SILICON-TO-SILICON SYSTEM OPTIMIZATION

SIGNAL INTEGRITY DESIGN GUIDE 2016

SILICON-TO-SILICON SYSTEM OPTIMIZATION

Increasing data rates, denser systems and shrinking product footprints challenge designers to meet their system signal integrity needs. Samtec's Silicon-to-Silicon capabilities provide engineers the service, products, tools and resources to optimize the entire signal chain of a system, from bare die to IC package and assembly, to PCB, to connectors and cable assemblies, and back again.

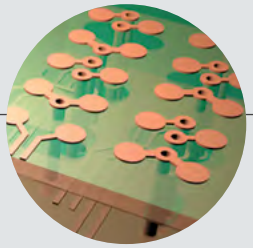
- Support for IC layout designers helps optimize power and signal integrity of bare die during IC design process
- Development of complex, customized IC packaging and assembly solutions enables maximum IC density, precision and ruggedness
- Factory and field-based technical support ensures ideal signal chain optimization, enabling PCB designers to create denser, faster PCBs
- Products, tools, design expertise and consulting services link high-speed signal chains between PCBs and through backplanes
- Engineering of industry standard and customized copper and optical cable assemblies at data rates up to 28 Gbps and beyond

To meet the interconnect challenges of tomorrow and beyond, Samtec has developed advanced Technology Centers dedicated to developing and advancing technologies, strategies and products designed to optimize both the performance and cost of a system. These complementary, cross-functional groups leverage their respective areas of expertise and experience to ensure complete system optimization - from **Silicon-to-Silicon**.

TECHNOLOGY CENTERS | INTEGRATION = INNOVATION

ADVANCED INTERCONNECT DESIGN

High precision stamping, plating, molding, and automated assembly for fine pitch and array interconnects used for board-to-board, interposers, micro backplane, and high-speed / high-density cable assemblies.

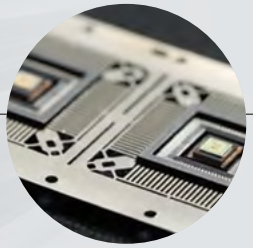


SIGNAL INTEGRITY GROUP

In-house signal integrity expertise for complex applications, with live EE support available 24/7 worldwide. Advanced design support, including Differential Vias™ and routing recommendations using Tri-Planar™ trace technology.

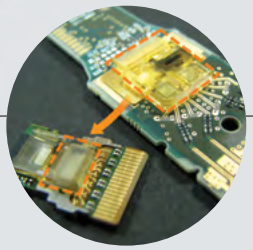
HIGH-SPEED CABLE PLANT

R&D and manufacturing of precision extruded micro coax and twinax cable used for high-speed, high-density cable assemblies, including 26-38 AWG, 50/75/85/100 Ω impedance, and systems rated at 28 Gbps and beyond.



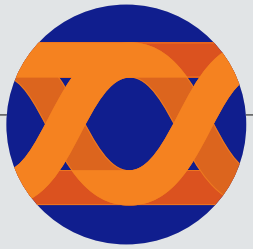
SAMTEC MICROELECTRONICS GROUP

Advanced IC packaging: precision die attach, fine pitch and low profile wire bond, flip chip, underfill and stacked die. Complete IC-to-Board design, support and manufacturing of IC packaging, substrates, micro high-density interposers, and micro optical engines.



SAMTEC OPTICAL GROUP

Engineering team dedicated to the design, development, and application support of high performance micro optical engines, active optical assemblies, and high-density ganged passive optical panel solutions.

