BROADR-REACH® TECHNOLOGY: ENABLING ONE PAIR ETHERNET

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Broadcom Corporation
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For additional financial and statistical information, including the information disclosed in accordance with SEC Regulation G, please see the Investors section of our website.
Broadcom End Market Segments

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Hand

Automotive

Infrastructure

Bringing Broadcom Innovation & Know-How to the Car
Agenda

• Ethernet PHY Overview
• Introduction to BroadR-Reach® Technology
• Standardization of BroadR-Reach® Technology
• BroadR-Reach® Technology Use Case
• Summary
Agenda

• Ethernet PHY Overview
  – Ethernet PHY Development

• Introduction to BroadR-Reach® Technology

• Standardization of BroadR-Reach® Technology

• BroadR-Reach® Technology Use Case

• Summary
Ethernet Physical Layers

IEEE Standard Physical Layers

- 10BASE-T 1991 Cat-3
- 100BASE-TX 1995 Cat-5
- 1000BASE-T 1999 Cat-5 >1B ports shipped
- 10GBASE-T 2006 Cat-6A now shipping

>4B 10/100 ports shipped (switch + client)

High volume deployment has driven continuous improvements in cost, power, performance, and reliability

Ethernet drawing by Bob Metcalfe, around 1976
PHY Strategy for Twisted Pair Cable Channels

• Twisted pair cable channels favor narrow baseband communications strategies
  – Insertion loss increases with frequency
  – Impairments increase with frequency
    – Crosstalk, return loss
  – *Balance degrades with frequency*
    – Emissions, immunity

• Best strategy is to **minimize bandwidth**
  – Maximizes available channel capacity

• Techniques for bandwidth efficient data transmission
  – Multi-level signaling
  – Equalization
  – Full duplex operation (echo cancellation)

\[\text{Widely Deployed in Std IEEE PHYs}\]
TP Ethernet Development CATs and PHYs

- TP Cable is developed in parallel to each new PHY
- Each new category is improved with respect to previous one
- Cabling and PHY standards development are coordinated for success
- TP Cabling standards have to date focused on LAN & data centers
- Need for 100Mb/s over one-pair UTP for Automotive Networks

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<td>10GBASE-T (an)</td>
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Agenda

• Ethernet PHY Overview

• Introduction to BroadR-Reach® Technology
  – Bandwidth Efficiency
  – Reach
  – EMC Results

• Standardization of BroadR-Reach® Technology

• BroadR-Reach® Technology Use Case

• Summary
• SerDes, 10BASE-T, 100BASE-TX all operate with unidirectional transmission per wire pair
  – At least 2 wire pairs (4 wires) required for full duplex data transmission

• BroadR-Reach® PHY, 1000BASE-T, 10GBASE-T all operate with bi-directional transmission per wire pair
• Higher layer “doesn’t care” beyond the MAC MII interface
  – Higher layers insulated from Physical Layer
  – Media Independent: UTP Copper, STP Copper, fiber, co-ax, POF, …
  – PHY Independent: 100BASE-TX, 100BASE-T2, 100BASE-T4, 100BASE-FX, or **100Mbps BroadR-Reach® Ethernet**
**IEEE Gigabit (1000Base-T) uses 5 level signaling**
- Full Duplex
- PAM-5, 125 Msps, 65~80MHz bandwidth
- Four twisted pairs
- Partial response transmit filter
- Additional level for error correction coding
- Echo and crosstalk cancellation in DSP
- Decision Feedback Equalization (DFE)

**IEEE 100TX uses 3 level signaling**
- Dual Simplex
- MLT-3, 125Mmps, 65~80MHz bandwidth
- Two twisted pairs
- Decision Feedback Equalization (DFE)

**BroadR-Reach® Ethernet**
**“Standards Based” Physical Layer**

**BroadR-Reach® Ethernet uses 3 level signaling**
- Full Duplex
- Echo cancellation
- PAM-3, 66.7Msps, ~27MHz bandwidth
- Single twisted pair
- Decision Feedback Equalization

