Automotive Ethernet

BRR 100BaseT1 1000BaseT1

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Defining Automotive Ethernet

- Can refer to any Ethernet-based network for in-vehicle electrical systems
- Enables faster data communication to meet rising demand
- Specifically tailored to meet the needs of automotive industry

Automotive Ethernet

BroadR-Reach

OABR
(OPEN Alliance
BroadR-Reach)

OPEN ALLIANCE

100Base-T1
1000Base-T1

RTPGE
(Reduced Twisted
Pair Gigabit
Ethernet)

IEEE

Industry Trends & Challenges

- Substantial increase in prevalence of in-vehicle electronics
  - Nearly doubled over the last decade
- Growing in volume and complexity
  - Substantial increase in cameras, diagnostics, ADAS, infotainment, etc.
  - In-dash display consoles evolving to computerized nerve centers
- Bandwidth challenges
  - More data requires higher transmission rates

Source: Broadcom

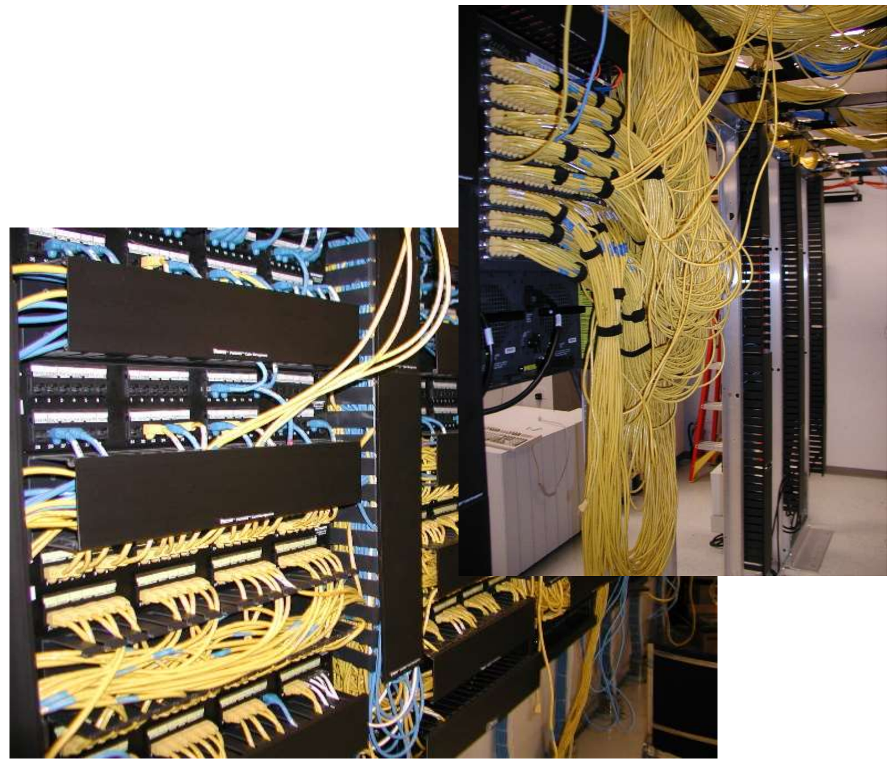
Industry Trends & Challenges (continued)

- Compatibility and need for open architecture
  - In-vehicle networks must be scalable, support multiple systems and devices
  - Auto makers value the time it takes to get to market
- Cable limitations
  - Auto makers seeking less costly forms of wiring
- Industry standards
  - In-vehicle technologies must meet strict regulations
  - Reliability, temperatures, minimal power consumption

Source: Broadcom

Why Not Just Use 100/1000Base-T?

- “Standard Ethernet” had limited use in automotive environments
- Optimized for enterprise, business, and consumer applications
  - 100meter reach
  - 4-pair per port Structured Cabling
(Cat 5, 5e)
  - EMC performance unspecified
  - Plug/unplug to different link partners