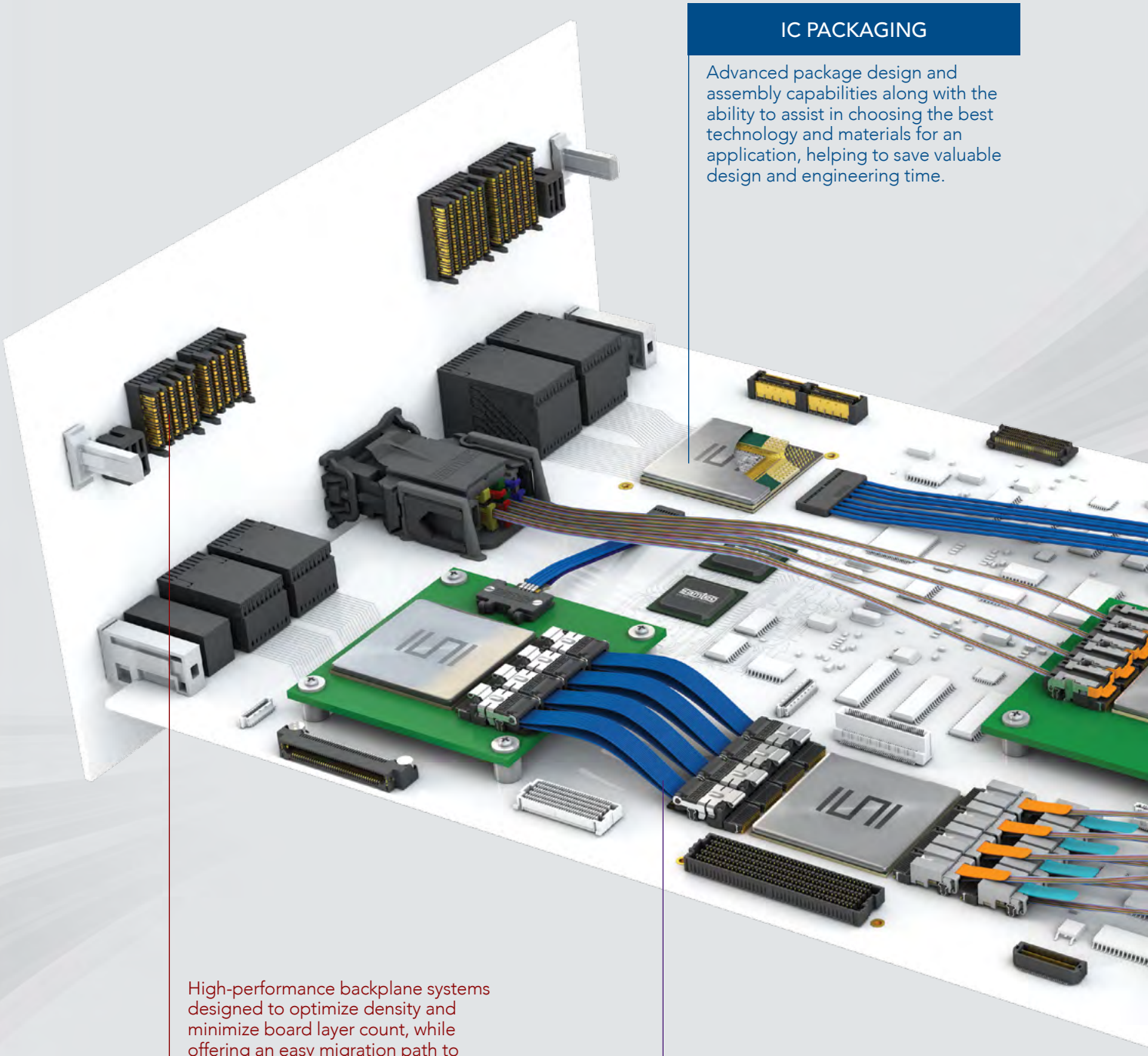


TERASPEED® CONSULTING

Signal integrity services team providing complete system design, full channel signal and power integrity analysis and modeling, thermal management, and signal integrity-optimized advanced IC packaging for 28 Gbps and beyond.

IC PACKAGING

Advanced package design and assembly capabilities along with the ability to assist in choosing the best technology and materials for an application, helping to save valuable design and engineering time.

