40GE 10km SMF PMD Technical & Economic Feasibility

IEEE 802.3ba Task Force

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Outline

40GE 10km duplex SMF (& 100m duplex OM3 MMF) PMD

- Approach to Proposed 40GE 10km PMD
- PMD Block Diagram
- SMF Link/Power Budget
- MMF OM3 Comments
- Gen1 Relative Cost
- Technical & Economic Feasibility Discussion

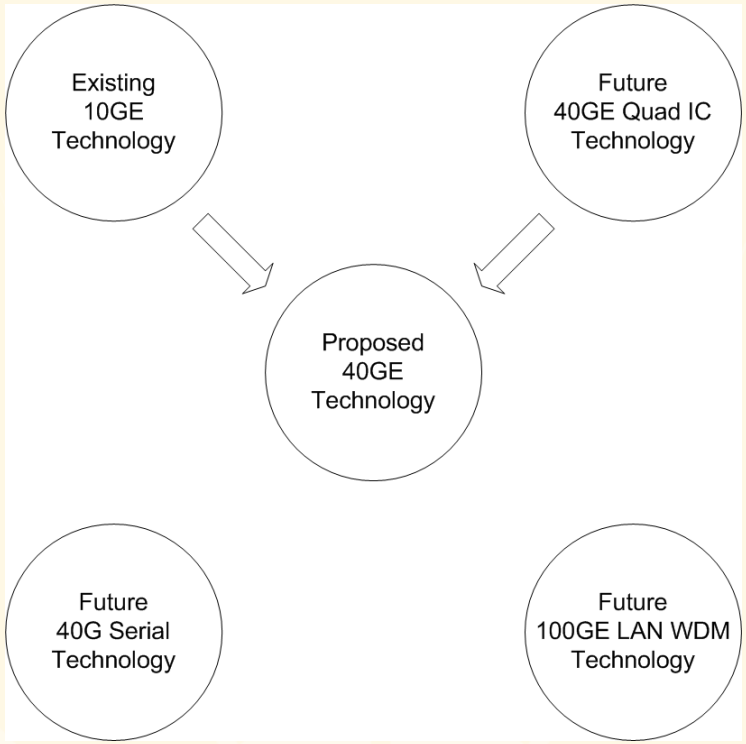
Reference 1: 100GE 10km SMF PMD

- Gen1 Relative Cost

Reference 2: 40GE 100m parallel OM3 MMF PMD

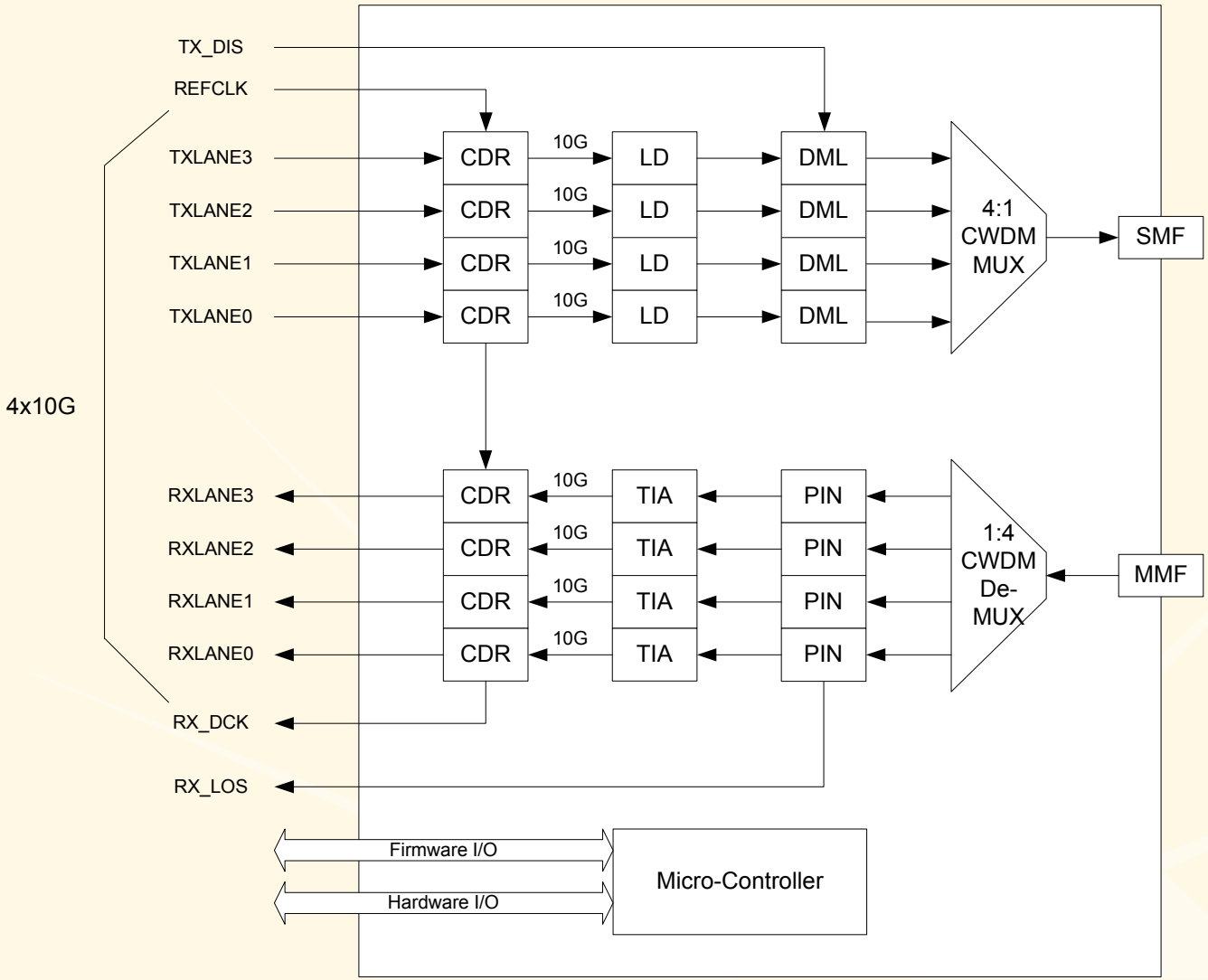
- PMD Block Diagram
- TX Specifications
- RX Specifications
- Jitter Budget
- Power Budget

