FINISAR

Automotive Fiber Standard

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Summary

- A 10G link standard targeted for automotive use is needed
  - 10GBASE-S is not optimized for this application
  1. Link budget Issues with 10GBASE-S when applied to this market
     - Performance
     - Reliability
     - Cost
  2. Environmental and reliability factors also affect the link budget
     - Temperature
     - Long Term Reliability
  3. Expectation of link initialization timing
     - <100ms
  4. Low power state
     - Sleep state (and awaken) to prevent battery drain

Issues with 10GBASE-S when applied to the automotive market

- 10GBASE-S was designed to maximize link length
  - Automotive use case is <15m
  - Can trade distance for other performance measures
- 10GBASE-S specification were created for low insertion loss connectors (e.g. LC, SC, etc.
  - Automotive fiber optic connectors are likely to be:
    - Higher count (minimum of 4),
    - Higher insertion loss (0.6dB)

    and
    - More varied (vibration, dirt, moisture)
  - A special additional loss case of field termination will be needed for serviceability in repair shop situations
- The link becomes power limited due to predicted higher losses.

Issues with 10GBASE-S when applied to the automotive market

- Rapid start up time needed for automotive
  - Fixed / Multi addressing at the device level to
  - State machine to confirm link and simplify fault detectability.
- 10GBASE-S is specified for 850nm only
  - higher wavelengths could provide better reliability
  - higher wavelengths could provide better eye safety
  - Lower minimum OMA
- Specialized fiber could be developed to:
  - Improve alignment tolerance
  - Minimize cost of connectors
  - Improve BW*distance product at mid 900's nm
- Triple trade off curve should be optimized for 15m max link length and possible new wavelength and fiber
  - Could result in as much as 1.5dB link margin improvement.
- Modern VCSELs have faster rise times than 10GBASE-S assumed. This implies that the eye can be vertically limited in 15m links.
  - Measuring OMA, TDP, and Stressed Rx sensitivity results in over rejection.
  - Suggest OMA-VECP and URS as the normative specifications

Environmental / Reliability differences that affect a short reach standard

- 105ºC operation
- Resilience and reparability of the link
  - Dirty environment, requires protective connectors note 1
  - High temperature and bend tolerant fibre optic cabling note 2
- Liability implications of catastrophic failure

Note 1: For examples of technical feasibility over a wide variety of applications see:

- *senko.com/featured/fiber-optic-ftth-ftta-solutions.html*
- *te.com/usa-en/products/fiber-optics/fiber-optic-connectors/rugged-fiber-connectors.html*
- *molex.com/molex/products/family?key=hermeticsealed_assemblies&channel=products&chanName=family&pageTitle=Introduction&parentKey=fiber_optic_product_families*
- *usconec.com/products/connectors/mxc.htm*

Note 2: For examples of technical feasibility see:

- *corning.com/worldwide/en/products/communication-networks/products/fiber/clearcurve-multimode-fiber.html*
- *prysmiangroup.com/en/business_markets/markets/fiber/downloads/datasheets/MMF---MaxCap-BB-OMx---10-Gbps-BI-MMF.pdf*
- *fiber-optic-catalog.ofsoptics.com/viewitems/graded-index/harsh-environment-graded-index-optical-fibers*

Transition to low power state

- Low power state is required to prevent battery drain during extended vehicle non-operation.

- Need to quantify & rationalize the need to exit low power state quickly.

Other considerations

- Low cost presumed essential for adoption of optics over competing technologies
  - and hard to discuss in an Ethernet meeting
- Ease of installation
- Resilience
- Weight
- Performance
  - When / at what bit rate does optics become compelling ?

Conclusion

- A 10G optical fiber link standard for automotive use could benefit from new requirements:
  1. Optimized link budget for 15m performance, reliability, cost
  2. Optimized for extended environmental conditions
  3. Limited latency when exiting sleep state
  4. Inclusion of a low/no power state to avoid draining automotive batteries during 6 week non-op states

Back up

Appendix 1: 10GBASE-S Transmitter Specs

Table 52–7—10GBASE-S transmit characteristics

Description	10GBASE-SW	10GBASE-SR	Unit
Signaling speed (nominal)	9.95328	10.3125	GBd
Signaling speed variation from nominal (max)	± 20	± 100	ppm
Center wavelength (range)	840 to 860		nm
RMS spectral width[a] (max)	See footnote[b]		
Average launch power (max)	See footnote[c]		
Average launch power[d] (min)	–7.3		dBm
Launch power (min) in OMA	See footnote[b]		
Average launch power of OFF transmitter[e] (max)	–30		dBm
Extinction ratio (min)	3		dB
$RIN_{12}OMA$ (max)	–128		dB/Hz
Optical Return Loss Tolerance (max)	12		dB
Encircled flux	See footnote[f]		
Transmitter eye mask definition[g] A {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.40, 0.45, 0.25, 0.28, 0.40}		
Transmitter eye mask definition[g] B {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} per sample	{0.235, 0.395, 0.45, 0.235, 0.265, 0.4}		
Transmitter and dispersion penalty[h] (max)	3.9 dB		dB

[a]RMS spectral width is the standard deviation of the spectrum.
[b]Trade-offs are available between spectral width, center wavelength and minimum optical modulation amplitude. See Figure 52–3 and Table 52–8.
[c]The 10GBASE-S launch power shall be the lesser of the Hazard Level 1 safety limit as defined by 52.10.2 or the average receive power (max) defined by Table 52–9.
[d]Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.
[e]Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable or other optional transmitter shut down conditions.
[f]The encircled flux at 19 µm shall be greater than or equal to 86% and the encircled flux at 4.5 µm shall be less than or equal to 30% when measured into Type A1a (50/125 µm multimode) fiber per ANSI/TIA/EIA-455-203-2001.
[g]Either transmitter eye mask definition A or B may be used. A transmitter is not required to comply with both definitions.
[h]TDP(max) and OMA(min) are at the respective wavelength and spectral width as specified in Table 52–8.

