Concept of test points in in-vehicle optical physical layer standardization for multi-vendorization

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JASPAR Next Generation High-Speed Network WG
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Takumi Nomura, Honda
Hideki Goto, Toyota

JASPAR, General incorporated association
Established in September, 2004, led by five board companies.
Introduction : Next Generation High-Speed Network Working Group

Next Generation High-Speed Network Working Group

To define standard specification of high reliability technology of in-vehicle high-speed networks with an eye focused on control system applications, and to define vehicle requirements/problem extraction and solution method of Automotive SDN (Software Defined Networking), Automotive TSN, 10Gb/s class Ethernet and SerDes.
Introduction: 3 presentations from JASPAR

- Automotive SDN: Proposal of Dynamically Configurable In-Vehicle Network as an Enabler of Software Defined Vehicle
- Ethernet TSN: A study of Ethernet TSN profile based on JASPAR's automotive use cases
- Optical Physical Layer: Concept of test points in in-vehicle optical physical layer standardization for "multi-vendorization"

Team Composition of Next Gen. High-Speed Network WG

- Next Generation Technology Study Team
  - SDN Sub-Team
  - Functional Development Team
  - Functional Verification Team
  - Hardware Team
  - Next Gen. Physical Layer Sub-Team

All layers are covered

OSI REFERENCE MODEL LAYERS

- APPLICATION
- PRESENTATION
- SESSION
- TRANSPORT
- NETWORK
- DATA LINK
- PHYSICAL

WG is composed by 4 teams and 2 sub-teams
Contents

• JASPAR Next Generation Technology Study Team
• Background
• JASPAR Optical Physical Layer Scope
• VCSEL Test
• Test Point
• Third-party Certification
• Conclusions
Focus on Automotive Ethernet Multi-Gig (Electrical/Optical) and 10 Mb/s

IEEE P802.3cy (Electrical)
Greater than 10 Gbps
Electrical Automotive Ethernet (25 Gbps)

IEEE P802.3cz (Optical)
Multi-Gigabit Optical Automotive Ethernet (~50 Gbps)

IEEE P802.3dh (Optical)
Multi-Gigabit Automotive Ethernet over Plastic Optical Fiber (~25 Gbps)

IEEE P802.3da
(10BASE-T1M)
Background: Why Optics?

**OEMs Requirements**

1. EMC resistant
2. High-speed communication
3. Weight saving and low power consumption for CO2 reduction

**Feature of Optical component**

- Optical fiber is no emission noise and no affected noise
- Quick response and Broadband
- Light weight
- Low power consumption

(1) Use cases – Why optics?

(2) Market Drivers Optical multi-gig use cases

<table>
<thead>
<tr>
<th>Use Cases</th>
<th>2.5 Gbps</th>
<th>5 Gbps</th>
<th>10 Gbps</th>
<th>25 Gbps</th>
<th>50 Gbps</th>
<th>Unidirectional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backbone</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Smart Antenna</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Camera, Sensors</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Display</td>
<td>✔</td>
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<td>✔</td>
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<tr>
<td>Data Loggers</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

(3) Optical fiber vs Electrical wire

- Weight 4g/m Φ 2mm
- Attenuation 0.003 dB/m @ 850nm

- Weight 40g/m Φ 5.5mm
- Attenuation 2.2 dB/m @ 4GHz (IEEE Std 802.3ch™-2020, IL Fmax 4GHz)

Source: https://www.ieee802.org/3/cfi/0719_1/CFI_01_0719.pdf
JASPAR Optical Physical Layer Scope

**JasPar Scope**
- PHY to PHY
- 10 Gb/s

- **VCSEL tests** as light source candidates for IEEE P802.3cz and P802.3dh

- **Test points are required for component test and third-party certification**
  - JASPAR contributed to the standardization of ISO21111-4 as a component standard and test standard for gigabit optical Ethernet communication using POF
  - ISO21111-4 clarifies the test points for the purpose of component test and third-party certification

- **Third-party certification** is required
  - To develop and manufacture components that comply with standards
  - To ensure interoperability

<table>
<thead>
<tr>
<th>Media</th>
<th>Glass, Plastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>~ 40 m</td>
</tr>
<tr>
<td>Wavelength</td>
<td>850 nm ~ 980 nm</td>
</tr>
</tbody>
</table>
VCSEL Test : Objectives

- JASPAR believes that multivendor environments for components are essential for the spread of Automotive Optical Ethernet
- In OPEN Alliance TC7, the necessity of setting test points is discussed before and after FOT (Fiber optic transceiver)
- However, regarding the semiconductor laser light source (or VCSEL), which is the main component of FOT, two wavelengths have been discussed in IEEE P802.3cz and P802.3dh, but only one manufacturer has been reported for each wavelength (1),(2)
- This presentation finds a VCSEL that can be substituted for each wavelength and evaluates its communication performance

Ref.  
VCSEL Test : Two VCSELs Evaluation

<table>
<thead>
<tr>
<th>Chip vendor</th>
<th>VIS</th>
<th>Inneos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model number</td>
<td>V25-850C-HT</td>
<td>V980-10GXA-1TGA</td>
</tr>
<tr>
<td>wavelength</td>
<td>850 nm</td>
<td>980 nm</td>
</tr>
<tr>
<td>bandwidth</td>
<td>25 Gb/s</td>
<td>10 Gb/s</td>
</tr>
</tbody>
</table>

**Test items:**
- Static characteristics (I-V-L)
- Frequency response
- Relative intensity noise (RIN)
- Eye pattern improvement by applying DSP

**Evaluation module**

The VCSEL chip was implemented in the evaluation module reported by KDPOF in IEEE (1)

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VCSEL Test : I-V-L (static) Characteristic

VCSEL I-L property

VCSEL I-V property
VCSEL Test: Frequency Response and RIN OMA

**Frequency response**

- **850 nm-VCSEL/VIS**
  - Frequency response at different temperatures: -40°C, 0°C, 25°C, 85°C, 105°C.
  - Bias current: $I_{bias} = 4$ mA.

