Over 10Gbps transmission

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Session Agenda & Objectives

- **Introduction to Signal Integrity Issues**
  - Where does loss come from
  - How materials effect transmission characteristics
  - Impedance discontinuities
- **Signal Conditioning Techniques**
  - EQ / Pre & De-Emphasis
  - Advanced SigCon techniques (DFE)
  - Retiming to remove random jitter
- **Tips**
  - Applications & Solutions
- **Summary**
- **Appendix**

Session Objectives:

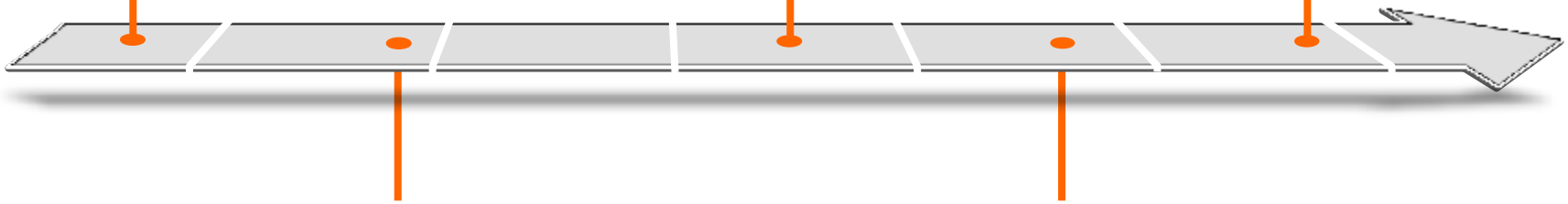
- Become familiar with where loss comes from
- Understand various SigCon features
- Identify Solutions for common problems

Introduction to Signal Integrity Issues

Subhead text here

Progression towards 100Gbps….

Year standardized	Data Rate	Unit Interval
1983	10 Mbps	100 ns
1995	100 Mbps	10 ns
1999	1 Gbps	1 ns
2006	10 Gbps	100 ps
2010	100 Gbps (4 x 25 Gbps)	40 ps

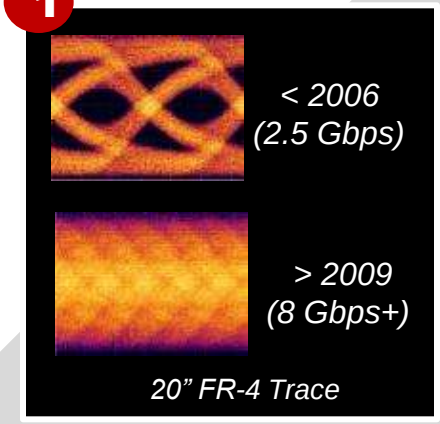


Interface Challenges

Doubling Data Rate, Reach Remains Same

Signal / Noise Problem

1



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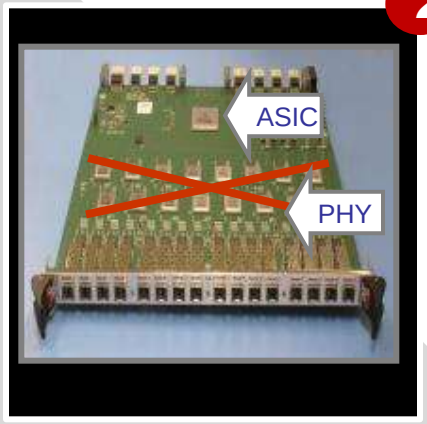


Shrinking CMOS Cells, PHY Integration,

Jitter Problem

Higher Density, Chassis Life Extension

Cross Talk Problem

Power Density Problem

3

Plethora of Standards, Complex Designs

Time-to-Market Problem

4

Doubling Data Rate, Reach Remains Same

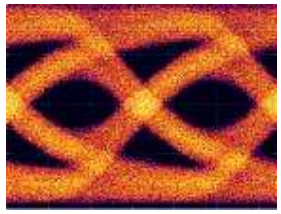
Signal Integrity Problem Growing

National Products from Texas Instruments

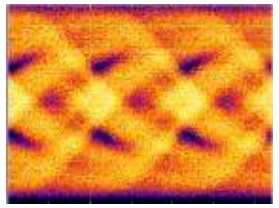
Doubling Data Rates, Reach Remains Same | Changing System Architecture | Design Expertise

	< 2009	2010	> 2010
Local Area Network (LAN)	1 Gbps	10 Gbps	100 Gbps
Server I/O	PCIe 2.5G	PCIe 5G	PCIe 8G
Storage Area Network (SAN)	FC 4G	FC 8G	FC 16G
CPRI	3 Gbps	6 Gbps	9.8 Gbps

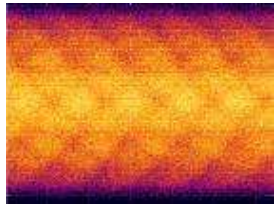
What happens to high speed signals after 26" of board trace?



< 2006 (2.5 Gbps)



2006-2009 (5 Gbps)

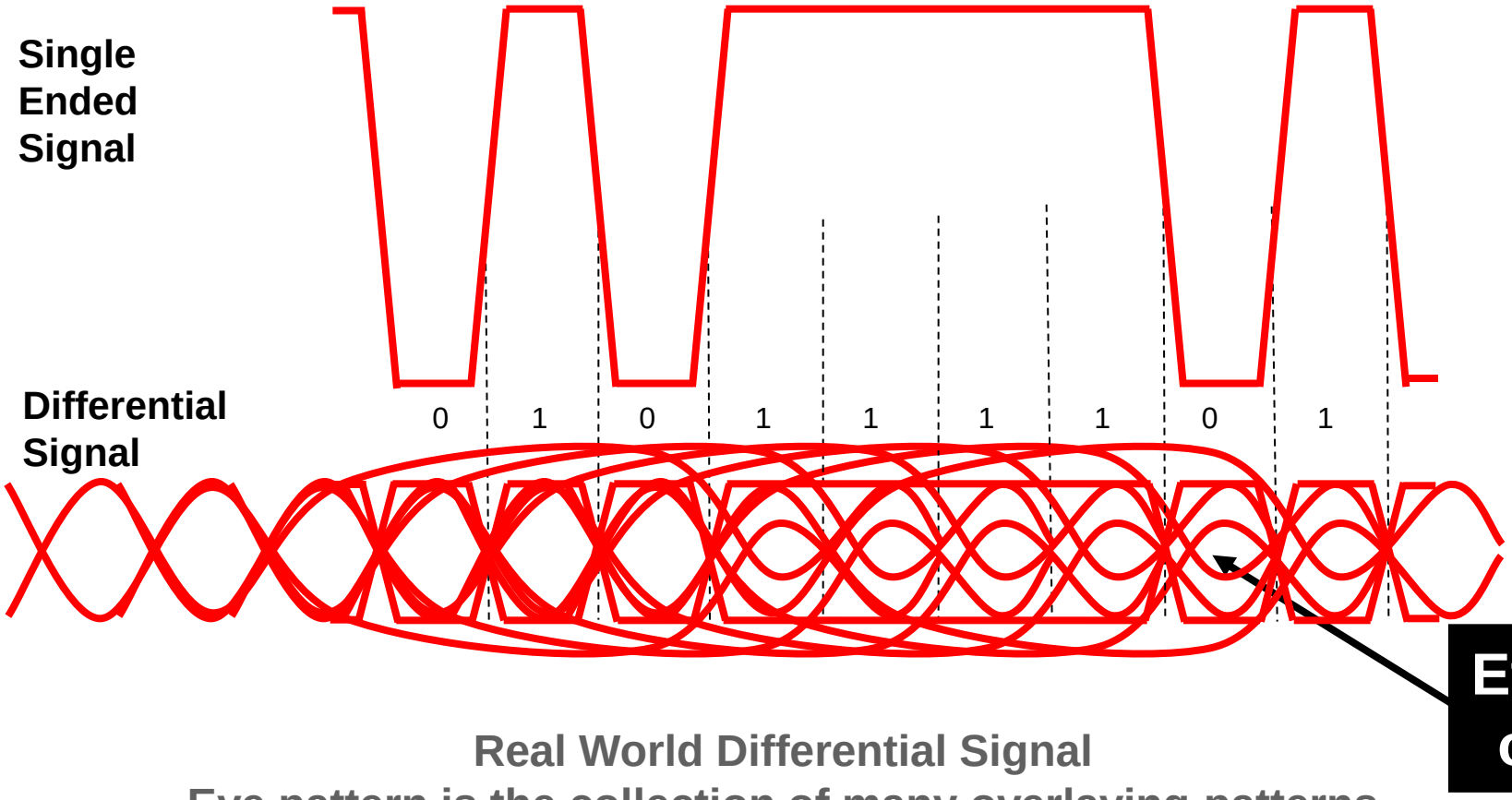


> 2009 (8 Gbps+)

Texas Instruments

Single Ended vs Differential

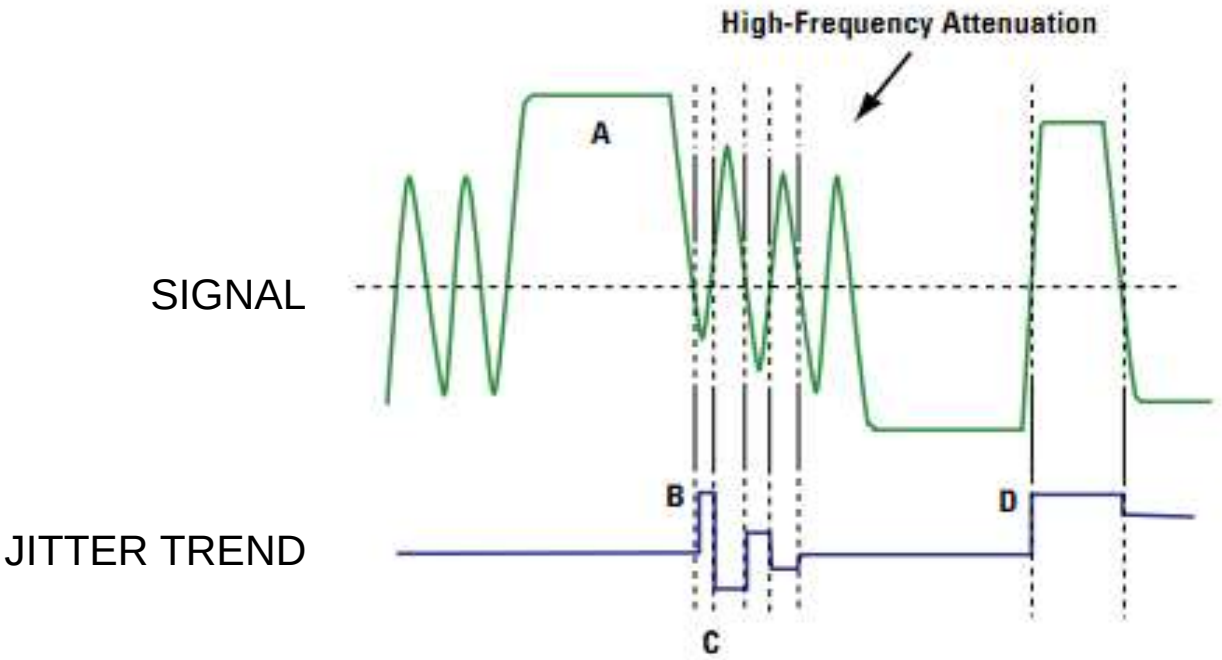
Inter Symbol Interference (ISI) and LOSS



Real World Differential Signal

Eye pattern is the collection of many overlaying patterns

Inter-Symbol Interference (ISI) Jitter

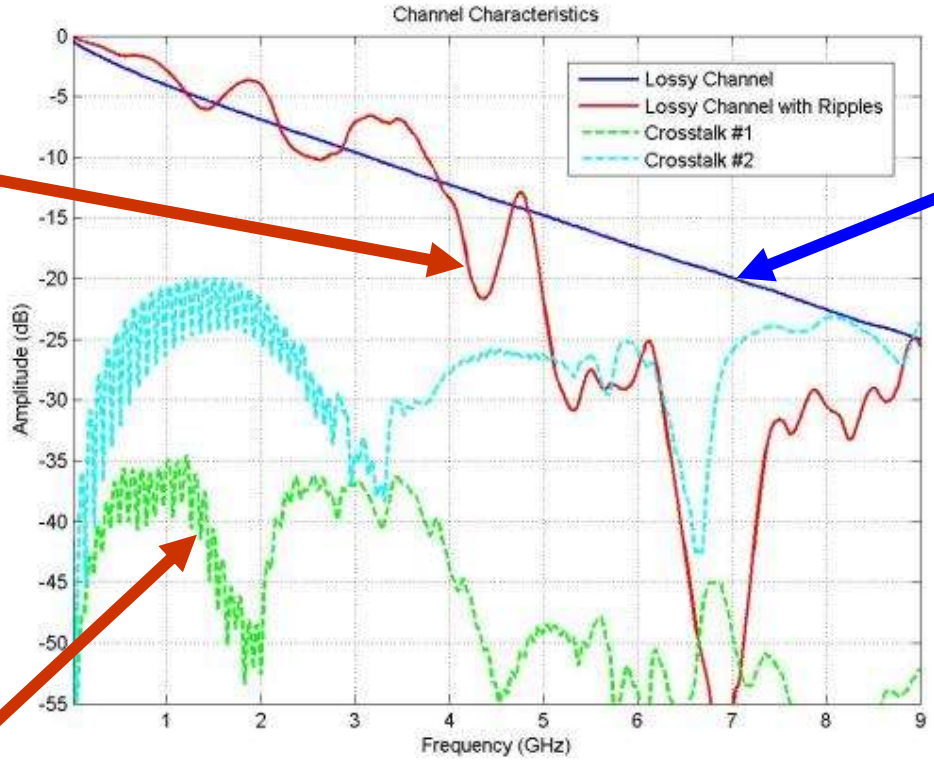


- ISI is data pattern dependant and is effected **by the history of the stream**
- **Longer run lengths** (i.e. PRBS-31) will tend to have **more ISI** if bandwidth is limited
- The “jitter trend” curve above shows how the pattern effects the jitter
- **Reflections complicate** the matter and add JITTER (not shown)

