WHITE PAPER

# 400GE Transceiver Characterization and Compliance Test

KEYSIGHT

# Addressing Top Three Concerns of Data Center Operators

Emerging technologies such as virtual reality (VR) and the Internet of Things (IoT) are fueling the need for speed in the data center. Data center operators are looking to upgrade network and storage interconnect speeds from 100 gigabits per second (Gb/s) to 400 Gb/s to meet ever-growing demand for bandwidth and high-speed access to high density storage. Moving from 100 gigabit Ethernet (GE) to 400GE in the data center is a complex task. Data center operators want to make the transition to 400GE as cost effectively as possible, while ensuring interoperability with 100GE network interfaces. The following are three main concerns that data center operators have when considering the move from 100GE to 400GE: **Cost**, **Footprint** and **Power**.

Cost Footprint Power

## Cost

400GE must offer a cost advantage over four independent 100GE interfaces. There are different ways that data center operators can reach 400 Gb/s. For example, they can add more servers while using existing storage density and 100GE transceiver technology. Many data centers are built in remote locations where land is inexpensive and plentiful. Expanding the data center footprint to increase capacity is a real option for increasing total storage and network throughput.

Figure 1 shows a Google data center in the Netherlands with plenty of surrounding land for expansion. But expanding the data center shell footprint has other costs, including time to deployment and long-term capital depreciation, making network upgrades a more attractive option. As a result, data center operators are relying upon transceiver manufacturers to provide a cost-effective solution to reach 400 Gb/s speeds.

**Figure 1.** Aerial view of Google data center near Delfzijl in the province of Groningen, Netherlands.

# Footprint

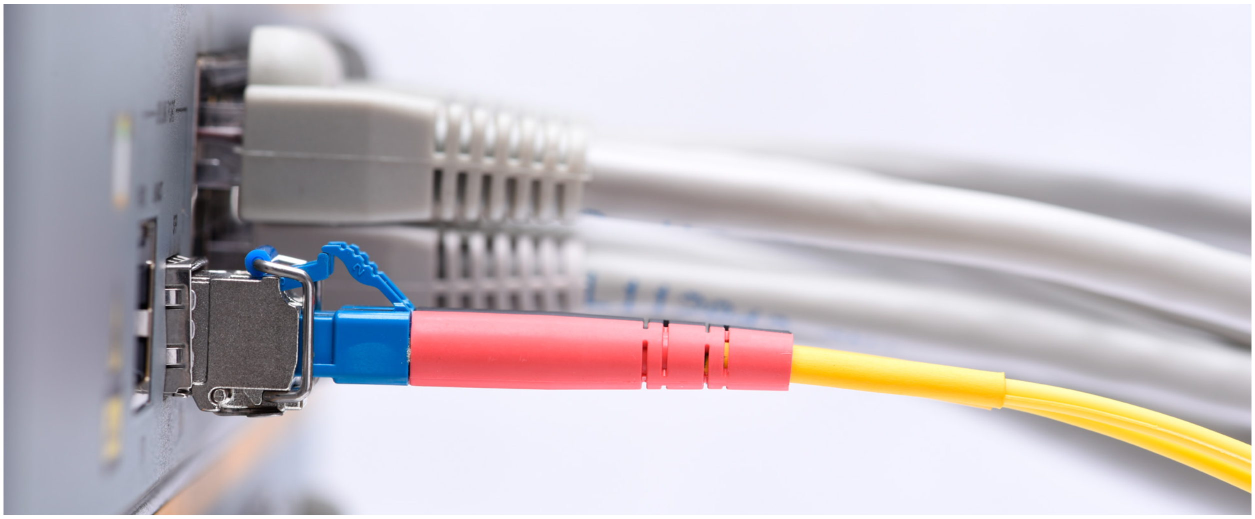
In the past, the only option to increase bandwidth was to increase footprint – network technology beyond 100 Gb/s was not available. Today, a more compelling option is emerging: 400GE. Currently, many data centers are maxed out in capacity, with no room for expansion. Therefore, transceiver manufacturers must address the need for higher performance interfaces. 400GE transceivers meet that need, providing four times the speed of 100GE, while maintaining approximately the same footprint. Advanced modulation and coding techniques, such as 4-level pulse amplitude modulation (PAM4), will be used to increase channel bandwidth. More complex transceiver circuitry is required to reach 400 Gb/s speeds without increasing the footprint of transceivers. This will significantly increase test complexity, as well as test time.