Approach to Proposed 40GE 10km SMF PMD



- Leverage existing 10GE technology investment
- Leverage future server 40GE Quad IC technology investment
- Focus development efforts on WDM 10G DFB lasers, quad 10G packaging, and transceiver engineering
- Deliver lowest risk, quickest time to market PMD
- Deliver lowest near and mid term PMD cost

4x10G 1310nm DML 10km SMF 100m MMF PMD



Common with LX4:

- Duplex SMF/MMF
- 10km SMF

Different from LX4:

- 4x10G I/O (vs. 4x2.5G I/O)
- 100m OM3 MMF (vs. 300m)
- CWDM grid (vs. LX4 grid)

DC Power

- 8W

Form Factor

- Shared with 100GE Transceivers for interoperability and future high DC power applications

4x10G 1310nm DML 10km SMF Power Budget

10G Link Budget 10km SMF TP2 → TP3	CWDM DML λ = 1331nm* ER = 3.5dB
Fiber Loss (G.652 A&B)	4.3 dB
Penalties (10GBASE-L)	3.2 **
Connector loss	2.0
Total budget	9.5 dB

10G Pwr. Budget 10km SMF TP2 → TP3 OMA	CWDM DML λ = 1331nm* ER = 3.5dB
TX Min → Max	2.5→ 5.5 dBm
TP2 TX Min 2.5dB Mux loss	0.0 **
Link Budget (dB)	9.5 dB
TP3 RX Min 2.5dB DeMux loss	-9.5
RX Min (with crosstalk penalty)	-12.0 dBm

* Additional Link Budget and Power Budget analysis at λ = 1331nm and λ = 1271nm required to confirm final Budget numbers

** TP2 TX Min can be reduced for lower cost by reducing Penalties using today's DML technology transmitter parameters (vs. 10GE parameters)

4x10G 1310nm DML 100m duplex OM3 MMF

- Fiber loss effects are small
- OM3 MMF fiber bandwidth @ 1310nm = 500MHz / km
- 100m bandwidth = 5GHz
- IEEE 10GBASE-S reach recommendation for 500MHz / km fiber (850nm):
  Max Reach = 82m
- ISI Penalty for 100m (assuming t_R, t_F = 35ps) = 4.2dB
- 40GE Transceiver shown on page 3 can support 100m duplex MMF OM3 (as well as OM2 MMF) reach, confirmed by IEEE 10GE spreadsheet model. Some TX laser driver pre-emphasis is required.
  DC Power = 8W
- Longer reach then 100m OM3 MMF requires LRM EDC per RX channel
  DC Power = 10W (with today's SiGe LRM EDC ICs)
  = ~ 9W (with next generation CMOS LRM EDC ICs)
- Further analysis is required on realistic fiber profiles and jitter budgets, including using 10GBASE-LRM models.

