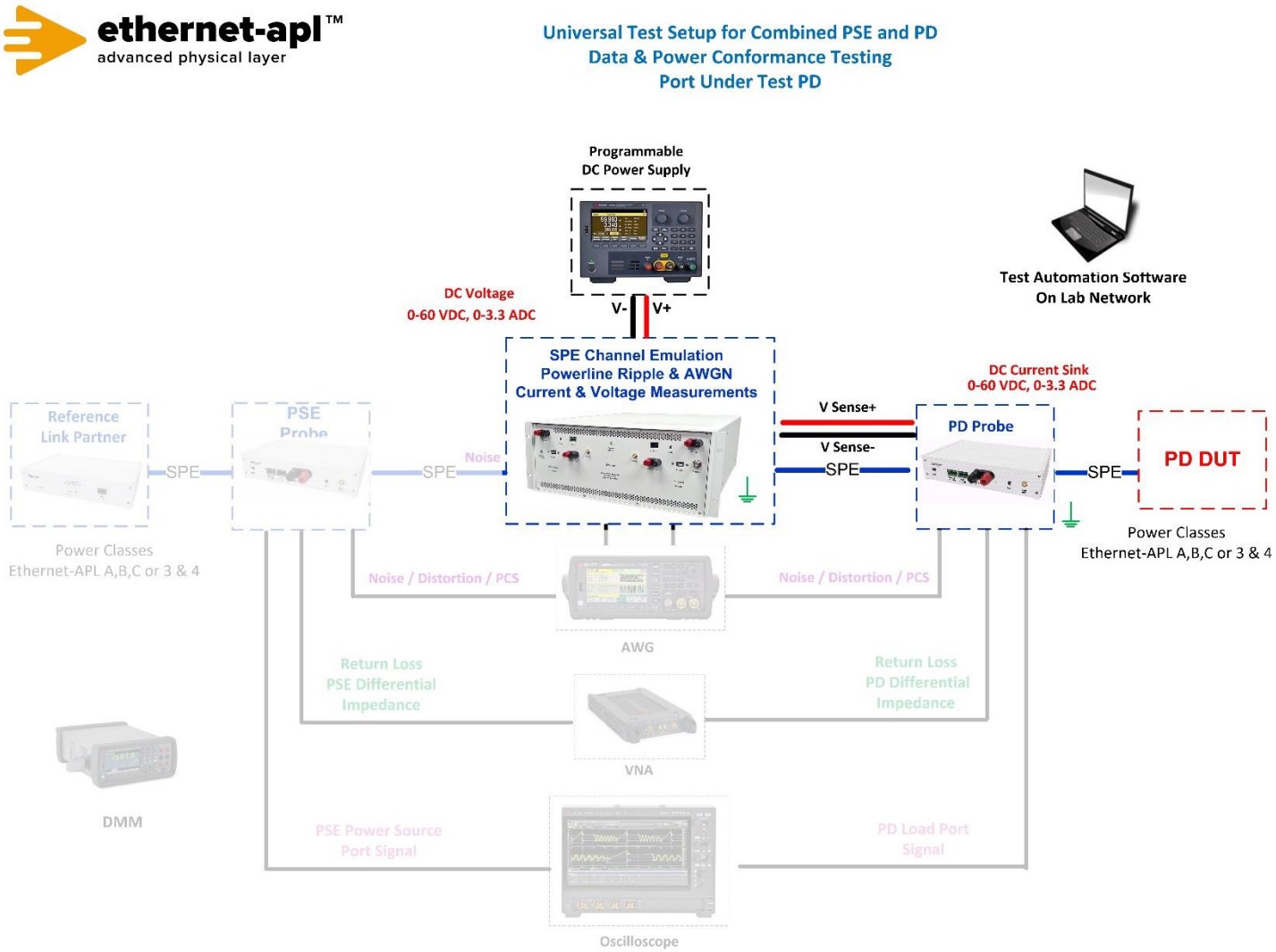
Test Type (Data or Power): Power
Test Name: SL.2.5 Under Voltage Current

Purpose/Description: To verify that a Spur Power Load port will limit its current draw during an undervoltage event.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
3	PASS	I_{PL} never exceeds $I_{PL(MAX)}$ for the port power class (Class A = 55.56mA, Class B = 115mA & Class C = 95mA)
3	FAIL	I_{PL} exceeds $I_{PL(MAX)}$ for the port power class at least once

Notes:

References:

[1] APL Port Profile 1.2 Section 5.4
[2] Methods Annex – Sampling with Digital Multimeter
[3] Methods Annex – Disabling PHY
[4] Methods Annex – Power Supply Voltage Sensing

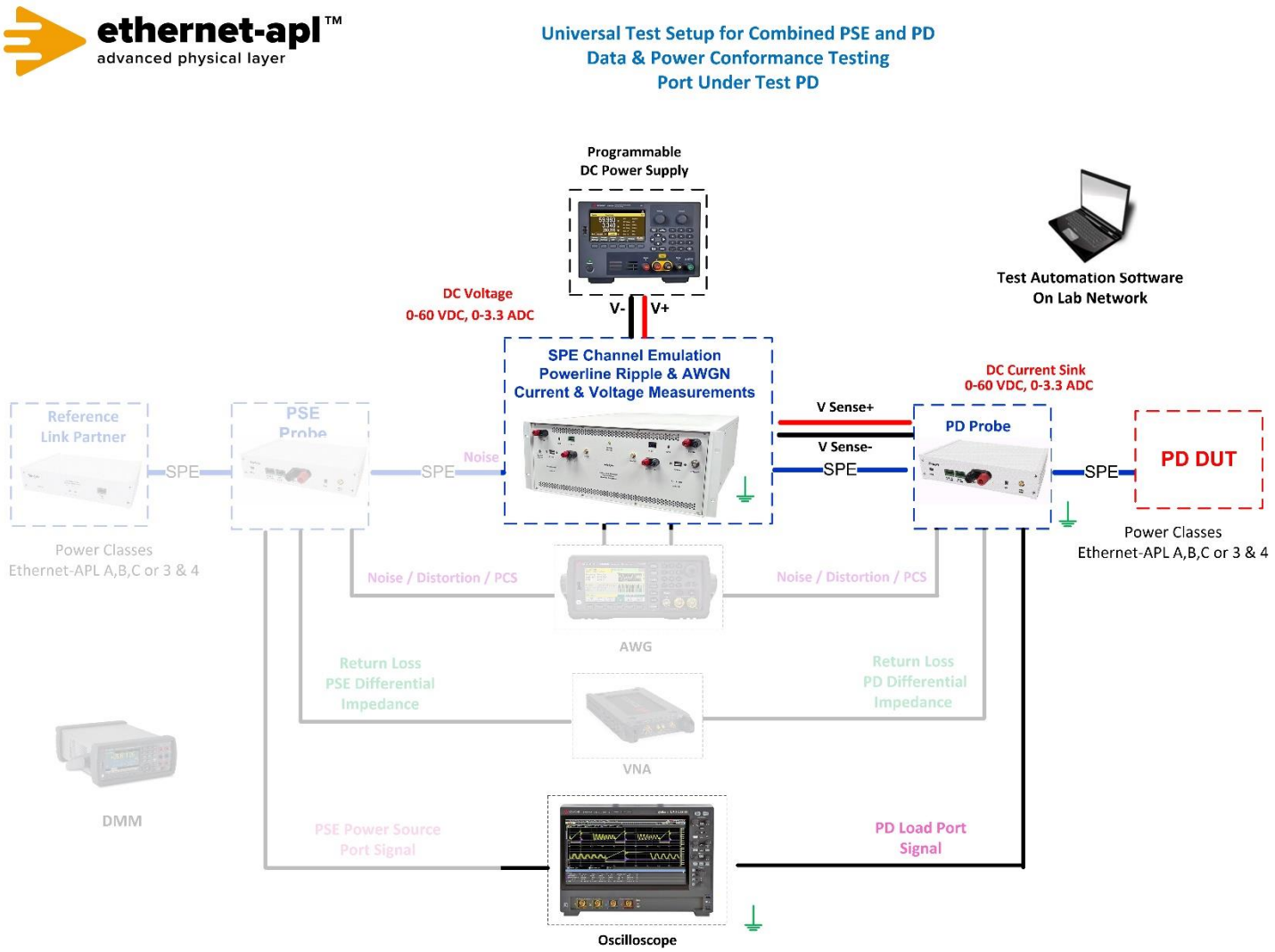
Test Type (Data or Power): Power
Test Name: SL.3.1 Terminal and Connectors

Purpose/Description: To verify that a Spur Power Load port uses a valid port connector and that the pins of the connector exhibit their assigned functions**.**