# Power

Huawei Technologies researcher Anders Andrae recently estimated that power usage by the Information and Communication Industry (ICT) could reach up to 5,860 terawatt hours (TWh) per year by 2025[1]. Data centers will account for more than 30% of that usage. Put another way, at current growth rates, 2025 data centers are on track to use 8% of the world's total power. Thankfully, large hyperscale data centers are moving to renewable energy sources to power their data centers. Regardless, power is a premium resource for data center operators, and transceiver manufacturers must do their part to ensure that next generation 400GE transceivers deliver optimal power efficiency.

Transceiver manufacturers must thoroughly test new 400GE transceiver designs to verify they meet power limits set forth by industry standards while ensuring a smooth transition from current to next generation network speeds. In addition, optical transceiver manufacturers must test to ensure their transceivers comply with strict specifications to ensure interoperability with network components and other transceivers. Network downtime due to faulty transceivers is not an option for data center operators which have guaranteed service level agreements (SLAs).

1 Andrae, Anders. (2017). Total Consumer Power Consumption Forecast: https://www.researchgate.net/publication/320225452_Total_Consumer_Power_Consumption_Forecast



# Characterization and Compliance Test

Several 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), govern optical transceiver specifications and define test procedures to ensure compliance to standards and interoperability with other vendors. However, standards organizations do not address packaging and connectors as part of their standards work. The form factor and electrical interface are defined by a multisource agreement (MSA) among multiple equipment manufacturers. The MSA guarantees compliant devices will function properly and allow for easy interoperability with devices from different vendors.

## Transmitter / receiver testing

In simple terms, an optical communication system consists of a transmitter, an optical fiber channel, and a receiver. High-speed electrical data links then interconnect the optical modules with the switching or networking chips. The transmitter of one transceiver sends data over optical fiber to the receiver of another in a different part of the network. Standards organizations define specifications and provide compliance test procedures to ensure that a receiver will operate with a worst-case transmitter and vice versa. There are different sets of optical and electrical tests that need to be performed for transmitters and receivers, and the tests must also include channel quality impairments. As systems become faster and more complex, it is also necessary to test receivers using non-ideal signals with different types of impairments. This is commonly referred to as a stressed signal. Since performance levels usually vary significantly from one generation to the next, standards and components often evolve together.

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## Advanced modulation and coding techniques increase test challenges

The use of multilevel PAM4 signaling has entirely changed Ethernet test requirements. More complex transmitter and receiver circuits are required to increase transceiver speeds to 400 Gb/s while maintaining the footprint of 100GE transceivers. Using PAM4 modulation to reach 400 Gb/s speeds means that engineers must now design, develop and validate transceivers that have multiple 28 or 56 Gb/s channels. They also need to ensure that the power requirements stay within standard specifications.

As data rates increase, so do the challenges of device design, validation, and test. One challenge is noise susceptibility, but another increasingly challenging issue is test probe or fixture interference. Test fixtures and cables have not traditionally been a substantial source of interference. However, at higher data rates, signal degradation occurs in even high-quality cables, and noise and interference become significant factors. Device test interference can occur from simple insertion of measurement instruments. In this case, it is important to de-embed the noise introduced by the test equipment from the signal. De-embedding is a post-measurement process that mathematically removes the noise characteristics of test fixtures from the overall measurement. Test equipment with built-in de-embedding will simplify transceiver characterization considerably.

There are many ways that errors may be introduced into the signal from the transmitter, through the channel, and to the receiver. The optical and electrical links are not expected to have raw, error-free performance. Due to the reduced signal to noise ratio (SNR), PAM4 links are not expected to run error-free, and require forward error correction (FEC). FEC is an advanced coding technique that sends the required information to correct errors through the link along with the payload data. The benefit of “forward” in FEC is that information does not need to be retransmitted to correct errors detected at the receiver. However, FEC introduces several new test challenges for physical layer testing of PAM4 signals. Standards organizations are actively discussing several FEC considerations for 400GE testing.

# Summary

400GE transceivers are expected to provide a cost-effective migration path from 100GE to 400GE in the data center. Advanced modulation and coding techniques, such as PAM4, will be used to increase channel bandwidth to reach 400 Gb/s speeds. However, PAM4 signaling increases the complexity of transceiver designs and introduces new test challenges. Required transmitter and receiver compliance tests for 400GE transceivers using PAM4 signaling are defined by standards organizations. Test engineers can reduce test times down from hours to minutes by selecting test equipment that has been designed specifically for testing PAM4 signals in accordance to industry specifications. Data center operators can guarantee the quality and interoperability of 400GE transceivers they introduce in their networks by selecting units that have successfully passed all characterization and compliance tests. Compliant transceivers address the cost, footprint and power concerns of data center operators.

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

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