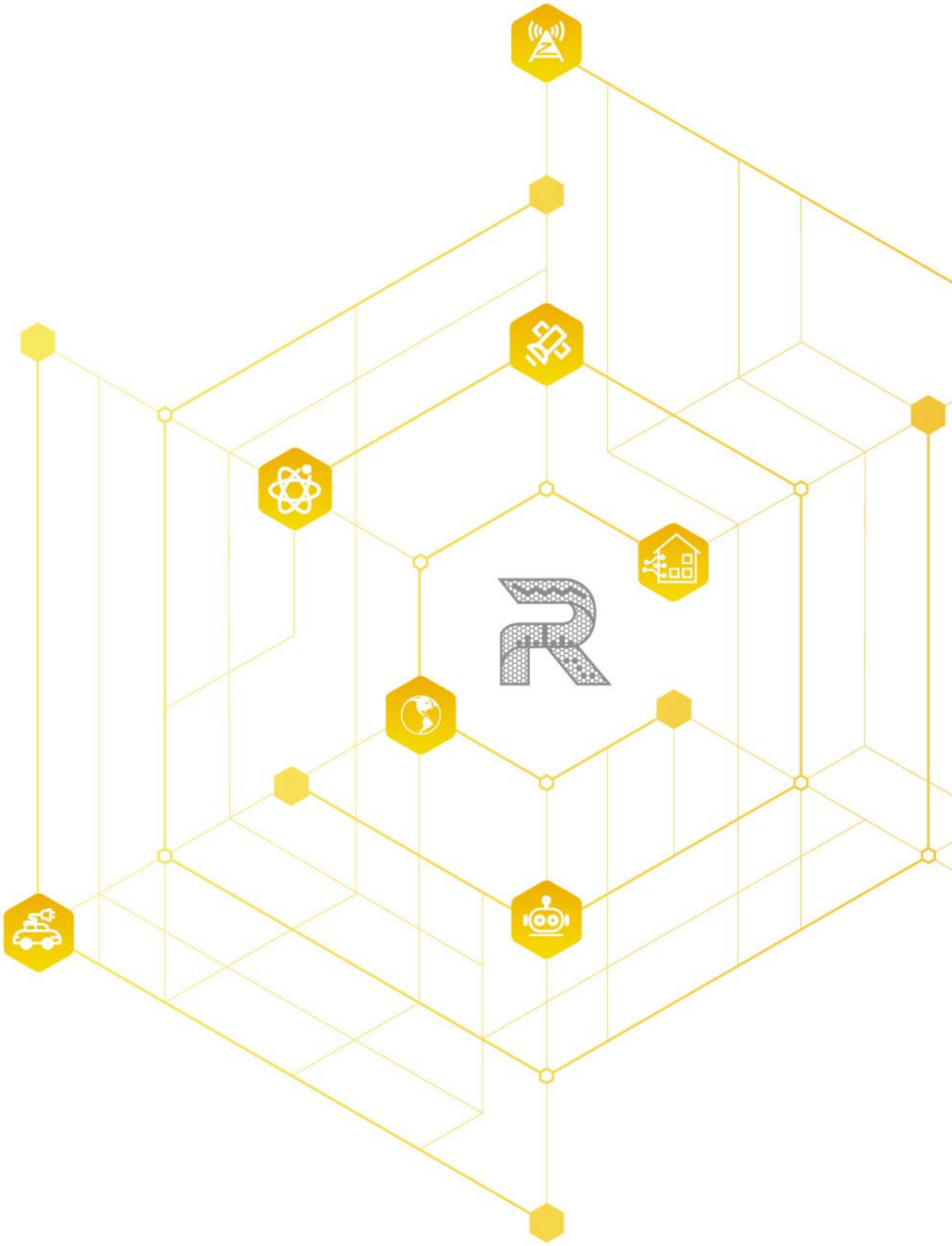
RIGOL

Application Note on MIPI D-PHY Compliance Testing for High-Speed Servo Laser Processing Systems



Executive Summary:

This application focuses on MIPI D-PHY compliance testing, specifically validating the signal quality of MIPI D-PHY V1.2 output from camera modules to ensure stable and reliable signal transmission.