Automotive Challenges Drove Specific Requirements

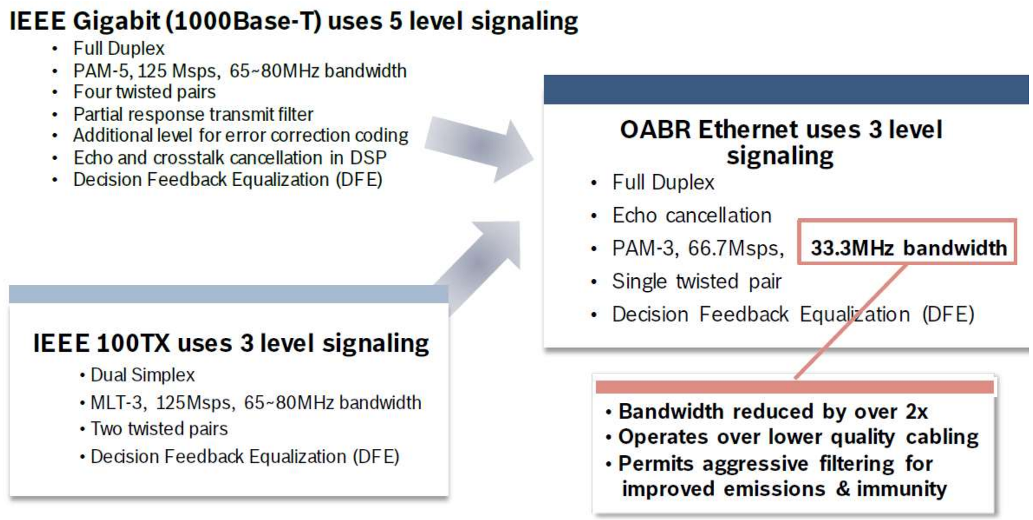
- Harsh environmental conditions
  - Temperature
    - Body: -40°C to 85°C
    - Chassis and Powertrain: -40°C to 125°C
  - Mechanical – acceleration up to 4G in body and cabin

- Stringent EMC requirements
  - Cost and weight constraints

- Very low standby power requirements

BroadR-Reach is a Hybrid of 1000Base-T and 100Base-Tx

- 1000Base-T (Gigabit Ethernet)
  - PAM-5, 125 MSps, 65-80 MHz
  - Full Duplex
  - Four twisted pairs
- 100Base-T
  - 3 level, 125 MSps, 65-80 MHz
  - Half duplex
  - Two twisted pairs
- BroadR-Reach
  - 3 level, 66.67 MSps, 33.33MHz
  - Full Duplex
  - Single twisted pair



