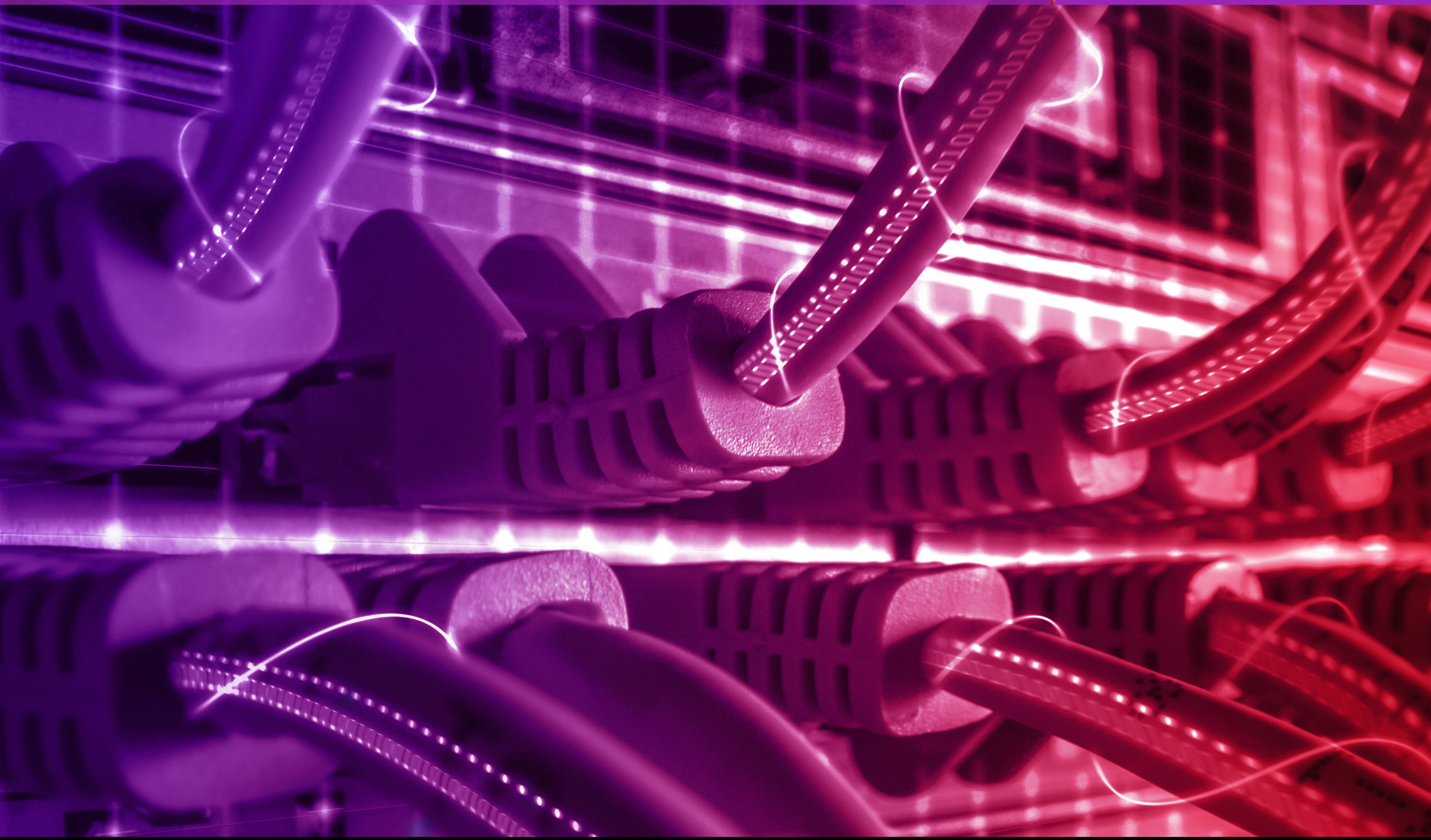
WHITE PAPER



800G / 1.6T Data Center Transceiver Test

Overcoming three key challenges

KEYSIGHT

Introduction

Emerging technologies such as artificial intelligence, virtual reality, the Internet of Things, digital twins, and autonomous vehicles generate extensive network data. Industry 4.0 also creates new computing, storage, and performance demands in the data center. Data center operators need to embrace new technologies to support the response times and high bandwidth these technologies require.

Today's 400 gigabit Ethernet (400G) networks will not be fast or power-efficient enough to handle the billions of forthcoming internet-connected devices running data-intensive, real-time applications. Data center operators need to evolve the speed of their networks from 400G to 800G and soon 1.6 terabit Ethernet (1.6T) to meet these demands.

The Basics

An optical transceiver comprises a transmitter and a receiver that share common circuitry and packaging (form factor). The connection speed of transceivers using advanced modulation and coding to increase data throughput over existing network infrastructure drives the speed of networking inside data centers.

