Link and connector requirements for 10 Gb/s interconnects

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IEEE 802.3ap provide backplane link performance guideline to meet 10G Ethernet compliant signal channels

Review of the guideline

Informative component level design rules
- Can a connector component specification be derived to ensure IEEE 802.3ap compliancy?

How confident can designers be following the guideline?
- An in-depth assessment is made based on BER link simulations

Summary & conclusions
Review of Annex 69B of the IEEE 802.3ap guideline
Supply informative recommendations to assist backplane designers in identifying backplane channels that are interoperable with “Backplane Ethernet compliant” devices

Backplane channel specification

- if you pass, you are quite sure (have a high confidence) that you don’t have to bother your channel performance any more
  - Arbitrary length
  - Independent of board material
  - Don’t mind individual component performance
    - Doesn’t matter if more budget is given to backpanel, component boards or connector as long as complete picture is OK
    - How to define connector compliance?
Model assumptions

- 100 ohm environment
- Up to 1m of differential traces
- Improved FR4
- 2 connectors
- AC coupling capacitors not part of the interconnect model
- BER = 10e-12
- 3 traps transmitter equalization (1 pre, 1 post cursor)
- No receive equalization defined

Requirements developed under the assumption of a 5-tap DFE

Receiver must exhibit an expected level of performance as established via the interference tolerance test

Examines the ability of the receiver to equalize a high-loss channel in presence of interference (jitter and noise)
5 frequency domain performance parameters defined
- Maximum fitted attenuation (A)
- Maximum insertion loss (IL)
- Maximum deviation of insertion loss from the best-fit attenuation (ILD)
- The minimum return loss (RL)
- Limit on crosstalk in relation to insertion loss (ICR)

3 Speeds
- Focus on 10GBASE-KR (10 Gb/s serial)
IEEE 802.3ap - Annex 69B – Performance Parameters

**Insertion loss**

**Fitted attenuation**

**Insertion loss deviation**

ILD = IL – A
IEEE 802.3ap - Annex 69B – Performance Parameters

- **Insertion loss**
- **Fitted attenuation**
- **Insertion loss deviation**

**Return loss**

**Insertion loss to crosstalk ratio**
Informative component level design rules
Informative component level design rules

- Insertion loss and Attenuation
  - Backpanel and Component Boards:
- Return loss, Insertion loss deviation and ICR
  - Connector and connector footprint
Insertion loss and Attenuation

Backpanel and component board performance determined by
- Length
- Trace width, trace to trace isolation
- Board material, board build-up
- ...

1m improved FR4

Improved FR4 vs Std FR4
Insertion loss deviation ILD – Return loss RL

CB - Component board: lossy TL
- Z = 100 ohm,
- Length = 12.5 cm
- Improved FR4

BP - Backpanel: lossy TL
- Z = 100 ohm,
- Length = 75 cm
- Improved FR4

CON - Connector: lossy TL
- Z = 100 ohm
- Delay = 150 ps

VIA - Via holes: lossy TL
- Z = 50 ohm, …, 100 ohm
- Delay = 50 ps
Insertion loss deviation ILD – Return loss RL

Insertion loss deviation

Return loss
Insertion loss deviation ILD – Return loss RL

Backpanel length = 75 cm

Insertion loss deviation

Return loss

Backpanel length = 25 cm
Insertion loss to crosstalk ratio - ICR

CB - Component board: TL
- Z = 100 ohm
- Length = 12.5 cm
- Improved FR4

BP - Backpanel: TL
- Z = 100 ohm
- Length = 25, 75 cm
- Improved FR4

Connector and footprint: coupled TLs
- Z = 100 ohm
- Next crosstalk levels = 25 dB, 30 dB, 35 dB, 40 dB, 45 dB
**Insertion loss to crosstalk ratio - ICR**

- **CB - Component board: TL**
  - $Z = 100 \text{ ohm}$
  - Length = 12.5 cm
  - Improved FR4

- **BP - Backpanel: TL**
  - $Z = 100 \text{ ohm}$
  - Length = 25, 75 cm
  - Improved FR4