Source: BroadR-Reach Spec Figure 1-1

BroadR-Reach/100Base-T1 Employs PAM-3 Signaling

Negative

Positive

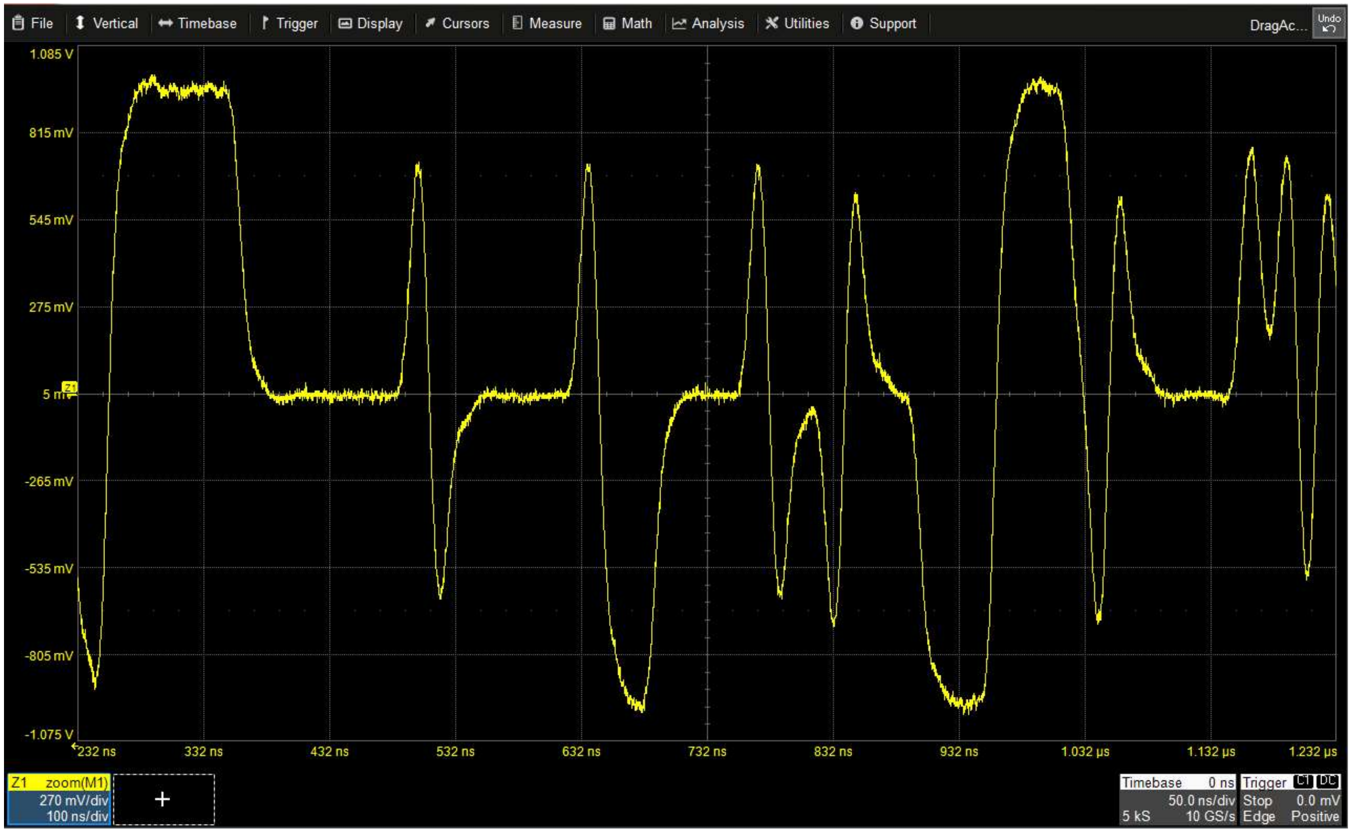
Differential

BroadR-Reach/100Base-T1 Employs PAM-3 Signaling

+1

0

-1

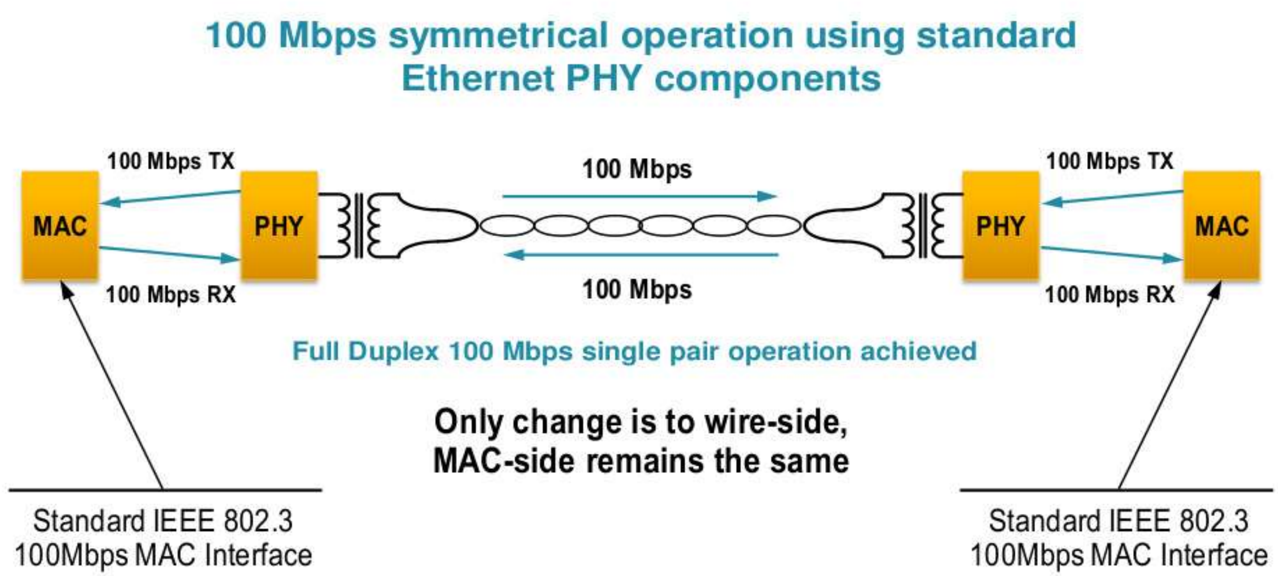


What are the benefits of Automotive Ethernet?

- Higher bandwidth
  - LIN: 19.2 Kbps
  - CAN FD: 15 Mbps
  - FlexRay: 10 Mbps
  - MOST: 25, 50, 150 Mbps (shared)
- Low-cost cabling solution (unshielded)
  - Reduces cable weight by ~30% and connectivity cost by ~80%*
- Engineered to meet stringent EMC/EMI and temperature grade automotive requirements
- Software interfaces on upper layers of Ethernet stack is pre-existing

*Source: Broadcom

BroadR-Reach Configuration



What is 100Base-T1?

- IEEE 802.3bw Physical Layer Specifications and Management Parameters for 100 Mb/s Operation over a Single Balanced Twisted Pair Cable (100Base-T1)

- IEEE specification for 100 Mb/s Automotive Ethernet
  - Interoperable with OPEN Alliance BroadR-Reach
  - Same RAND terms apply

- Nearly the same thing as BroadR-Reach
  - Often times names are used interchangeably
  - Few exceptions
    - Electrical PMA has a Transmit Peak Differential Output
    - Changes in the protocol timing for wake up commands

- Why create a new spec?
  - Driven by other applications: industrial automation and avionics

What to Expect in the Near Future … tomorrow…

- Automotive Ethernet continues to increase in popularity in Automotive and other industries

- 1000Base-T1 (IEEE 802.3bp) – Gigabit Automotive Ethernet
  - Standard has been completed
  - Products from chip vendors will start to appear in the second half of 2017
  - Will allow Automotive Ethernet to serve as the network backbone

- 1000Base-RH – Automotive Ethernet over POF (Plastic Optical Fiber)
  - Gigabit POF is currently being standardized
  - Targeted for other applications with longer reach
    - Home and industrial

What to Expect in the Future (~5 years)?