Transmission Loss Profile

Linear loss, Resonance, Reflections, X-talk

Ripples – Impedance discontinuities

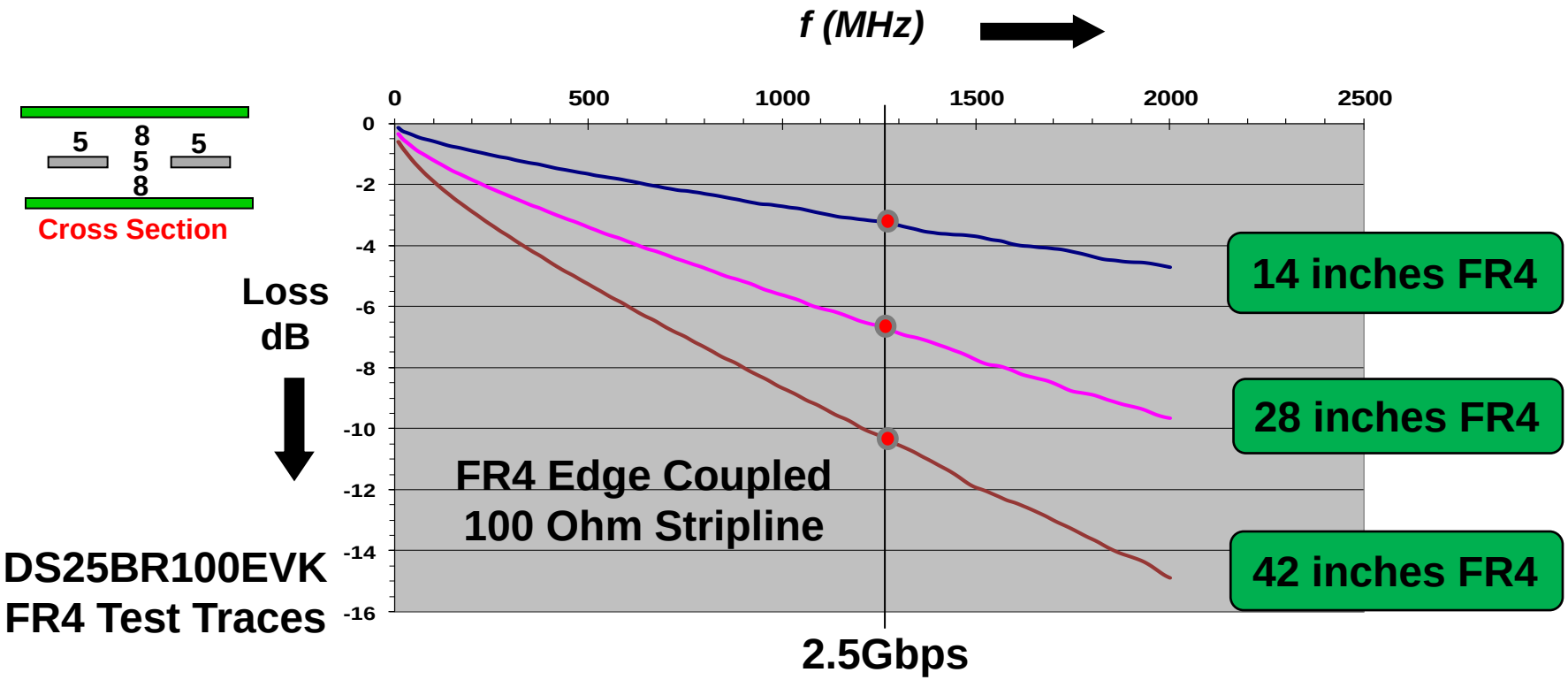


Linear Loss

Choppy – Crosstalk

Where does LOSS come from?

FR4 Loss vs. Length vs. Frequency



- Loss proportional to SQRT(f) (copper losses) and f (dielectric losses)
- Depends on transmission line geometries
- Depends on material properties

Common PCB Materials

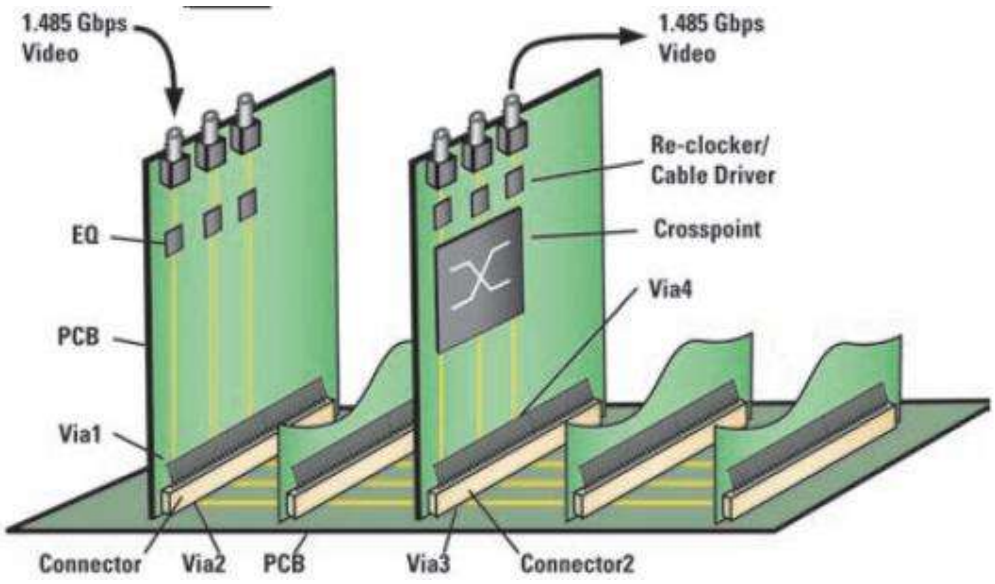
- Better materials have low dielectric constants that are flat with frequency
- More exotic materials have lower loss, thus providing better signal quality over the same distance or longer reaches

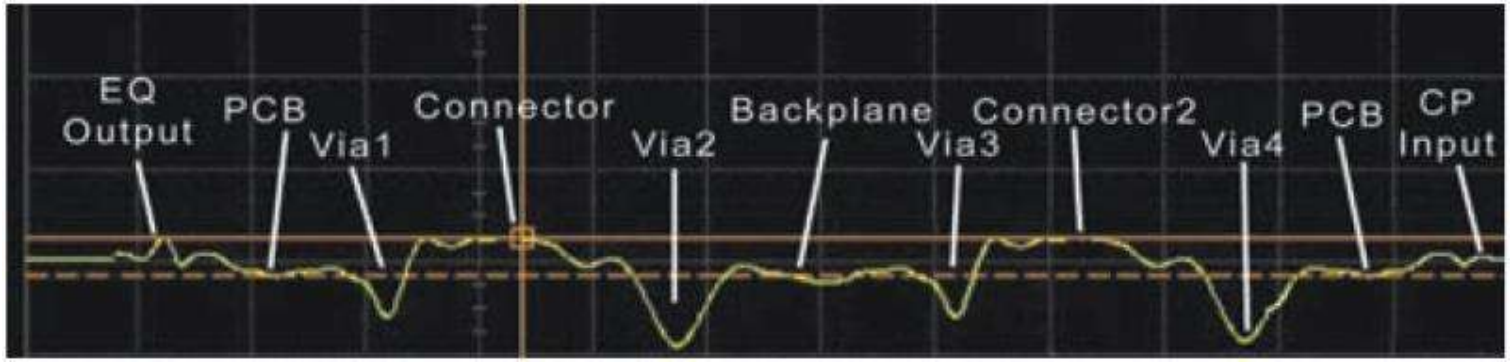
Name	Material	Dk (1MHz)	Dk (1GHz)	Dk (10GHz)
FR-4	GE	5.25	-	4.10
Nelco 4000-13	GE (Mod)	-	3.70	3.60
Hitachi FX-II	PTFE	-	3.60	3.40
Panasonic Megtron-6	PTFE	-	3.40	3.40

* PTFE: Polytetraflouroethylene (Teflon), GE: Glass Epoxy

Overcoming Impedance Discontinuities

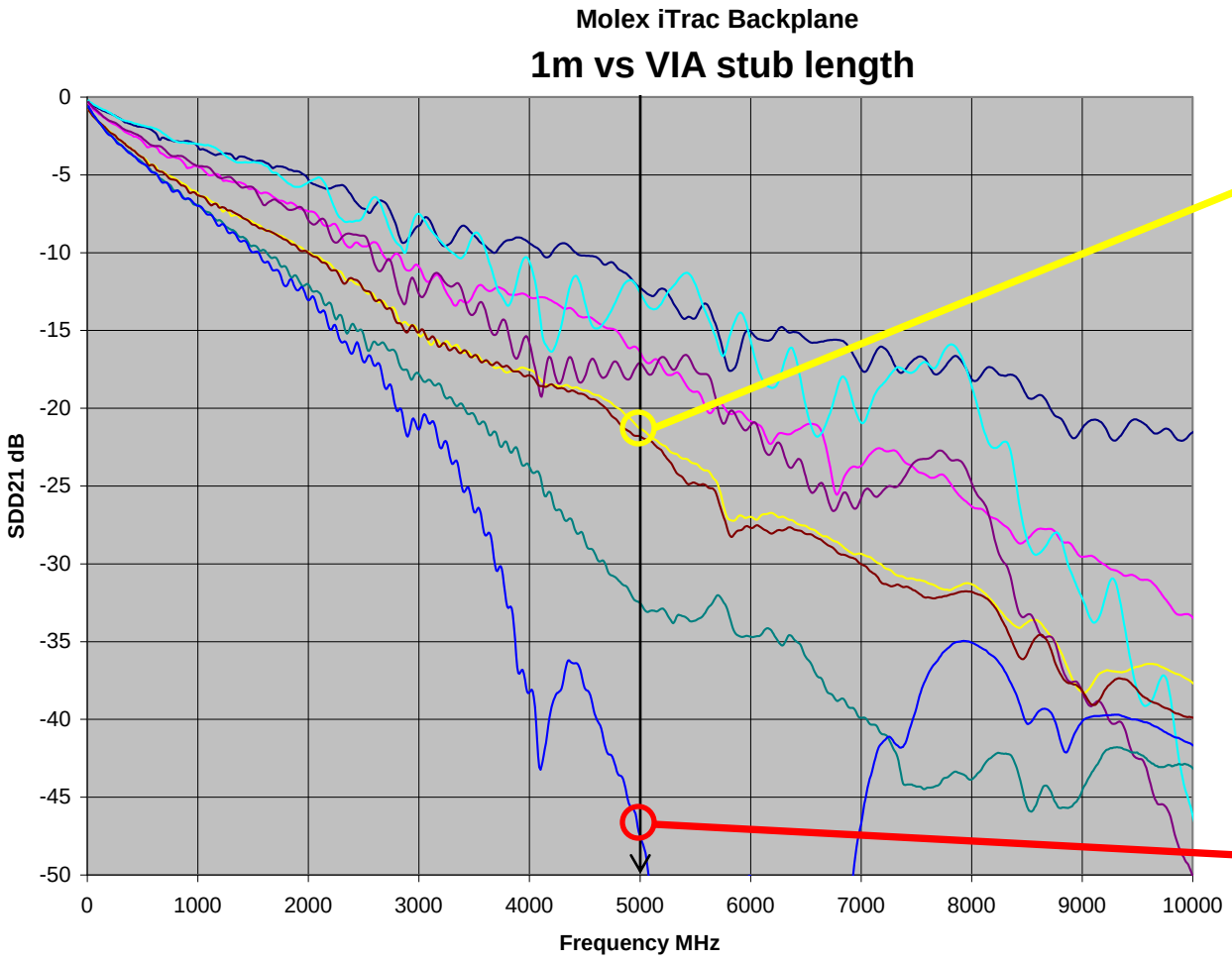
- As signals propagate from board-to-board through traces, feed-thru's and connectors, there are inevitable impedance discontinuities
- A TDR evaluation will highlight these discontinuities
- Careful layout, connector selection, and circuit board materials all factor into maintaining a relatively constant characteristic impedance

