Baseline Proposal for In-band training functions for 200 Gb/s per lane
Electrical Interfaces

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Introduction

• Link Training (LT) continues to be a key tool to maximize electrical SERDES performance
• LT in use since 10G/lane rates for backplane and copper cables
  • LT on AUI C2C starting at 50G/lane
• Many contributions on electrical link training, including but not limited to:
  • lusted_3dj_02a_2303
  • ghiasi_3dj_01_230116
  • mehta_3dj_elec_01a_230831
  • ran_3dj_elec_01a_240104
  • Straw Poll from 4 January 2024 Electrical ad hoc showed support
• We are not discussing the “optical link training” topic
Agenda

• Brief description of the PMD control function defined in clause 136 (with additional updates in clause 162)
• Lay out the benefit of in-band training on electrical interfaces
• Propose adopting the Cl 162 PMD control function as the basis of the baseline for backplane and copper cable PMDs
  • All the pieces are there. Update as needed in D1.x
• Propose defining an in-band PMA training function as the basis of the baseline for electrical interfaces at 200 Gb/s per lane
Benefits of in-band training

• Enables optimization of joint performance of the transmitter, receiver, and channel.

• Allows a wide range of receiver implementations.

• Provides well-defined startup process and conditions for detection of a valid signal.

• Enables decentralized optimization of SerDes without requiring pervasive management
  • Providing shorter power-up time.
  • Simplifying software development and system integration.

• An established method is available (clause 136 PMD control)
  • The training frame structure (Figure 136-3) can be re-used.
The PMD control function is currently specified for use with most of the backplane and passive copper cable PHYs (e.g., 50GBASE-CR, 800GBASE-KR8, etc.)

- P802.3dj should follow the same approach for these types of PHYs

- Some AUI C2C (e.g. Annex 120D, Annex 120F, etc.) provide a method to configure by management a transmit equalizer using a set of control and status variables based on the PMD Control Function
  - No training frames are used
  - P802.3dj could follow the same approach for these types of electrical interfaces

- Not used (to date) in IEEE on AUI C2M interfaces
Elements of the Cl 136 PMD Control Function

• Exchange training frames consisting of
  • Marker, used for alignment
  • Message portion – control and status field, using Differential Manchester Encoding (DME)
  • Training pattern
• Asynchronous request/acknowledge messaging
• “Link-up” process defined by state diagrams
Control and status fields (Clause 162, 802.3ck)

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<tr>
<th>Bit(s)</th>
<th>Name</th>
<th>Description</th>
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<tbody>
<tr>
<td>15:14</td>
<td>Reserved</td>
<td>Transmit as 0, ignore on receipt</td>
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</table>
| 12:11  | Initial condition request | 13 12 11  
1 0 1 = Reserved  
0 1 1 = Preset 5  
0 0 1 = Preset 4  
1 1 0 = Preset 3  
1 0 0 = Preset 2  
0 1 0 = Preset 1  
0 0 0 = Individual coefficient control |
| 10     | Reserved | Transmit as 0, ignore on receipt |
| 9:8    | Modulation and preceding request | 9 8  
1 1 = PAM4 with preceding  
1 0 = PAM4  
0 1 = Reserved  
0 0 = PAM2 |
| 7:5    | Reserved | Transmit as 0, ignore on receipt |
| 4:2    | Coefficient select | 4 3 2  
1 0 0 = Reserved  
1 0 1 = e(-3)  
1 1 0 = e(-2)  
1 1 1 = e(-1)  
0 0 0 = e(0)  
0 0 1 = e(1)  
0 1 1 = Reserved |
| 1:0    | Coefficient request | 1 0  
1 1 = No equalization  
1 0 = Decrease  
0 1 = Increase  
0 0 = Held |

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| 15     | Receiver ready | 1 = Training is complete and the receiver is ready for data  
0 = Request for training to continue |
| 14:12  | Reserved | Transmit as 0, ignore on receipt |
| 11:10  | Modulation and preceding status | 11 10  
1 1 = PAM4 with preceding  
1 0 = PAM4  
0 1 = Reserved  
0 0 = PAM2 |
| 9      | Receiver frame lock | 1 = Frame boundaries identified  
0 = Frame boundaries not identified |
| 8      | Initial condition status | 1 = Upward  
0 = Not updated |
| 7      | Parity | Even parity bit |
| 6      | Reserved | Transmit as 0, ignore on receipt |
| 5:3    | Coefficient select echo | 5 4 3  
1 0 1 = e(-3)  
1 1 0 = e(-2)  
1 1 1 = e(-1)  
0 0 0 = e(0)  
0 0 1 = e(1) |
| 2:0    | Coefficient status | 2 1 0  
1 1 1 = Coefficient at limit and equalization limit  
1 1 0 = Coefficient at limit  
1 0 1 = Reserved  
1 0 0 = Equalization limit  
0 1 1 = Coefficient not supported  
0 1 0 = Coefficient at limit  
0 0 1 = Upward  
0 0 0 = Not updated |
Clause 136 state diagrams
For Backplane and Copper Cable PMDs

- IEEE Std. 802.3ck-2022, Cl 162.8.11 can be used as the training baseline for 200G/lane Backplane and Copper Cable PMDs
  - Some changes will likely be required, e.g. max_wait_timer value
  - But this is a good starting point.