- 10 Mb/s
  - Provides data rates similar to CAN FD but will be more cost and energy efficient than 100 Mb/s
    - Will only make sense if it is cost competitive
- MGBase-T1 (2.5 G and 5 G)
  - Based off of 2.5GBase-T and 5GBase-T, which are based off of 10GBase-T
  - 100M is fine for streaming video but not enough for processing

Basics of Automotive Ethernet Test Requirements

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Categories of Automotive Ethernet Testing

- Electrical Signaling: Physical Media Attachment (PMA)
  - Determine if product conforms to electrical transmitter and receiver specifications

- Physical Coding Sublayer (PCS) & PHY Control
  - Evaluates functionality of the protocol
    - PCS transmit/receive
    - State diagrams
    - Encoding/decoding
    - Scrambling/descrambling

- There are recommendations for other elements
  - Common Mode Choke (CMC), EMC, Communication Channel, ECU, switches

What is Compliance Testing in the Context of Automotive Ethernet?

- The 100Base-T1 spec includes requirements for PMA, PCS, and PHY Control
- IEEE does not write test specifications
  - UNH has traditionally written test documents which describe how tests can be performed
- It is up to the OEM, PHY Vendor, Tier 1, etc. to work with a test equipment manufacturer or test house to perform testing

Why is PHY Compliance Important?

- OEMs have a lengthy development cycle for an ECU
  - Need assurance that PHY chip meets requirements prior to implementation

- Once the PHY chip has been incorporated into the ECU it should also be tested – testing is not just for PHY vendors
  - This may be full compliance testing or a subset of compliance tests

- Compliance to 100BASE-T1 does not guarantee interoperability
  - Transmitter requirements are well defined, the receiver is left up to the implementer

7 Differential Electrical Physical Layer Compliance Tests

- BroadR-Reach & 100Base-T1
  - Maximum Transmitter Output Droop
  - Transmitter Clock Frequency
  - Transmitter Timing Master Jitter
  - Transmitter Timing Slave Jitter
  - Transmitter Distortion
  - Transmitter Power Spectral Density (PSD)

- 100Base-T1 Only
  - Transmitter Peak Differential Output

Test Equipment Requirements

- 1 GHz Oscilloscope with at least 2 GS/s sample rate
  - We recommend 10 GS/s
- Oscilloscope with Spectral Analysis capability or Spectrum Analyzer
- Disturbing Sine Wave Generator
  - 5.4 Vpk-pk at 11.11 MHz
  - 2 BNC cables
  - 2 BNC-SMA adapters
- Ethernet Test Fixture
  - 2 SMA cables
  - 2 SMA-BNC Adapters
- 1 GHz Differential Probe
- Short Automotive Cable
- Vector Network Analyzer
  - For return loss and common mode

What about 1000BaseT1?

	1000Base-T1	100Base-T1
Data Rate		
Bit Rate	1 Gb/s	100 Mb/s
Baud Rate	750 MBd	66 2/3 MBd
Tx_TCLK rate (1/6 symbol rate)	125 MHz	11 1/6 MHz
Number of Test Modes	7	5
Droop Test		
Test Mode	6	1
Limit	10%	45%
Location of Initial Peak	4 ns	After first crossing
Location of V dropped	16 ns	500 ns
Jitter Test		
Number of Cases for Jitter Tests	3	2
Test Cases for TX_TCLK	Master and Slave	Slave
Test Mode for TX_TCLK probed tests	1	3
PSD Test		
Start of Lower Mask	40 MHz	DC
Peak Differential Output		
Maximum limit	1.3 Vpk-pk	2.0 Vpk-pk

Test equipment needed for 1000Base-T1 compliance test

Oscilloscope:	Minimum bandwidth of 2 GHz
Software Option:	QPHY-1000Base-T1
Test Fixture:	TF-ENET-B (same used for 1000/100/10Base-T and 100Base-T1)
Probes:	D420-A-PBS (required for TX_TCLK)
Disturbing AWG:	T3AWG3252