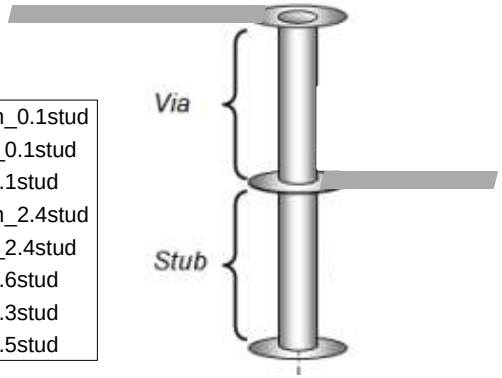




L
C

10G Design Considerations
Stubs matter





Crosstalk – FEXT & NEXT

Crosstalk contributes to periodic jitter that can degrade system performance

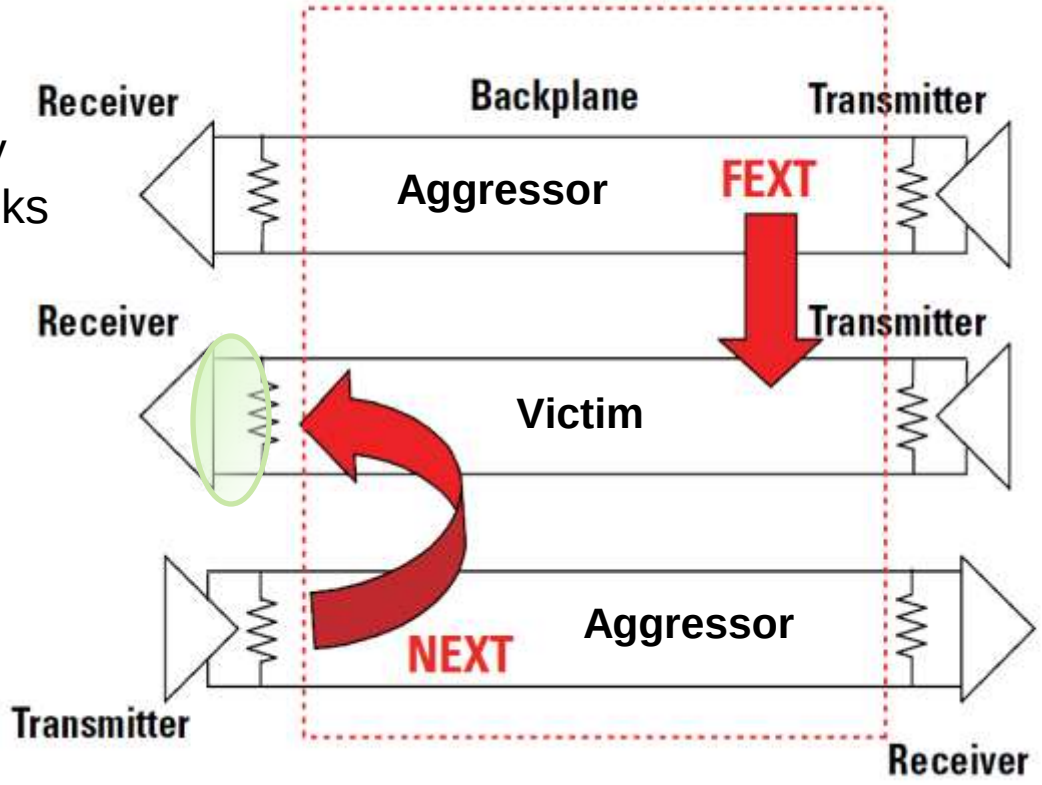
- Crosstalk is interference caused by adjacent data channels and/or clocks

Far-End Crosstalk (FEXT)

- Crosstalk noise is injected into the victim channel at the far end of a channel and is measured at the receiver

Near-End Crosstalk (NEXT)

- Crosstalk noise usually from an adjacent transmitter is injected at the receive end and is measured at the receiver



Far-End & Near-End Crosstalk Examples

Signal Conditioning Techniques

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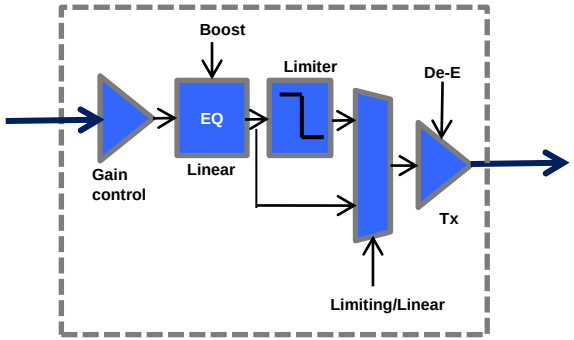
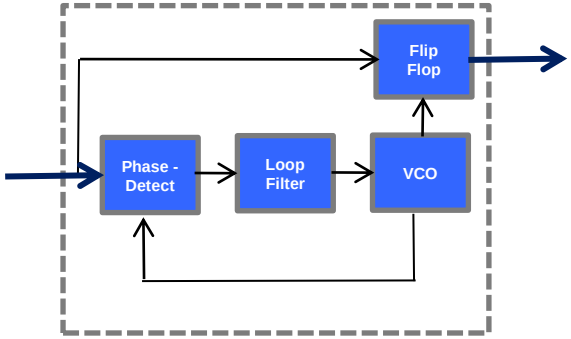
Right Tool for The Right Job

Redrivers, Retimers, and Advanced SigCon

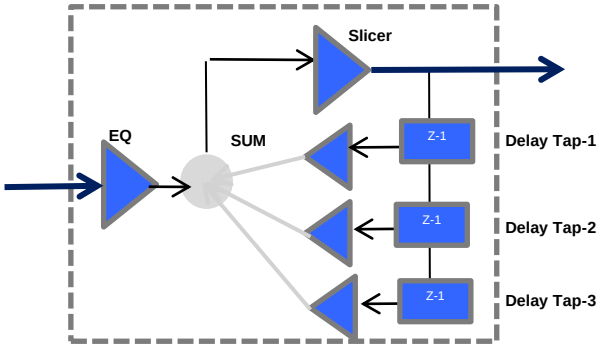
Equalization & De-Emphasis Driver



Clock Data Recovery (CDR)



Decision Feedback EQ (DFE)



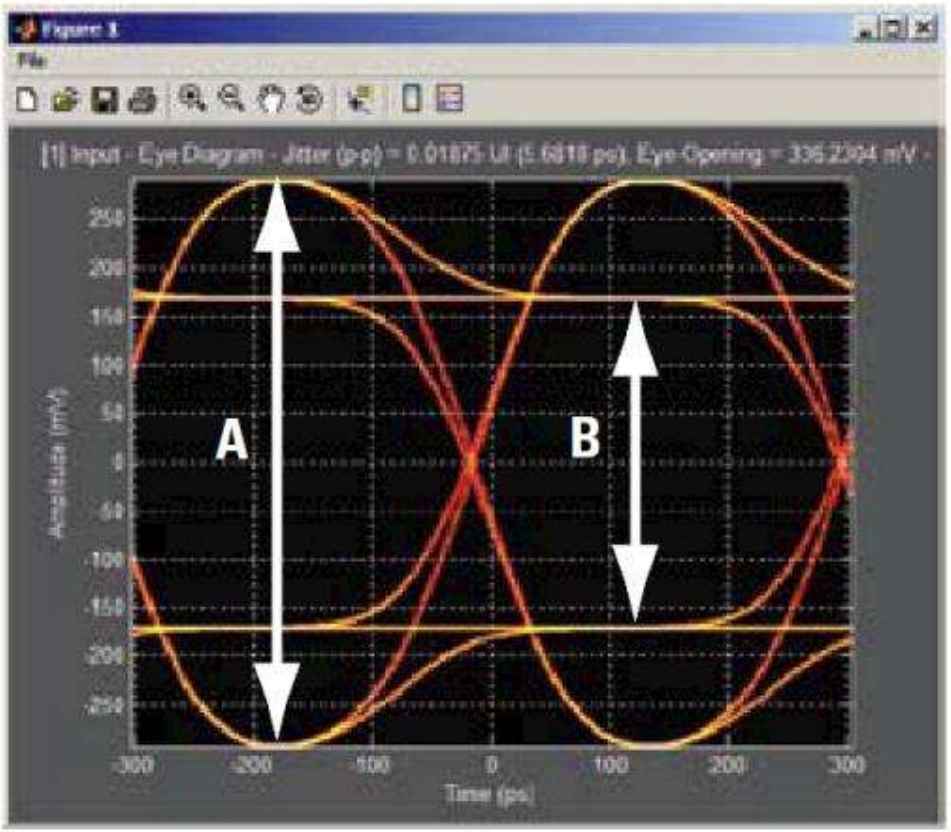
✓ **Insertion Loss**

✓ **Jitter**

✓ **X-Talk, Reflections**

Signal Conditioning: PE and DE

- Pre-Emphasis & De-Emphasis techniques address high frequency media loss by applying a frequency-selective boost or attenuation component to the data at the **transmit** end
- **Pre-Emphasis (PE)**
  - Edge energy is boosted by creating an overshoot on every edge
  - Typically used with LVDS
- **De-Emphasis (DE)**
  - Edges are kept the same, but the settled amplitude is attenuated
  - Typically used with CML

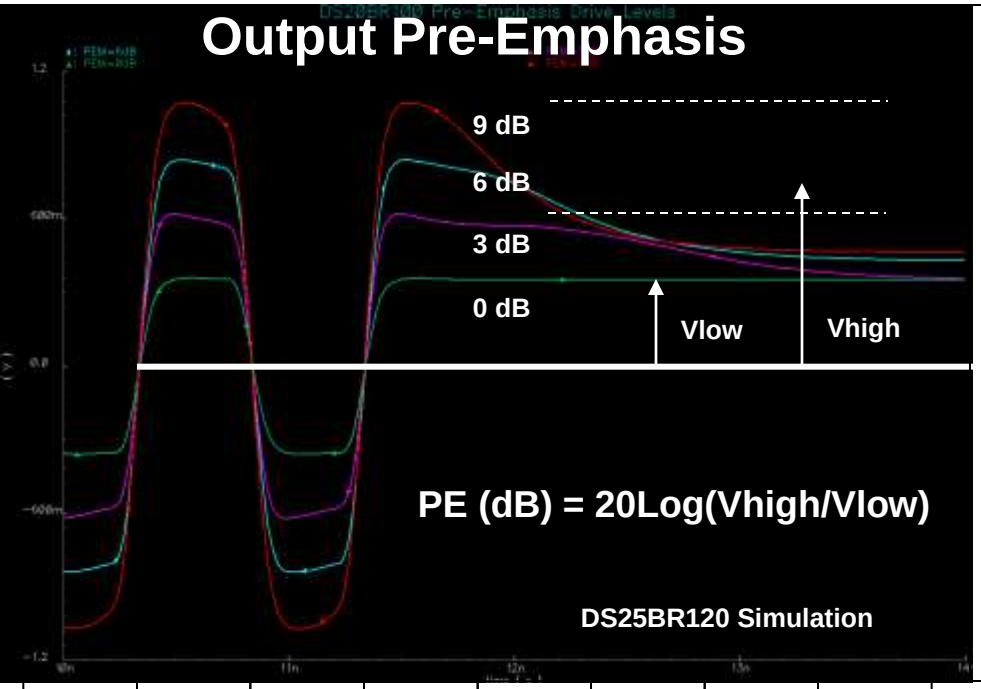


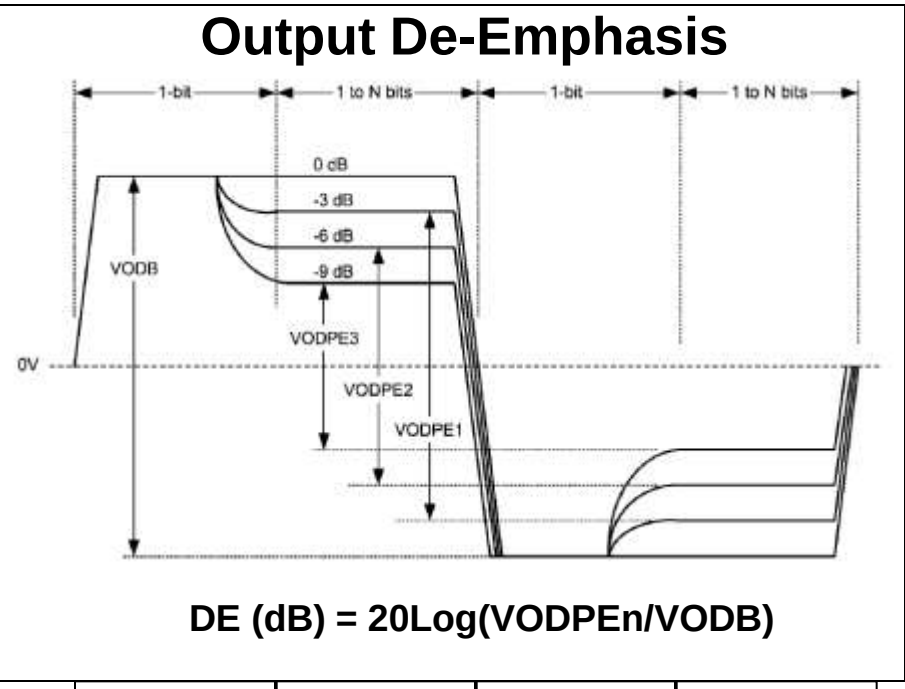
$PE = 20 \times \log10(A/B)$: Transmit $V_{OD} = B$

