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Initial Analysis of DFE Error Bursts on Primitive Sequences

Considerations for SAS 2.0

Steve Gorshe

www.pmc-sierra.com

Introduction

- Contribution 05-263 examined the potential error bursts that can result from a DFE receiver.
  - Focused on the 5-tap reference receiver from the OIF CEI for 5/6 Gbit/s
  - Error bursts will be 7 bits or less. (Specifically, the probability of a bit error 8 or more bits past in the initial error is no greater than the probability of a channel error in that bit.)
    - Note: Even in a 7-bit burst, the probability is much smaller that all 7 bits will contain errors.
- This contribution examines the impact of this error multiplication on the SAS primitive sequences.

OIF analysis for a 5-tap DFE (10^{-12} BER)

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Burst	P = Prob Error	Gain in Prob due to DFE	Error rate due to DFE	
1	1	0	0	<- Error injection site
2	0.018559815	1.85068E+10	0.018559815	
3	1.92979E-12	1.924277649	9.26925E-13	
4	1.00286E-12	1	0	
5	1.15258E-10	114.9285952	1.14255E-10	
6	8.90643E-09	8.88099E+03	8.90542E-09	
7	1.20615E-12	1.202701207	2.03282E-13	
8	1.00286E-12	1	0	
9	1.00286E-12	1	0	
10	1.00286E-12	1	0	
11	1.00286E-12	1	0	

- Searched all tap configurations (tap weights from OIF, see Appendix of 05-263). Longest burst when we have taps at positions 1, 4 and 5, none at 2 and 3.
- DFE has measurable effect on Prob(error) only at burst length <= 7.
- Spreadsheet here data-mined from OIF2003.267.02 by Winston Mok of PMC-Sierra for RapidIO

Impact on SAS Primitive Sequences

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- Per Annex J, the Hamming distance between SAS primitives (in the 10B domain – 40-bit dword) is at least 8.
  - Hence, a DFE-induced error burst won’t cause aliasing problems.
- The other consideration is redundant primitive sequences

Impact on SAS Redundant Primitive Sequences

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- The redundant SAS primitive sequences are sent 6 times with receiver needing to receive three consecutive good ones.
  - BREAK, BROADCAST, and HARD_RESET
- A DFE-induced error burst will either corrupt one or two consecutive primitives.
  - If only a single primitive is corrupted, there's no problem.
  - If 2 primitives are corrupted, it's only a problem if it's the middle two (leading to a sequence of 2 good / 2 bad / 2 good).

Impact on HARD_RESET

- HARD_RESET is only sent after speed negotiation, in place of an IDENTIFY address frame. Losing a HARD_RESET results in the intended recipient going back to OOB in 1 ms because an IDENTIFY address frame never shows up). The sender of HARD_RESET won't know it was not received, however, so will go ahead and send an IDENTIFY address frame the next time through.

- Conclusion: This may require the HARD_RESET to be sent twice to insure that it was received.

- Note: Thanks to Rob Elliot for his help with this initial analysis

Impact on BREAK

- Losing a BREAK could result in going back to OOB (which gets both phys in sync), or one or both phys just assume the physical link is idle again. They might reach this conclusion at different times, creating some race conditions.

- Conclusion: Needs more study

Impact on BROADCAST

- Losing a BROADCAST could result in missing a topology CHANGE notice or an enclosure services notification (e.g. over-temperature). Since they are not guaranteed delivery, software is supposed to routinely poll as a backup. So DFE would just increase the need for polling.

- Conclusion: BROADCAST messages reception isn't guaranteed. It's a problem as long as the polling is being performed

Conclusions

- Initial analysis indicates that the error bursts probably won't cause serious issues.
  - Some modification may be required (e.g., requiring that HARD_RESET be sent twice).
  - More study is need on the scenarios involving BREAK

Appendix – OIF Tap Weight Limits

(See "Reference Receiver", OIF-CEI-02.0, p.131)

- 1. Rx equalization: 5 tap DFE, with infinite precision accuracy and having the following restriction on the coefficient values:
- Let W[N] be sum of DFE tap coefficient weights from taps N through M where
  - N = 1 is previous decision (i.e. first tap)
  - M = oldest decision (i.e. last tap)
  - R_Y2 = T_Y2 = 400mV
  - Y = min(R_X1, (R_Y2 - R_Y1) / R_Y2) = 0.30
  - Z = 2/3 = 0.66667
- Then $W[N] \le Y * Z^{(N-1)}$
- For the channel compliance model the number of DFE taps (M) = 5. This gives the following maximum coefficient weights for the taps:
  - W[1] ≤ 0.2625 (sum of taps 1 to 5)
  - W[2] ≤ 0.1750 (sum of taps 2 to 5)
  - W[3] ≤ 0.1167 (sum of taps 3 to 5)
  - W[4] ≤ 0.0778 (sum of taps 4 and 5)
  - W[5] ≤ 0.0519 (tap 5)
  - Notes:
    - These coefficient weights are absolute assuming a T_Vdiff of 1Vppd
    - For a real receiver the restrictions on tap coefficients would apply for the actual number of DFE taps implemented (M)

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