Gen1 40GE 10km 1310nm PMD Relative Cost

Gen1 10GE-LR 10km XFP Component	Relative Cost	Gen1 4x10G 10km Transceiver Component	Relative Cost
2 CDRs	1x	8 CDRs	2x
Single LD	1x	Quad LD	2x
DML (DFB) TOSA	1x	Quad DML TOSA w/ CWDM Mux	4x
PIN/TIA ROSA	1x	Quad PIN/TIA ROSA w/ CWDM DeMux	4x
FR4 PCBA, XFP parts & connector	1x	FR4 PCBA, new form factor parts & connector	4x
Single channel testing	1x	Four channel parallel testing	1x
Weighted average	**1x**	**Weighted average at similar volumes, stages in product life cycle**	**4x ***

* Amortization of development and parallel test equipment costs not included.

* May increase up to 2x depending on volume and ROI assumptions.

Discussion

- 40GE 10km SMF 4x10G 1310nm un-cooled DML PMD is Technically Feasible.
- 40GE 10km SMF 4x10G 1310nm un-cooled DML PMD is Economically Feasible.
- Economic Feasibility is enhanced (development cost driven) by leveraging existing 10GE-LR Transmitter, 10GE-LRM Receiver, future server 40GE Quad IC and 100GE form factor technology investments.
- Economic Feasibility is enhanced (yield driven) by taking advantage of new 10G DML technology and relaxing 802.3 10GE-LR Transmitter assumptions to reduce the 10km Link Budget and improve DML yield.
- Economic Feasibility is enhanced (volume driven) by using 40GE SMF PMD for 100m duplex OM3 MMF applications.
- Economic Feasibility is enhanced (volume driven) by 40GE addressing near term cost sensitivity markets that can not be addressed by 100GE

  Gen1 100GE 10km SMF PMD cost (p6) is 8x to 12x Gen1 40GE 10km SMF PMD cost (p4)

Reference 1: Gen1 100GE 10km PMD Relative Cost *

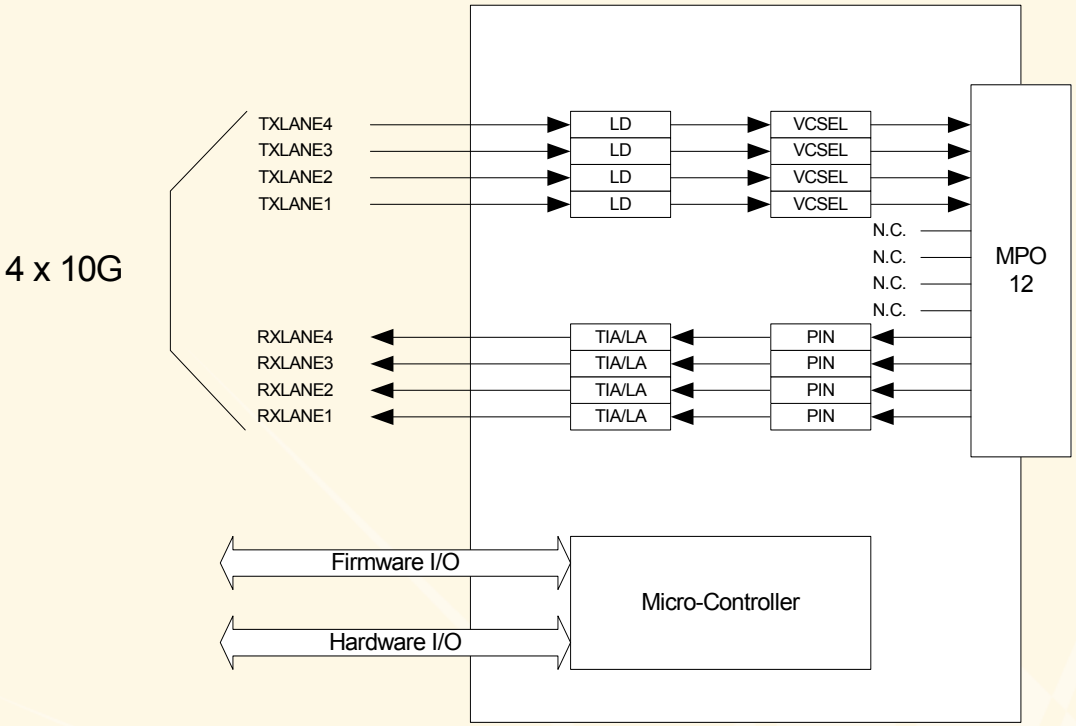
Gen1 10GE-ER 40km XENPAK Component	Relative Cost	Gen1 4x25G 10km Transceiver Component	Relative Cost
XAUI (SiGe)	1x	10:4 SerDes (SiGe)	3x
Mod Driver (InP)	1x	Quad MD (InP)	3x
EML + TEC TOSA	1x	Quad EML + TEC TOSA w/ WDM micro-optic Mux	4x
PIN/TIA ROSA	1x	Quad PIN/TIA ROSA w/ WDM micro-optic DeMux	4x
FR4 PCBA, XENPAK parts & PT20 connector	1x	Nelco PCBA, new form factor parts & connector	2x
Single channel testing	1x	Four channel parallel testing	1x
Weighted average	**1x**	**Weighted average at similar volumes, stages in product life cycle**	**4x ****