As a high-speed data transmission interface between camera modules and displays in mobile devices, MIPI D-PHY offers advantages such as low power consumption, strong anti-interference capabilities, and high-speed data transfer. It is widely adopted in smartphones, imaging systems, and other high-performance electronic devices. The test environment includes a camera module, motherboard, high-speed motion control system (EtherCAT servo system), and utilizes an oscilloscope DS81304 with PVA8700 high-bandwidth probes for signal acquisition and analysis, enabling automated physical-layer compliance testing.

Key Application Factors:

- **Protocol Compliance for Testing Accuracy**

The RIGOL MIPI D-PHY compliance test solution strictly adheres to CTS standards and supports user-defined test ranges to accommodate diverse requirements.

- **Efficient Automated Testing to Enhance Productivity**

This solution provides intuitive waveform previews, automated parameter configuration, and wiring guidance, enabling engineers to complete tests rapidly. Compared to the industry average of 20+ minutes per test, RIGOL's solution reduces testing time to 10-15 minutes.

- **Comprehensive Test Reports for Precise Analysis**

Automatically generated post-test reports include test results, detailed parameters, and waveform screenshots, empowering engineers to swiftly identify issues and optimize product designs.

Overall Contributions & Synergies:

Throughout the testing process, we executed full compliance tests, performed root-cause analysis for failed items, and provided corrective recommendations. Multiple rounds of retesting validated improvement effectiveness. Additionally, comparative testing of different signal transmission lines optimized signal integrity and enhanced overall system stability.

Figure 1：EtherCAT Bus Servo and Laser Cutting Head

Application Scenario Overview:

MIPI D-PHY is a physical-layer interface designed for high-speed data transmission between cameras and displays in mobile devices, meeting demands for high bandwidth and low power consumption. It has become the dominant interface for cameras and displays in smartphones and portable devices, widely used in high-performance imaging and display systems. Its key advantages include low power consumption, robust anti-interference capabilities, and support for high-speed data transfer, aligning with mobile devices' stringent requirements for efficient and stable connectivity.

A D-PHY comprises one clock lane module and one or more data lane modules, providing a source-synchronous interface between master and slave devices. It includes a pair of unidirectional differential clock signals supporting SSC modulation, configurable with 1 to 4 pairs of unidirectional/bidirectional differential data lines. Each D-PHY lane module communicates via two lines with its counterpart on the opposite end. A standard D-PHY structure includes LP-TX, LP-RX, HS-TX, HS-RX, and LP-CD modules, with the external differential signal interface being Dp and Dn.