The tradeoffs between center wavelength, maximum RMS spectral width and minimum optical modulation amplitude are defined in Table 52–8 and are shown graphically in the informative Figure 52–3. In Table 52–8 the minimum optical modulation amplitude (dBm) allowed by this standard is given for the various ranges of center wavelength and spectral width.

Table 52–8—Minimum 10GBASE-S optical modulation amplitude (dBm) as a function of center wavelength and spectral width

Center wavelength (nm)	RMS Spectral width (nm)								
	Up to 0.05	0.05 to 0.1	0.1 to 0.15	0.15 to 0.2	0.2 to 0.25	0.25 to 0.3	0.3 to 0.35	0.35 to 0.4	0.4 to 0.45
840 to 842	–4.2	–4.2	–4.1	–4.1	–3.9	–3.8	–3.5	–3.2	–2.8
842 to 844	–4.2	–4.2	–4.2	–4.1	–3.9	–3.8	–3.6	–3.3	–2.9
844 to 846	–4.2	–4.2	–4.2	–4.1	–4.0	–3.8	–3.6	–3.3	–2.9
846 to 848	–4.3	–4.2	–4.2	–4.1	–4.0	–3.8	–3.6	–3.3	–2.9
848 to 850	–4.3	–4.2	–4.2	–4.1	–4.0	–3.8	–3.6	–3.3	–3.0
850 to 852	–4.3	–4.2	–4.2	–4.1	–4.0	–3.8	–3.6	–3.4	–3.0
852 to 854	–4.3	–4.2	–4.2	–4.1	–4.0	–3.9	–3.7	–3.4	–3.1
854 to 856	–4.3	–4.3	–4.2	–4.1	–4.0	–3.9	–3.7	–3.4	–3.1
856 to 858	–4.3	–4.3	–4.2	–4.1	–4.0	–3.9	–3.7	–3.5	–3.1
858 to 860	–4.3	–4.3	–4.2	–4.2	–4.1	–3.9	–3.7	–3.5	–3.2

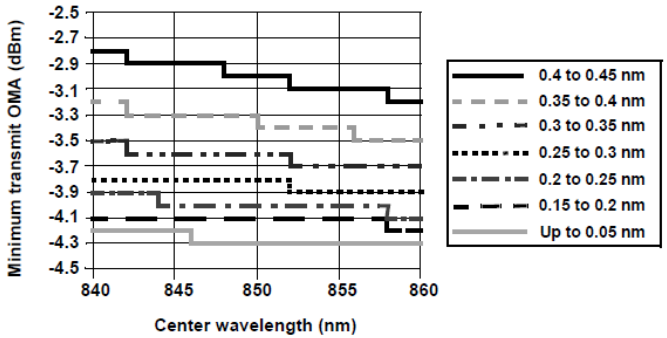

Figure 52–3—Triple tradeoff curve for 10GBASE-S (informative)

Appendix 2: 10GBASE-S Receiver Specs

Table 52–9—10GBASE-S receive characteristics

Description	10GBASE-SW	10GBASE-SR	Unit
Signaling speed (nominal)	9.95328	10.3125	GBd
Signaling speed variation from nominal (max)	± 20	± 100	ppm
Center wavelength (range)	840 to 860		nm
Average receive power[a] (max)	–1.0		dBm
Average receive power[b] (min)	–9.9		dBm
Receiver sensitivity (max) in OMA[c]	0.077 (–11.1)		mW (dBm)
Receiver Reflectance (max)	–12		dB
Stressed receiver sensitivity in OMA[d] [e](max)	0.18 (–7.5)		mW (dBm)
Vertical eye closure penalty[f] (min)	3.5		dB
Stressed eye jitter[g] (min)	0.3		UI pk-pk
Receive electrical 3 dB upper cutoff frequency (max)	12.3		GHz

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the average receive power (max) plus at least 1 dB.
[b]Average receive power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c]Receiver sensitivity is informative.
[d]Measured with conformance test signal at TP3 (see 52.9.9.3) for BER = 10^{-12}.
[e]The stressed sensitivity values in the table are for system level BER measurements which include the effects of CDR circuits. It is recommended that at least 0.4 dB additional margin be allocated if component level measurements are made without the effect of CDR circuits
[f]Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.
[g]Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

Table 52–10—10GBASE-S link power budgets[a,b]

Parameter	62.5 μm MMF		50 μm MMF				Unit
Modal bandwidth as measured at 850 nm	160	200	400	500	2000	4700	MHz•km
Power budget	7.3	7.3	7.3	7.3	7.3	7.3	dB
Operating distance	26	33	66	82	300	400	m
Channel insertion loss[c, d]	1.6	1.6	1.7	1.8	2.6	2.9	dB
Allocation for penalties	4.7	4.8	5.1	5.0	4.7	4.4	dB
Additional insertion loss allowed[e]	1.0	0.8	0.5	0.5	0.0	0.0	dB

[a]Budget numbers are rounded to nearest 0.1 dB.
[b]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.
[c]Operating distances used to calculate the channel insertion loss are the maximum values specified in Table 52–6.
[d]The specifications for a wavelength of 840 nm and a spectral width of 0.29 nm in Table 52–8 is used to calculate channel insertion loss, allocation for penalties, and additional insertion loss allowed.
[e]This portion of the link budget is permitted to be used to overcome insertion loss higher than the "Channel insertion loss" value and in some cases may be less than the value shown.