$DE = 20 \times \log10(B/A)$: Transmit $V_{OD} = A$

Transmit Signal Conditioning Explained

Pre-Emphasis (Pre-E) vs De-Emphasis (De-E) Waveforms





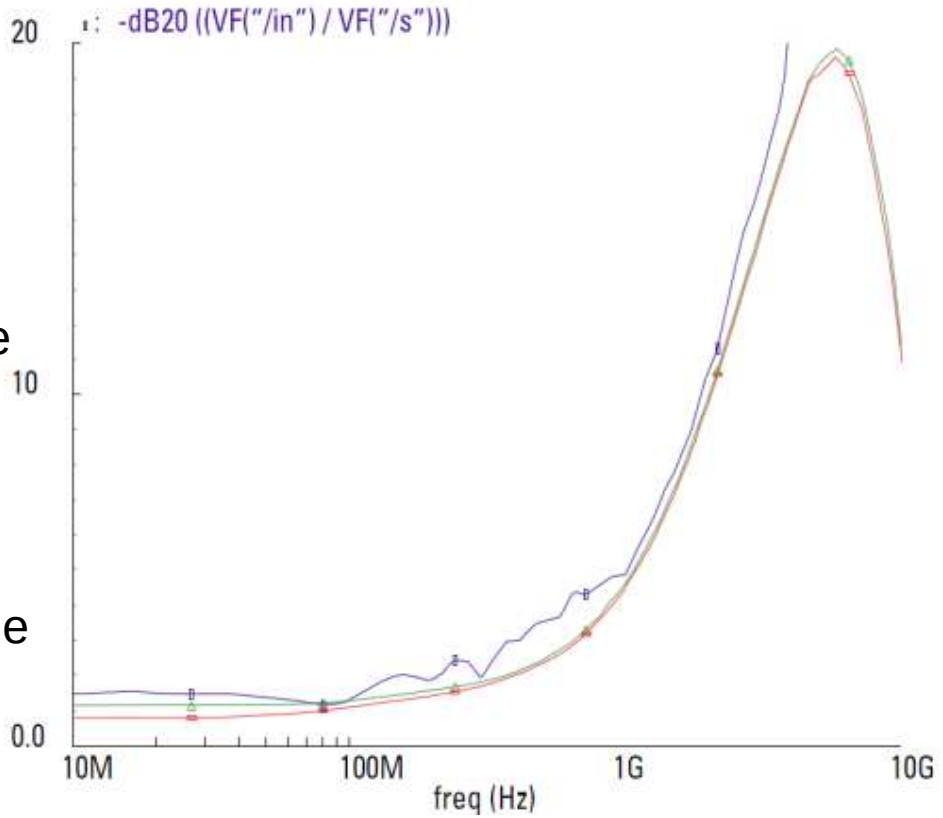
0	1	0	1	1	1	1	1	DATA PATTERN	1	1	0	0

Pre-E Tends to be used with LVDS
Single direction – Longest links

De-E Tends to be used with CML
Low EMI, Low Power, Bidirectional
Shorter

Signal Conditioning: Receive Equalization

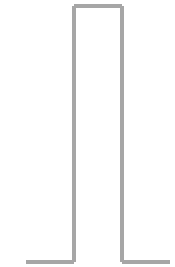
- **Equalization is applied at the <u>receive</u> end**
  - Selectively boosts high-frequency data
  - Compensates for the media's high frequency roll-off
  - Includes a high-pass filter that ideally has a frequency response exactly opposite to the media loss that the equalizer is attempting to compensate
  - Equalizers may be active or passive; fixed, variable or adaptive
- **Active Equalizers**
  - Can add gain to high frequencies while attenuating low frequencies
  - Works best with low-level signals
  - Can often be "programmable" or "adaptive"



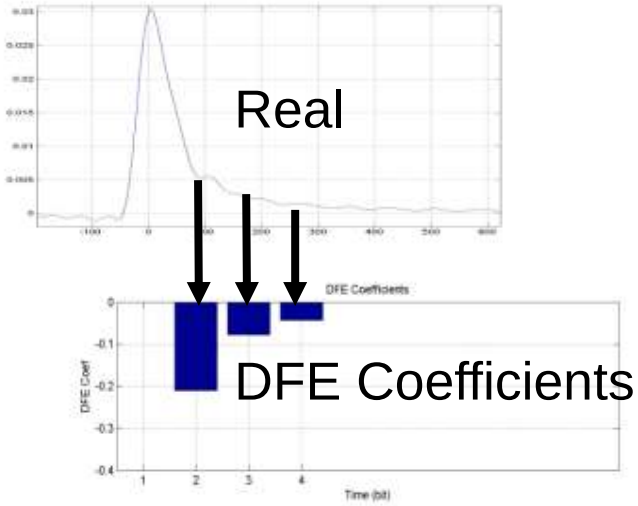
Inverse Channel Response (blue) and Matching Equalizer Response (green)

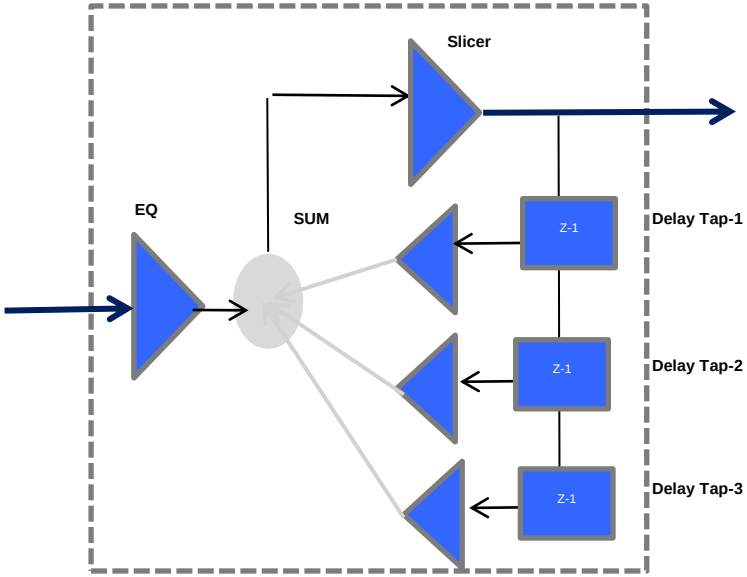
Advanced SigCon

Decision Feedback Equalizer (DFE)



Impulse
0-1-0

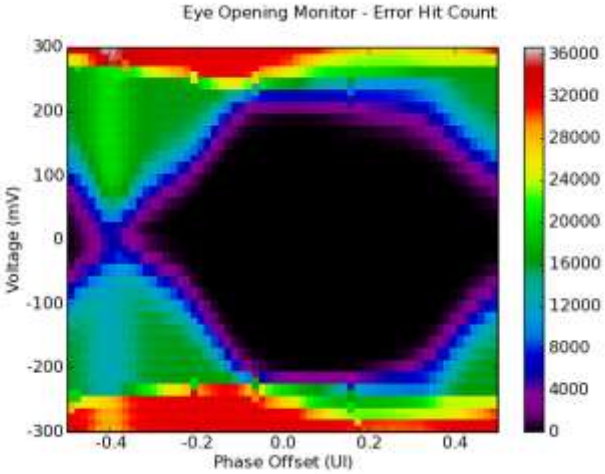




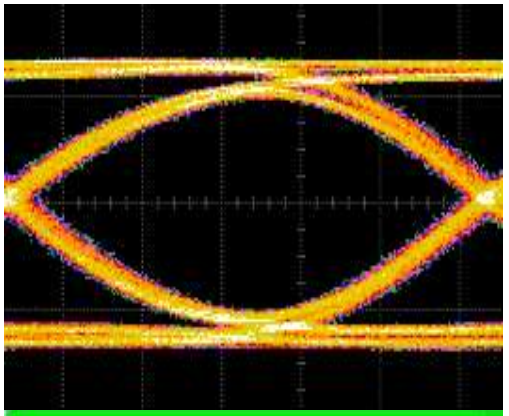
- Helps to **open** the EYE in the amplitude domain to **reduce BER**
- Counters impact of **X-Talk** and **Reflections**
- Useful at the higher data rates where every ps matters most
- **Eye Openers**
  - **Equalizers** reduce Jitter in the X axis to open the **EYE**
  - **DFEs** reduces amplitude noise in the Y axis to open the **EYE more**

Eye-Opening Monitor (EOM)

- **Many Uses: prototype,** lab, factory test, remote diagnostics, Figure of merit (FOM) and more!
- **Signal Fidelity measurement where it matters without probing effects, HEO, VEO (reg value)**
- Featured on most high-speed RETIMER and DFE based Advanced SigCon solutions

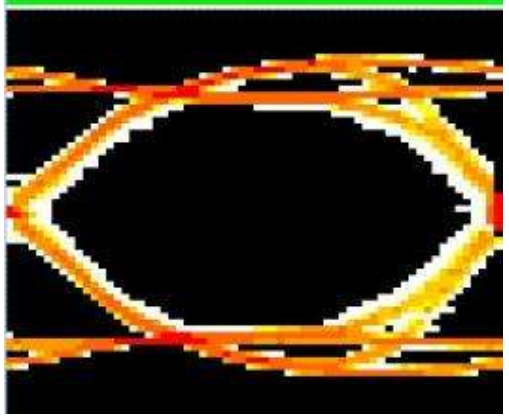


Lab Data from Sampling Scope



Internal Eye Monitor Raw Hits

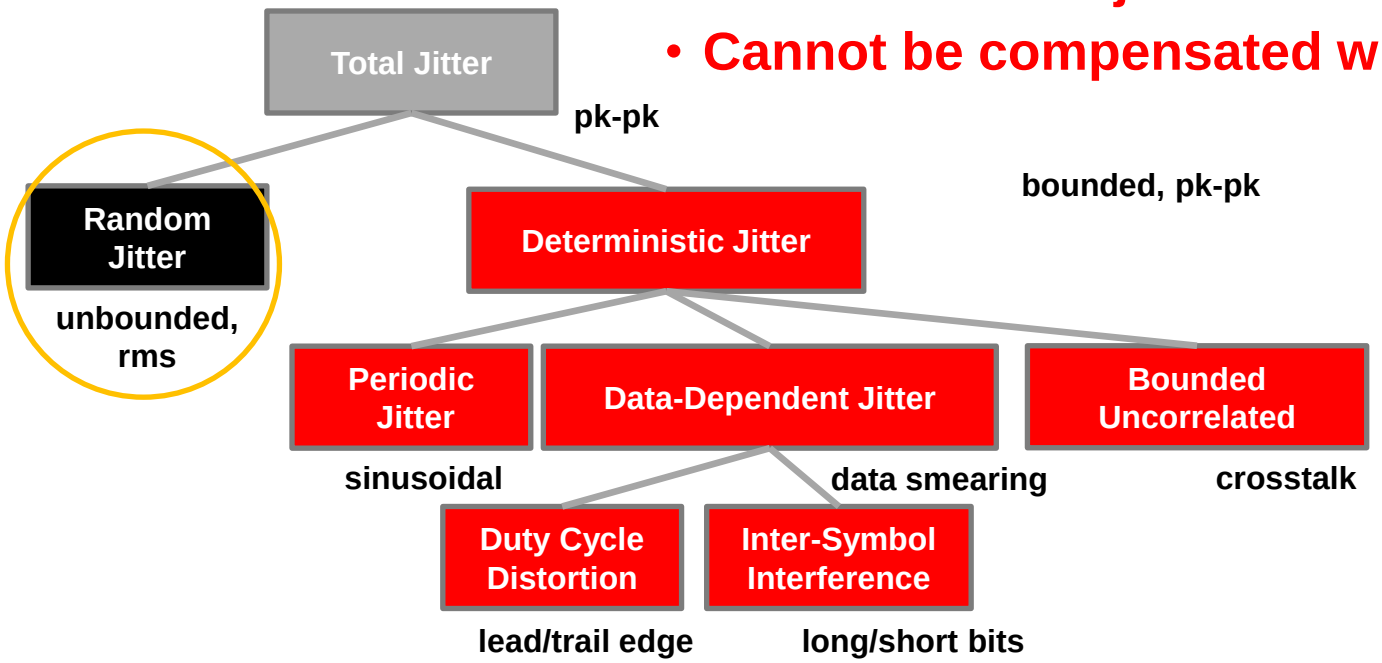
Density of Hits



10G, 100ps, 1.5ps & 6mV resolution

Random Noise and Jitter Revisited

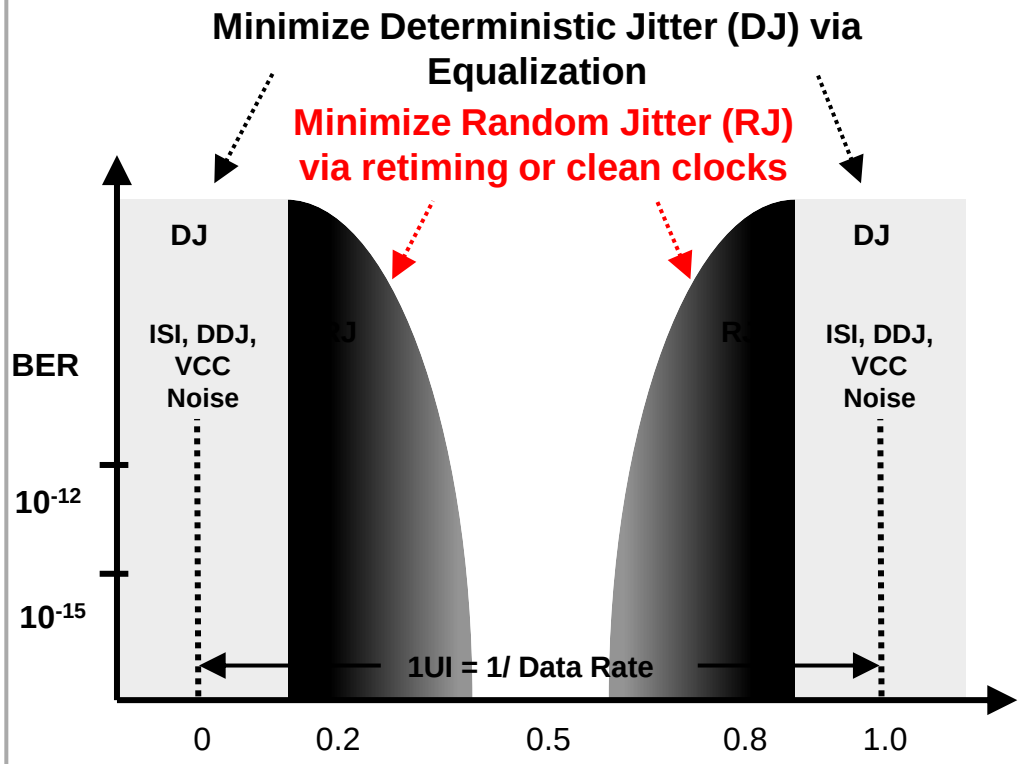
- **Random noise / jitter is not predictable**
- **Cannot be compensated with equalization**