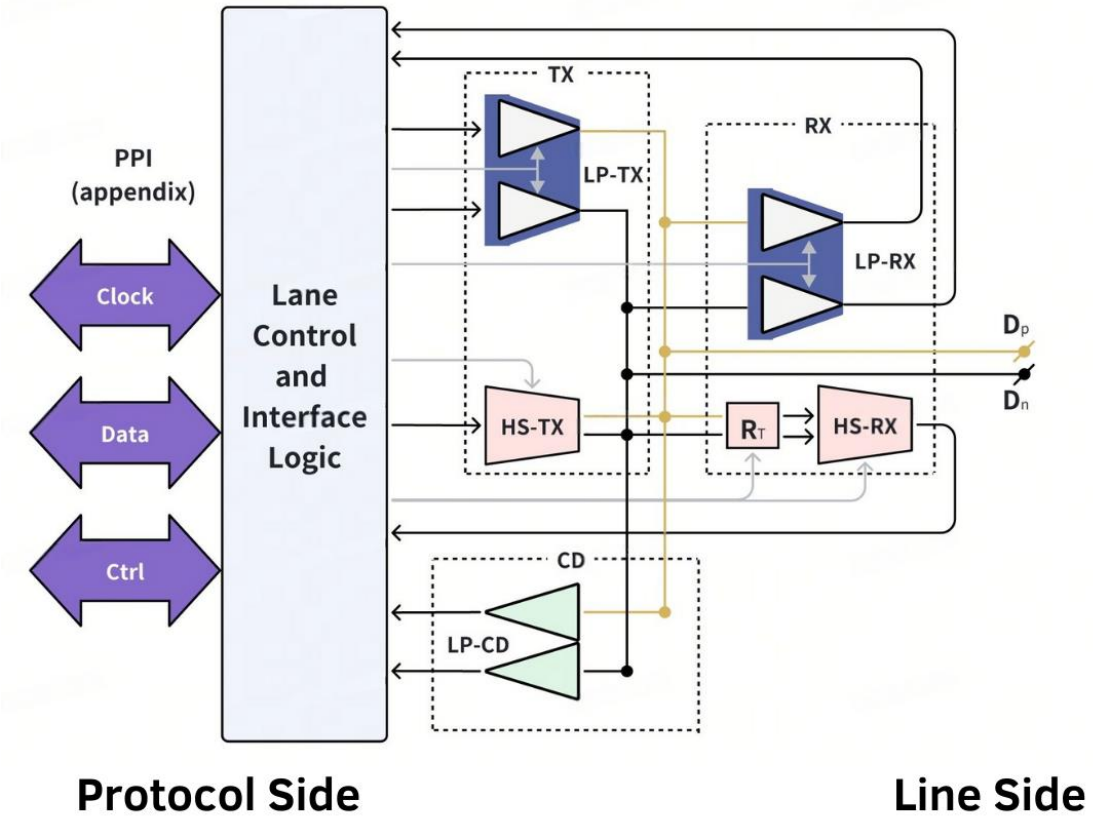


Figure 2: Common Module Architecture

D-PHY operates in two modes: **High-Speed Mode (HS)** for high-speed data transfer and **Low-Power Mode (LP)** for control signal communication.

High-Speed Mode:Each channel employs termination and is driven by low-swing differential signals (typically 200mV). This mode supports single-lane data rates up to 2.5 Gbps, ideal for high-speed data transmission.

Low-Power Mode:All signal lines operate in single-ended, unterminated configurations. To minimize EMI, drivers in this mode feature controlled slew rates and current limits, with a typical signal voltage of 1.2V and maximum data rate of 10 Mbps, suitable for low-power control and standby data exchange.

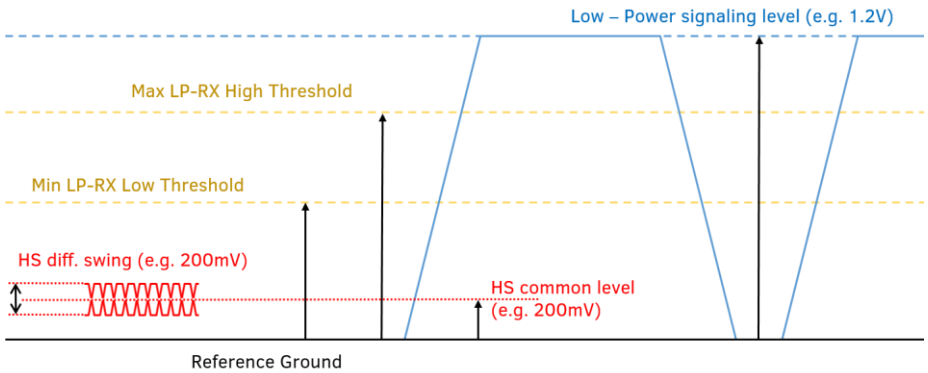


Figure 3 Voltage Swing of MIPI Differential Signals for High-Speed and Low-Power Modes

Test Environment Details:

The customer's test environment validates MIPI D-PHY V1.2 signals at 1.2 Gbps from a camera module. The signal chain includes a camera module, motherboard, and high-speed motion control system (EtherCAT servo system), with final data processed and analyzed via a host computer and display.