Required Test Equipment:

1. PSE Probe
2. DC Power Supply (To power the PSE Field Switch DUT)
3. Programmable DC Load
4. 4950 Channel Emulator
5. Oscilloscope
6. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
2, 6,	PASS	a. The observed connector is an M8 or M12 socket (A-Coded), or a terminal block connection; **and** b. b. An auto-negotiation signal is present between the APL signal+ and APL signal– pins 10BASE-T1L is using Low Speed Mode (LSM) DME clock edge to clock edge is 625kHz
2	FAIL	The observed connector is not an M8 or M12 socket (A-Coded) or a terminal block connection
6	FAIL	An auto-negotiation signal is not present between the APL signal+ and APL signal– pins

Notes:

References:

[1] APL Port Profile 1.2 Section A.1, A.3, A.4
[2] IEC 60603-7-3
[3] IEC 61076-2-101
[4] IEC 61076-2-104
[5] Methods Annex – Power Supply Voltage Sensing

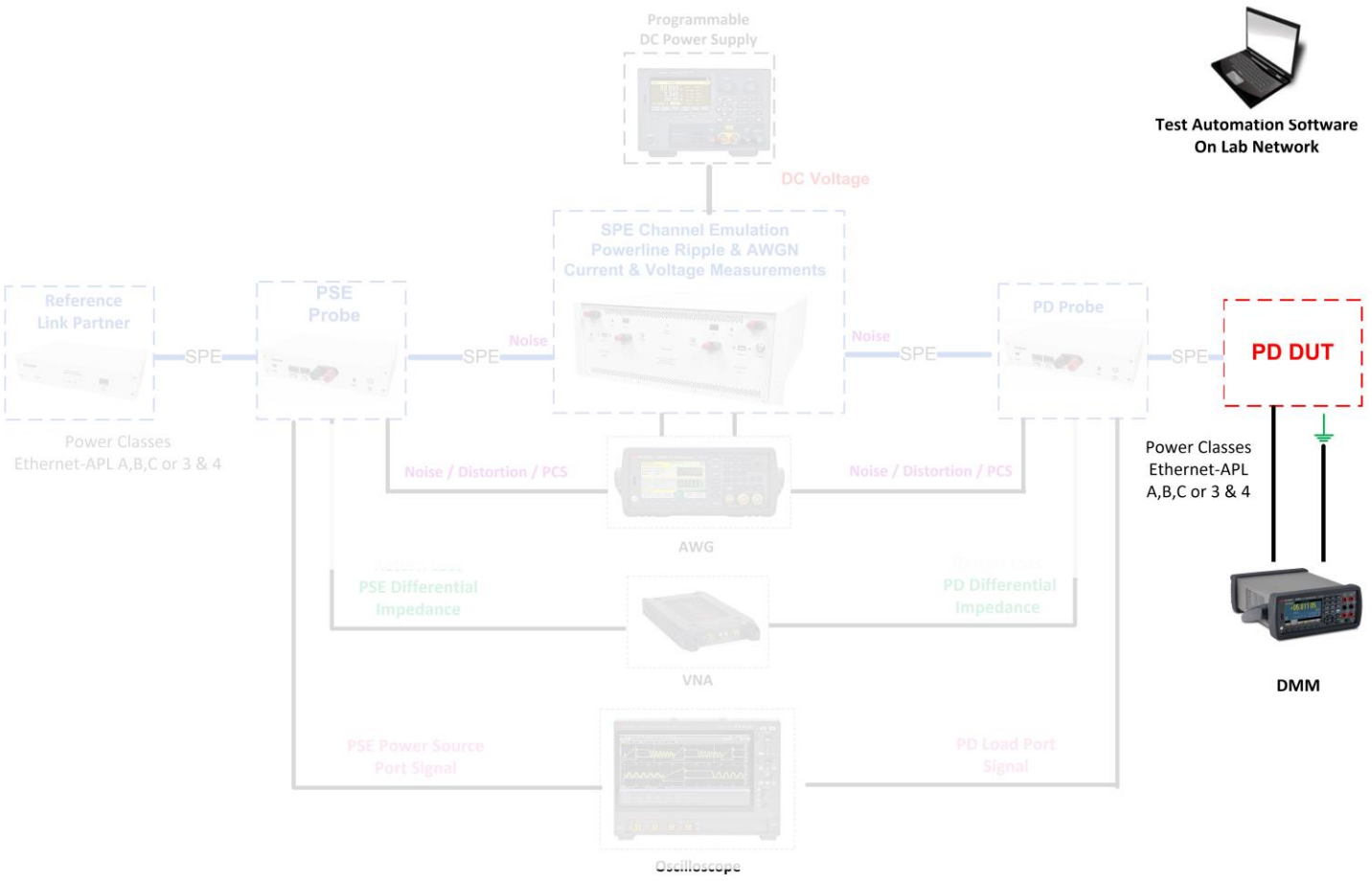
Test Type (Data or Power): Power
Test Name: SL.3.2 Shielding Options

Purpose/Description: To verify that a Spur Power Load port implements a direct shielding connection to ground at the port interface.

Required Test Equipment:

1. Digital Multimeter
2. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
6, 8	PASS	a. The port provides a direct shielding connection with a resistance less than 200 mOhm; **and** b. If the port provides a capacitive shielding connection (optional), capacitive shielding connection with a capacitance in the range of 3 – 10 nF
6	FAIL	The port provides a direct shielding connection, the resistance is greater than 200 mOhm
8	FAIL	If the port provides a capacitive shielding connection (optional), it has a capacitance not in the range of 3 – 10 nF

Notes:

References:

[1] APL Port Profile 1.2 Section 6.2
[2] APL Port Profile 1.2 Section A.1, A.3, A.4
[3] Methods Annex – Shield Capacitance and Resistance Measurements
[4] Methods Annex – Disabling PHY
[5] Methods Annex – Power Supply Voltage Sensing

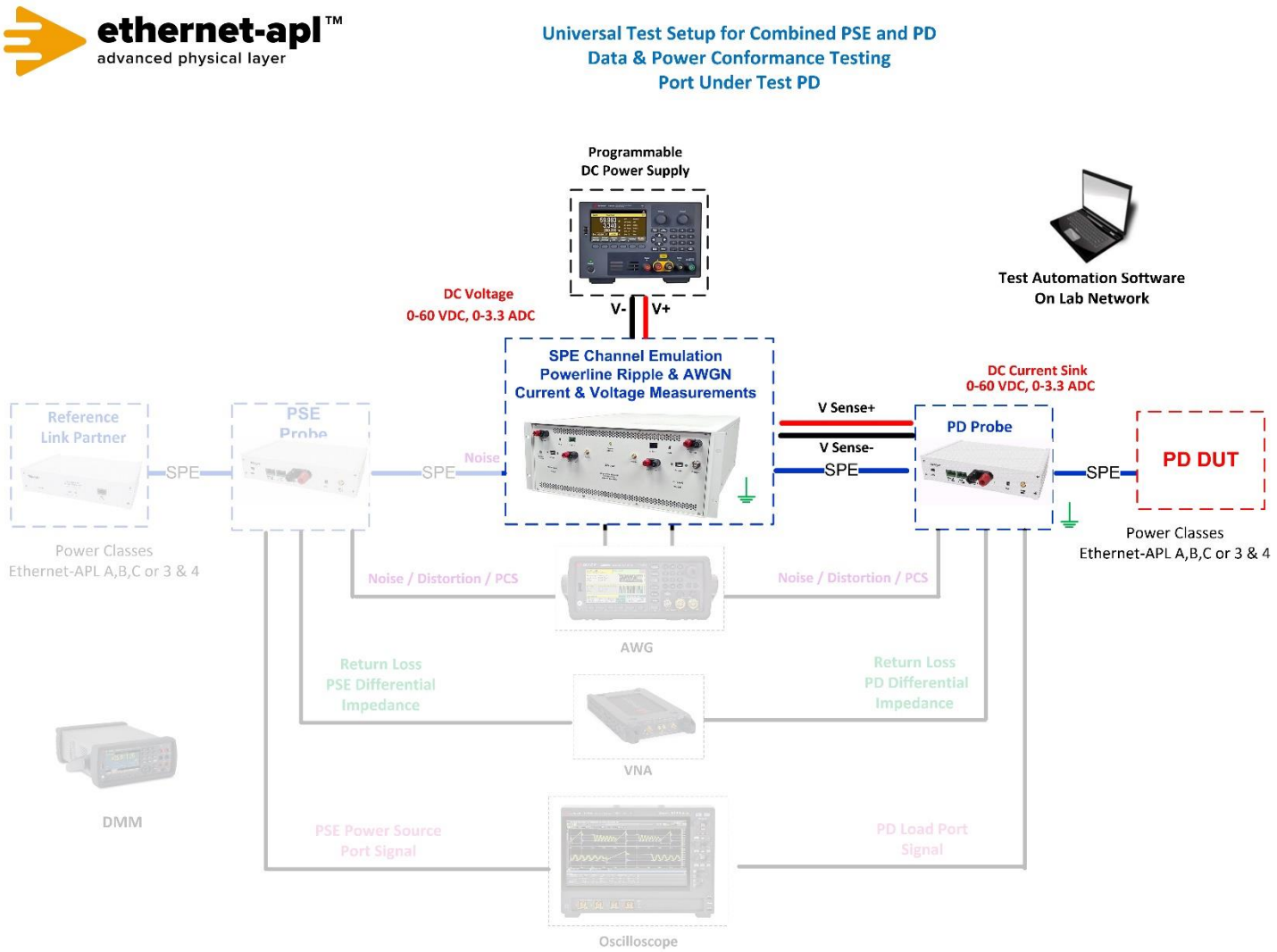
Test Type (Data or Power): Power
Test Name: SL.3.3 Polarity Sensitivity

