MODULE OUTPUT/HOST INPUT CHARACTERISTICS AT TP4/TP4A – STATUS SUMMARY AND PROPOSAL

Adee Ran, Intel

Comments, presentations, focus group

- Comments related to module output / host input
  - 11060
  - 107, 108, 109, 115, 116, 130, 135
  - 175,176, 177, 178, 228
  - 191, 192, 193, 194, 196, 197, 211, 212
  - 215
  - 238
- Addressed by presentations
  - ran_3ck_adhoc_01_052720 Transmitter control for module output in the AUI-C2M interfaces
  - hidaka_3ck_01_0720 C2M Module Output Spec at TP4
  - ghiasi_3ck_02_0720 C2M Methodology, CTLE Gain, and DFE Taps
- Intensive discussions over email with several individuals
  - Yasuo Hidaka, Ali Ghiasi, Jeffery Maki, Phil Sun, Adam Healey, Piers Dawe, Rob Stone, Eric Baden, Pirooz Tooyserkani, Jane Lim

Status

- There is consensus on some high-level concepts
- **No clear consensus on a few key questions**
- Comments suggest several different remedies based on different assumptions
- Looking for task force guidance to choose a direction

Summary of proposals

Comment group		**11060**	**107, 108, 109, 115, 116, 130, 135**	**175,176, 177, 178**	**191, 192, 193, 194, 196, 197, 211, 212**	**215**	**238**
Max VEC	NE	N/A	7.5 dB	9 dB	7.5 dB	N/A	N/A
	FE	N/A	7 dB	9 dB	7.5 dB	N/A	N/A
Min EH	NE	N/A	50 mV	15 mV	40 mV	N/A	N/A
	FE	N/A	24 mV	15 mV	20 mV	N/A	N/A
Host stressed input		N/A	Calibrate @FE, VEC 7-7.5 dB	Choose either FE or NE calibration; pass one	Calibrate FE EH & VEC to values above	N/A	N/A
Module equalization		**Multiple settings**	**Multiple settings (results of COM search)**	**Two settings, NE and FE Control interface**	**One setting**	**One setting**	**One setting or two settings**
Other details			Updated proposal: With two settings: as above With one setting (optimized for FE): • NE: 8 dB / 45 mV • FE: 7 dB / 24 mV	Limit Vdiff PtP ≤ 400 mV (instead of 900 mV)	Higher η_0 in host Rx	Channel equalization provided by an adaptive equalizer in the host	

Consensus in discussion

- C2M should be plug-and-play / zero-touch
- Any expected behavior of the module should be fully specified within the standard and testable
- Host input characteristics should be based on (match limits of) module output characteristics

Ideas raised in discussion beyond the comments

(possible paths forward, but without clear consensus)

- Some SERDES developed for modules may be more capable than C2M assumes (“superset”, e.g. CR PMDs) but are restricted to run in VSR mode when used in the C2M application
  - Using link training to configure equalization, when available on both sides, can help getting to “zero-touch”
- If hosts are designed to be AUI C2M compliant then there should be no need for “appropriate settings” of the module. The assumption that the host’s receiver is more capable than the module’s should be understood when reading the standard.
- Module output swing specification in 120E.3.2 enables an extremely wide range of host input signals. Unknown signal conditions burdens receiver design, makes stress definitions ambiguous, and can lead to integration issues (see backup)
  - Changing “Differential peak-to-peak output voltage (max)“ in Table 120G–3 from 900 mV to ~500 mV (and corresponding tolerance in Table 120G–4) can improve receiver performance and system integration

Points of contention from email discussion

1. Is the host's reference receiver equivalent to the module's reference receiver?
   - Host Rx input is subject to the wide range of possible host channels; Module Rx input is less so
   - In 120E.3.1.7, the "reference Rx" is the same for host/module, but host input has higher stress (lower EH, EW) than input module – implies better host Rx (in addition to variable channels)
   - In 120G there are many TBDs; we could follow precedence and use different stress, or define equivalent stressed eye but different reference Rx parameters ($g_{DC}, g_{DC2}, N_b, B_{max}, \eta_0$)
   - Probably acceptable if we assume host is a universal port (CR capable)
2. Should the host Rx deal with the range of host channels without help from module Tx?
   - If not – need more than one setting – seen as burden to system integrator
   - If it should – it has to be stronger than the module's Rx (module gets help from host)
3. Should the module's output swing limits be reduced to make the signal more like the output of a cable assembly?

