Challenges of one pair automotive Ethernet from the wiring harness point of view

Advanced Automotive Cabling 2013, Stuttgart 2013-06-11
Speaker: Magnus Nigmann
Co-Speaker: Marco Preuß
Leoni and Intedis

- Leoni Wiring Systems is one of the worldwide leading full service provider of wiring systems
- Intedis is an independent experts specialized in E/E architecture development
Agenda

- Short overview about the Open Alliance
- Wiring Harness Requirements and Limitations
- Measurements of different cables and connectors
  - Main focus to the characteristic differential Impedance
- Qualitative evaluation by means of “real” Ethernet Link with an Evaluation-Board
- Conclusion and outlook
Open Alliance Special Interest Group

- Open Alliance (One-Pair Ether-Net) SIG was founded by BMW, Broadcom, Freescale, Harman, Hyundai and NXP in 2011
  - [http://www.opensig.org/](http://www.opensig.org/)

- Establishing of 100Mbps Ethernet as the standard in automotive networking applications

- Proliferation of Broadcom’s BroadR-Reach® technology as an open standard

- BroadR-Reach® is a new Ethernet physical layer optimized for use of unshielded single twisted pair cables

- Invented to reduce mainly wire cost because standard Ethernet was not designed for automotive requirements

- Compatibility to the higher layers of “standard Ethernet”, e.g. standard Ethernet MII

- Leoni and Intedis are members of the Open Alliance SIG

Source: Open Alliance Version 2.1, 2013-03-20

Adopters 103
Main Wiring Harness Requirements and Limitations

- Measurements and investigation are done for the OPEN Alliance single pair unshielded Ethernet based on BroadR-Reach® technology by Broadcom®:
  - Point2Point connection with reduced wire lengths and connectors compared to standard Ethernet
  - Operating over one-pair UTP cable
  - Operating within a temperature range of -40°C to 105°C

- Specification and Tests are defined by the Open Alliance (draft status)
  - Measurement method: e.g. TDR (Time Domain Reflectometry)
  - Limits for characteristic Impedance, RF and S-Parameters
Objective:
- Evaluation of different cables and connectors according to the Open Alliance requirements
- Investigation and rating of influences to “Link Quality” from the harness point of view

Evaluation criteria of the “Link Quality”

- Harness view
  - Cable & Connector parameters
    - Differential Mode Impedance
    - Insertion Loss
    - Return Loss
    - …

- System view & signal integrity
  - Eye pattern, Signal Quality Indication, …
  - Status: First investigation done
Selected Cables & Connectors

Cables tested*
- Twisted Pair (unshielded) 0.17mm² CuAg
- PVC Dacar 609
- PVC with PVC jacket Dacar 612
- XPE Dacar 617
- XPE with PU jacket Dacar 618
- Star Quad cable as high quality alternative
  - unshielded with PVC jacket Dacar 615
  - Alu shield +PVC jacket Dacar 625

Connectors and Inline-Connectors tested
- MQS (grid dimension 2,54)
- NanoMQS (grid dimension 1,8)
- HSD (Star Quad)

*typ. Characteristic Impedance of tested cable within 100Ω±10
Measurement Setup

- Use case assumed: “surround view camera” located in the mirrors and displayed in Mid-Console

- Lengths and Inline-Connector position measured in Labcar

- Two harness setups are defined
  - Without Inline-Connectors
  - With Inline-Connectors

- Measurement environment
  - Air environment
  - Ground plane
  - Labcar
Measurement of untwisted cable ends

- Untwisted cable end clearly affects the characteristic Impedance

- Measured Impedances at untwisted area up to 109 Ω (l ≈ 3mm, d ≈ 2mm )*

- Measured Impedances at untwisted area up to 242 Ω (l ≈ 35mm, d ≈ 2mm )*

Conclusion:

- Significant influence to the Impedance due to the untwisted cable ends/undefined distance between the wires

- Possible violation of the specified characteristic Impedance (typ. 100Ω±10%)
  - Measurement parameters and limits are not finally defined (currently “draft”)

*Untwisted area „d“ measured from Connector/Inline-Connector housing to the first twist. Measured with a TDR pulse rise time of 17.5ps.
Measurement of untwisted cable ends in combination with a connector

- Untwisted cable end at connector clearly affects the characteristic Impedance

- Measured Impedances at untwisted area up to 115 Ω ($l \approx 4\text{mm}, d \approx 2\text{mm}$)*
  - Max. Impedance is dominated by the connector (144 Ω)

- Measured Impedances at untwisted area up to 226 Ω ($l \approx 25\text{mm}, d \approx 2\text{mm}$)*

**Conclusion:**

- Significant influences to the Impedance due to the untwisted cable ends/undefined distance between the wires and the connectors

- Possible violation of the specified characteristic Impedance (typ. 100Ω±10%)
  - Measurement parameters and limits are not finally defined (currently “draft”)

*Untwisted area „d“ measured from Connector/Inline-Connector housing to the first twist. Measured with a TDR pulse rise time of 17,5ps.
Measurement in Air versus Ground plane

- Measured Impedance-Variation in Air versus Ground plane*:
  - Cables without jacket up to 8Ω
  - Cables with jacket up to 2Ω

*Measured with a TDR pulse rise time of 17,5ps.