Purpose/Description: To verify that a Spur Power Load port is reverse polarity protected if it is polarity sensitive or that it operates normally regardless of polarity if it is polarity insensitive.

Required Test Equipment:

1. PD Probe
2. Programmable DC Power Supply (To power the PSE Field Switch DUT)
3. 4950 Channel Emulator
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class A, B or C) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
4, 8	PASS	The port powers normally in both polarity configurations; **and** $I_{PL(1)}$ and $I_{PL(2)}$ are in the range of $I_{PL(MIN)}$ (Class A,B & C = 20mA) to $I_{PS(MAX)}$ (Class A = 55.56mA, Class B = 115mA & Class C = 95mA)
4, 8	FAIL	The port does not power normally in both polarity configurations; **or** $I_{PL(1)}$ and/or $I_{PL(2)}$ are not in the range of $I_{PL(MIN)}$ to $I_{PS(MAX)}$ (20mA to Class A = 55.56mA, Class B 115mA or Class C = 95mA)

Notes:

References:

[1] APL Port Profile 1.2 Section 6.3
[2] Methods Annex – Disabling PHY
[3] Methods Annex – Power Supply Voltage Sensing

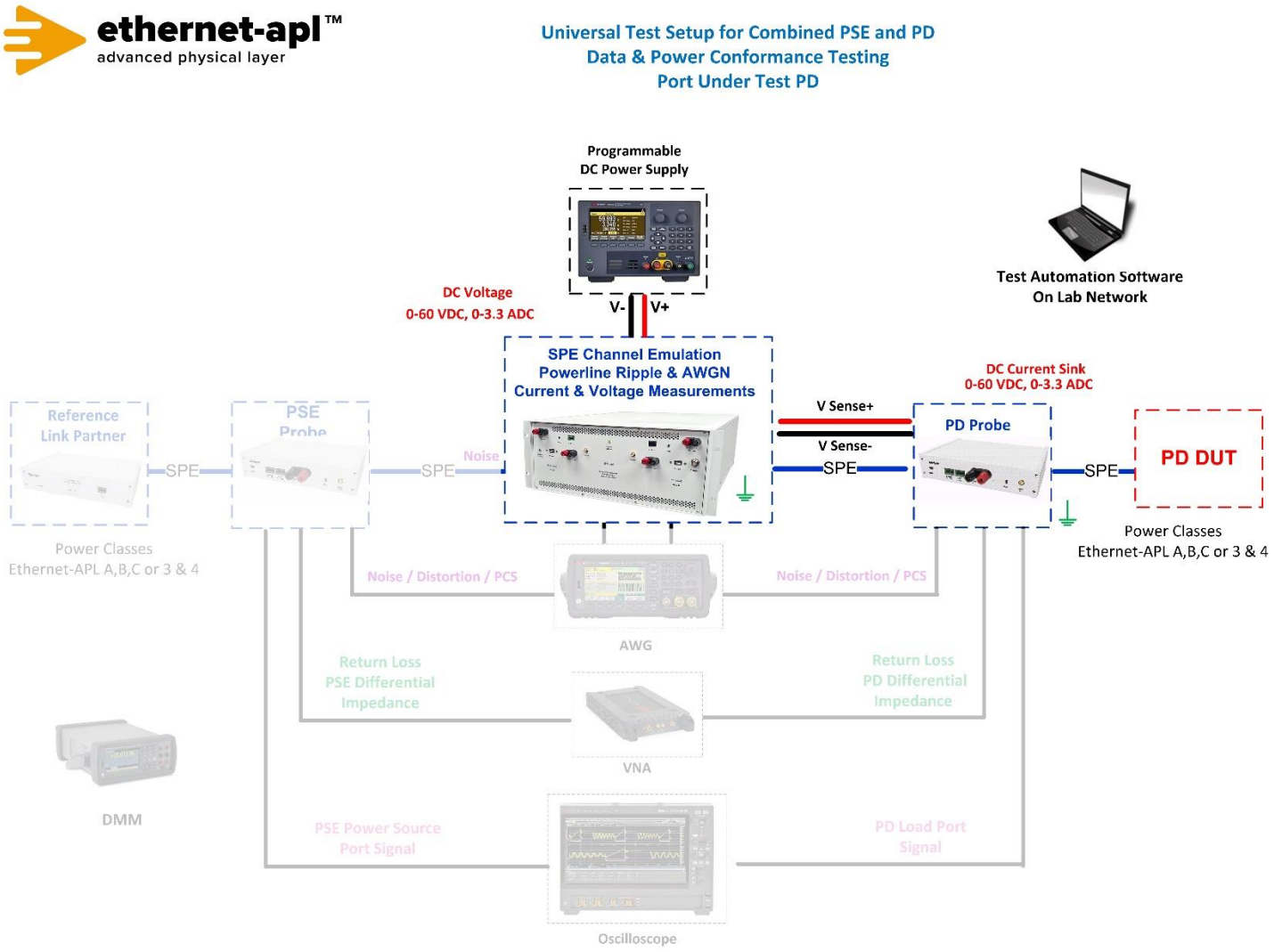
Test Type (Data or Power): Power
Test Name: TL.1.1 Minimum Current Draw

Purpose/Description: To verify that a Trunk Power Load port will draw the minimum required current during steady state operation if it implements a diode function. Minimum and Maximum Supply Voltage.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class 3 or 4) into the test automation software.

Expected Results (Pass/Fail Criteria):

Spur Power Load Port will continuously draw the specified value of current during steady state. Class A and C IPL(min)=20mA

Step	Status	Description
4	PASS	The port utilizes a diode in the signal path and all measurements of I_{PL} are at least $I_{PL(MIN)}$ (≥ 40 mA)
4	FAIL	The port utilizes a diode in the signal path and at least one measurement of I_{PL} is less than $I_{PL(MIN)}$ (< 40 mA)
-	N/A	The port does not utilize a diode function in the signal path

Notes:

References:
[1] APL Port Profile Draft 1.2 Section 5.4
[2] Methods Annex – Disabling PHY

