10G-BASE-T

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Acknowledgment

- My thanks to David Cunningham, from Hewlett Packard, for pointing at the original mix-up between optical and electrical SNR in the Idaho presentation.

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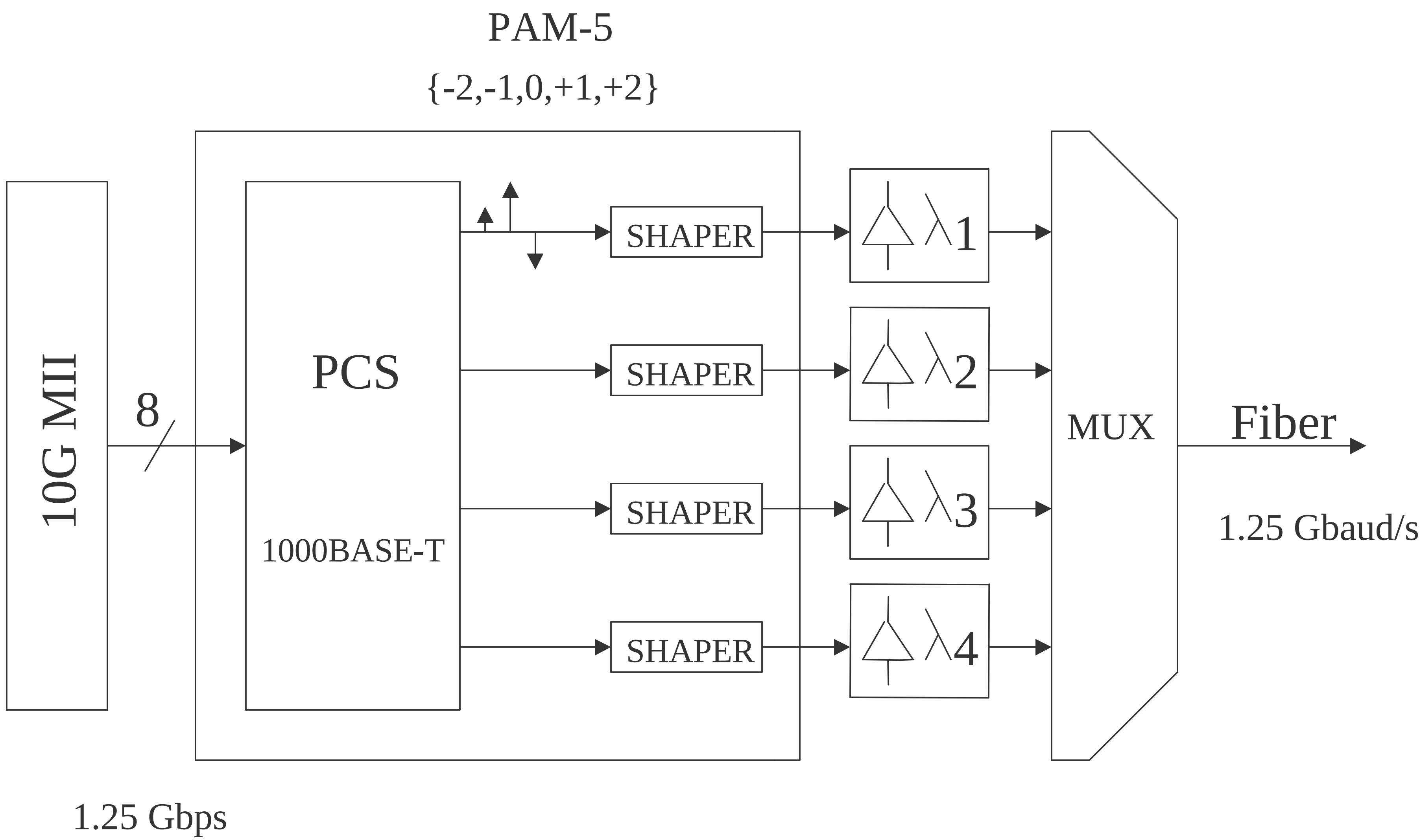
10G-BASE-T ARCHITECTURE



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10G-BASE-T architecture

- It uses the 1000BASE-T PCS + 4-WDM
  - The idea behind this architecture is to get the most out of the installed fiber, which is bandwidth limited.
  - It uses a baud rate of 1.25 Gbaud/sec, i.e., the same baud rate used in 1 GbE.