During testing, MIPI D-PHY V1.2 differential signals are transmitted from the camera module to the motherboard. Signals are captured at specific test points on the motherboard using an oscilloscope DS81304 with three PVA8700 probes. Automated electrical testing evaluates signal integrity and data transmission performance.

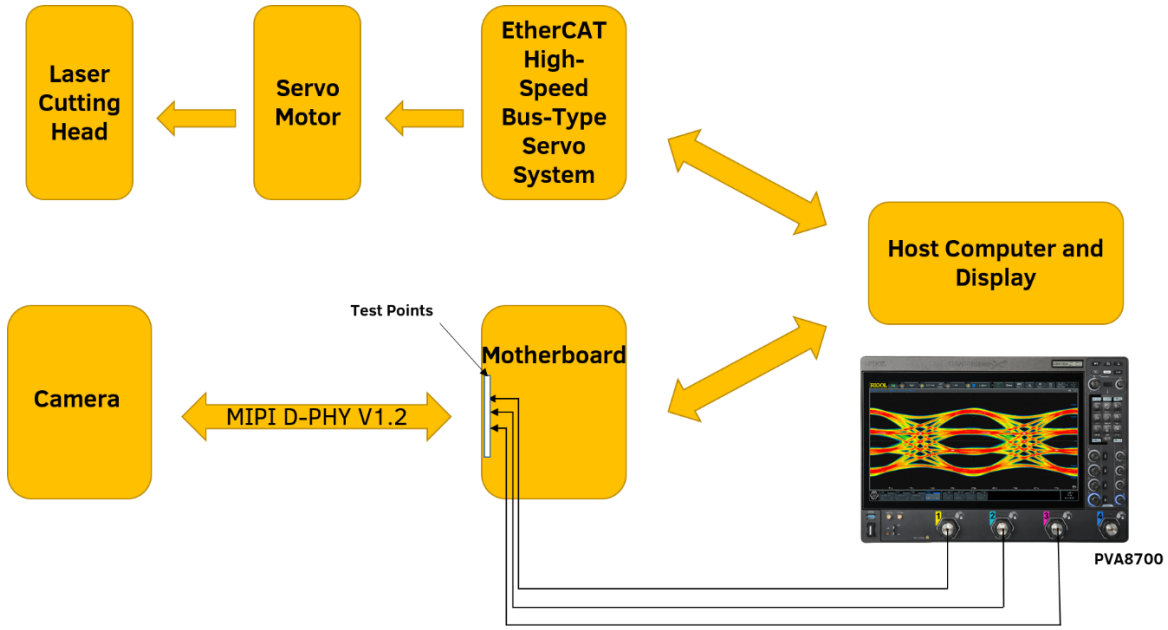


Figure 4：Equipment Connectivity Diagram

Figure 5: Field Connection Diagram

Key Application Factors:

The RIGOL DS81304 series high-end digital oscilloscopes, combined with high-bandwidth differential/single-ended probes PVA8700 and MIPI compliance test options, form a complete board-level testing solution. This system effortlessly addresses physical-layer interface compliance testing for MIPI D-PHY versions V1.0, V1.1, and V1.2. The solution offers the following advantages:

(1) Protocol Compliance Ensures Testing Accuracy

The RIGOL MIPI D-PHY compliance test solution strictly adheres to CTS protocol specifications while automating the execution of all test items per standard requirements. Additionally, it supports user-defined pass/fail ranges for test items, enabling flexible specification management to accommodate diverse testing needs.

(2) High-Efficiency Automated Testing for Enhanced Productivity

RIGOL's MIPI D-PHY compliance test solution provides intuitive waveform previews, automated parameter configuration, and connection guidance. This allows engineers to achieve precise testing without complex debugging. Compared to the industry average of 20+ minutes per test cycle, the RIGOL solution completes full testing in just 10-15 minutes, significantly accelerating R&D and quality validation workflows.