* Gen1 100GE 10km SMF 1310nm Transceiver Economic Feasibility, cole_01_0307 (p12)

** Amortization of development and parallel test equipment costs not included.

** May increase up to 2x depending on volume and ROI assumptions.

Reference 2: 40GE 100m parallel OM3 MMF PMD



- 4x10G 850nm VCSEL
- 100m parallel OM3 MMF (12 fiber MPO cable)
- QSFP form factor

Reference 2: 100m OM3 850nm PMD TX specifications

Description	Value	Unit
Signaling speed (nominal)	10.3125	GBd
Signaling speed variation from nominal (max)	±100	ppm
Center wavelength (range)	840-860	nm
RMS spectral width (max)	0.65	nm
Average Launch Power (max)	1 *	dBm
Launch Power (min) in OMA	-3 *	dBm
Average launch power of OFF transmitter (max)	-30	dBm
Extinction ratio (min)	3	dB
$RIN_{12}OMA$ (max)	-128 *	dB/Hz
Optical return Loss Tolerance (max)	-12	dB
Encircled Flux	86% at 19um * 30% at 4.5um *	
Transmitter eye mask definition	TBD	
TP1 jitter allocation	0.30	U.I.
Rise/Fall Time	40 *	ps

* Subject to further study

Reference 2: 100m OM3 850nm PMD RX specifications

Description	Value	Unit
Signaling speed (nominal)	10.3125	GBd
Signaling speed variation from nominal (max)	±100	ppm
Center wavelength (range)	840-860	nm
Average receiver power (max)	1	dBm
Receiver sens (max) in OMA – Informative	-11.3 *	dBm
Average power at receiver input (min)	-7.9 *	dBm
Receiver reflectance (max)	-12	dB
Stressed receiver sensitivity in OMA (max)	TBD	dBm
- Vertical eye closure penalty (target)	TBD	dB
- Stressed eye jitter (target)	TBD	UI pk-pk
TP4 jitter allocation	0.63 *	UI

* Subject to further study

Reference 2: 100m OM3 850nm PMD Jitter Budget

Methodology:

Target greater TP1 TJ (Total Jitter) and lower TP4 TJ relative to SFI specification, to allow for more host crosstalk penalties

Jitter Assumptions / Calculations			
	Parameter	**Unit**	**Proposed 40/100G**
TP1	DCD / PWS	UI	0.07
	DDJ	UI	**0.14**
	TJ	UI	0.30
TP2	DCD / PWS	UI	0.15
	DDJ	UI	0.22
	TJ	UI	0.50
TP4	DCD / PWS	UI	N/A
	DDJ	UI	0.30
	TJ	UI	**0.63**

Reference 2: 100m OM3 850nm PMD Power Budget

Parameter	Value	Unit
Modal Bandwidth	2000	MHz km
Power Budget	>8.3	dB
Operating Range	0.5-100	m
Channel insertion loss	1.86 *	dB
Allocation for penalties **	2.97 *	dB
Penalty for required random jitter reduction	3.47 *	dB
Additional insertion loss allowed	0	dB

* Subject to further study

** ISI (2.03dB), RIN and other vertical penalties from 10GbE Spreadsheet