PCS main features

- The PCS (Physical Coding Sublayer) consists of 3 elements
  - scrambling
  - PAM-5 encoding
  - coding gain (FEC, Forward Error Correction)

PCS additional features

- It uses PAM-3 {-2,0,+2} IDLE encoding during start-up to make it more robust (also between frames)
- The encoding is such that the receiver PCS can detect differential skew delays and align the 4D symbols correctly.
- The encoding is such that the local receiver knows the status of the remote receiver (OK or NOK)

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Static and Dynamic Views

Static view

Infinite BW

Risetime = 0

(static SNR)

LINEAR SYSTEM

8b/10b + 4-WDM ?

1000BASE-T + 4-WDM ?

Dynamic view

Finite BW

Risetime > 0

(impulse response)

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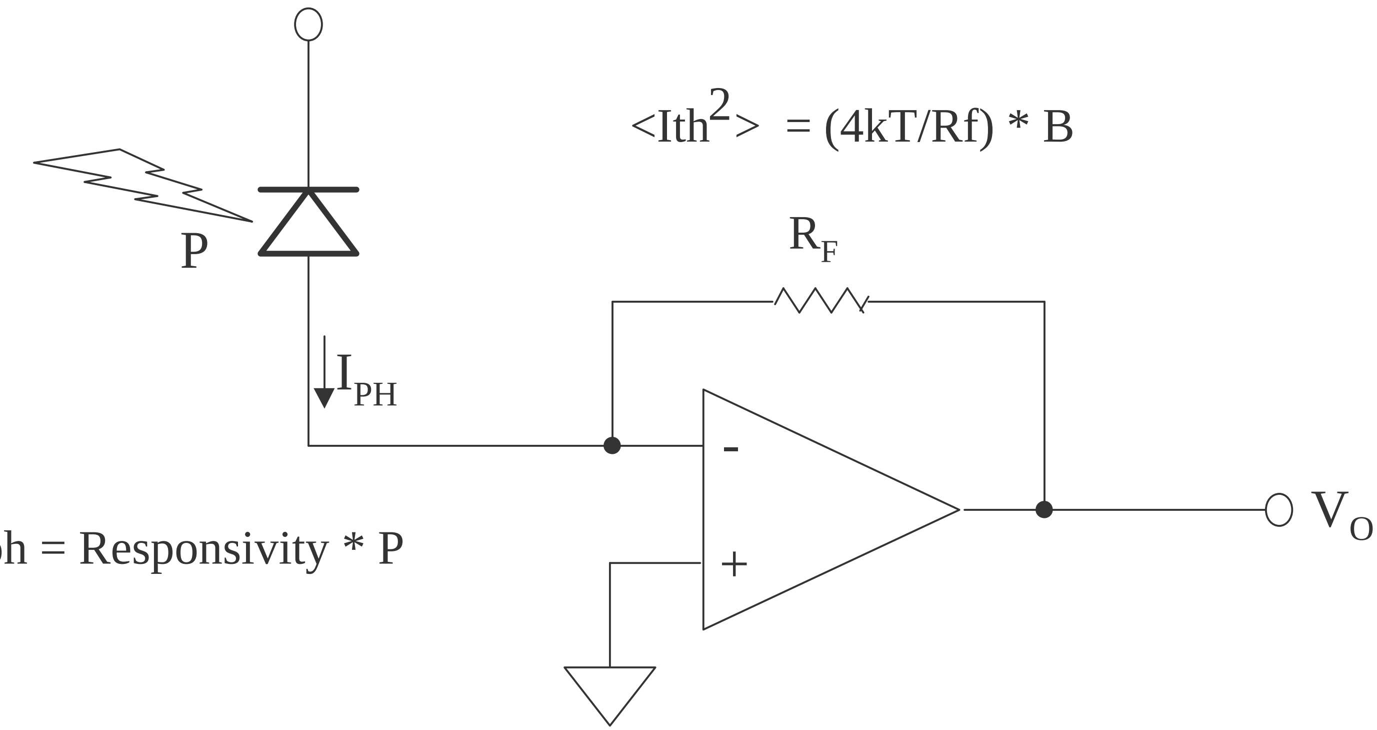
Static view