MIPI

Basic of D-PHY Physical Layer

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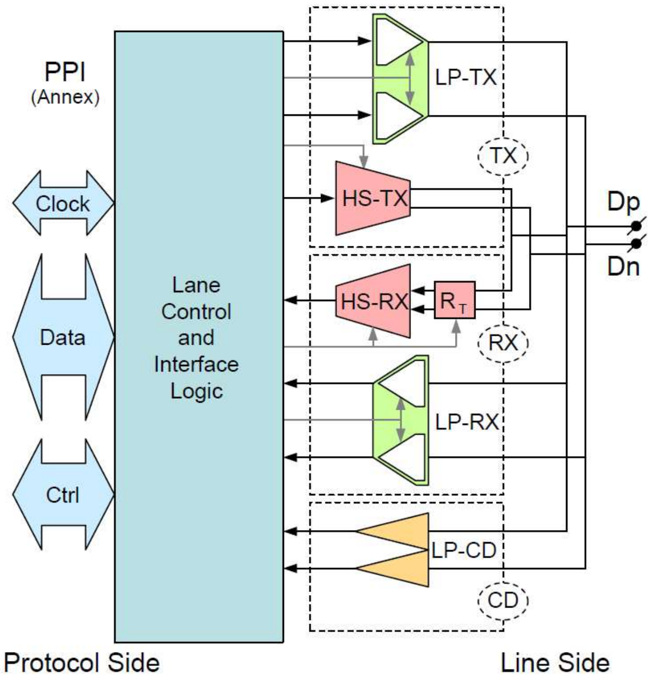
Purpose

The D-PHY specification is used by manufacturers to design products that adhere to MIPI Alliance interface specifications for mobile device such as, but not limited to, camera, display and unified protocol interfaces.

Point to note: D-PHYs communicate on the order of 500 Mbit/s hence the Roman numeral for 500 or "D."

PHY Functionality



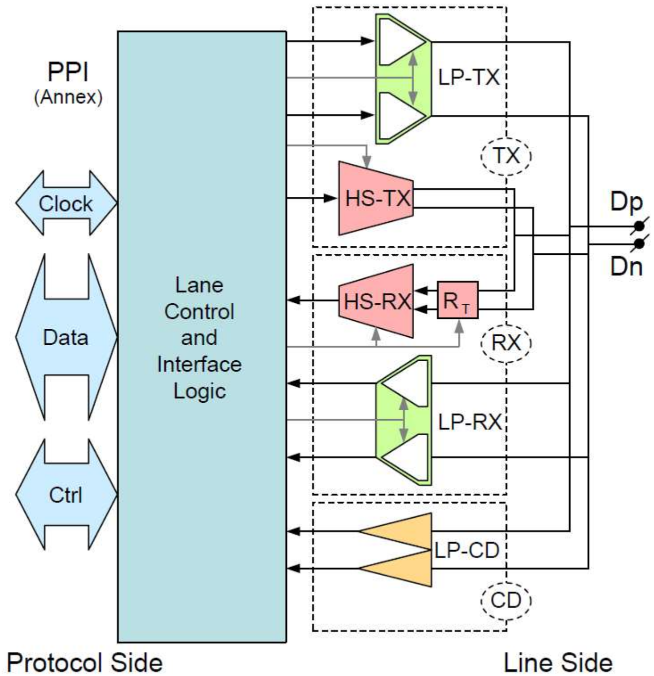
The D-PHY provides a synchronous connection between Master and Slave.

A practical PHY Configuration consists of a clock signal and one or more data signals.

The clock signal is unidirectional, originating at the Master and terminating at the Slave.

The data signals can either be unidirectional or bi-directional depending on the selected options.

PHY Functionality … cont.

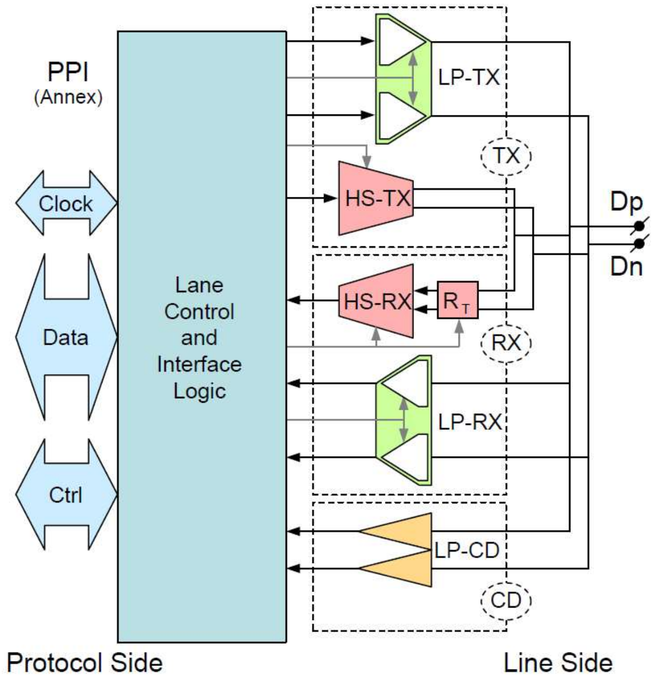


The Link includes a High-Speed signaling mode for fast-data traffic and a Low-Power signaling mode for control purposes.

Optionally, a Low-Power Escape mode can be used for low speed asynchronous data communication.