Transition from 400G to 800G

Data center speeds have swiftly evolved over the past two decades from 10G to 400G, and soon they will reach 800G. Each new speed class built upon the previous generation but faced limits of high cost and constrained data capacity. For example, data center operators began deploying the 400G standard (IEEE 802.3bs) soon after its ratification in 2017. Yet full manufacturing build-out only became cost-effective over the last couple of years with the introduction of more efficient optical transceiver modules. As soon as operators moved into rapid deployment of 400G, they needed to start planning the move to higher speeds.

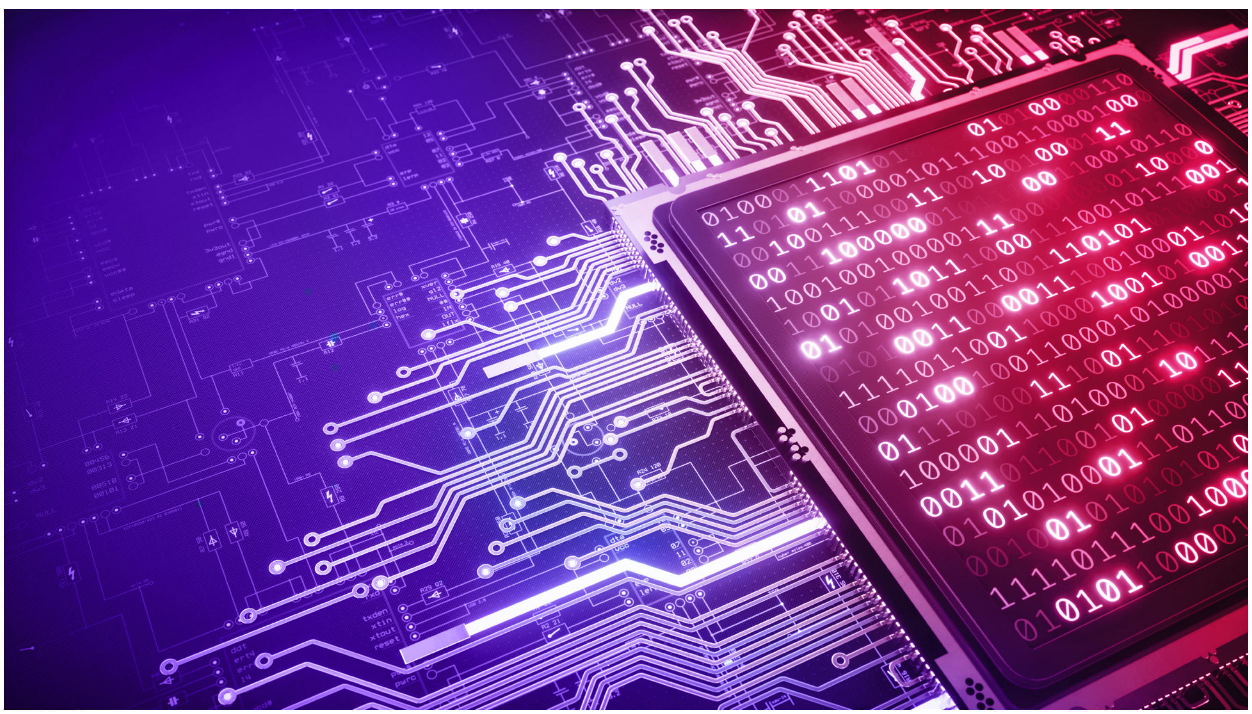
Traditionally, service providers were the early adopters of new technology and the first to test transceivers for the next speed class. However, because of demands for increased networking bandwidth from Industry 4.0 applications, data center operators no longer have the luxury of learning from the growing pains of service providers. Instead, they have taken on a larger share of intensive testing for 800G and 1.6T technologies.

In addition, data center operators face different requirements and challenges than service providers. For example, modern hyperscale data centers house more than 50,000 fibers with an optical transceiver at each end, so transceiver cost drives data center operators to pioneer technology. The following are three key challenges they need to tackle to ensure that data centers support 800G and 1.6T speeds:

- Increase interface bandwidth.
- Ensure quality and interoperability.
- Reduce test time, power, and cost.

Challenge 1: Increase interface bandwidth

Traditionally, data center operators upgraded their network architecture every couple of years. However, many data centers have reached maximum capacity, and operators need to find a way to process more data faster to reach 800G speeds. Reducing the power per bit is equally important. Data center operators rely on transceiver manufacturers to move to the next-generation speed class.



Solution: Faster switching silicon and forward error correction

Advancement from non-return-to-zero signaling to four-level pulse amplitude modulation (PAM4) enabled the move from 100G to 400G with 56 Gb/s lane speeds at 28 GBd/s. Soon after, 112 Gb/s lanes followed. To reach 800G speeds and satisfy the demand for faster data centers, developers will first double the lane count (eight 112 Gb/s lanes), but they will eventually need 224 Gb/s lanes.

The road to faster lane speeds has many components. Improvements in CMOS process technology enable faster and more efficient switch silicon. Innovations in high-bandwidth-switching silicon (from 25.6T to 51.2T) enable faster lane rates without increasing server switch radix. At these faster data rates, digital signals become more susceptible to channel loss, necessitating more sophisticated forward error correction (FEC) algorithms to minimize symbol loss. FEC is an advanced coding technique that sends the required information to correct errors through the link along with the payload data.