- **Results from the random nature of electrons and the random obstacles that the electrons overcome as they carry info down electrical channels**
- **Gaussian in nature**
- **3 main system Components:** driver jitter, channel jitter, and receiver jitter

Jitter Limits Performance

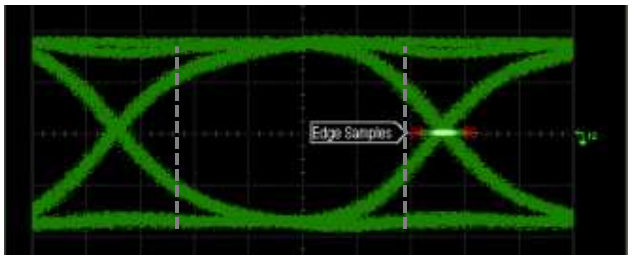
Bathtub Curve Performance



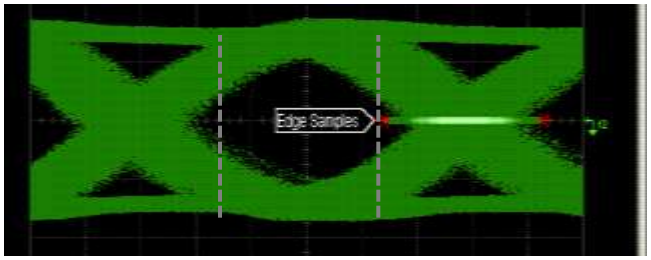
Random jitter reduces the eye opening

Scope Results

Eye Open



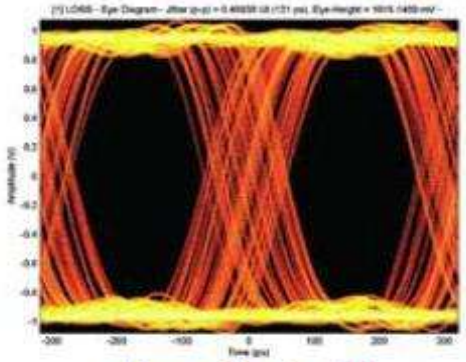
Eye closing due to jitter



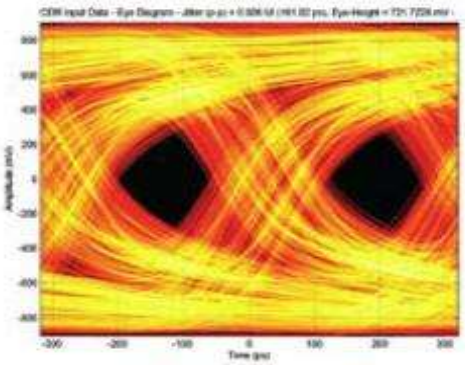
Clock jitter is a critical requirement in high speed communications

23

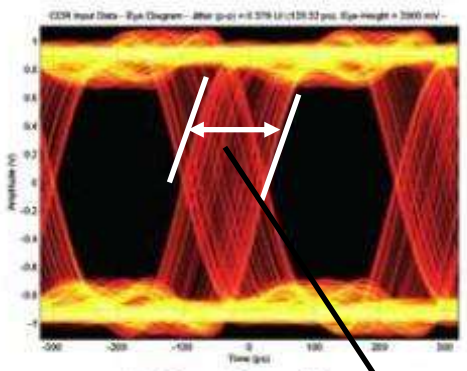
Using Re-timers to Overcome RJ



a) Input Clock with
0.4 UI Jitter @ 20 MHz

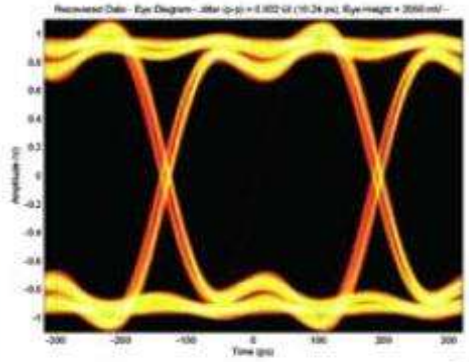


b) After Channel

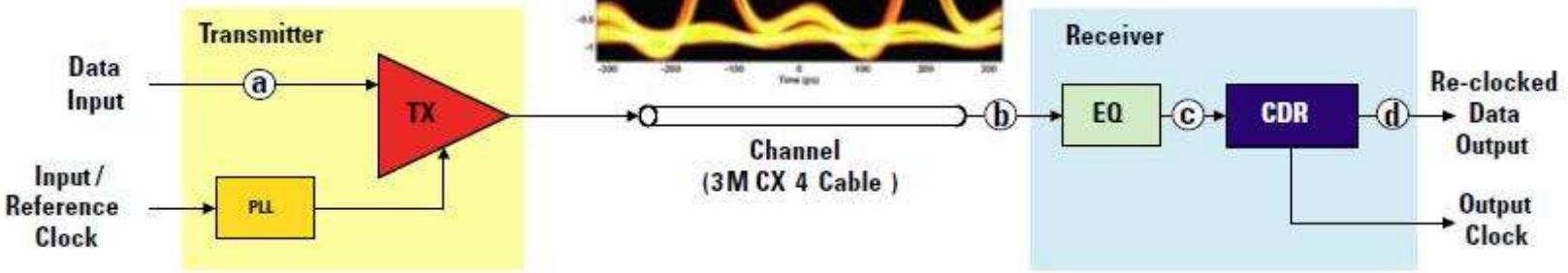


c) After Equalizer

Residual Jitter Left by EQ



d) After Re-clocking



Helps with minimizing Random Jitter (RJ), crosstalk, reflection, and residual Deterministic Jitter (DJ) in a channel

Tips

Subhead text here

Today's Tips

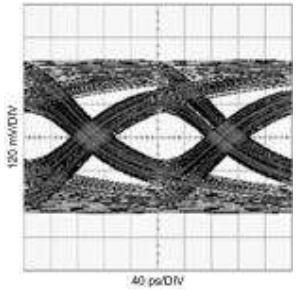
1 – **How to extend a chassis' life?** – *Life Extender, Reach extender, Eye Opener*

2 – **Active Cable –** *Optimization!*

3 – **10G Backplane, PCIe-Gen3, SAS-3 –** *Protocol Savvy*

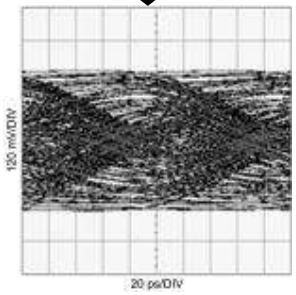
1 How to extend a chassis' life?

5 Gbps



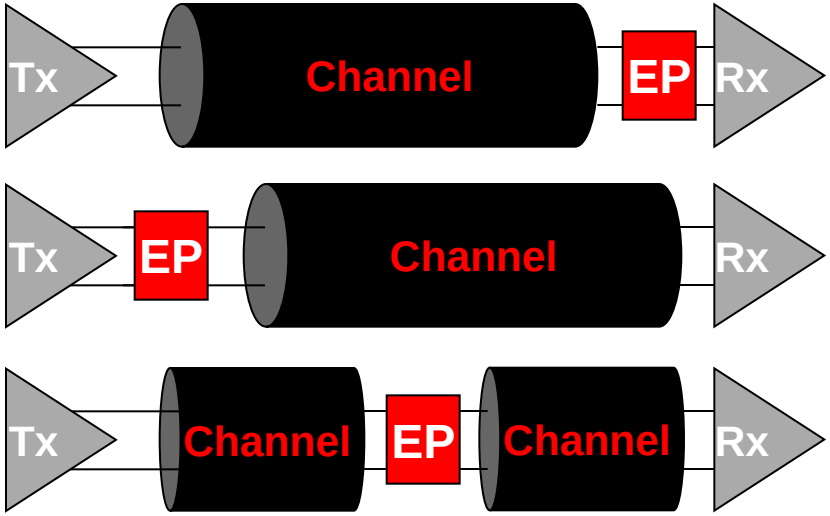
Double the Data Rate and the Eye closes!

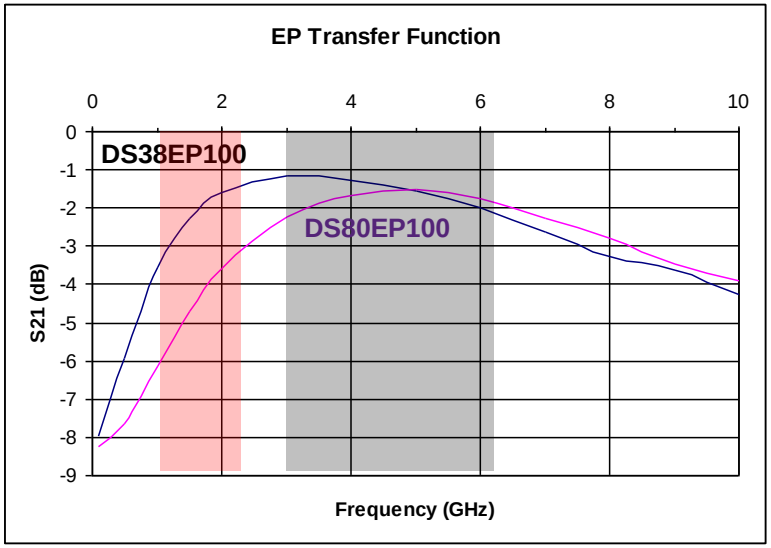
10 Gbps



- Loss is a function of channel
  - Trace (e.g. FR4, 6mil, microstrip)
  - Via
  - Connectors
  - Data Rate
- Doubling of Data Rate – huge impact!
- Life Extension of H/W
- But Eye is closed!
  - Jitter 100%
  - Amplitude
- **Open the EYE with a PowerSaver Equalizer Solution**

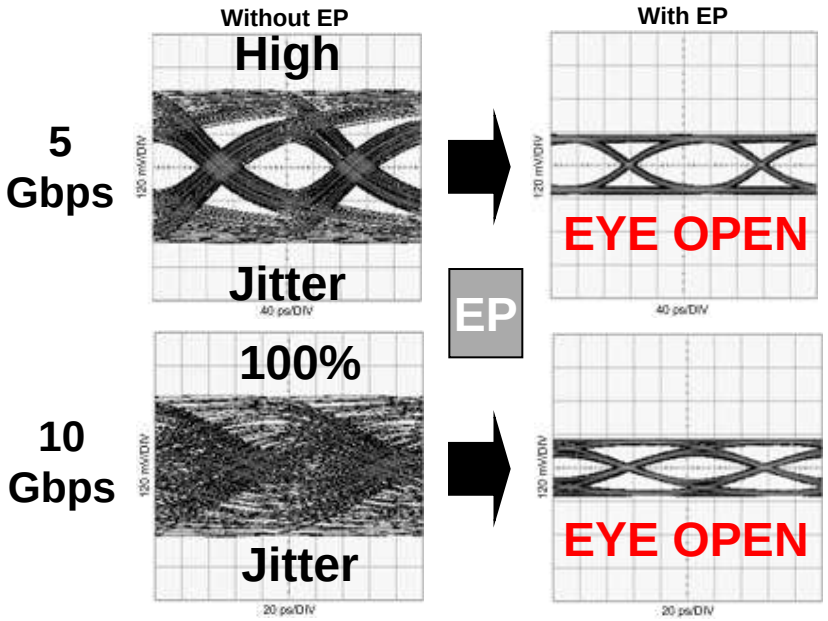
PowerSaver Equalizers – EP Family

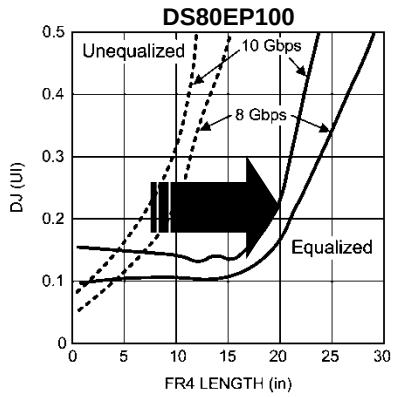




- DS38EP100 (2 to 5Gbps)
- DS80EP100 (5 to 12.5Gbps)
- EPs can be located at **ANY** point in the path
- Small Size (2.2mm x 2.5mm)
- **No Power or GND connection required!**
- **Works with CML, LVPECL, or LVDS signaling**
- **Works with any codes: 8b10b, scrambled, DC….**
- **Bi-directional**
- Economical boost solution that extends the life of a unit!

