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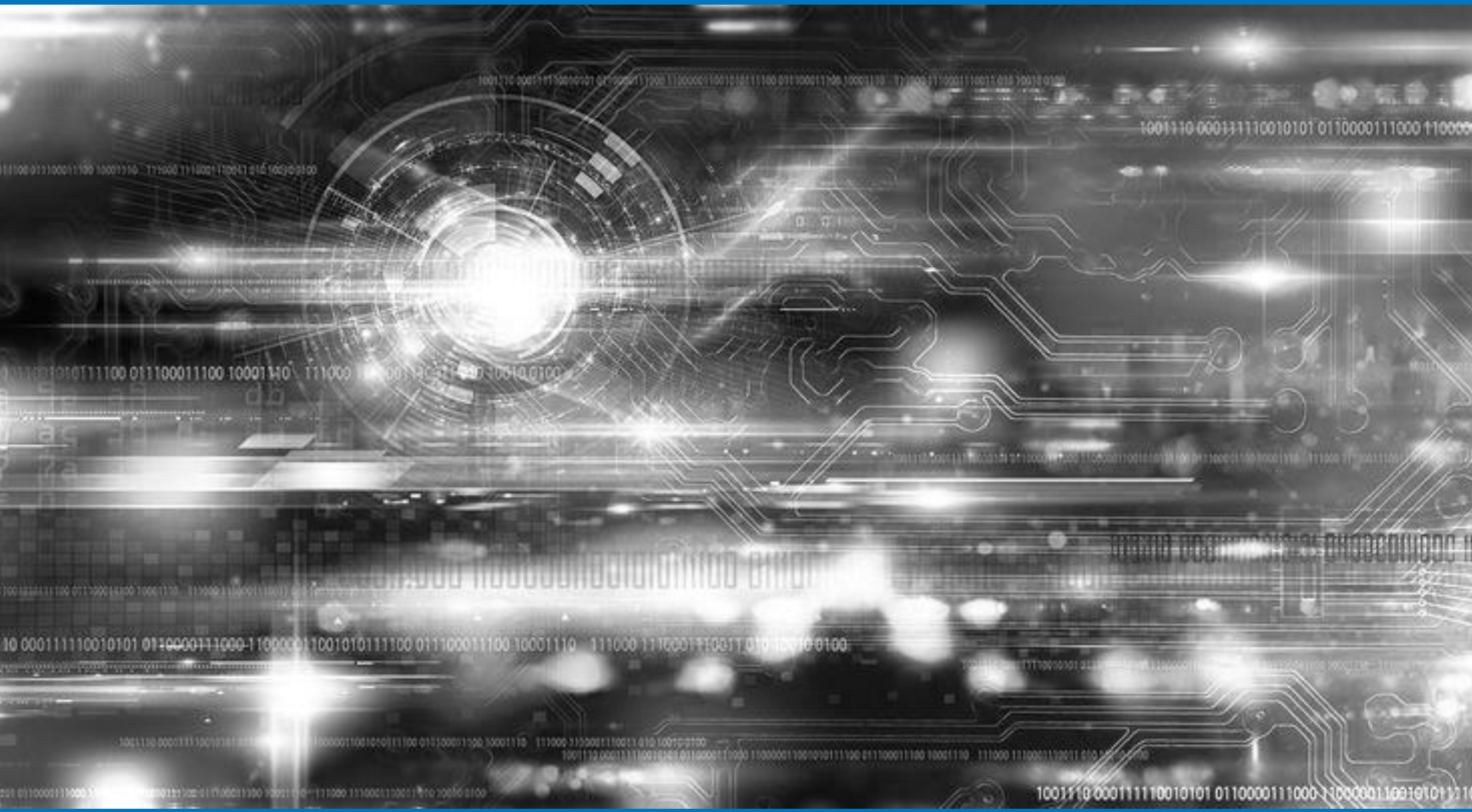
How to test AN/LT protocol and performance



APPLICATION NOTE

Using FreyaCompact AN/LT Test Appliance and XOA ANLT Utility.

Testing 100 Gbps, 200 Gbps, 400 Gbps and 800 Gbps using 56/112 Gbps SerDes requires extra focus on the physical layer (Layer 1) because the signals are heavily degraded even over relatively short transmission lengths.