- **Bandwidth reduced by over 2x**
- Operates over lower quality cabling
- Permits aggressive filtering for improved emissions & immunity
Bandwidth Efficiency of BroadR-Reach® Technology

- Achieves 100Mbps in < ½ the bandwidth and with 2x fewer wire pairs than 100BASE-TX
- Lower emissions, improved immunity
• The reach is dependent on the application requirements and it can be extended based on the channel and/or data rate

• The BroadR-Reach transceiver is designed to carry ample system margin which can be traded off for better noise immunity performance as dictated by the applications’ requirements
BroadR-Reach® 100Mbps EMC Results

- BroadR-Reach® Ethernet PHY, using single-pair UTP, without shielded enclosure, substantially meets automotive component level EMC requirements

- **CISPR 25, Component-level ALSE method**
  - Passes Class 5 with margin

- **Stripline Emission**
  - BroadR-Reach demo boards show adequate performance using a custom limit

- **ISO 11452-4 2005 Bulk current injection, Substitution method**
  - Data transmission not effected
  - Tested at levels far beyond any known requirements, with 100Mbps bidirectional traffic
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• Ethernet PHY Overview
• Introduction to BroadR-Reach® Technology
• Standardization of BroadR-Reach® Technology
  – OPEN and IEEE
  – Higher Speeds
• BroadR-Reach® Technology Use Case
• Summary
**IEEE 802.3 reduced twisted pair gigabit Ethernet**

- Call for interest accepted in March 2012
- IEEE 802.3 Study group is formed
- Demonstrates clear potential for future of twisted pair cabling for automotive

**OPEN (One Pair Ether-Net) special interest group**

- Enables proliferation of 100Mbps single pair Ethernet, including interoperability and compliance testing
- Driving higher data rate
- Enables migration to open, scalable Ethernet-based network
OPEN (One Pair Ether-Net) Special Interest Group

- Establishes Industry Standard for Automotive Ethernet Connectivity
- Enables Migration from Closed to Open, Scalable Ethernet-based Network
- Encourages Joint Development
- Complementary to All Existing Ethernet IP Technologies

www.opensig.org
OPEN Alliance Membership

More than 100 Leading Auto & Tech Members
Agenda

• Ethernet PHY Overview
• Introduction to BroadR-Reach® Technology
• Standardization of BroadR-Reach® Technology

• BroadR-Reach® Technology Use Case
  – Automotive
  – Announcements
  – Emerging Applications

• Summary
Potential Industrial and Commercial Applications

Traditional Markets

- Industrial Automation
  - Factory Automation
    - e.g. Material handling, Automotive Manufacturing, Transfer lines,
  - Process Automation
    - e.g. Oil, Gas, Chemical / Petrochemical, Food & Beverage

- Energy Automation
  - Power Generation
    - e.g. Fossil Power Plants, Wind Turbines
  - Power Transmission and Distribution

- Building Automation
  - Climate Control
  - Fire Safety

New Markets

- Avionics
  - Fly-by-Wire, Passenger Experience,

- Railway Systems
  - Train Control
  - Railway Traffic Management Systems

- Medical
  - Patient Imaging, Patient Management
Use Case: BroadR-Reach® Ethernet for Automotive

BroadR-Reach Automotive Ethernet

- 100Mbps Ethernet PHY
- Single unshielded twisted pair design
- 2 wire Ethernet replaces 4 wire proprietary systems
- Reduces Cost, Reduces Weight
- Meets Automotive EMC requirements

<table>
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<tr>
<th>Cable</th>
<th>Connector (2 ends, on-board &amp; cable)</th>
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<tr>
<td>LVDS</td>
<td><img src="image" alt="LVDS Cable and Connector" /></td>
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<tr>
<td>BroadR-Reach®</td>
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Broadcom, Freescale and OmniVision Enable World's First Ethernet-Based 360-Degree Surround View Parking Assistance System

Collaboration results in lower cost, higher resolution solution - technology now accessible for broad range of automobiles

IRVINE, SANTA CLARA, Calif. and AUSTIN, Texas, Oct. 10, 2011 /PRNewswire/ -- Broadcom Corporation (NASDAQ: BRCM), Freescale Semiconductor (NYSE: FSL), and OmniVision Technologies, Inc. (NASDAQ: CVTI), today announced a jointly developed 360-degree surround view parking assistance system — the world's first Ethernet-based parking assistance solution.

