

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:
 - https://www.ieee802.org/3/dj/public/23_03/lusted_3dj_02a_2303.pdf
 - https://www.ieee802.org/3/dj/public/23_01/23_0116/ghiasi_3dj_01_230116.pdf
 - https://www.ieee802.org/3/dj/public/adhoc/electrical/23_0831/mehta_3dj_elec_01a_230831.pdf
- Not discussing “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 CI 162 PMD control function as 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 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.

PMD Control Function Usage

- 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 CI 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

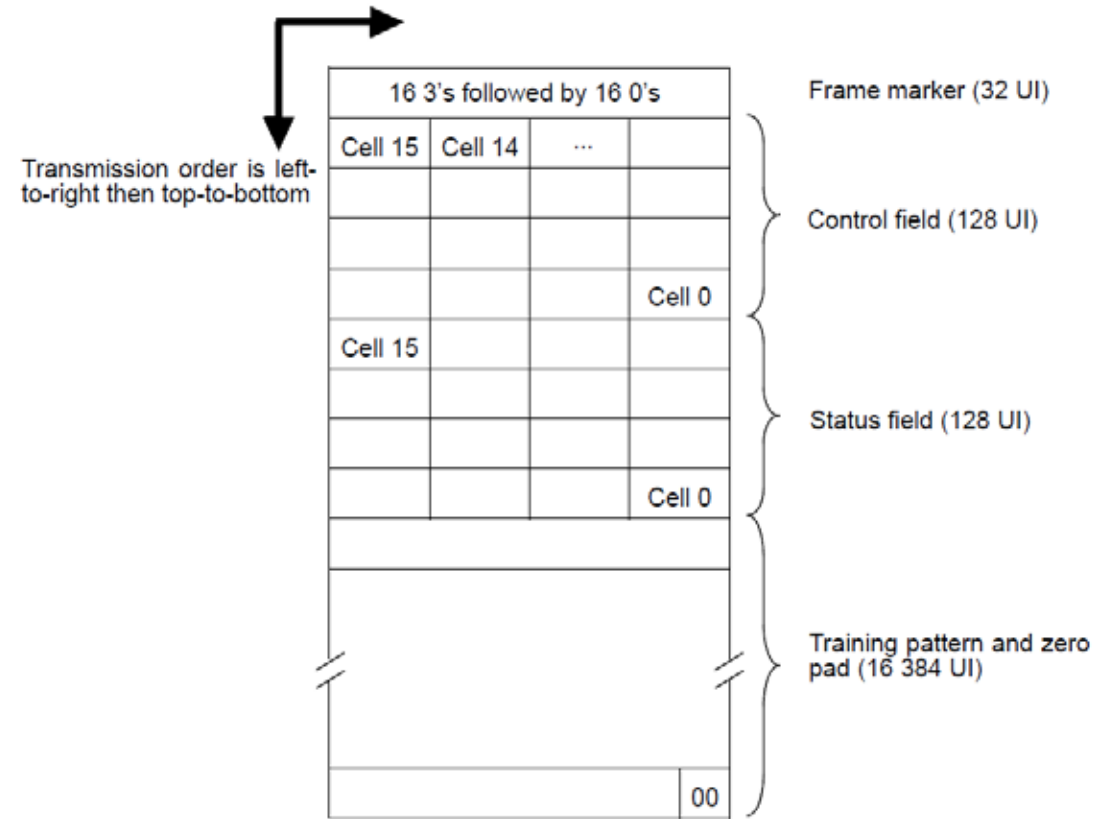


Figure 136-3—Training frame structure

Control and status fields (Clause 162, 802.3ck)

Table 162-9—Control field structure

| Bit(s) | Name | Description |
|--------|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15:14 | Reserved | Transmit as 0, ignore on receipt |
| 13:11 | Initial condition request | 13 12 11 1 1 1 = Reserved 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 precoding request | 9 8 1 1 = PAM4 with precoding 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 = $c(-3)$ 1 1 0 = $c(-2)$ 1 1 1 = $c(-1)$ 0 0 0 = $c(0)$ 0 0 1 = $c(1)$ 0 1 x = Reserved |
| 1:0 | Coefficient request | 1 0 1 1 = No equalization 1 0 = Decrement 0 1 = Increment 0 0 = Hold |

Table 162-10—Status field structure

| Bit(s) | Name | Description |
|--------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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 precoding status | 11 10 1 1 = PAM4 with precoding 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 = Updated 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 = $c(-3)$ 1 1 0 = $c(-2)$ 1 1 1 = $c(-1)$ 0 0 0 = $c(0)$ 0 0 1 = $c(1)$ |
| 2:0 | Coefficient status | 2 1 0 1 1 1 = Reserved 1 1 0 = Coefficient at limit and equalization 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 = Updated 0 0 0 = Not updated |