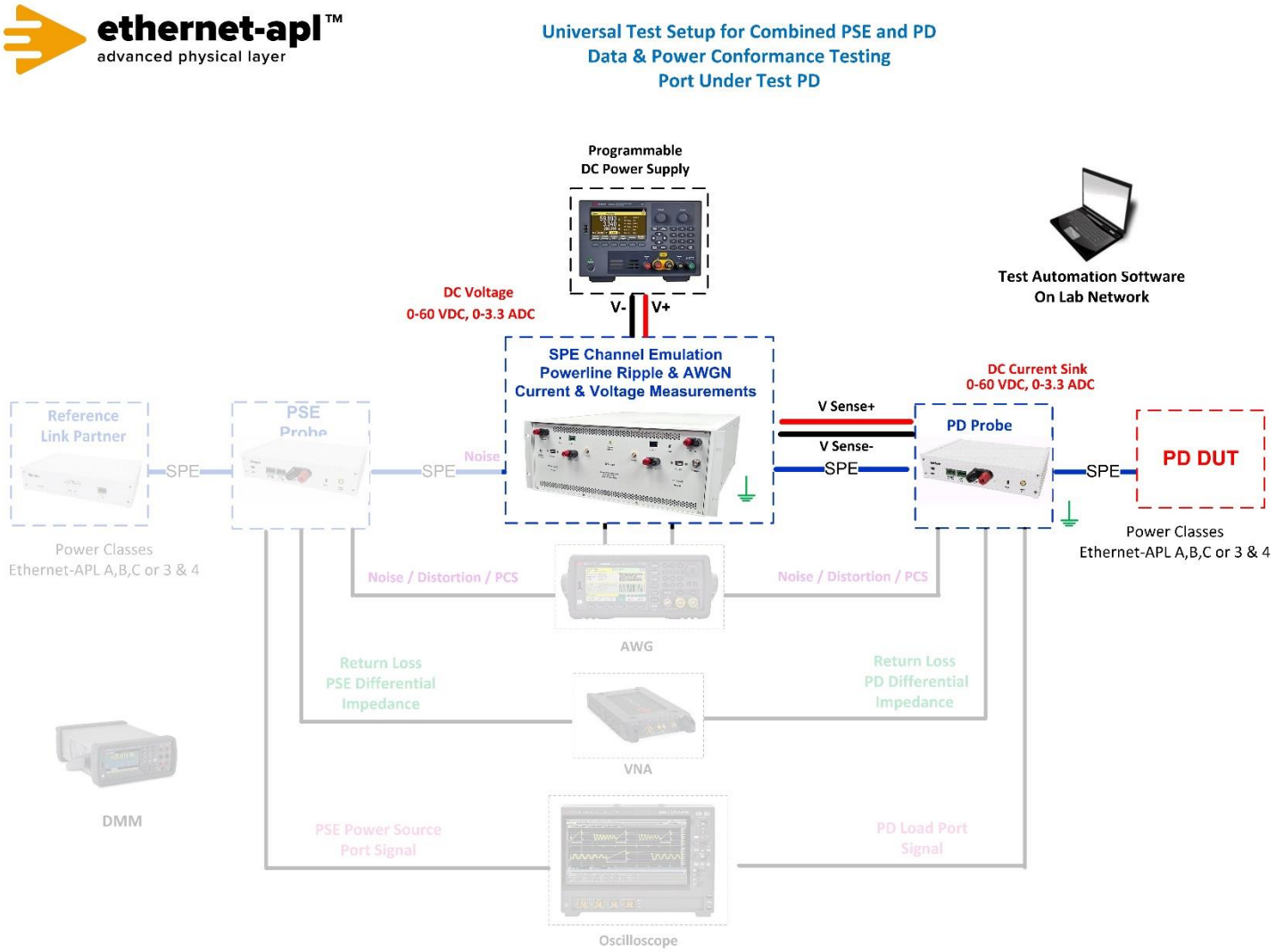
Test Type (Data or Power): Power
Test Name: TL.1.2 Inrush Current

Purpose/Description: To verify that a Trunk Power Load is within the bounds of inrush energy limits.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class 3 or 4) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
5, 6	PASS	a. The value of t_{inrush_end} is less than or equal to 500 µs; **and** b. E_{in} does not exceed 5000 µJ ; **or** a. The inrush current does not exceed $I_{PS(MIN)}$ (Class 3 = 1.250 A and Class 4 =2000mA)
5	FAIL	The value of t_{inrush_end} is greater than 3ms
6	FAIL	E_{in} exceeds 5000 µJ

Notes:

References:

[1] APL Port Profile Draft 1.2 Section 5.4

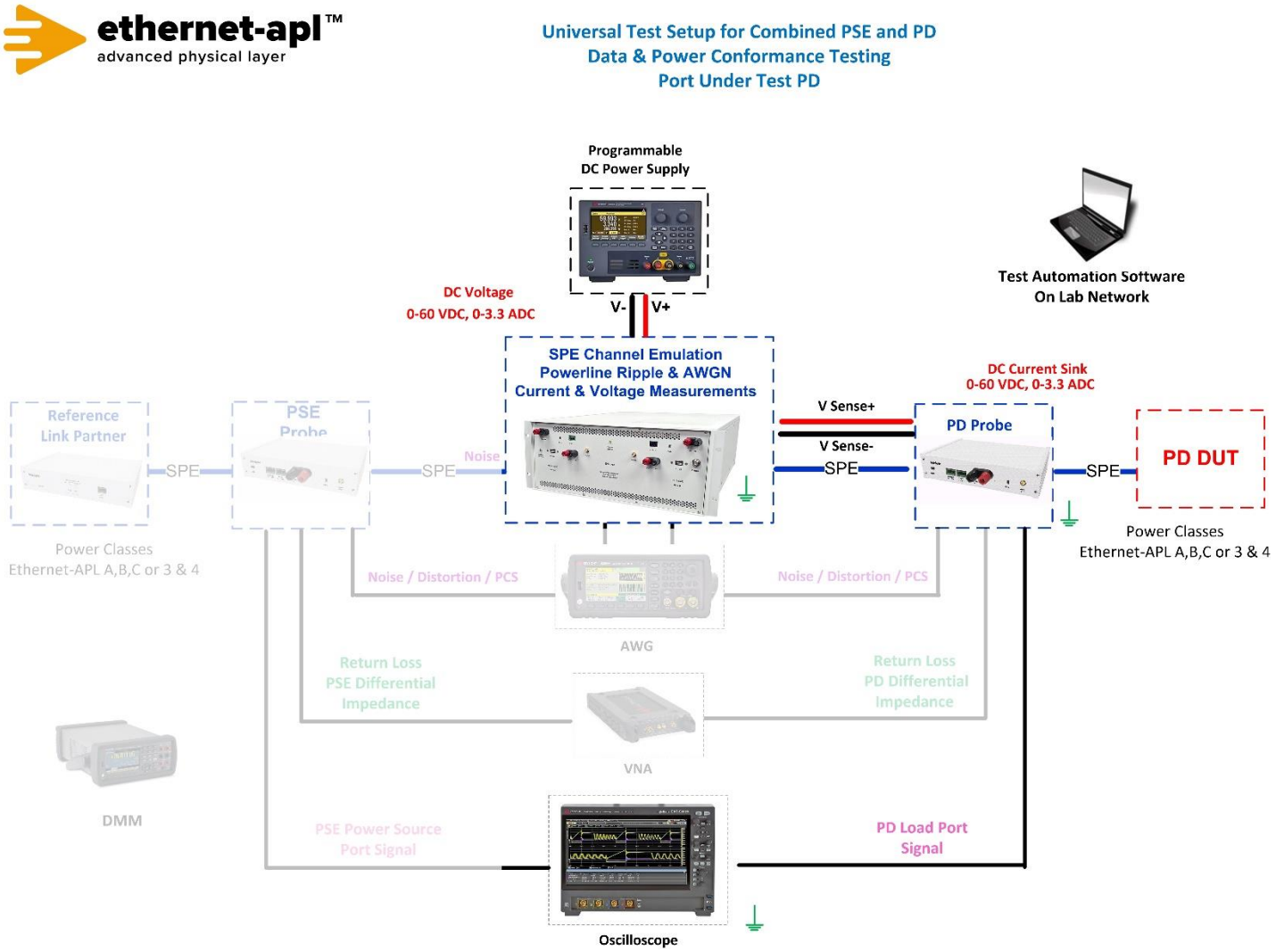
Test Type (Data or Power): Power
Test Name: TL.2.1 Differential In-Band Ripple and Noise

Purpose/Description: To verify that a Trunk Power Load introduces a level of ripple and noise below the required level in the normal operating band.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Oscilloscope
5. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class 3 or 4) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
6	PASS	All filtered measurements of U_{Noise} are less than or equal to 10 mV_{PP} with a maximum supply voltage
6	FAIL	At least one filtered measurement of U_{Noise} is greater than 10 mV_{PP} with a maximum supply voltage
7	PASS	All filtered measurements of U_{Noise} are less than or equal to 10 mV_{PP} with a minimum supply voltage
7	FAIL	At least one filtered measurement of U_{Noise} is greater than 10 mV_{PP} with a minimum supply voltage

Notes:

References:

[1] APL Port Profile Draft 1.2 Section 5.4

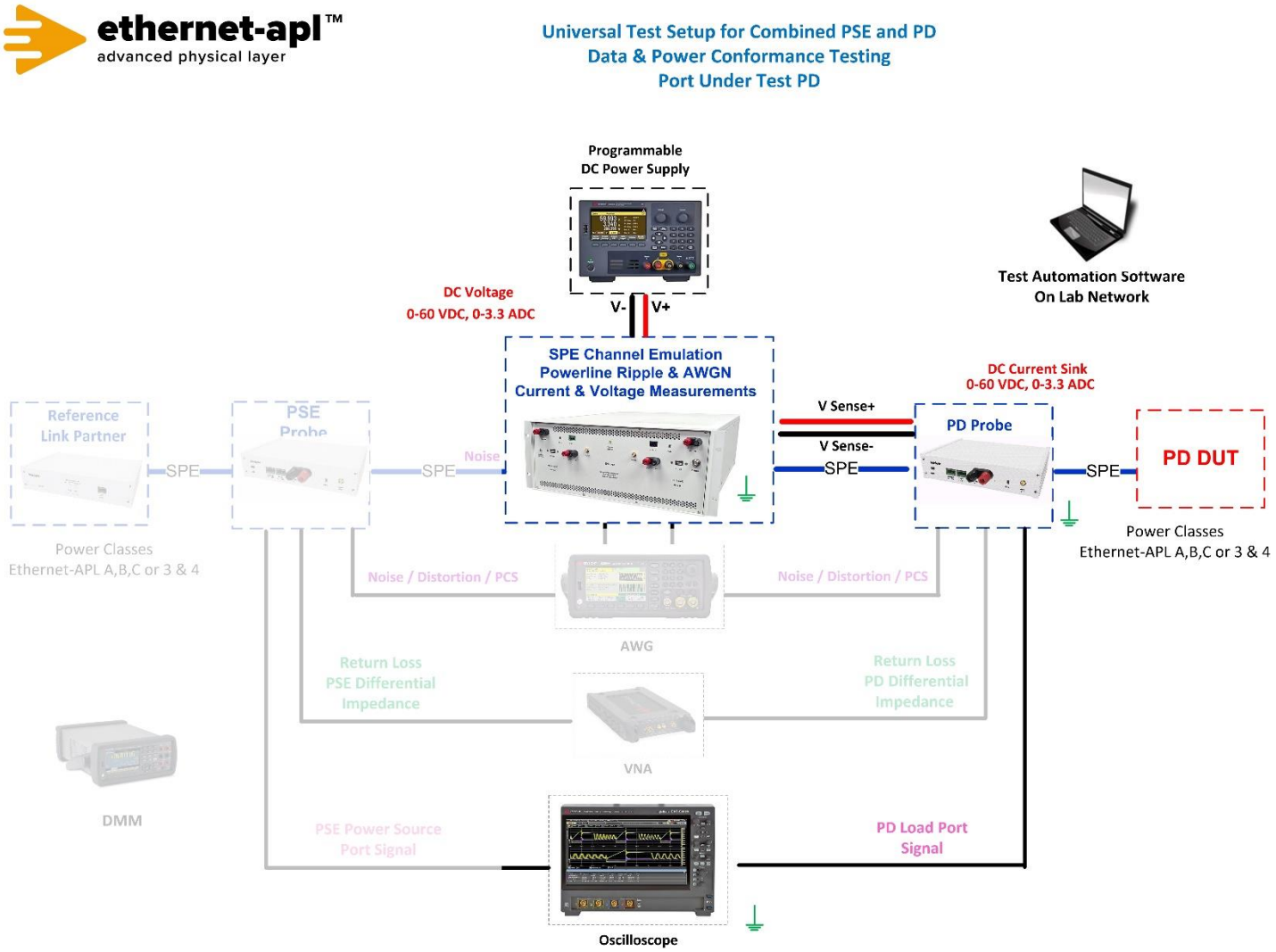
Test Type (Data or Power): Power
Test Name: TL.2.2 Differential Out-Band Ripple and Noise

Purpose/Description: To verify that a Trunk Power Load introduces a level of ripple and noise below the required level outside the normal operating band.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Oscilloscope
5. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class 3 or 4) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
6	PASS	All filtered measurements of U_{Noise} are less than or equal to 100 mV_{PP} with a maximum supply voltage
6	FAIL	At least one filtered measurement of U_{Noise} is greater than 100 mV_{PP} with a maximum supply voltage
7	PASS	All filtered measurements of U_{Noise} are less than or equal to 100 mV_{PP} with a minimum supply voltage
7	FAIL	At least one filtered measurement of U_{Noise} is greater than 100 mV_{PP} with a minimum supply voltage

Notes:

References:

[1] APL Port Profile Draft 1.2 Section 5.4

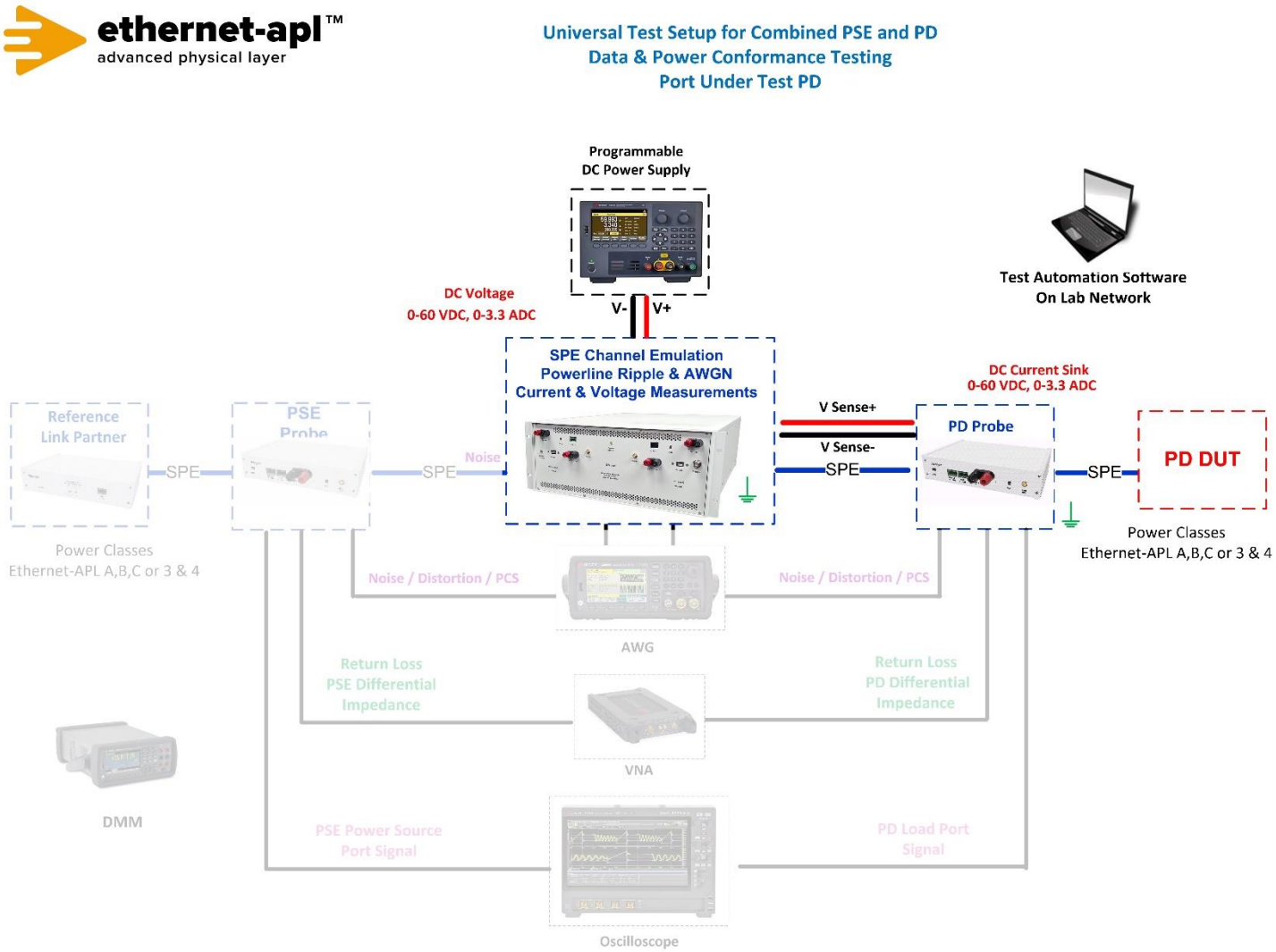
Test Type (Data or Power): Power
Test Name: TL.2.3 Current Derivatives

Purpose/Description: To verify that a Trunk Power Load limits the load current slew rate after inrush has occurred.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class 3) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
5	PASS	All measurements of dI_{CR} /dt less than or equal to 100 mA/ms
5	FAIL	At least one measurement of dI_{CR} /dt is greater than 100 mA/ms
7	PASS	All measurements of dI_{CR} /dt less than or equal to 100 mA/ms
7	FAIL	At least one measurement of dI_{CR} /dt is greater than 100 mA/ms

Notes:

References:

[1] APL Port Profile Draft 1.2 Section 5.4

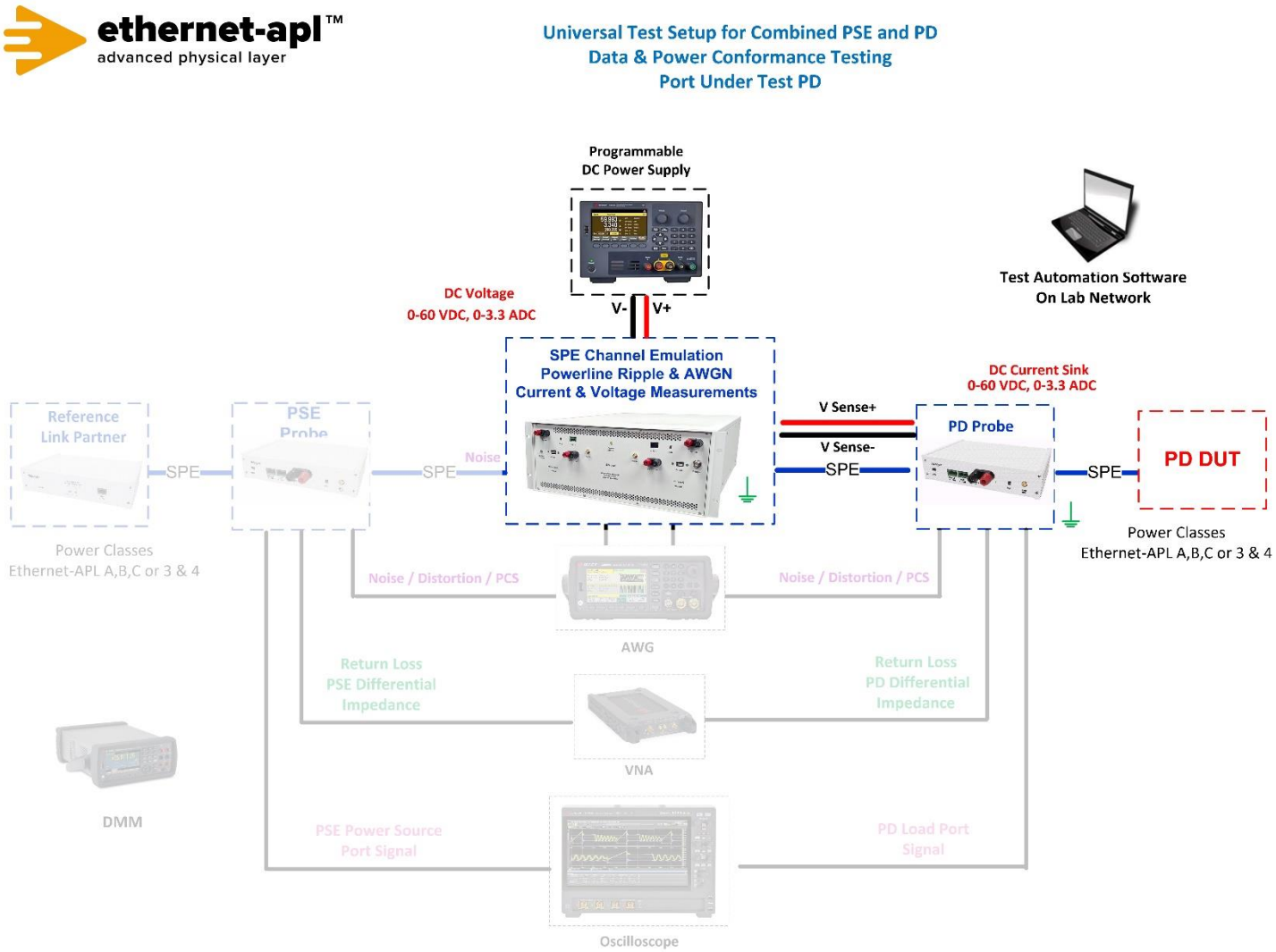
Test Type (Data or Power): Power
Test Name: TL.2.4 Current Events

Purpose/Description: To verify that a Trunk Power Load properly regulates its usage of current steps and spikes during start up.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class 3) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
6,7	PASS	a. The current steps have a maximum amplitude of 50 mA **and** b. All current spikes have a maximum charge of 20 µC and c. No current spike causes the current consumption of the port under test to exceed IPS(MIN) for the port power class and d. There is a maximum of six current events in any sliding window of 1000 ms
6, 7	FAIL	At least one current step has a magnitude greater than 50 mA
6, 7	FAIL	In any sliding window of 1000 ms, there are more than six current events

Notes:

References:

[1] APL Port Profile Draft 1.2 Section 5.4

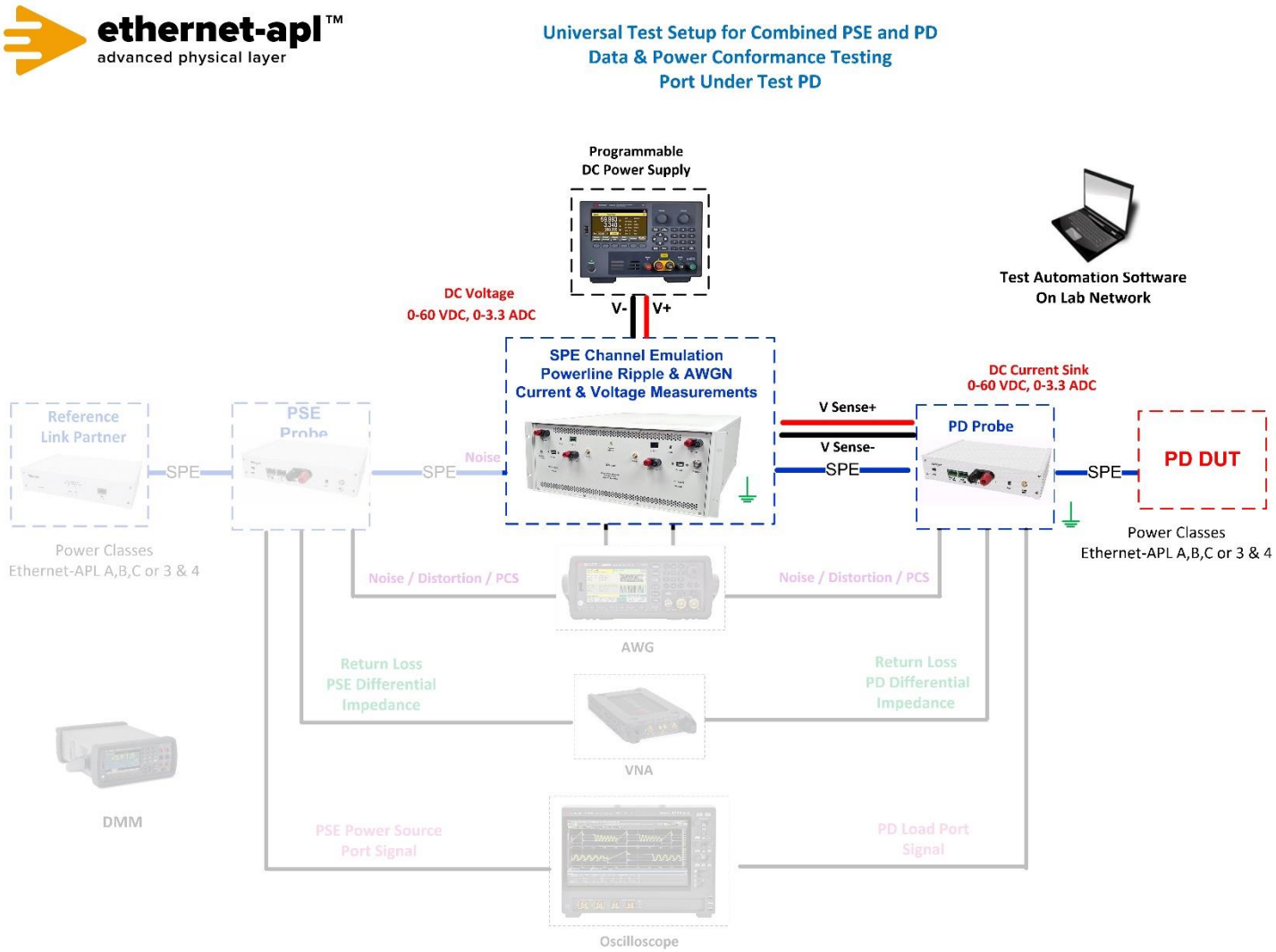
Test Type (Data or Power): Power
Test Name: TL.2.5 Under Voltage Current

Purpose/Description: To verify that a Trunk Power Load will limit its current draw during an undervoltage event.