The collaboration, combining best-in-class semiconductor innovation and automotive electronics expertise, is an important step in the migration from a closed application to an open, and scalable Ethernet-based driver assistance network in which several systems can easily access information. The combination of the high image resolution now accessible from affordable Ethernet hubs provides OEMs an opportunity to deploy 360-degree parking assistance camera systems with valuable assistance options to luxury cars and luxury markets alike.

The system is based on the Broadcom® BroadR-Reach® BCM89810 system-on-chip (SoC), Freescale Qoriwa MPC5604E 32-bit microcontroller (MCU), and OmniVision's AEC-Q100 qualified OV10630 color high dynamic range (HDR) system-on-a-chip (SoC) CMOS image sensor.

The OV10630's unique color HDR SoC structure with fully processed YUV output format enables a streamlined camera module architecture. Using this approach, the video signal can be fed directly into the Freescale Qoriwa MPC5604E encoder encoding pipeline without the need for any additional processing ICs for RAW image to YUV format conversion.

“Broadcom Corporation, Freescale Semiconductor, and OmniVision Technologies, Inc., jointly developed world's first Ethernet-based parking assistance solution.”

World’s First BroadR-Reach Enabled ADAS Camera
• BroadR-Reach Ethernet supports key requirements:
  – Dedicated bandwidth per port
  – Flexible speed per port
  – Advanced cable diagnostics for each link
  – Redundancy for failover mechanism
  – IEEE standard (AVB) for entertainment audio/video processing
BMW and Broadcom Partnership News

• http://blogs.strategyanalytics.com/auto/?cat=11

“The development comes from a cooperation with Broadcom – using a version of BroadR-Reach technology for enabling full-duplex operation over a single twisted pair.”

“For model year 2013, the company intends to bring an Ethernet-based videolink to market for a park assist camera solution for the X5.”
Hyundai and Broadcom Partnership News
(Announced 10/15/12)


Broadcom and Hyundai Motor Power Next-Generation Connected Car

Joint Development Enables Advanced Infotainment and Safety Features in Hyundai Vehicles

DETROIT, Oct 15, 2012 News Highlights:
- Advances wide-scale adoption of automotive Ethernet
- Extends infotainment and passenger safety features across price points
- Delivers 100Mbps connectivity for in-vehicle networks, with future scalability up to 1Gbps


Broadcom Corporation (NASDAQ: BRCM), a global innovation leader in semiconductors solutions for wired and wireless communications, today announced a joint development agreement with Hyundai Motor to power the next-generation connected car. The collaboration will integrate infotainment, telematics, and advanced driver-assistance systems, such as surround view parking and lane departure warning, in Hyundai vehicles, enabling faster connectivity for a broader number of drivers.

Based on Broadcom’s BroadR-Reach® Ethernet technology, the single high-bandwidth in-vehicle network will deliver cost-effective, lightweight 100Mbps connectivity to advance integration of safety applications in the vehicle.

- “Based on Broadcom’s BroadR-Reach® Ethernet technology, the single high-bandwidth in-vehicle network will deliver cost-effective, lightweight 100Mbps connectivity to advance integration of safety applications in the vehicle.

Ethernet going mainstream in high volume cars.
Summary

• BroadR-Reach® technology permits standard Ethernet packets to be transferred over a single unshielded twisted pair cable
  – Indistinguishable from a standard IEEE PHY to higher Ethernet layers
  – Single pair operation for lower cost, power, size, and weight

• BroadR-Reach® technology extends reach and data rate over single pair
  – Enabling automotive in-car networks
  – Well suited for other applications like Industrial Ethernet

• BroadR-Reach® 100Mbps products sampling today (Switch & PHY)

• BroadR-Reach® technology already licensed to leading semiconductor suppliers
Thank You