162.8.11 PMD control function

The PMD control function performs the PMD start-up protocol. This protocol facilitates timing recovery and equalization while providing a mechanism through which the receiver can configure the transmitter to optimize performance. The protocol supports these functions through the continuous exchange of fixed-length training frames.

The PMD shall implement one instance of the PMD control function described in 136.8.11 for each lane with the following exceptions:

a) The control field structure is specified in Table 162–9 and the status field structure is specified in Table 162–10.

b) For k_list as specified in 136.8.11.4.4, the set of valid transmitter equalizer coefficient indices is \{-3, -2, -1, 0, +1\}.

c) For the initial condition request as described in 136.8.11.2.1, five predefined transmitter equalizer settings are specified in 162.9.4.1.3.

d) The “No equalization” value (see 136.8.11.2.4) of \(c(-3)\) is 0.

e) The terminal count of max_wait_timer as specified in 136.8.11.7.3 is 12 s.

f) A receiver is expected to assert local_tq_lock within 275 ms from entry into the AN_GOOD_CHECK state in Figure 73–11 provided that there is a compliant signal containing valid training frames at the PMD input.

g) The value of use_quiet_in_training (see 136.8.11.7.1) is TRUE.
For AUI C2M and C2C – PMA Training

- Ethernet links defined in this project typically consist of multiple segments
  - Optical links: optical (PMD to PMD) and electrical (AUI) segments
  - Electrical links can also be segmented with AUI-C2C

- Optimization of the electrical output signal on each of these segments has proven to be beneficial even at existing rates
  - IEEE Std. 802.3ck-2022 introduced “AUI-S” and “AUI-L”
  - OIF is adding CMIS Support for Host-Module Link Training on 112G links

- AUI C2M, in particular, are much more challenging that in the past
  - 3bs: Annex 120E ~13 dB (die-to-die)
  - 3ck: Annex 120G ~22 dB (die-to-die)
  - 3dj: discussing the range of 30-36 dB (die-to-die)

- We should consider in-band PMA training
  - Or “PMA output control function”
Reuse for PMA output control function

• The PMD control function has a great architecture for the PMA output control function

• Establishes:
  • Commonality across electrical PMDs and electrical interfaces
  • Reusable building blocks within implementations, which increases interoperability

• All PMAs with physically instantiated interfaces (AUIs) at 200 Gb/s per lane (within type 1/2 PHYs and extenders) should use the same definitions.

• Propose to adopt the Cl 136-3 Training Frame structure as the basis of the PMA output control function
  • Control Field and Status Field bit definitions may need modifications.
Necessary updates for in-band PMA training (training over AUIs)

• Operation across multiple segments
  • The PMD training function does not address segmented links

• Consideration of different segment types
  • AUIs in the link may be of different speeds, with/without support for in-band training
  • Unknown number of AUIs on each side of the link
  • Optical segments may or may not have a training function

• Considerations of out-of-band management, e.g., CMIS
  • Detection of module type, control of PMD output, etc.
  • Observability, debugging

• Effects on electrical specification methodology

• All these are future work items that should be addressed during the project.
  • There may be others, based on contributions.
Summary

• Reviewed existing PMD control function
• In-band PMA training has a lot of potential benefits
  • There is a good starting point (PMD control function)
  • Some changes may be required for PMAs, e.g. message content and state diagrams
• Recommend to adopt link training based on IEEE Std. 802.3ck-2022, Cl 162.8.11 as the baseline for 200G/lane Backplane and Copper Cable PMDs
• Recommend to adopt in-band training based on the clause 136 training frame structure (Figure 136-3) for all AUI segments with electrical interfaces at 200 Gb/s per lane.

Straw Poll results from 4 January 2024 Electrical ad hoc:

Straw Poll #1

I would support adopting link training based on IEEE Std. 802.3ck-2022, Cl 162.8.11 as the baseline for 200G/lane Backplane and Copper Cable PMDs

Results (all): Y: 34, N: 1, A: 15

Straw Poll #2

I would support adopting in-band training based on the clause 136 training frame structure (Figure 136-3) for all AUI segments with electrical interfaces at 200 Gb/s per lane.

Results (all): Y: 36, N: 2, A: 15