Required Test Equipment:

1. PD Probe
2. 4950 Channel Emulator (for current and voltage measurements)
3. Programmable DC Power Supply (to power the PD Load DUT)
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class 3) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
4	PASS	I_{PL} never exceeds $I_{PL(MAX)}$ for the port power class (Class 3 = 1.250 A and Class 4 = 2.0 A)
4	FAIL	I_{PL} exceeds $I_{PL(MAX)}$ for the port power class at least once

Notes:

References:

[1] APL Port Profile Draft 1.2 Section A.1, A.3, A.4

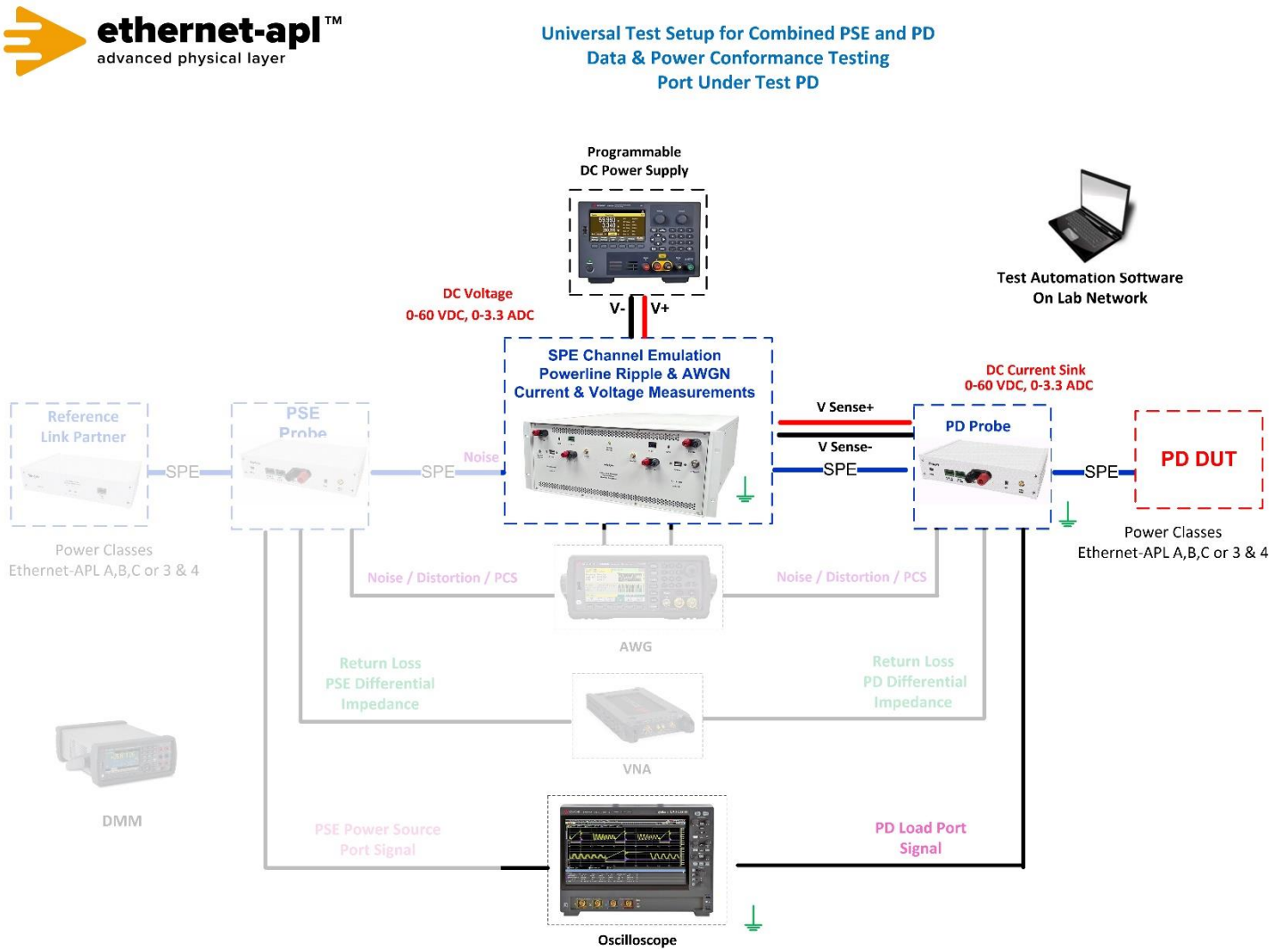
Test Type (Data or Power): Power
Test Name: TL.3.1 Terminal and Connectors

Purpose/Description: To verify that a Trunk Power Load uses a valid port connector and that the pins of the connector exhibit their assigned functions.

Required Test Equipment:

1. PSE Probe
2. DC Power Supply (To power the PSE Field Switch DUT)
3. Programmable DC Load
4. 4950 Channel Emulator
5. Oscilloscope
6. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- Enter the Power Class for the Device Under Test (Class 3 or 4) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
2, 6	PASS	a. The observed connector is an M8 or M12 socket (A-Coded), or a terminal block connection; **and** b. b. An auto-negotiation signal is present between the APL signal+ and APL signal– pins 10BASE-T1L uses Low Speed Mode (LSM) DME clock edge to clock edge is 625kHz.
2	FAIL	The observed connector is not an M8 or M12 socket (A-Coded) or a terminal block connection
6	FAIL	An auto-negotiation signal is not present between the APL signal+ and APL signal– pins

Notes:

References:

[1] APL Port Profile Draft 1.2 Section A.1, A.3, A.4
[2] IEC 60603-7-3
[3] IEC 61076-2-101
[4] IEC 61076-2-104
[5] Methods Annex – Power Supply Voltage Sensing

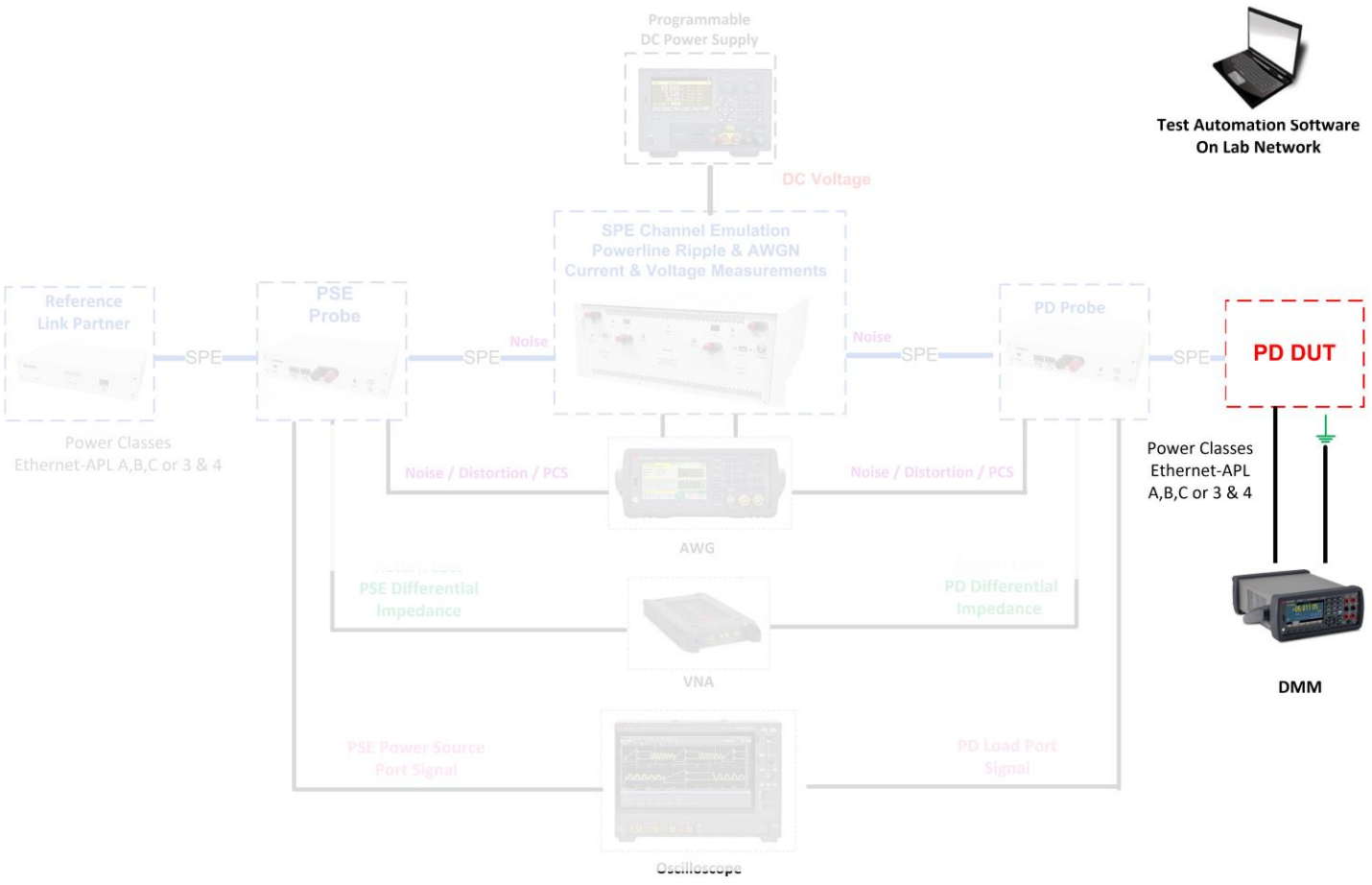
Test Type (Data or Power): Power
Test Name: TL.3.2 Shielding Options

Purpose/Description: : To verify that a Trunk Power Load implements capacitive and direct shielding connection to ground at the port interface.