As a result, AN and LT are Ethernet features that are growing in importance for high-speed, short distance connections over electrical cables because they help establish a link between two devices prior to sending real L2/L3 traffic.

Contents

Transmitting PAM-4 signals at 106.25 Gbps over electrical cables, backplanes and PCB traces leads to severe degradations of the signal in terms of frequency dependent loss, inter-symbol-interference, and cross talk. For this reason, both equalizing and Forward Error Correction (FEC) become mandatory to maintain a sufficient Bit Error Rate (BER).

Auto Negotiation (AN) and Link Training (LT) are key elements of Ethernet transmission over electrical connections and can reduce overall installation time, minimize the risk of configuration mistakes and optimize performance. During the AN process, two connected devices exchange information about their transmission speed and FEC abilities and agree on a common set of transmission parameters. LT is then used to automatically tune the transmit equalizer settings at each device for minimum BER at the selected transmission speed.

Although the AN and LT protocols are standardized by IEEEE802.3 it has proven challenging for developers of silicon and network equipment to verify performance of their products. Slight differences in implementations may cause products to fail in interoperability tests against 3rd parties. And often vendors have a hard time troubleshooting what the root cause of the malfunctioning.

Xena Networks' FreyaCompact ANLT Test Appliance is designed for performance verification and troubleshooting of the AN/LT protocols.

FreyaCompact ANLT Test Appliance

Figure 1: Xena's FreyaCompact ANLT Test Appliance

The FreyaCompact ANLT Test Appliance is a stand-alone product for advanced testing and troubleshooting of the Auto Negotiation (AN) and Link Training (LT) protocols for 56G and 112G Serdes Ethernet ports. The product is controlled via the Xena Open Automation (XOA) ANLT Utility described in the next section.

The overall features of the ANLT Tester are listed in the table below.

FreyaCompact ANLT Test Appliance Features:	
Port speeds	100GE/200GE/400GE/800GE
Interfaces	QSFP-DD800 / OSFP-800
Serdes Speeds	56G and 112G Serdes speeds
Autonegotiation	802.3 Clause 73 compliance
	Live and stored logging of protocol communication
	Single stepping through protocol
Link training	IEEE 802.3 Clause 162 compliant
	Live and stored logging of protocol communication
	Single stepping through protocol
	Automatic and interactive Tx Equalizer tuning modes
Software	XOA ANLT Utility

Freya 112G SerDes TGA with ANLT license

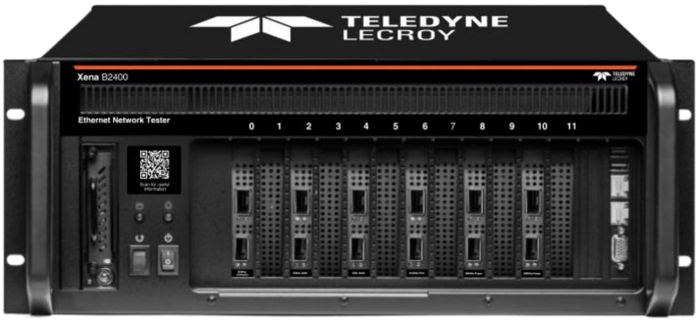


Figure 2: XenaBay chassis with Freya module

Xena's Freya Traffic Generator and Analyzer (TGA) test modules enables you to perform stateless Ethernet traffic generation and analysis at 100, 200, 400 and 800 Gbps Ethernet using 112G PAM-4 SerDes. The product supports normal (automatic) operation of AN and LT. However, with an extended license, interactive testing of the AN and LT protocols can be added to the Freya TGA.

XOA ANLT Utility

The Xena OpenAutomation (XOA) ANLT Utility is a Command Line Interface (CLI) shell application used to configure and run AN/LT test sequences from a client PC on Xena test equipment. Compared to the XenaManager GUI application, the XOA ANLT Utility enables more advanced control and test features of AN/LT.

The XOA Utility package is open source and can be downloaded and installed from github here: https://github.com/XenaNetworks. The XOA ANLT Utility works under Windows, Linux and MacOS. Xena also offers other XOA REST APIs for running L2 and L3 test sequences like RFC-2544 as shown on Figure 3.

You can connect to a Xena tester by opening a TCP/IP connection on your PC to the Xena chassis using TCP port 22611.

