

Eye diagrams of optical modules at different speeds



Overview

The Role of Eye Diagrams in High-Speed Optical Design | CinchLearn how to read an eye diagram to verify signal integrity — jitter, bit error rate, and comp.

Key Takeaways

Eye diagrams visually reveal the quality of optical signals, with higher-speed modules typically showing narrower and more sensitive eye openings due to increased jitter and intersymbol interference. What is an Eye Diagram?

An eye diagram is a graphical representation of a digital signal over time, created by superimposing multiple cycles of a waveform on an oscilloscope or bit error rate tester (BERT) display. The resulting pattern resembles a human eye, where the eye opening—both in height and width—indicates signal integrity. A wide and tall eye suggests strong timing margins and clear amplitude levels, while a narrow or closed eye signals degraded performance due to jitter, noise, or intersymbol interference (ISI).

Eye Diagrams in Optical Modules

In optical communication, eye diagrams are critical for evaluating transmitter and receiver performance. They capture the effects of dispersion, noise, and channel impairments on the optical signal. Key parameters include:

- Extinction Ratio: Ratio of optical power between logic “1” and “0” levels; higher ratios indicate better signal contrast.

- **Q Factor:** Reflects signal quality; smoother and thinner “1” level lines correspond to higher Q factors .
- **Jitter:** Horizontal blurring at transitions indicates timing uncertainty, which increases with higher data rates .

Impact of Speed on Eye Diagrams

As the data rate increases, optical modules face greater challenges:

- **Eye Width Shrinks:** Faster bit rates reduce the unit interval (UI), making the eye narrower and more sensitive to timing errors .
- **Increased Jitter and Noise:** High-speed signals are more susceptible to intersymbol interference and channel impairments, causing horizontal and vertical eye closure .
- **Reduced Margin for Error:** Narrower eyes at higher speeds require precise transmitter and receiver design to maintain low bit error rates (BER), . For example, a 10 Gbps optical module may show a wide, open eye with minimal jitter, while a 100 Gbps module often exhibits a smaller eye opening with noticeable vertical and horizontal blurring, reflecting the increased difficulty in maintaining signal integrity at ultra-high speeds .

Practical Use

Engineers use eye diagrams to:

- Verify compliance with standards like IEEE 802.3.
 - Diagnose impairments such as reflections, crosstalk, or dispersion.
 - Optimize transmitter and receiver settings to maximize Q factor and minimize BER .
- By comparing eye diagrams at different speeds, designers can assess the scalability of optical modules and ensure reliable high-speed data transmission in applications like data centers, 5G networks, and fiber-to-the-home systems .

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Table 1 shows the relationship between the length of the optical fiber (from 5 Km to 100 Km) and the quality factor (Q-Factor) as well

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Figure 7(a) & 7(b). Taking multiple slices through the eye at different angles to construct a more complete anatomical view. 7(b)

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Thanks to the high repetition rate of the optical sampling pulse train, the eye diagram and the time-domain parameters

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