Required Test Equipment:

1. Digital Multimeter
2. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class 3) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
6, 8	PASS	a. The port provides a direct shielding connection with a resistance less than 200 mOhm; **and** b. b. If the port provides a capacitive shielding connection (optional), capacitive shielding connection with a capacitance in the range of 3 – 10 nF
6	FAIL	The port provides a direct shielding connection, the resistance is greater than 200 mOhm
8	FAIL	If the port provides a capacitive shielding connection (optional), it has a capacitance not in the range of 3 – 10 nF

Notes:

References:

[1] APL Port Profile Draft 1.2 Section 6.2
[2] APL Port Profile Draft 1.2 Section A.1, A.3, A.4
[3] Methods Annex – Shield Capacitance and Resistance Measurements
[4] Methods Annex – Disabling PHY
[5] Methods Annex – Power Supply Voltage Sensing

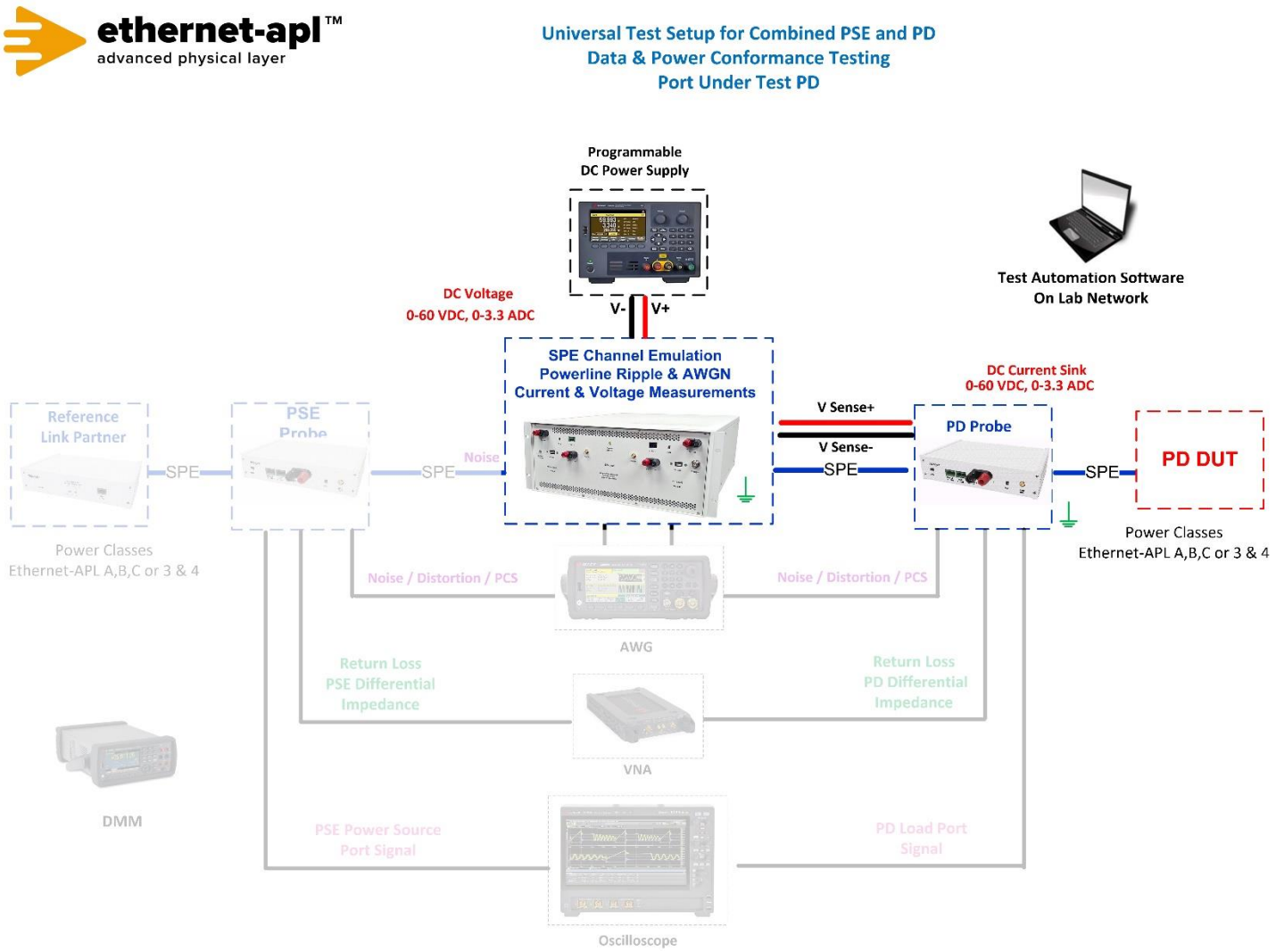
Test Type (Data or Power): Power
Test Name: TL.3.3 Polarity Sensitivity

Purpose/Description: To verify that a Trunk Power Load is reverse polarity protected if it is polarity sensitive or that it operates normally regardless of polarity if it is polarity insensitive. Mode A + / – and Mode B – / + .

Required Test Equipment:

1. PD Probe
2. Programmable DC Power Supply (To power the PSE Field Switch DUT)
3. 4950 Channel Emulator
4. Test Automation Software

Test Setup / Connection Diagram:



Device Under Test Setup:

- It is expected that all tests are performed with PHY communication abilities disabled. This is achieved by disabling Auto-Negotiation and setting the PHY to SLAVE mode. Regardless of the PHY state, each data line of the port under test shall be terminated with a 50 Ohm resistance behind a 1 µF series capacitor in the Telebyte Probe.
- Enter the Power Class for the Device Under Test (Class 3 or 4) into the test automation software.

Expected Results (Pass/Fail Criteria):

Step	Status	Description
8, 12	PASS	The port is polarity insensitive; **and** powers normally in both polarity configurations; **and** $I_{PL(1)}$ and $I_{PL(2)}$ are in the range of $I_{PL(MIN)}$ (Class 3 and 4 = 40mA) to $I_{PS(MAX)}$ (Class 3 = 1.250 A or Class 4 = 2000mA)
8, 12	PASS	a. The port is polarity sensitive (according to manufacturer documentation) and is distinctly marked with "+" and "-" polarity marking (markings only required if the port uses a terminal block connector); **and** b. IPL(1) is less than or equal to IPL(2); **and** c. The port automatically resumes normal operation when power is applied in forward polarity (IPL(2) is in the range of IPL(MIN) to IPS(MAX))
8, 12	FAIL	The port is polarity insensitive and does not power normally in both polarity configurations; **or** $I_{PL(1)}$ and/or $I_{PL(2)}$ are not in the range of $I_{PL(MIN)}$ (Class 3 and 4 = 40mA) to $I_{PS(MAX)}$ (Class 3 = 1.250 A or Class 4 = 2000mA)
8, 12	FAIL	The port is polarity sensitive (according to manufacturer documentation) and uses a terminal block connector that is not distinctly marked with "+" and "-" polarity markings
8, 12	FAIL	The port is polarity sensitive and IPL(1) is greater than IPL(reverse) = 10mA
8, 12	FAIL	The port is polarity sensitive and does not power normally in forward polarity (IPL(2) is not in the range of IPL(MIN) to IPS(MAX))

Notes:

References:

[1] APL Port Profile 1.2 Section 6.3
[2] APL Port Profile 1.2 Section A.1, A.3, A.4
[3] Methods Annex – Disabling PHY
[4] Methods Annex – Power Supply Voltage Sensing

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