The XOA Utility builds upon the XOA HL-FUNC (High-level functions) which groups several XOA PYTHON API calls into common functions for ease of use.

The XOA PYTHON API can also be used directly in case you want to write your own Python scripts.

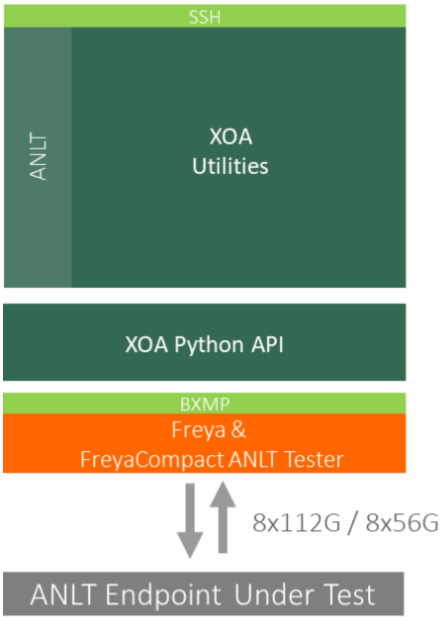


Figure 3: Structure of the Xena OpenAutomation packages.

The command structure of the XOA Utility looks like the following:

```
<command> [<subcommand>] [<arguments>] [<options>]
```

In the following chapters we will describe how to use a few of these commands to perform common AN/LT test cases. A full list of the XOA Utility commands can be found in the Reference Manual built into the software.

Auto Negotiation protocol

The main purpose of Auto Negotiation (AN) is for two connected devices at the end-points of a link to communicate together and agree on a common set of transmission parameters. AN is standardized in IEEE802.3 Clause 73.

For multi lane connections AN is done on lane 0 only and the remaining lanes have their SerDes disabled during AN.

The AN protocol uses 48 bits long Link Code Words (LCWs) for communication and a low bit rate of 156.25 Mbps. The LCW is also called DME pages and the standard defines both a Base Page as well as Next Pages.

During the AN Process each link partners continuously sends the same DME page until the remote link partner has acknowledged the correct receipt of the DME page. If at least one link partner has Next Pages, they exchange those in the same manner until there are no more Next Pages to send.

The two link partners will compare their technology abilities (like transmission speed) and choose the highest common denominator based on a priority resolution table as defined in 802.3.

As part of the AN process a number of time-outs are defined to avoid the two link partners sending DME pages endlessly.

Link Training protocol

Link Training (LT) is a process defined in IEEE802.3 for Ethernet over electrical cables whereby two end points communicate together to tune the settings of their respective transmitter equalizers for optimum transmission.

During LT, it is the weights of the coefficients (for instance c(-3), c(-2), c(-1), c(0) and c(1)) of the transmitter equalizer at each link partner that are being adjusted. In contrast to AN, the LT protocol operates at the actual speed on the cable.

The standard also defines several preset Tx equalizer settings which can be used to establish a well-defined basis for LT.

The link partners use Training Frames to communicate during LT. A training frame consists of control information as well as training data. The control words exchange information about equalizer settings and the training pattern is used to test the performance of a given equalizer setting. The performance is evaluated by the Bit Error Rate (BER).

The Training Frames are sent independently on all lanes of multilane connections.

What to test?

The key purposes of testing the AN and LT protocols are the following:

- Ensure compatibility with 3rd party vendors
- Test resilience against corner case scenarios
- Test of consistency
- Prove compliance

The FreyaCompact ANLT Test Appliance can be configured by software to run the protocols in the following 4 modes:

- **AN/LT disabled**: The tester will not run AN and LT
- **AN only**: runs the AN protocol only
- **AN and LT in automatic mode**: Runs AN followed by LT in automatic (normal) mode
- **AN and LT in interactive mode**: Runs the AN followed by LT interactive mode that lets you step through the LT protocol one command at a time and analyze the responses per command

The general procedure for any test of ANLT requires the steps displayed on Figure 4.