- **980 nm-VCSEL/Inneos**
  - Frequency response at different temperatures: 40°C, 0°C, 25°C, 85°C, 105°C.
  - Bias current: $I_{bias} = 4$ mA.

**RIN OMA**

- **850 nm-VCSEL/VIS**
  - RIN vs. ER at different temperatures: 40°C, 0°C, 25°C, 85°C, 105°C.

- **980 nm-VCSEL/Inneos**
  - RIN vs. ER at different temperatures: 40°C, 0°C, 25°C, 85°C, 105°C.

- **Chamber SH-642**
  - GI-MMF (OM3, 3 m, APC) to VCSEL.
  - OE converter N4377A to Network analyzer E5080B.
  - RF cable to Bias-T SMU B2902A.

- **Sampling oscilloscope N1092C**
  - Arbitrary Waveform Generator (AWG) M8196A.
  - Data rate: 10.625 Gb/s.
VCSEL Test: Eye Pattern Evaluation

**Bit rate**: 10.625 Gb/s

**Signal pattern**: PRBS2^{11-1}

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{bias}$</td>
<td>4 mA</td>
</tr>
<tr>
<td>ER</td>
<td>4 dB</td>
</tr>
<tr>
<td>EQ Tap #</td>
<td>4</td>
</tr>
</tbody>
</table>

**Temperature**

- 25 ºC
- 105 ºC
- -40 ºC
VCSEL Test: Summary

Tested two commercial VCSEL chips:
(1) I-V-L, (2) frequency response, (3) RIN OMA, (4) eye pattern evaluation (-40 ~ +105 ºC)

<table>
<thead>
<tr>
<th>VCSEL vender</th>
<th>Catalogue spec.</th>
<th>Actual operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>wavelength</td>
<td>rate</td>
</tr>
<tr>
<td>VIS</td>
<td>850 nm</td>
<td>10 Gb/s</td>
</tr>
<tr>
<td>Inneos</td>
<td>980 nm</td>
<td>10 Gb/s</td>
</tr>
</tbody>
</table>

Future work:
- Evaluate the actual system performance
- Optimize the launching optical condition, VCSEL bias current and optical waveform DSPs, etc.

Confirmed VCSELs are applicable to in-vehicle applications
As defined in ISO and IEEE, Test Points (TPs) are required for component evaluation and third-party certification.
Test Point : Use Case Study

Use cases considered for in-vehicle Ethernet under OPEN Alliance

1) Smart Header and Plug (Integrated PMD/PCS and Driver/TIA)

2) Smart Header and Plug (Separated PMD/PCS and Driver/TIA)

3) Active Optical Component (AOC) (Integrated PMD/PCS and Driver/TIA)

4) Active Optical Component (AOC) (Separated PMD/PCS and Driver/TIA)

Set test points corresponding to various use cases
Test Point: Proposal

The definition of TPs are necessary for a uniform evaluation.

FOT: Fiber Optic Transceiver
Test point: Define I/F requirements
→ Input / output condition of the component
→ The performance and quality of the component can be confirmed

If each part satisfies the TP requirements, the communication establishment of the entire system can be confirmed.
Enable to ensure the establishment of overall communication even when parts from different suppliers are connected.
Optical Ethernet

Time domain analysis (High-speed optical waveform evaluation system)
- ~ 100 Gb/s (50 Gbaud-PAM4), @-50 ~ +150 °C
- TDECQ / TDFOM evaluation

Frequency domain analysis
- 100 k ~ 44 GHz network analyzer (4ch)

Space (or optical) domain analysis
- NFP/FFP evaluation system
- Optical spectrum analyzer, wavelength: 0.6 ~ 1.7 μm
Electrical Ethernet & EMC

**Compliance & Level evaluation**
- 100BASE-T1, 1000BASE-T1 (Tx, Rx, Lx)
- 10BASE-T1S (Tx)
- MultiGigBASE-T1 (2.5 GTx, Lx), other: 2023~

**Frequency domain analysis**
- DC ~ 40 GHz network analyzer (4ch)

**EMC**
- Emission / DPI / BCI&TWC / ESD
- Transmission Line Pulse (TLP) 2023~
Mission & Scope:
Contribution to society regarding higher reliability of mobility communications, especially for automobiles
• Basic research (light propagation, QoS, EMC, …)
• Standards (ISO, IEC, IEEE)
• Test House (L1 (Opt/Elec), L2, EMC)

History & Plan:
Jan. 2021 Established CffC at NITech
Mar. 2023 Scheduled to open test house

http://cfcr.web.nitech.ac.jp/english/index_en.html
Conclusions

✓ Optical components are
  - highly EMC resistant
  - able to communicate at high speeds
  - able to reduce CO₂

✓ VCSEL has a good performance from -40 ~ +105 ºC temperature environment

✓ Confirmed VCSELs are applicable to in-vehicle applications

✓ Test point definition is mandatory for the component test to be guaranteed whole network system

✓ Establishing test house at Nagoya Institute of Technology (NITech) in Japan

Preparing to install optical communication system at any time!
Thank you for your kind listening.