1 EP Design Considerations



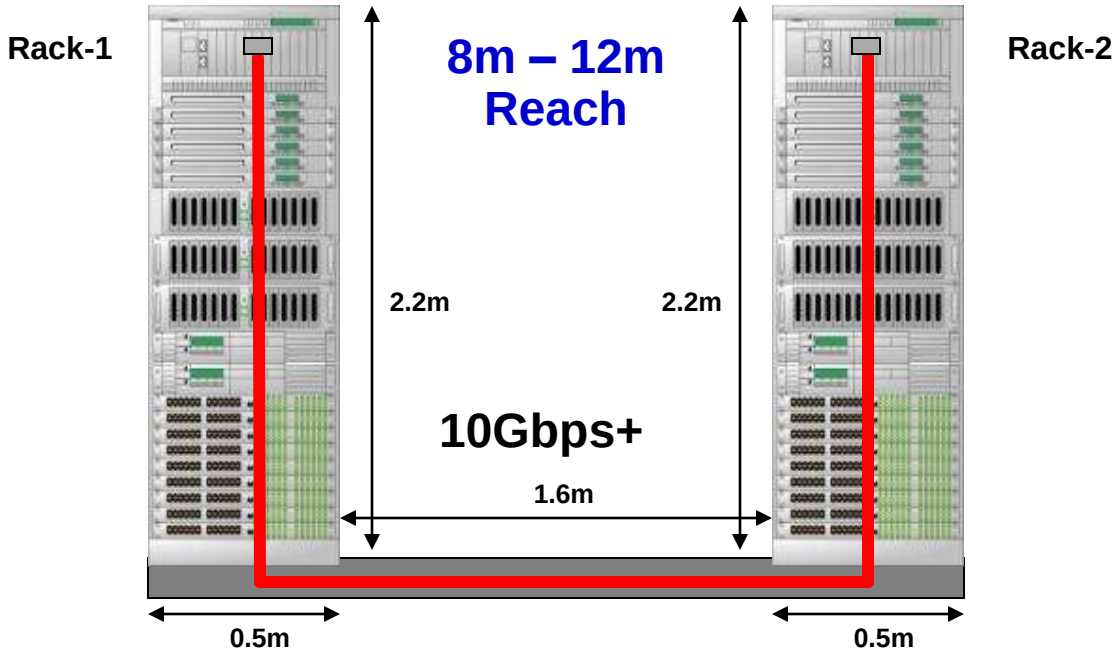


- PowerSaver Equalizers **reduce jitter** and **open the eye** – provides a DE function
- **Will attenuate** the signal (8dB)
  - Must meet RX minimum sensitivity requirement
  - TX optimization – increase VOD (1Vpp) or use Pre-Emphasis – De-Emphasis not recommended
  - Can work with Active EQs
    Can stack but watch attenuation
- **DS38EP100** targeted at:
  - 2 to 5Gbps
  - 40” FR4 6mil microstrip or other
- **DS80EP100** targeted at:
  - 5 to 12Gbps
  - 20” FR4 6mil microstrip or other
- ***Extends the Data Rate or Extends the Reach***

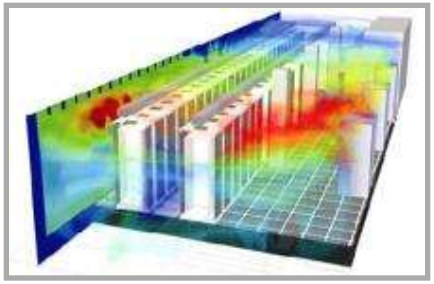
2 Active Copper Cables

Rack-to-Rack Reach

How to extends the reach on lower gauge wires to replace fiber for lengths under 15 meters?



Permit Airflow



Installation Flexibility

2 Data Center & HPC Cabling Solutions

Passive Copper, Active Copper, Active Optical

Passive Copper

QSFP : 5m, $X, 0W

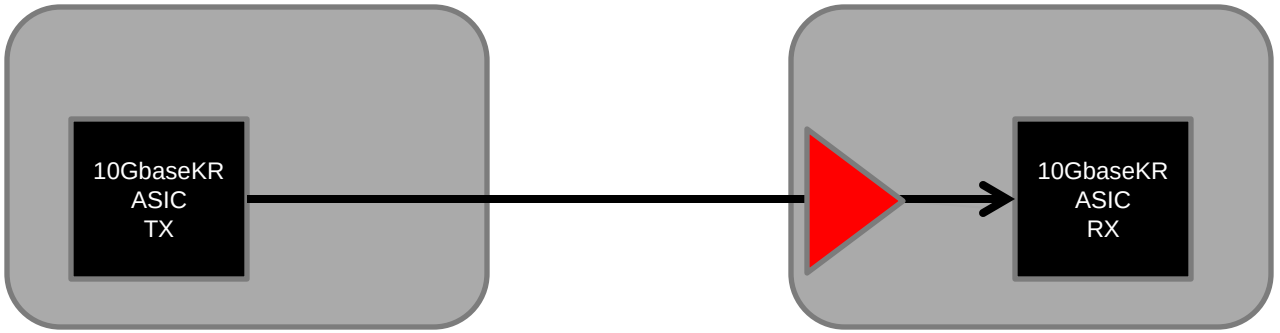
Active Copper Cables

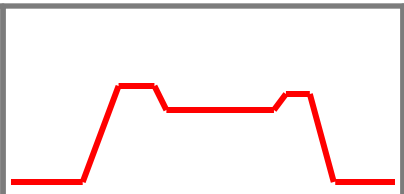
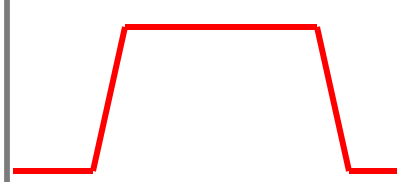
QSFP : 20m, $3X,440mW

Active Optical Cables (AOC)

QSFP : 100m, $6X, 1000mW+

3 10G Base KR link training optimizes system level signal performance and power between TX and RX ASICS.

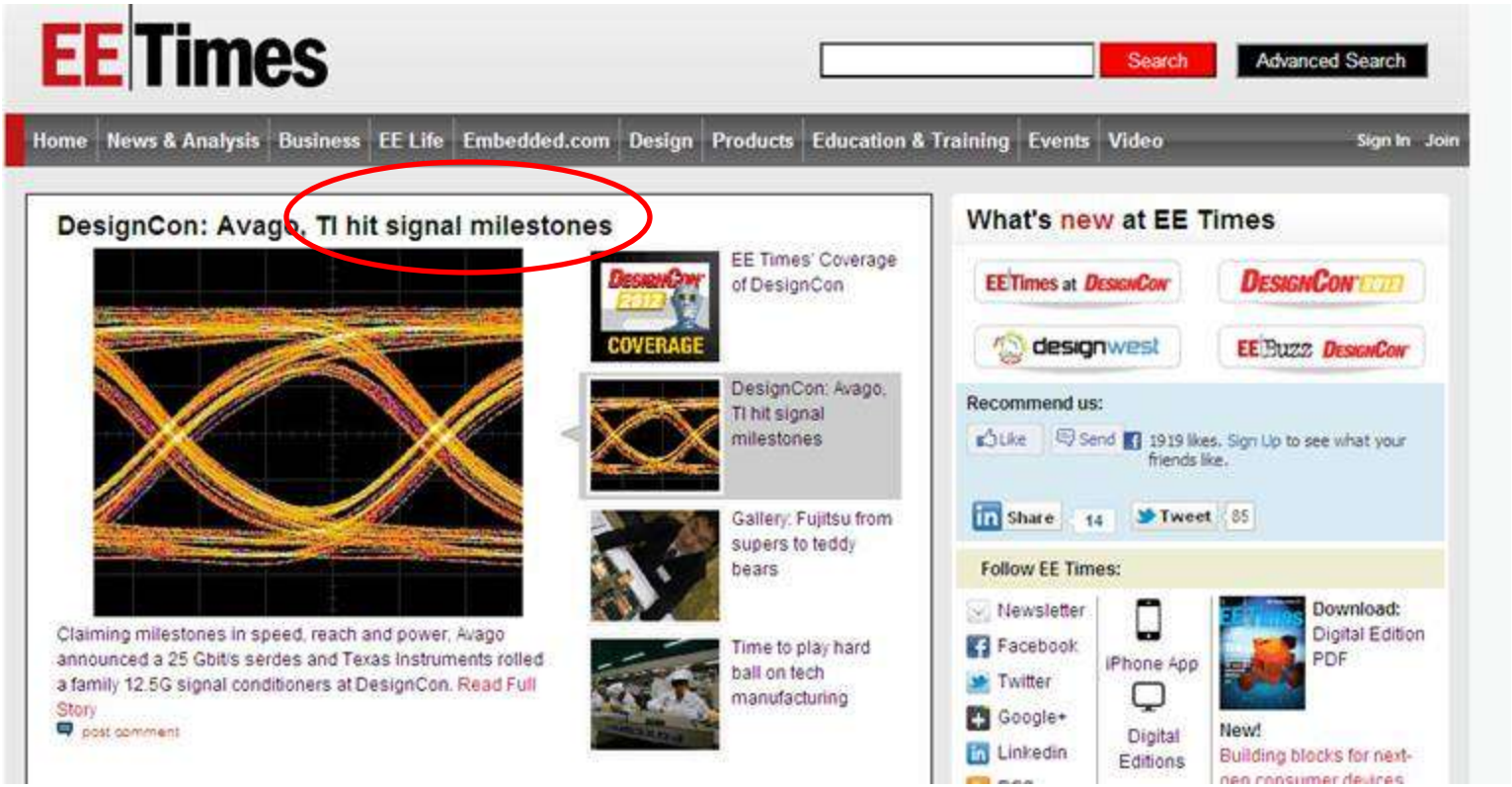


Passive (PowerSaver)			• Passes Link Training • Low Power • Attenuation impact
Limiting Stage			• Impacts Link Training
Linear Stage			• Passes Link Training • Preserves waveshape • Preserves Amplitude

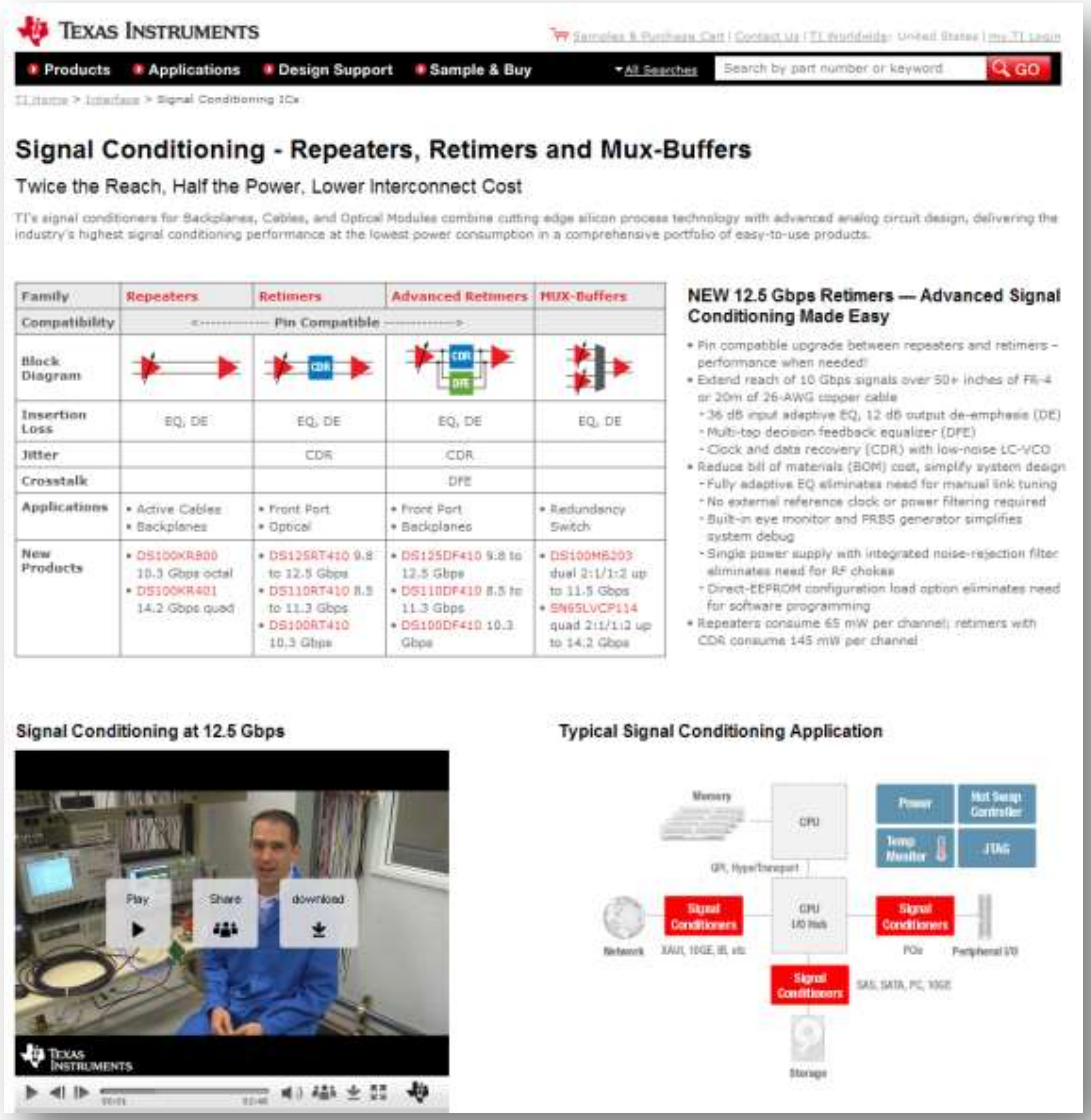
Summary

Subhead text here

TI Sigcon in the NEWS! (JAN 31, 2012)



www.ti.com/sigcon



NEW SigCon Feature Site!