High speed data communication appears in bursts with an arbitrary number of payload data bytes.

PHY Functionality … cont.



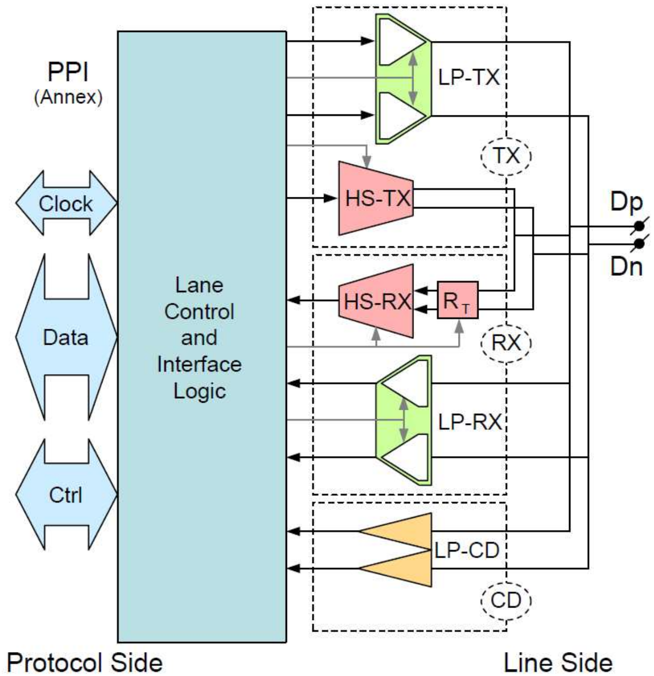
The PHY uses two wires per Data Lane plus two wires for the Clock Lane. This gives four wires for the minimum PHY configuration.

In High-Speed mode each Lane is terminated on both sides and driven by a low-swing, differential signal.

In Low-Power mode all wires are operated single-ended and non-terminated.

For EMI reasons, the drivers for this mode shall be slew-rate controlled and current limited.

PHY Functionality … cont.

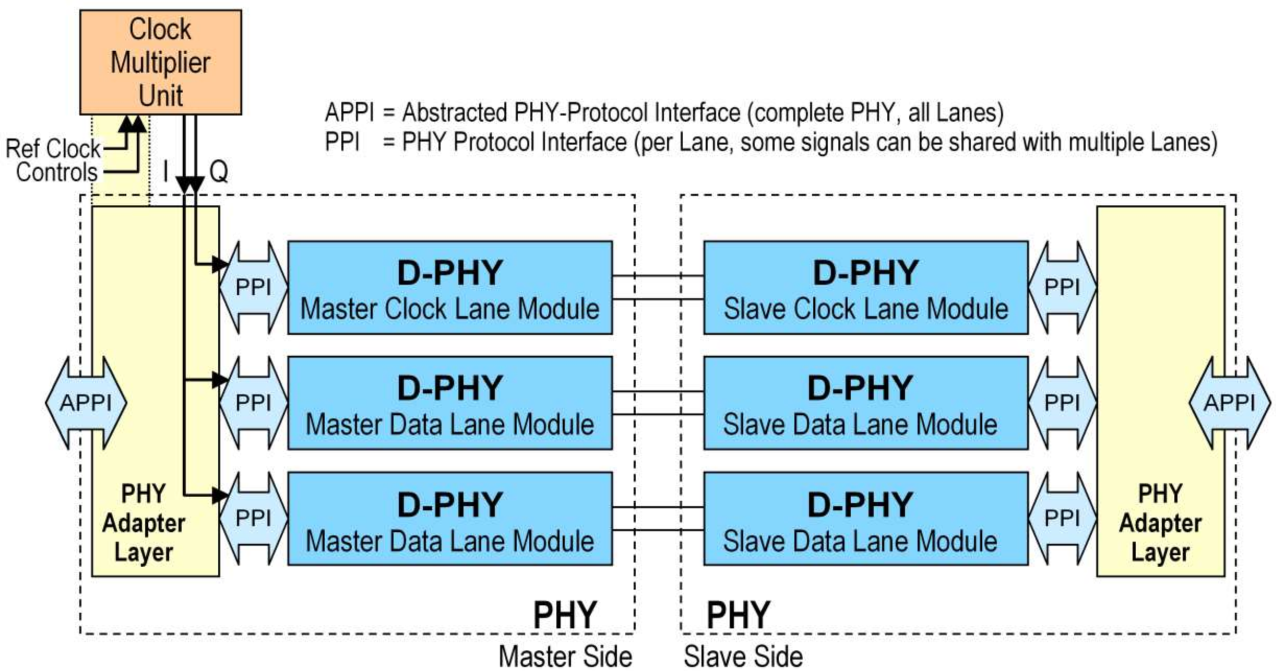


The actual maximum achievable bit rate in High-Speed mode is determined by the performance of transmitter, receiver and interconnect implementations.