- Update on SNR calculations (ignoring dispersion effects in the fiber and laser risetime)

Receiver Front End

Assume PIN Photo Diode + Trans-Impedance Amplifier

$\langle Ith^2 \rangle = (4kT/Rf) * B$

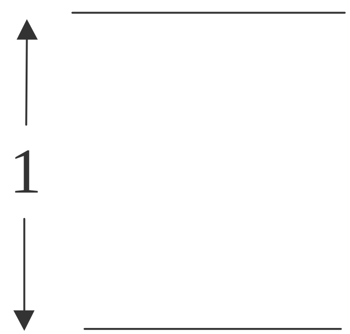


Iph = Responsivity * P

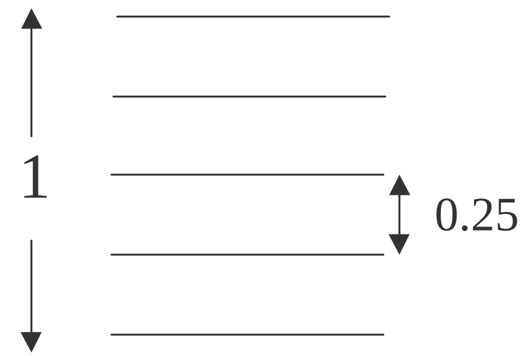
$$\text{Electrical SNR} = 10 * \log (Iph^2 / Ith^2)$$

Efficient use of bandwidth

8b/10b + 4-WDM



PAM-5 + 4-WDM



Symbol period = 0.32 nsec

Symbol period = 0.8 nsec

P_opt = 0 dB

P_opt= - 6 dB

P_elec = 0 dB ← 12 dB penalty → P_elec = -12 dB

↓ ↓

- 4 dB noise penalty ← **Only 2 dB total penalty** → + 6 dB coding gain

(and we stay at 1.25 GHz)

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Electrical SNR comparison Table

1000BASE-X (reference)	0 dB
8b/10b + 4-WDM	- 4 dB (noise penalty)
PAM-5 + 4-WDM	- 12 dB (signal penalty)
PAM-5 + EVEN Coding	- 10 dB (2.2 dB coding gain,*)
PAM-5 + Trellis Coding	- 7 dB (5.2 dB coding gain,*)

(*) comment by Sailesh Rao

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Dynamic View - Longer Links
ISI Limited Link Length (*)

Fiber bandwidth	500 MHz * km		
Laser risetime	260 ps	130 ps	
8b/10b @ 3.125 GHz	280 m	320 m	(a)
PAM-5 @ 1.25 GHz	**330 m**	**480 m**	(b)

(*) See David Cunningham's presentation, Montreal 99, slide "Non-Equalized Worst Case Link Length versus number of levels"

(a) 700*(1.25/3.125) = 280m; 800*(1.25/3.125) = 320m;

(b) not including coding gain (FEC)

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Other advantages

- Reuse of the PCS of 1000BASE-T.
  - There is no need to change/add anything to the existing (standardized) 1000BASE-T PCS. It fits perfectly with 4-WDM.
  - Only approach that offers a complete, finished, PCS solution. Saves development time.

… and more advantages

- Electrical Transceivers in CMOS
  - It is compatible with CMOS technology (lowest clock, 1.25 GHz)
  - Possibility to integrate the MAC with the PHY, eliminating the need to implement the high-speed parallel I/O 10G-MII interface.

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What do we loose ?

- OOK signaling
  - Multilevel direct modulation of lasers was seldom used in the past.
  - A lot of work must be done here, specially in the area of a tighter control of the linearity of the Light vs Current (L-I) characteristics:
    - thermoelectric cooling ? (very cost effective here)
    - Nonlinear I vs Level CDAC driver ? (to get an overall linear Light vs Level characteristics)