Clause 136 state diagrams

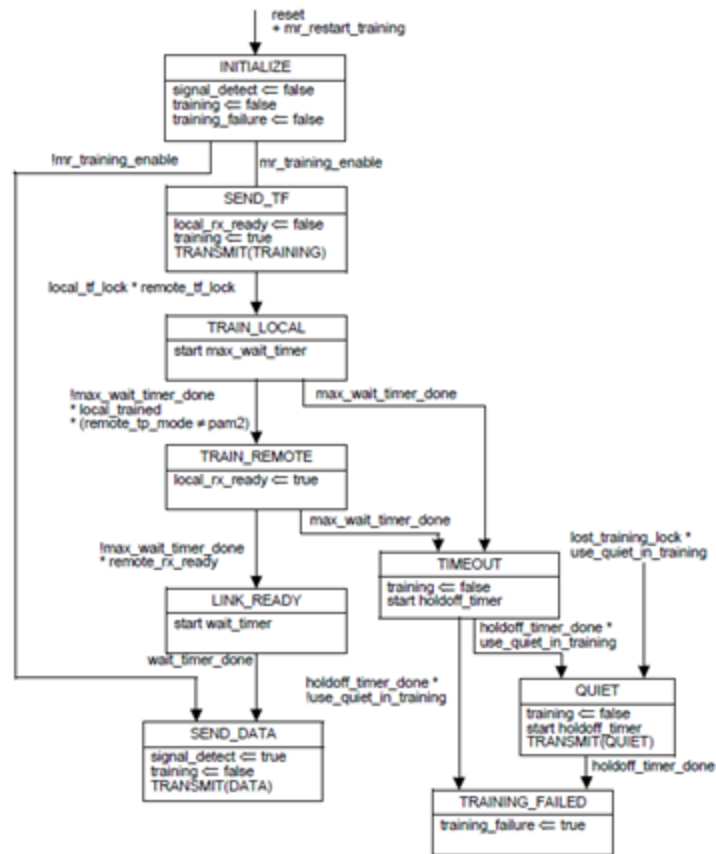


Figure 136-7—PMD control state diagram

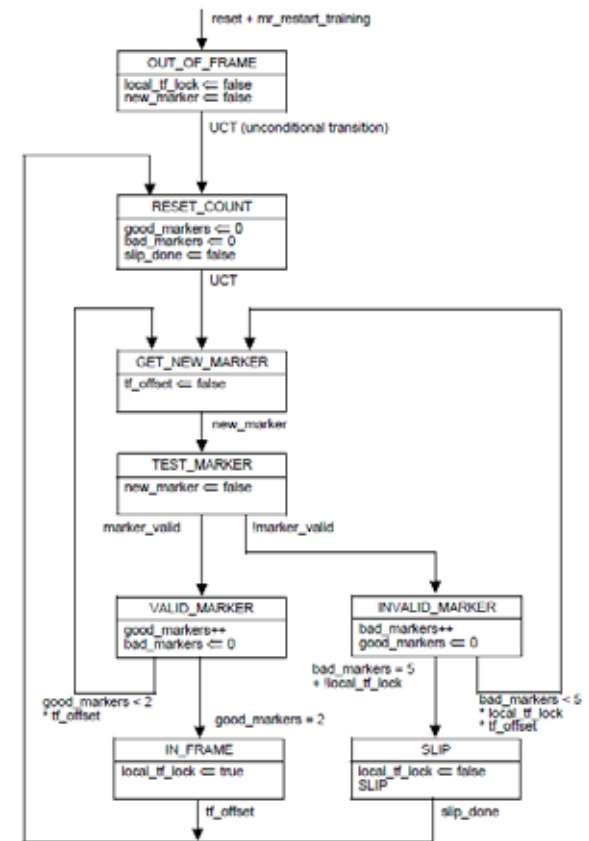


Figure 136-8—Training frame lock state diagram

For Backplane and Copper Cable PMDs

- IEEE Std. 802.3ck-2022, CI 162.8.11 can be used as the “link 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_tf_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 than in the past
 - 3bs: Annex 120E ~13 dB (die-to-die)
 - 3ck: Annex 120G ~22dB (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 AUIs with physically instantiated 200 Gb/s per lane interfaces (within type 1/2 PHYs and extenders) should use the same definitions.
- Propose to adopt the CI 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, CI 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 PMAs with electrical interfaces at 200 Gb/s per lane.**