Challenge 2: Guarantee quality and interoperability

Before being inserted into the network, any new transceiver technology used in pluggable modules requires thorough testing to ensure that it complies with specifications and offers seamless compatibility. Optical transceiver manufacturers must test to ensure that their transceivers meet defined specifications and interoperate with other network components and transceivers from different vendors. Network downtime caused by faulty transceivers is not an option for data center operators because of their guaranteed service-level agreements with users.

Solution: Characterization and compliance test

Several standards organizations govern optical transceiver specifications and define test procedures to ensure compliance with standards and interoperability with other vendors. They include the Institute of Electrical and Electronics Engineers (IEEE), the International Committee for Information Technology Standards, and the Optical Internetworking Forum. Data center operators can ensure the quality and compatibility of their next-generation data centers by selecting a transceiver vendor that has successfully passed all physical Layer 1 characterization and compliance tests defined by industry standards.

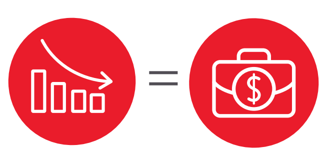
Standards organizations define specifications and provide compliance test procedures to ensure that a receiver will operate with a worst-case transmitter and vice versa. Transmitters and receivers need different sets of optical and electrical tests. The effects of the channel between them also require consideration. Faster and more complex systems increase the difficulty and time of test.

Challenge 3: Reduce test time, cost, and power

The cost and time commitment to test next-generation optical transceivers is a major hurdle for data center operators transitioning to 800G. Generally, the cost of transceivers is directly proportional to the complexity of the design and the number of optical components. Test time is also significant and contributes to the overall cost of the transceiver.

The complexity of the test systems will also increase as devices under test will have 8, 16, or 32 lanes. The need to measure complex specifications according to standards complicates the design and validation process and requires a long learning curve for test engineers. The move to PAM4 reduced the margin for error in test processes because of its tighter thresholds. In 224 Gb/s lanes, margins reduce further.

Cost and power consumption define the overall footprint of a transceiver. Hyperscale data centers consume about 3% of the power generated worldwide. To maintain the current growth rate and scale with the need for higher bandwidth, data center technology needs to reduce power consumption per bit and cost per bit.



Solution: Test and power efficiency

The number of communication standards and transceiver types proliferated during the last decade, creating more complexity for R&D and manufacturing test. Thankfully, several techniques significantly reduce test time and the overall cost of transceivers, from design and simulation through device characterization and compliance to, finally, manufacturing. Tighter test margins require more precise, higher-bandwidth instruments. Automated compliance testing eases the learning curve, assists with debugging, and increases test efficiency by automating test procedures.

New technologies can help increase power efficiency. For example, co-packaged optical modules lower the power consumption of the module per bit compared with pluggable optics. The faster, more efficient switch silicon and 224 Gb/s lane rates help process twice as much data while lowering power consumption. Some technologies will require test time, cost, and power efficiency trade-offs. For example, photonic integration, enabled by silicon photonics, helps drive down the cost of assembly but requires more advanced testing

Testing starts in the design phase

Using innovative simulation technologies in the design phase ensures first-pass success and high yields. Powerful software simulation tools simplify the design process and enable post-processing and data analysis without rerunning simulations. Software simulation makes it possible to pinpoint problems early in the design cycle and avoid costly manufacturing issues later.

Engineers continue to struggle with how to test and troubleshoot FEC burst errors. However, once 800G transceivers reach the manufacturing phase, real-time analysis and monitoring of process, test, and equipment data help drive manufacturing improvements and efficiencies, mitigating risks of failure and downtime. Real-time containment of operational or product quality issues increases productivity and asset utilization, reducing test time and cost.

Summary

400G is in wide use in data centers around the world today, but 800G links are the next step to increase network bandwidth for Industry 4.0-capable data centers. Next-generation transceivers that increase interface bandwidth, ensure quality and interoperability, and reduce test time, cost, and power consumption enable data center operators to seamlessly transition from 400G to 800G and soon 1.6T Ethernet.

With 800G transceiver technology squarely on the horizon, data center operators need new ways to design and operate their networks to withstand the kind of traffic generated by billions of devices. Virtualized networks using software-defined networking (SDN) and network functions virtualization (NFV) are one option. SDN is a network architecture that enables software-programmable network control of a virtualized network infrastructure. Network functions virtualization is an architecture concept that automates entire classes of network node functions into building blocks that connect to create communication services.

Once a virtual network is set up, data center operators must ensure data flows through it as expected. The next hurdle they will need to overcome is the full network test of Layers 2 through 7, including SDN / NFV validation and traffic loading.

For information on how Keysight's solutions can help you address your 800G and 1.6T data center implementation challenges, visit the following links:

- Hear about the latest in 1.6T development from data center industry experts.
- To read more about the challenges of developing and testing at 224 Gb/s, read Data Center Ethernet Technology and Evolution to 224 Gbps.
- Learn about overcoming the challenges of evolving your data center from 400G to 800G / 1.6T.