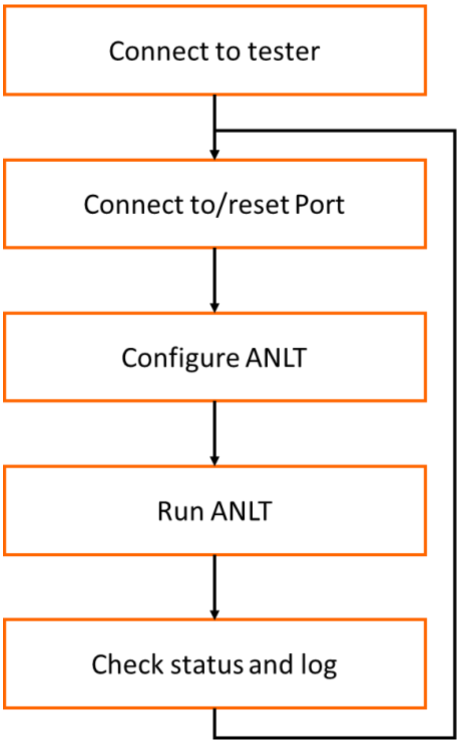


Figure 4: General steps in any ANLT test procedure

Test case examples

In this section we provide examples of how the XOA utility can be used to define and runs various useful tests of the AN/LT protocols.

Test set-up

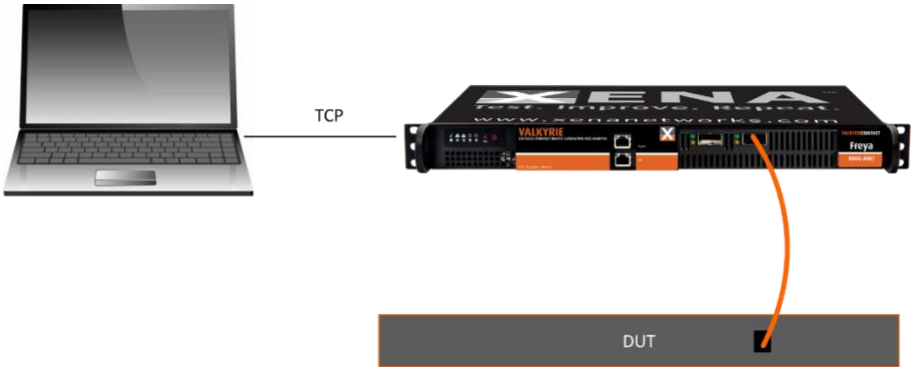


Figure 5: Test set up

The test set-up used for all test examples is shown on Figure 5 and includes an ANLT tester connected via TCP to your laptop running the XOA application. One of the ports on the ANLT tester is furthermore connected via an electrical cable to one of the ports on the Device Under Test (DUT). Please note, that the Freya TGA with additional ANLT license can be used for the testing as well.

The following steps will set up the port on the tester for the subsequent tests.

1. **Connect to a tester**

   First, you need to connect to your tester using the command **connect** and the IP address xx.xx.xx.xx of the tester.

   If you don't know which ports you will use at the time of connecting to the port, just leave the option **--ports** empty as the example shows below. You can reserve ports later.

   ```
   xoa_util$ connect xx.xx.xx.xx xoa_anlt
   ```

2. **Reserve a port**

   Then, reserve a port on the tester using the command **port**, as shown in the example below.

   ```
   xoa_util$ port 0/0 --reset --force
   ```

3. **Disable link recovery**

   Before doing ANLT testing, remember to disable link recovery on the port using command **recovery**.

   This is because the port always tries to re-do ANLT command sequence every five seconds if it detects no sync on the port.

This will disturb your manual link training procedure if you do not disable it prior to your interactive test.

```
xoa_util[port 0/0]$ recovery  --off
```

AN ONLY

This example tests if the DUT can complete the AN process on the link (no-loopback) with-out starting LT and lets you analyze the log afterwards. The steps in the test are the following

1. Reset port

Reset the port with the command **port <PORT> --reset** to ensure you are starting from a well-defined state of the port.

```
xoa_util[port0/0]$ port 0/0 --reset
```

2. Configure ANLT

Both ANLT and LT need to be configured using the commands **an config** and **lt config**

```
xoa_util[port0/0]$ an config --on –no-loopback
```

```
xoa_util[port0/0]$ lt config --off
```

3. Write the log

To display the log of the AN process on the screen and write it into the file use the command **an log <FILENAME>**

```
xoa_util[port0/0]$ an log ”anlog1.txt”
```

4. Run ANLT

The configured test sequence is started with the command **do anlt**

```
xoa_util[port0/0]$ do anlt
```