- Highlights
- Selection Tables
- Video Features / Demos
- System Block Diagrams
- Tools
- Applications Notes
- Design Guides

Thank You for attending!

APPENDIX

Appendix

時間が余ったときに使用します。

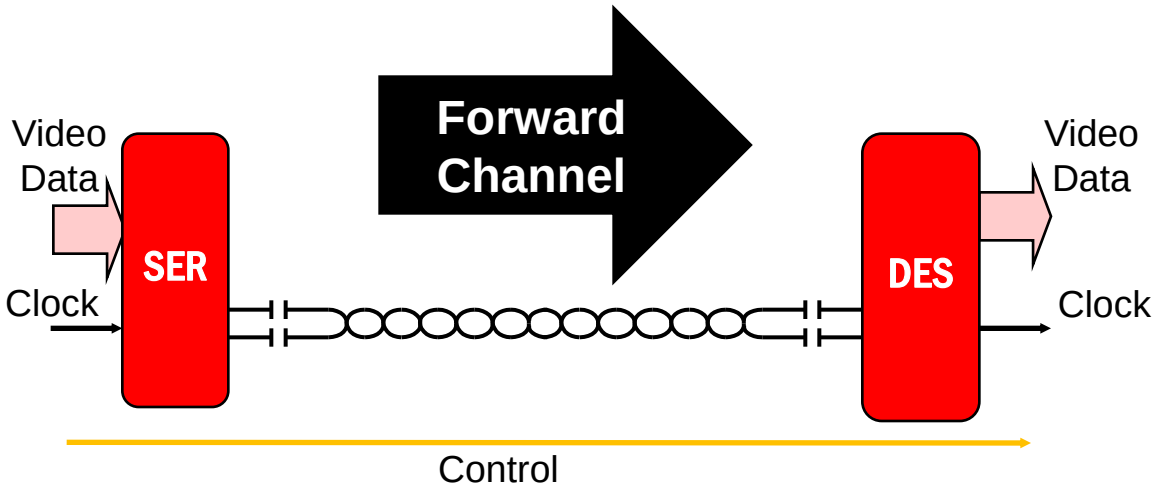
4 What is the easiest way to reduce pins, cable bulk, interconnect cost, and GO FAR?

USE TI's Channel Link II Ser/Des

System Benefits

- **Reduces Wide Data bus and clock to one pair**
- **Extends interconnect length**
  - **Eliminates clock/data skew issues**
- **SigCon Features for Link extending**
  - **TX Equalization**
  - **RX Equalization**

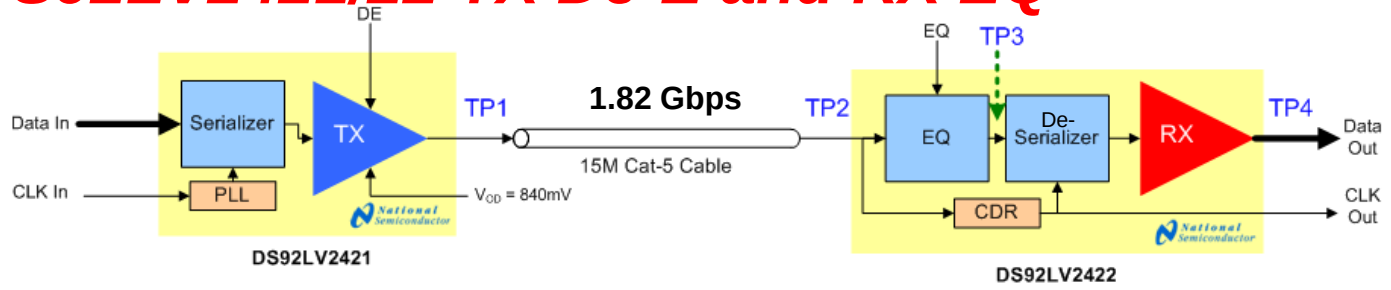
Block Diagram

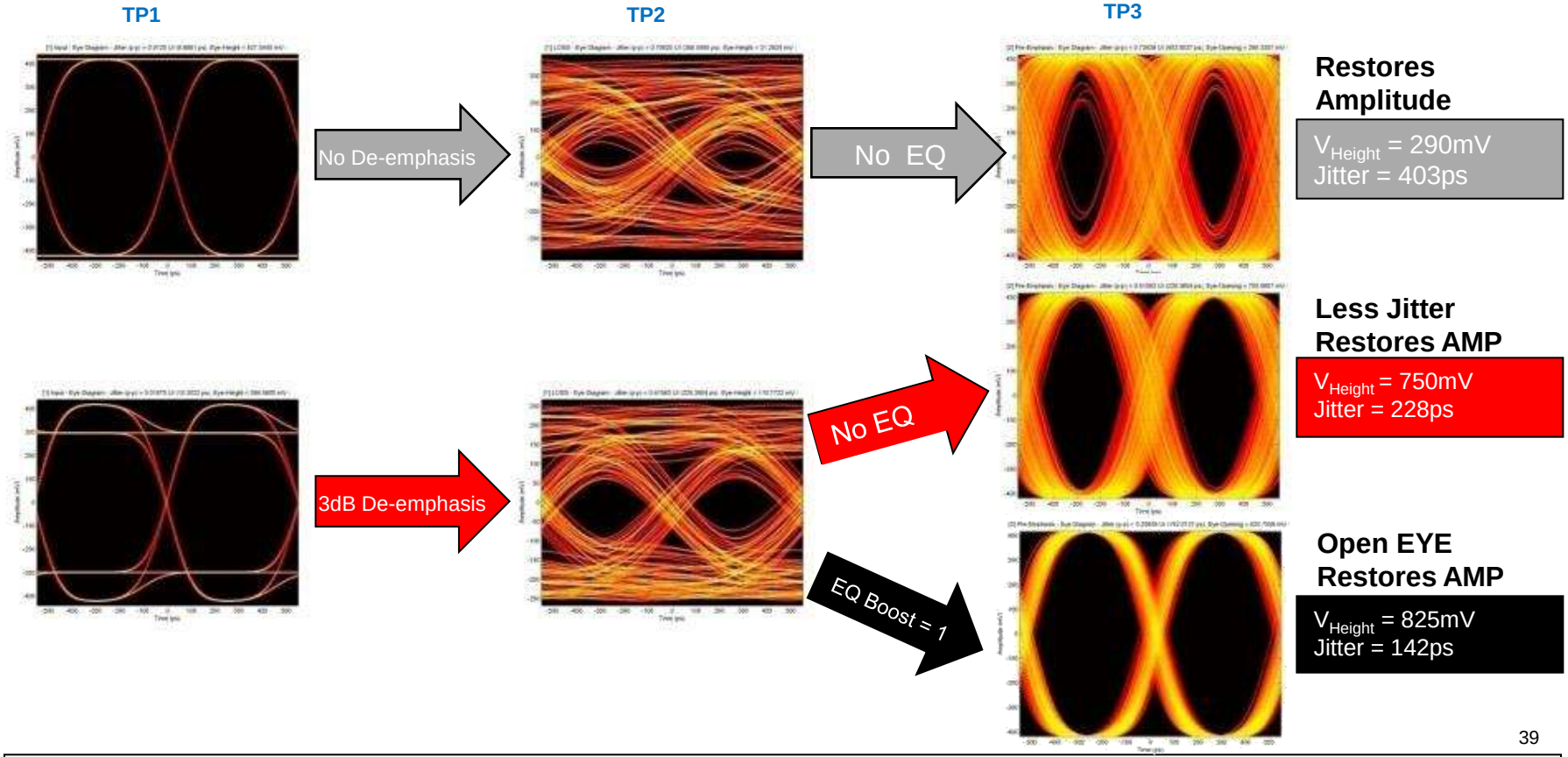


Data and Embedded Clock use a single pair of wires!

4 Channel Link II Signal Conditioning

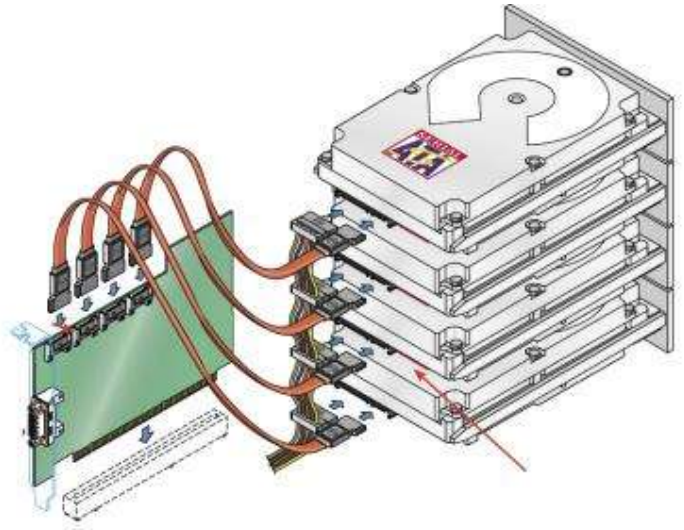
DS92LV2421/22 TX De-E and RX EQ

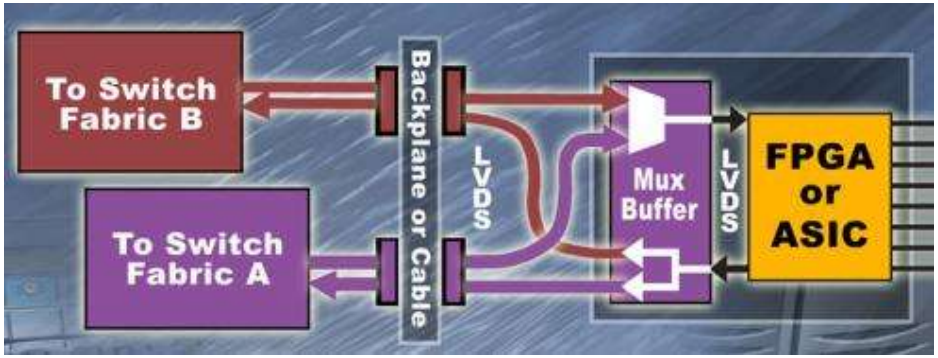




5 How do I get a high speed signal to <u>two</u> places?

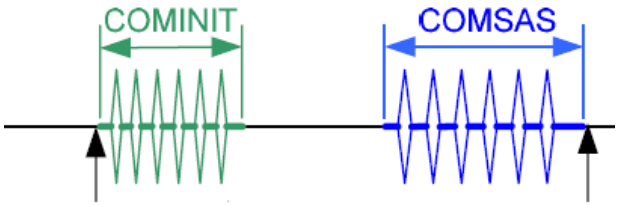
- Multi-drop, Multi-Point usually **limited** to <500 Mbps due to T-Line effects
- Point-to-Point Links are **best** for Signal Integrity when every ps matters!
- Desirable for many applications:
  - Redundancy
  - Fail Over
  - Front / Back Panel Options
- **MUX Buffers provide a 1:2 FANOUT and 2:1 SELECT function**





5 Storage: SAS / SATA

- **SAS 1.0 (3 Gbps), SAS 2.0 (6 Gbps)**
  - Primary target : Enterprise storage
  - Supports multiple initiators
  - Target length 8 meters of cable OR 30” FR4
- **SATA – 6 Gbps, 3 Gbps, 1.5 Gbps**
  - Primary target : Consumer storage
  - Target media length 1 meters of cable
  - eSATA (External SATA) supports 2 meter of cable
- **Both define OOB (Out-of-band) signaling**
  - OOB signal is a pattern of idle times and burst times
    - Idle time : Differential 0 V, No transitions (DC idle)
    - Burst time : Transmitted as a burst of ALIGN(0) primitives
  - Length of idle time distinguishes between OOB signal: COMINIT, COMWAKE, and COMSAS



Serial Attached SCSI

SERIAL ATA

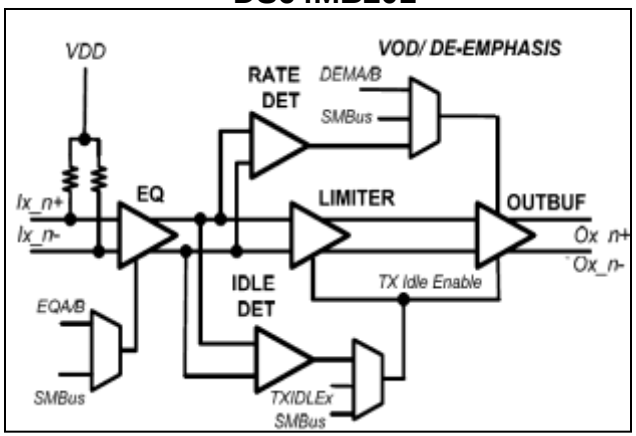
- Server storage applications:
  - HBA (Host Bus Adapters), servers, storage racks, switches and routers
  - RAID (Redundant Array of Individual Disks) devices/JBODs (Just a Bunch of Disks)

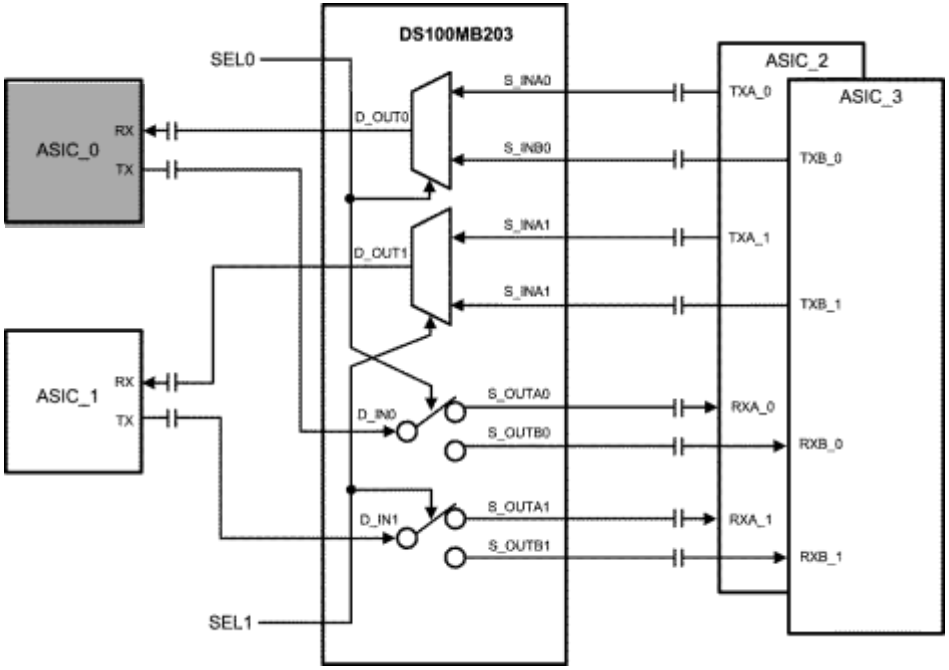
REDRIVERS cannot block Protocol features!