Conclusion:
- Impedance-Variation may occur depending on the assembly inside the vehicle
- Effect is significantly smaller for cables with jacket compared to cables without jacket
Measurement of Connector / Inline-Connector

- Measured Impedances of the connectors:
  - NanoMQS from ≈95Ω to 144Ω*
  - MQS from ≈85 Ω to 153Ω*
- Same effect measured at the Inline-Connectors

**Conclusion:**
- Significant influence to the Impedance has been noted, independent from the measured Connector / Inline-Connector
- Possible violation of the specified characteristic Impedance (typ. 100Ω±10%)
  - Measurement parameters and limits are not finally defined (currently “draft”)

*Measured with a TDR pulse rise time of 17,5ps.
Influence of different cables

- Impedances of the cables*:
  - Small variation of the cable Impedance from 100Ω, but within the cable specification
  - Small Impedance variation between the different cables: e.g. Leoni Dacar 609 ≈ 101Ω, Leoni Dacar 617 ≈105Ω, ...

Conclusion:
- Cables with jacket have a “quite soft” Impedance variation compared to cables without jacket
- Note: Environmental-, Temperature- and Mechanical-Influences are not considered here

*Measured with a TDR pulse rise time of 17,5ps.
Influence of water to the cables

- Impedance variation of the cables in water*
  - Leoni Dacar 609 without jacket: Measured Impedance change for the submerged segment up to ≈ 16Ω
  - Leoni Dacar 612 with jacket: Measured Impedance change for the submerged segment up to ≈ 5Ω

Conclusion:
- Significant changes in Impedance observed for submerged cable segments, in particular for cables without jacket
- For UTPs with jacket the impedance drop is visible, but “quite soft” compared to UTPs without jacket

*Measured with a TDR pulse rise time of 17.5ps. Max. Impedance change may not reached, because of less submerged segment (20cm)
Influence of Temperature to the cables

- Characteristic Impedance* and Insertion Loss variation of the cables for:
  
  - Leoni Dacar 609 (PVC) without jacket:
    - Impedance at 22°C ~99Ω
    - Impedance at 105°C ~65Ω
    - Insertion Loss (see picture)

  - Leoni Dacar 617 (XPE) without jacket:
    - Impedance at 22°C ~107Ω
    - Impedance at 105°C ~110Ω
    - Insertion Loss (see picture)

Conclusion:

- Significant Impedance changes observed for Leoni Dacar 609 (PVC)

- Insertion Loss outside the specified range for Leoni Dacar 609 (PVC)

*Measured with a TDR pulse rise time of 17.5ps.
Qualitative evaluation of “Link quality”

› Objectives & Goal:
  › Establish a link using BroadR-Reach® for general measurements related to the Signal quality
  › Investigation to the robustness of communication (e.g. at impedance change)

› Status:
  › Initial tests with the board done
    › Initiate Idle link
    › Send Dummy traffic
    › Read/Calculate Signal quality indicator (SQI)
    › Switch to different supported Test modes

› TBD:
  › Define proper criteria for signal integrity evaluation
  › Investigation on Board “Signal Integrity capabilities”
    › e.g. detailed knowledge about SQI Register
Conclusion & Outlook

Conclusion:
- Identified influences to the characteristic Impedance in order of dimension (max->min):
  - Untwisted cable end at Connectors/Inline-Connectors
  - Connectors/Inline-Connectors
  - Environmental influences (Water, Heat)
  - Cable routing inside vehicle/harness (Ground plane, Air,...)
  - Cable construction (jacket, w/o jacket)

Outlook:
- Additional measurements planned
- Further investigations to the qualitative evaluation of “Link quality”
- Investigation of the next generation Ethernet “Reduced Twisted Pair Gigabit Ethernet” (RTPGE) requirements related to the harness
  - Currently under development within the IEEE
Thanks!

Questions?

Contact:
Magnus Nigmann
Intedis GmbH & Co. KG
magnus.nigmann@intedis.com

Marco Preuß
LEONI Bordnetz-Systeme GmbH
marco.preuss@leoni.com