WHITE PAPER

Reduce Test Time, Reduce Cost: Data Center Component and Transceiver Test

KEYSIGHT

Massive growth in data center traffic is urgently driving the need for bandwidth upgrades in the data center. Data center operators require cost-effective next generation optical transceivers to support their migration from 100 gigabit Ethernet (GE) to 400GE. Large hyperscale data centers have more than 50,000 optical fibers in them. With a transceiver at each end of the fiber, these data centers house upwards of 100,000 transceivers. Keeping the cost of the optical transceivers low is a high priority for data center operators. To be competitive, transceiver manufacturers must find ways to drive down production costs.

Like most new technologies, the price of new optical transceivers tends to drop sharply after introduction to the market, and development costs are amortized as volume ramps. Next generation transceiver technology, such as 400GE, will reach mature pricing within a year of introduction. At maturity, the cost of transceivers is directly proportional to the complexity of the design and the number of optical components. Test time contributes significantly to overall transceiver cost. More efficient testing of the broad range of transceiver data rates accelerates innovation and lowers cost. The process begins in the research and development phase with the design of transceiver components, continues to the design and validation of the transceivers, and then through manufacturing test.

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Next generation optical transceivers are expected to use less power per gigabit, be less expensive per gigabit, and operate at four times the speed of 100GE transceivers. They will use advanced modulation and coding techniques, such as 4-level pulse amplitude modulation (PAM4), to reach 400 gigabits per second (Gb/s) speeds. In addition to high-bandwidth operation, low power consumption is a very important part of 400GE transceiver design. By using PAM4 modulation, it is possible to reach 400 Gb/s speeds with 8 optical channels (lanes) of 56 Gb/s. However, PAM4 modulated signals are very susceptible to noise distortion since four signal levels are packed into an amplitude swing of two. More complex transceiver circuitry is needed to overcome these challenges, and test time and complexity increase proportionally.

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Design and Simulation

In the research and development (R&D) phase, starting with powerful design simulation software is the first step to ensure test efficiency and lower the cost of test. Today's design and simulation software enable transceiver designers to optimize their designs, ensure performance and robustness, and avoid costly additional board design cycles. They can identify the most sensitive design components early on and decide how to set specifications to improve manufacturing yield. Once optimized, designers can test design performance using post-processing data analysis functionality without rerunning simulations.

Characterization and Compliance Test

As new 400GE transceiver designs transition from simulation to first prototype hardware, engineers face the challenging task of developing a thorough, yet efficient, test plan. Data center operators will weigh cost heavily when selecting next generation 400GE transceivers, but quality is obviously also crucial when using tens of thousands of them in a data center. Once deployed in data centers, marginally performing transceivers can bring down the network link, lowering the overall efficiency of the data center as the switches and routers need to re-route the faulty link. The cost associated with failed transceivers once deployed in the data center is enormous. Since large hyperscale data centers can house more than 100,000 transceivers, even a small one tenth of one percent failure rate would equate to 100 faulty links.

Industry standards organizations, such as the Institute of Electrical and Electronics Engineers (IEEE), International Committee for Information Technology Standards (INCITS) and the Optical Internetworking Forum (OIF), generate and maintain optical transceiver specifications and define test procedures to ensure interoperability of modules from different vendors. The operating margins in 400GE optical links are the tightest of any generation thus far. This creates additional test challenges, as small measurement errors can easily consume the entire operating margin. Fortunately, the methods that describe how to characterize 400GE designs are becoming more stable, and engineers can review and follow the guidelines set forth in the standards when developing their test plan to characterize their transceivers. In addition, the use of test automation software developed in accordance to industry specifications can reduce errors, improve repeatability and reduce test times down from hours to minutes.

Test Automation

There are different sets of optical and electrical tests that need to be performed for transmitters and receivers, and the effects of the channel between them also need to be considered. The standard configuration for 400GE transceivers is to use eight lanes of PAM4 traffic operating at 56 Gb/s per transceiver. For most standards, there are six different compliance tests suites that must be performed on each lane. Each set of tests has several different steps that must be followed.

It can take several hours to manually test a single transceiver, and this can extend to days if any problems associated with the test setup or calibration are found during testing. Since 400GE transceivers using PAM4 require complex circuit designs not previously used in non-return-to-zero (NRZ) based 100GE designs, it is difficult for test engineers to determine which component caused a failure.

Test automation software can reduce test time down from hours to minutes. Choosing automated compliance test software that is verified to test to the exact specifications of each technology standard is important. Test automation software provides insights to the test engineer about any detected issues and can quickly pinpoint failures, saving hours of debug time. Test automation software guides the test engineer through setup, calibration and compliance measurements, and allows them to quickly run through test cases without being an expert on test procedures. By using compliance test applications, transceiver manufacturers are assured that a test that passes in their lab will pass in their customers' labs as well. More importantly, ensuring transceivers are compliant to standards will minimize the risk of interoperability issues with network switches and routers once millions of them are installed in data centers around the world.

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Data Analytics

The results of automated tests are available in real time reports to test engineers. These reports typically include details about the test setup and configuration, the measurements made, the pass/fail status, margin analysis and output waveforms. With this information, it is easy for test engineers to replicate the test scenario later. However, sometimes the sheer amount of data collected is overwhelming for a test engineer to analyze and understand. Therefore, test automation software that has integrated data analytics capabilities is ideal.

Data analytics tools provide insightful analysis of test results. Visualization methods, such as line and histogram charts, show pass/fail limits and statistical information so test engineers can see at a glance the performance of the device under test. Often results are stored in a cloud repository, so they can be shared instantly among global and distributed teams. Test engineers can quickly make design decisions with confidence that would otherwise take days or weeks to analyze and decide upon. Data analytics software can be used at all phases of 400GE transceiver test; from design and simulation, characterization and compliance, to manufacturing. The result is that test time and costs are reduced, and next generation transceivers can get to market faster.

Manufacturing Test

Research and development of 400GE transceivers is well under way. Engineers are still struggling with how to test PAM4 modules, and 400GE standards continue to evolve. 400GE transceivers have a tight time-to-market window to meet the demands of emerging technologies such as 5G, IoT, as well as massive public cloud growth. Furthermore, they must be produced at the lowest possible cost and with extremely high quality.

Once 400GE transceivers reach the manufacturing phase, any issues found will mean costly rework of designs. The ideal is to design for manufacturing. There are several tools that can help transceiver manufacturers create manufacturing-friendly designs. For example, by using a common software platform with built-in data analytics from initial design concept through manufacturing and deployment, it is possible to accelerate the overall product development workflow and minimize errors found during manufacturing. Costs increase significantly as issues are uncovered later in the development process. Ideally, all issues would be uncovered early in the design phase.

Summary

The data center transceiver market is extremely cost sensitive and competitive. Test time is a significant factor that contributes to the overall cost of transceivers. By reducing test time, transceiver manufacturers can reduce overall costs and be first-to-market with next generation transceivers. At each phase of the product development lifecycle, there are test solutions that can be used to maximize test efficiency. These tools can shorten design cycles, dramatically improve productivity, ensure quality and significantly reduce costs.

For information on how Keysight's solutions can help you address your 400GE data center implementation challenges, check the following links:

- To accelerate your data center infrastructure innovations, check out Data Center Infrastructure Solutions
- To learn about the three key challenges of moving from 100GE to 400GE in the data center, check out Data Center Transceiver Test Solutions

For more information on Keysight Technologies' products, applications, or services, please visit: www.keysight.com