New

These are fundamental questions; We need to assess the preference of the TF

Summary of proposals

New

Comment group		11060	107, 108, 109, 115, 116, 130, 135	175,176, 177, 178	191, 192, 193, 194, 196, 197, 211, 212	215	238
Max VEC	NE	N/A	7.5 dB	9 dB	7.5 dB 7.5 dB (achievable)	N/A	N/A
	FE	N/A	7 dB	9 dB	7.5 dB 7.5 dB (achievable)	N/A	N/A
Min EH	NE	N/A	50 mV	15 mV	40 mV 24 mV (host can work)	N/A	N/A
	FE	N/A	24 mV	15 mV	20 mV	N/A	N/A
Host stressed input		N/A	Calibrate @FE, VEC 7-7.5 dB	Choose either FE or NE calibration; pass one	Calibrate FE EH & VEC to values above	N/A	N/A
Module equalization		**Multiple settings**	**Multiple settings (results of COM search)**	**Two settings, NE and FE Control interface** Two settings	**One setting**	**One setting**	**One setting or two settings**
Other details			Updated proposal: With two settings: as above With one setting (optimized for FE): • NE: 8 dB / 45 mV • FE: 7 dB / 24 mV	Limit Vdiff PtP ≤ 400 mV (instead of 900 mV) 600 mV (compromise)	Higher η_0 in host Rx	Channel equalization provided by an adaptive equalizer in the host	

Proposal

New

(based on collection of suggested remedies, and offline discussion; may require subsequent work to verify feasibility and maybe modify some values)

Use the table below for resolving comments: 11060, 107, 108, 109, 115, 116, 135, 175, 176, 177, 178, 191, 192, 193, 194, 196, 197, 211, 212, 215, 238.

	Near-end, “S” setting	**Far-end, “L” setting**	**Details**
Measurement point	TP4 NE	TP4 FE (after loss channel)	Define new management variable and MDIO register to select between settings S and L in the module output. Support of both settings is mandatory. Module shall meet the respective requirements for both settings at the respective measurement point.
VEC (max.)	7.5 dB	7.5 dB	Measured after processing by the reference receiver
Min EH (max.)	24 mV	24 mV	Measured after processing by the reference receiver
Max diff. PtP (max.)	600 mV	600 mV	Measured before processing by the reference receiver
Host stressed input @TP4a	Calibrate @TP4 NE (max VEC + min EH)	Calibrate @TP4 FE (max VEC + min EH)	Host shall meet the BER requirements at least in one of the two calibrated conditions

BACKUP

Recap: need for updated module output characteristics

- Problem description in a nutshell:
  - In Annex 120E, module output is allowed to have a very large swing (900 mV PtP) and does not sufficient requirement for being well equalized (VEC is not specified in 120E.3.2 at all).
  - Modules are allowed a wide range of output settings including large signal with little pre-emphasis (a lot of ISI) and/or high noise, or small signal with good pre-emphasis and low noise, as long as the required EH is met.
  - Receivers in devices using advanced CMOS processes and low supply voltages have limited linear range and large input signal may exceed it.
  - Unlike in NRZ, PAM4 receivers need good linearity to detect symbols correctly. Attenuating the input is sometimes difficult, and may not help if the signal is noisy and can't be equalized.
  - Designing a receiver for a port that supports both cable assembly (high loss channel with specified low jitter and noise, and training for optimizing Tx equalization) and optical module (low loss channel with loose specifications of the above) in 50G PAM4 is challenging.

- There may be hosts and modules that solved the engineering challenges and don't have any issues. But there is evidence from several people that, unlike what is expected, in general 50G C2M is not zero-touch.
- Things are going to be tougher in 100G with more challenging SI and ASIC design.
  - The expected addition of VEC for module output is a step forward but the module's output (swing, EH, VEC) still has too much freedom.
- Not addressing these issues will burden wide market adoption.