5. Check status of AN

The status of the AN run can be checked with the command **an status**

```
xoa_util[port0/0]$ an status
```

AN followed by LT, automatic mode

This example tests if the DUT can complete the AN and LT process automatically and lets you analyze the log afterwards. The steps in the test are:

1. **Reset port**

Reset the port with the command **port <PORT> --reset** to ensure you are starting from a well-defined state of the port.

```
xoa_util[port0/0]$ port 0/0 --reset
```

2. **Configure ANLT**

Configured AN and LT using the commands **an config** and **lt config**

```
xoa_util[port0/0]$ an config --on –no-loopback
xoa_util[port0/0]$ lt config --on --mode=automatic
```

3. **Write the logs to file**

To display the log of the AN process on the screen and write it into the file “log1.txt” use the command **an log <FILENAME>**

```
xoa_util[port0/0]$ an_log ”log1.txt”
```

To display the log of the LT process for lane 0 on the screen and write it into the file “ltlog0.txt” use the command **lt log <LANE> <FILENAME>**

```
xoa_util[port0/0]$ lt log 0 ”ltlog0.txt”
```

4. **Run ANLT**

The configured test sequence is started with the command **do anlt**

```
xoa_util[port0/0]$ do anlt
```

5. **Check status of AN and LT**

The status of the AN run can be checked with the command **an status**

```
xoa_util[port0/0]$ an status
```

The status of the LT run can be checked with the command **lt status**

```
xoa_util[port0/0]$ lt status
```

LT protocol, consistency

To test the consistency of the LT protocol the AN and LT in automatic mode should be repeated several times starting from the same initial setting of Tx equalizers. If the equalizers on all lanes complete with identical settings for the taps, the protocol has been verified to be consistent.

LT protocol, interactive mode

This example shows how to enable interactive mode for LT and send a few interactive commands to the DUT:

- Ask remote port to use a specific preset
- Ask remote port to change one of it’s taps
- Ask remote port to use a specific coding in the training pattern
- Tell the remote port that a specific lane has been trained

This example tests if the DUT can complete the AN and LT process automatically and lets you analyze the log afterwards. The steps in the test are the following

1. Reset port

Reset the port with the command **port <PORT> --reset** to ensure you are starting from a well-defined state of the port.

```
xoa_util[port0/0]$ port 0/0 --reset
```

2. Configure ANLT

Configured AN and LT using the commands **an config** and **lt config**

```
xoa_util[port0/0]$ an config --off
```

```
xoa_util[port0/0]$ lt config --on --mode=interactive
```

3. Write the logs to file

To display the log of the LT process for lane 0 on the screen and write it into the file use the command **lt log <LANE> <FILENAME>**

```
xoa_util[port0/0]$ lt log 0 ”ltlog0.txt”
```

4. Run ANLT

The configured test sequence is started with the command **do anlt**

```
xoa_util[port0/0]$ do anlt
```

The tester is now in interactive LT mode and waiting for you to enter a command.

5. Ask remote port to use a specific preset on a specific lane

The command **lt preset <LANE> <PRESET>** instructs the DUT to use a specific preset on the Tx equalizer on a specific lane. The following command sets preset to preset1 on lane 0.

```
xoa_util[port0/0]$ 0 1
```

6. Ask remote port to increment a specific tap on a specific lane

The command **lt inc <LANE> <EMPHASIS>** instructs the DUT to increment a specific tap (emphasis) on the Tx equalizer on a specific lane. Increments can only be done by 1 step at a time. The following command increments c(0) (main) on lane 0.

```
xoa_util[port0/0]$ lt inc 0 main
```

7. Ask remote port to us a specific coding in the training pattern on a specific lane

The command **lt encoding <LANE> <ENCODING>** instructs the DUT to use a specific encoding in the training pattern on the Tx equalizer on a specific lane. The following set the encoding the PAM4 with precoding on lane 0.

```
xoa_util[port0/0]$ lt encoding 0 pam4pre
```

8. Tell the remote port that a specific lane has been trained

The command **lt trained <LANE>** tells the DUT LT has completed on a specific lane. The following tells that LT has completed on lane 0.

```
xoa_util[port0/0]$ lt trained 0
```

Useful Links

- The XOA Utility package is open source and can be downloaded and installed from github here: https://github.com/XenaNetworks
- Download the AN/LT for 112Gbps SerDes White Paper