The maximum bit rate is not specified in the specification, however is primarily intended to define a solution for a data rate range:

- 80 to 1500 Mbps per Lane without deskew calibration
- up to 2500 Mbps with deskew calibration
- up to 4500 Mbps with equalization.

Lane Modules



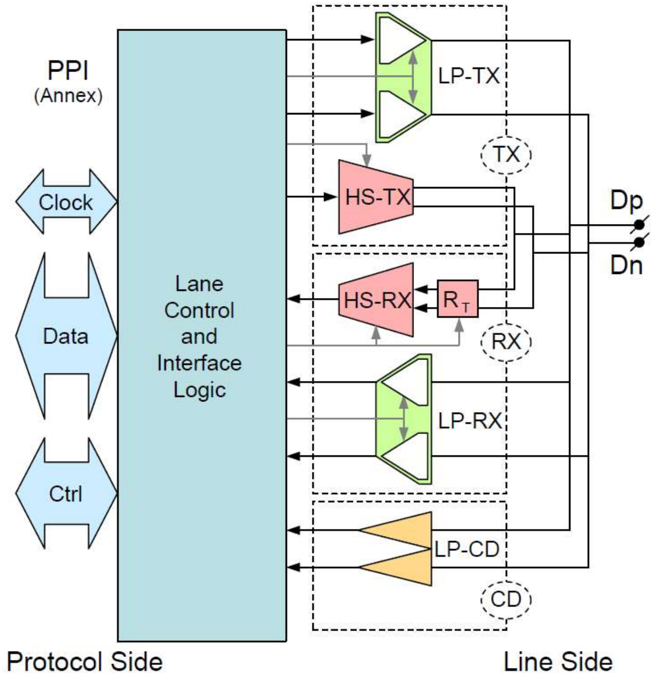
A PHY configuration contains a Clock Lane Module and one or more Data Lane Modules.

Each of these PHY Lane Modules communicates via two Lines to a complementary part at the other side of the Lane Interconnect.

Lane Modules … cont

Each Lane Module consists of one or more differential High-Speed functions utilizing both interconnect wires simultaneously, one or more single-ended Low-Power functions operating on each of the interconnect wires individually, and control & interface logic.

High-Speed signals have a low voltage swing, e.g. 200 mV, while Low-Power signals have a large swing, e.g. 1.2V.



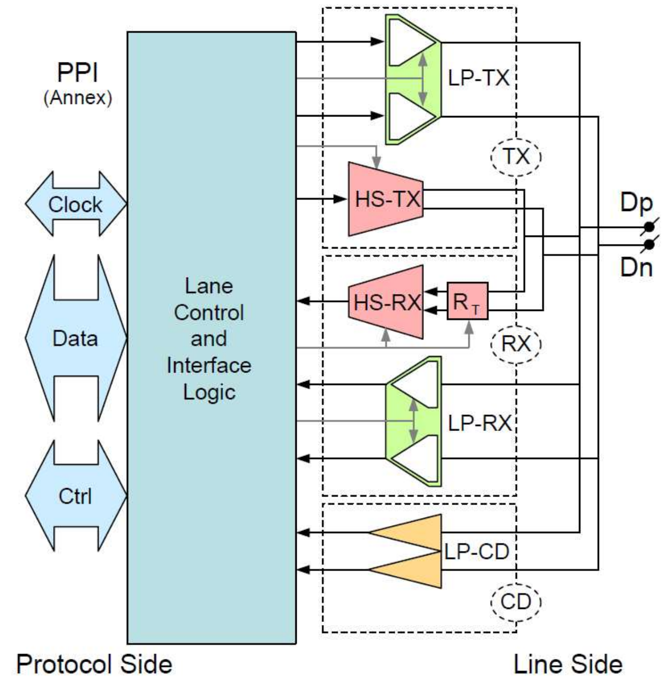
Lane Modules … cont

High-Speed functions are used for High-Speed Data transmission.

The Low-Power functions are mainly used for Control, but have other, optional, use cases.

High-Speed functions include a differential transmitter (HS-TX) and a differential receiver (HS-RX).

A HS-TX and a HS-RX within a single Lane Module are never enabled simultaneously during normal operation.