(3) Comprehensive Test Reports Enable Precise Problem Analysis

Upon test completion, the RIGOL MIPI D-PHY compliance test solution automatically generates detailed reports containing overall results, itemized test data, and corresponding waveform screenshots. Engineers can swiftly evaluate product performance, identify potential issues, and obtain actionable insights for design optimization.

This comprehensive RIGOL solution empowers engineers to efficiently execute MIPI D-PHY physical-layer compliance testing while ensuring stable and reliable high-speed signal transmission.

Overall Contributions & Synergies:

During this MIPI D-PHY compliance testing initiative, we not only completed full test procedures and generated professional reports but also provided in-depth troubleshooting support for failed test items. We assisted the client in analyzing potential failure root causes, conducted multiple rounds of retesting post-modification, and validated the effectiveness of corrective actions to ensure compliance with performance standards.

In practical testing scenarios, the client performed comparative compliance testing using multiple signal transmission lines between camera modules and motherboards. Through

systematic analysis of test results across different cables, we enabled their engineering team to:

- Evaluate product performance variations
- Identify optimal solutions
- Optimize product design
- Enhance signal transmission quality
- Improve overall system stability

This testing initiative not only delivered comprehensive compliance verification but also supported product optimization, laying a solid technical foundation for subsequent mass production.

Summary of Results

Test Statistics	
Failed	5
Passed	19
Total	24

Pass	#Failed	#Trials	Test Name(click to jump)	Actual Value	Margin	Pass Limits
√	0	1	1.3.1 Data Lane HS Entry: Data Lane TLPX Value	53.94ns	7.88%	VALUE >= 50ns
√	0	1	1.3.2 Data Lane HS Entry: THS-PREPARE Value	59.6ns	65.14%	43.3334ns <= VALUE <= 90ns
√	0	1	1.3.3 Data Lane HS Entry: THS-PREPARE + THS-ZERO Value	163.95ns	6.92%	VALUE >= 153.3334ns
√	0	1	1.3.4 Data Lane HS-TX Differential Voltage (VOD(0), VOD(1))	VOD[0]: -213.8136mV VOD[1]: 181.455mV	56.78% 68.11%	-270mV <= VOD[0] <= -140mV 140mV <= VOD[1] <= 270mV
×	0	1	1.3.5 Data Lane HS-TX Differential Voltage Mismatch (VOD)	32.3585mV	-131.13%	VALUE <= 14mV
√	0	1	1.3.6 Data Lane HS-TX Single-Ended Output High Voltage (VOHHS(DP), VOHHS(DN))	VOHHS(DP): 298.8406mV VOHHS(DN): 314.0362mV	16.99% 12.77%	VOHHS(DP) <= 360mV VOHHS(DN) <= 360mV
						150mV <=

Conclusion:

The MIPI D-PHY compliance test of the high-speed servo laser processing system successfully verified the signal quality of the MIPI D-PHY V1.2 output from the camera module, ensuring stable and reliable signal transmission. This lays a solid foundation for product optimization and mass production.

The RIGOL DS81304 oscilloscope and PVA8700 high-bandwidth probe, combined with the MIPI compliance test option, constructed a comprehensive board-level testing solution, enabling automated testing and significantly improving both efficiency and accuracy. Compared to traditional manual testing, this solution reduces complex setup steps, allowing engineers to focus more on data analysis and product optimization.

During the test, we not only generated detailed test reports but also assisted the customer in diagnosing and troubleshooting failed test items, providing optimization recommendations, and verifying corrective actions through multiple rounds of retesting. Additionally, the customer conducted comparative testing of different signal transmission lines to optimize signal integrity.

This test not only ensured that the product met industry standards but also provided technical support for future mass production. Moving forward, RIGOL will continue to optimize testing solutions, advancing the fields of intelligent manufacturing and high-speed signal transmission, and providing customers with more efficient and accurate testing solutions.

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