**Connector and footprint: coupled TLs**
- $Z = 100 \text{ ohm}$
- Next crosstalk levels = 25 dB, 30 dB, 35 dB, 40 dB, 45 dB
- Coupling length = 71 ps, 100ps, 167 ps
- Nr of crosstalk channels
- Tx, Rx pin assignment
Insertion loss to crosstalk ratio - ICR

Nr Next channels = 1, Nr Fext channels = 1

Backpanel length = 25 cm

Coupling length = 167 ps

Coupling length = 100 ps

Coupling length = 71 ps

Backpanel length = 75 cm

Coupling length = 167 ps

Coupling length = 100 ps

Coupling length = 71 ps
IEEE 802.3ap informative reference

Backpanel length = 75 cm
Coupling length = 71 ps

0 Next, 2 Fext channels

2 Next, 0 Fext channels

2 Next, 2 Fext channels

4 Next, 4 Fext channels
Summary design rules

- **IL, Attenuation**
  - PCB + CB’s: performance better than 1m Improved FR4

- **ILD, RL**
  - Via hole impedance > 70 ohm

- **ICR**
  - Maximum allowed crosstalk level determined by
    - Crosstalk duration (coupling length),
    - Nr of channels
    - Tx and Rx pin assignment
  - A connector and associated footprint that works for one application will not necessarily work for another application
  - Not possible to put a single crosstalk number
IEEE 802.3ap - channels meeting/not meeting informative reference and BER link performance: is there a match?
Example: Metral 4000 backpanel link

Backpanel link
- 8 cm
- Standard FR4
- 2 Metral 4000 connectors
- designed for 3.125 Gb/s
- 5 crosstalk aggressors (2 Fext, 3 Next)

BER testing: AMCC QEB2025 Evaluation Board
Example: Metral 4000 backpanel link
Example: Metral 4000 backpanel link

BER testing during 24 hours - 8.6400e+014 bits (including 2 fext and 1 next crosstalk channel)

No errors detected
To have a better feeling about the IEEE informative reference, a number of link simulations have been performed. Links with varying IL, large small ripple, much crosstalk, no crosstalk, high impedance mismatch, low mismatch.
For each of the links

- performance is compared to the IEEE 802.3ap informative reference
- BER simulations performed
  - No Jitter, No noise
  - 3 taps adaptive transmit equalization (1 pre-, 1 post-cursor)
  - 5 taps DFE
- Performance figure: width BTC for BER = 10e-12
Backpanel length = 25 cm

Total link length = 50 cm
Links that pass IEEE with BTC<0.6

Backpanel length = 25 cm
Total link length = 50 cm
Examples links that fail IEEE with BTC>0.6

Backpanel length = 25 cm
Total link length = 50 cm
Backpanel length = 75 cm
Total link length = 1 m
Links that pass IEEE with BTC<0.6

Backpanel length = 75 cm
Total link length = 1 m
Examples links that fail IEEE with BTC>0.6

Backpanel length = 75 cm
Total link length = 1 m
Conclusions

- Links that pass IEEE and have bad BER
  - Links with high crosstalk resonance in ICR
  - Further analysis required

- Links that have good BER and fail IEEE
  - Links with no/low crosstalk and fail ILD/RL
  - Links with low ILD/RL and fail ICR
Why fitted crosstalk?

Backpanel length = 25 cm
Total link length = 50 cm

Fitted crosstalk requirement replaced by actual crosstalk requirement

Links that pass fitted crosstalk requirement

Links that pass actual crosstalk requirement

Links that Fail actual crosstalk requirement, but pass fitted requirement
IEEE 802.3 ap – 5 Informative channel requirements for 10 Gb/s data transmission

Informative component level design rules have been derived
IEEE very good indication if a link will operate at 10 Gb/s

But
If your system has nearly no crosstalk
  More ripple allowed and mismatch than defined by IEEE
System is well impedance matched, small ripple
  More crosstalk allowed than what is advised by IEEE
System with high crosstalk resonance may pass IEEE but still have a limited BER

For final System verification BER simulations with actual driver and receiver are recommended
QUESTIONS?