Lane States and Line Levels

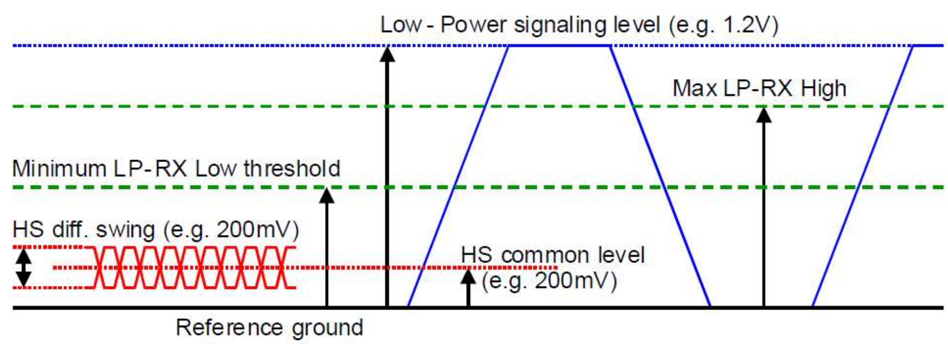
Transmitter functions determine the Lane state by driving certain Line levels.

During normal operation either a HS-TX or a LP-TX is driving a Lane.

A HS-TX always drives the Lane differentially.

The two LP-TX's drive the two Lines of a Lane independently and single-ended.

This results in two possible High-Speed Lane states and four possible Low-Power Lane states.

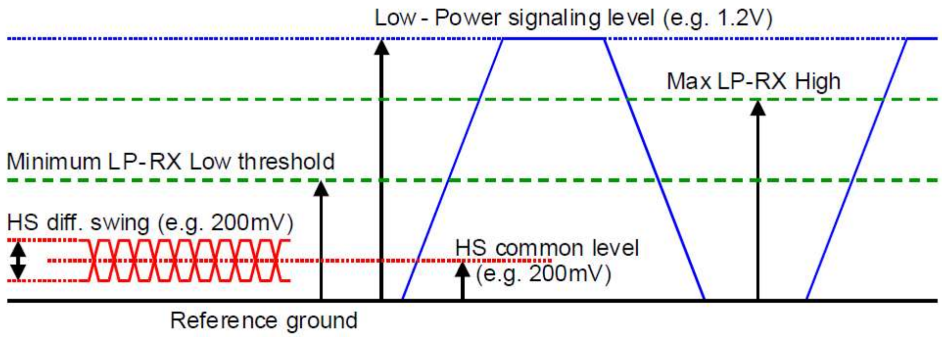


Lane States and Line Levels

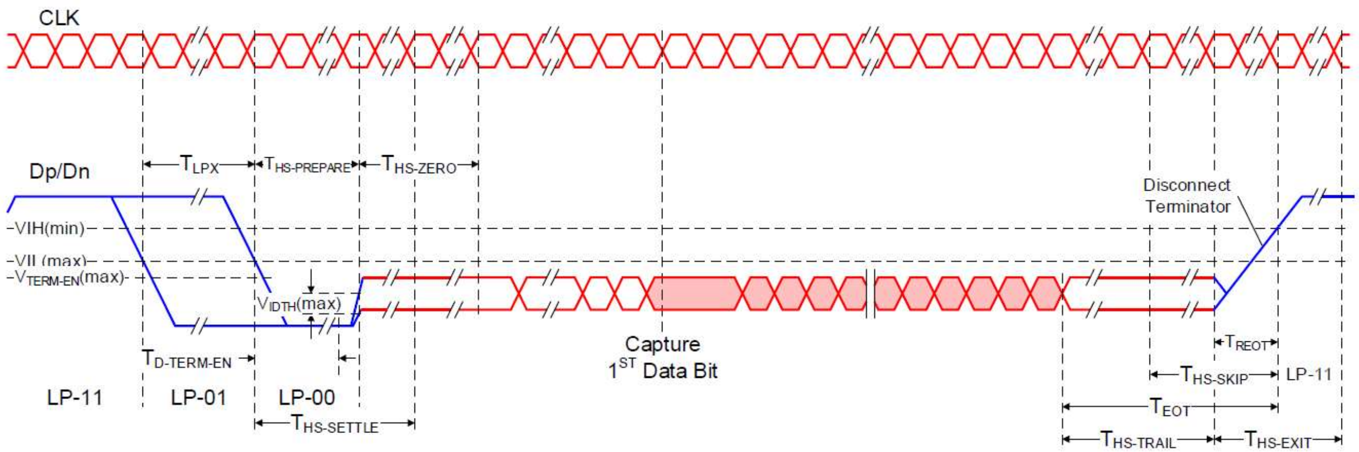
The High-Speed Lane states are Differential-0 and Differential-1.

The interpretation of Low-Power Lane states depends on the mode of operation.

The LP-Receivers shall always interpret both High-Speed differential states as LP-00.



Operating Modes: Control, High-Speed, and Escape



During normal operation a Data Lane will be either in Control or High-Speed mode. High-Speed Data transmission happens in bursts and starts from and ends at a Stop state (LP-11), which is by definition in Control mode.

The Lane is only in High-Speed mode during Data bursts.

The sequence to enter High-Speed mode is: LP-11, LP-01, LP-00 at which point the Data Lane remains in High-Speed mode until a LP-11 is received