- Link Training
- OBB
- Idle
- LFPS

5 MUX Buffer Magic

DS64MB201

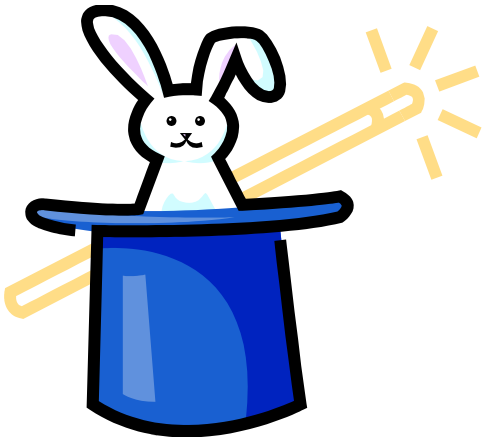




- Signal conditioning on both input and output stages for maximum flexibility in physical placement
- Implement system redundancy with 2:1 Multiplex or 1:2 Fan-out option
- Extend reach on back-plane or cable for SATA/SAS/XAUI/ RXAUI/Infiniband etc.
- **DS64MB201 for SATA/SAS and 6Gbps applications**
- **DS100MB203 for KR and 10GE 10Gbps applications**

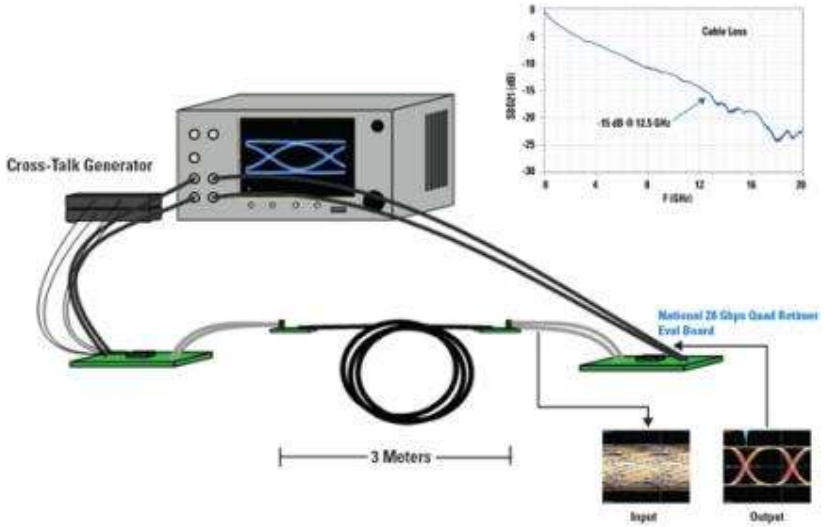
Are 25/28 Gbps copper Interface even possible?

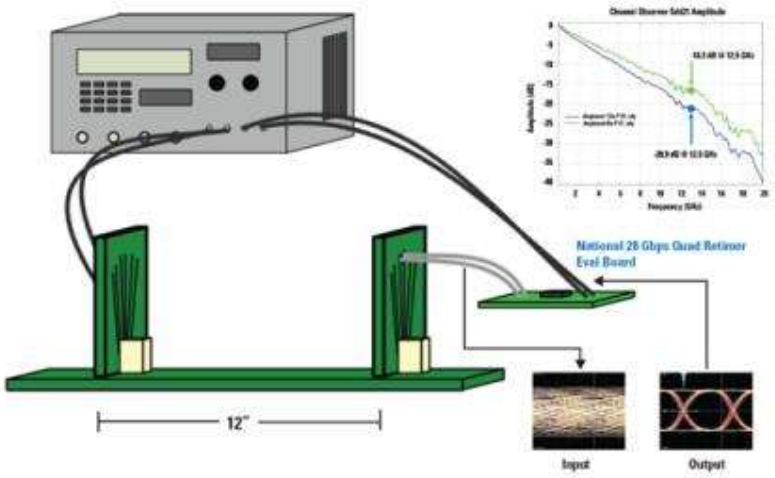
- **YES – with TI's BiCMOS 13 Process Technology**
- **100GE Applications** –
  - Quad 25G Electrical
  - Quad 28G Electrical (adds overhead for FEC, etc.)
- An alternative to Optical (power, post, ease of connections)
- **Challenges**:
  - Edge rate required
  - Open EYE
  - Unit Interval of 40ps to 35.7ps!
  - Interconnect Losses
  - Signal to Noise
  - EMI



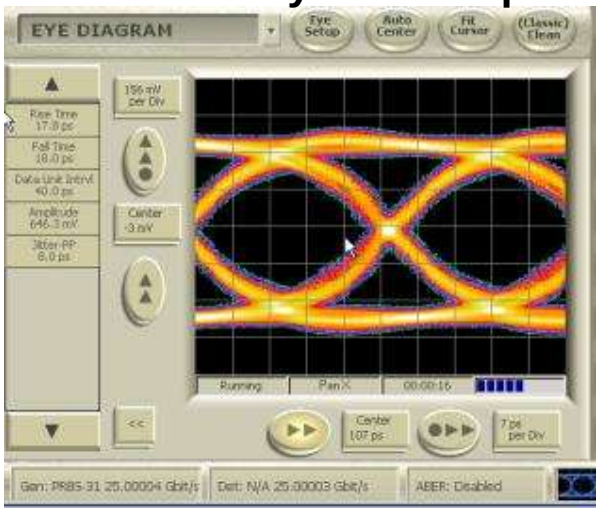
25 Gbps Retimers

5m Cable & 20” Backplane Performance

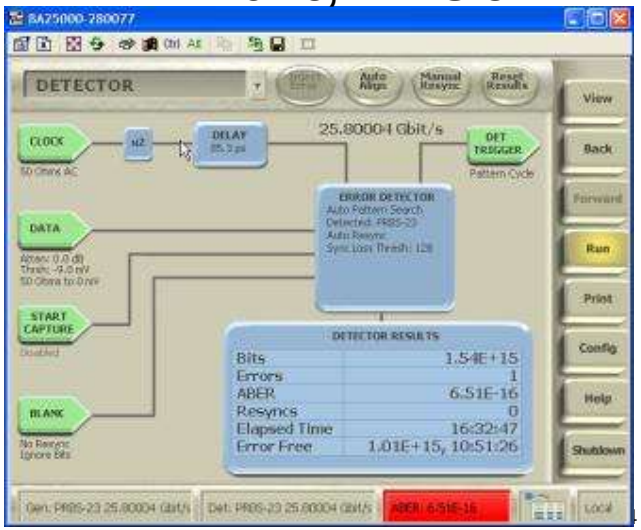




Recovered Eye – 25 Gbps

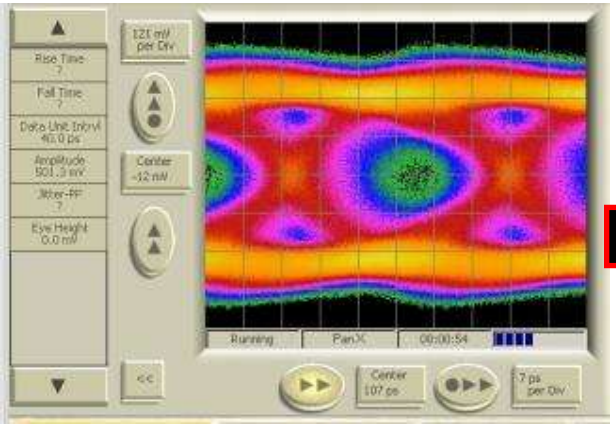


BER < 1e-15, PRBS-31

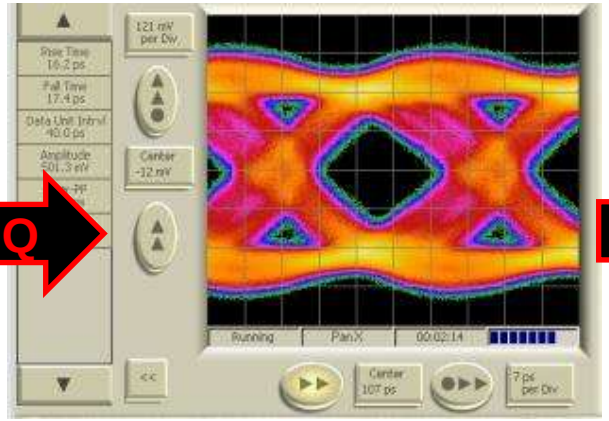


6 25G is real today

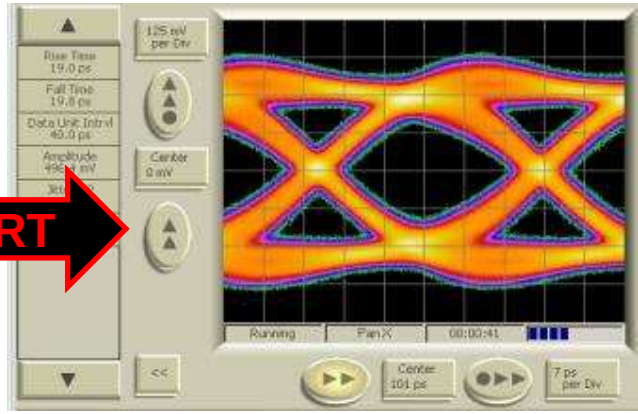
with TI's BiCMOS13 >100GHz process



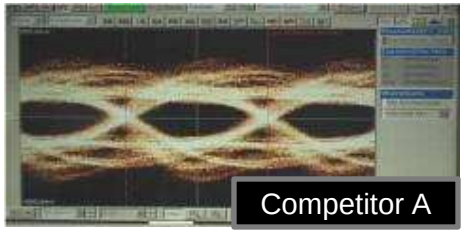
Un-equalized data after a 7.5inch stripline and 2 meters of cable at 25Gbps

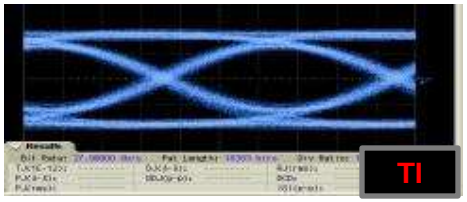


Equalized data after a 7.5inch stripline and 2 meters of cable at 25Gbps

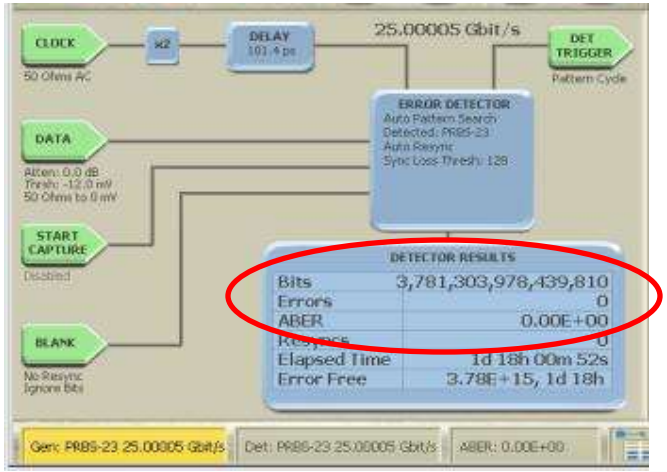


Re-timed data after a 7.5inch stripline and 2 meters of cable at 25G





- **25/28 Gbps**
- **Advanced SigCon**
- **Low Power**
- **OPEN EYE**
- **Zero Error**



Zero BER after 1day and 18Hrs

3.7 Peta-bits !

Texas Instruments