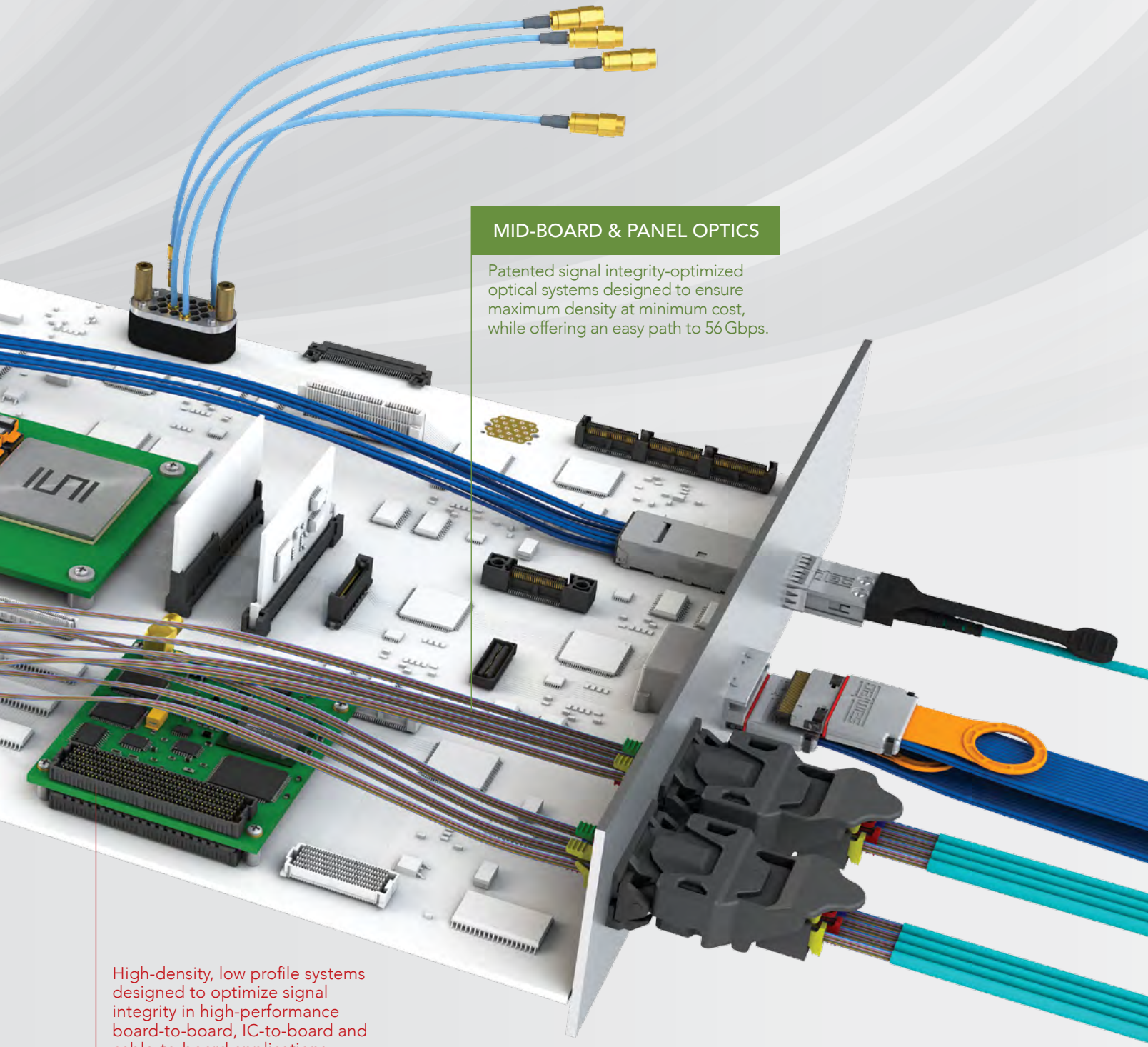


High-performance backplane systems designed to optimize density and minimize board layer count, while offering an easy migration path to 56 Gbps performance.

HIGH-SPEED BACKPLANE

Ultra high-performance cable systems engineered to extend signal reach and performance by routing high-speed signals via ultra low skew twinax cable rather than through the PCB.

TWINAX FLYOVER



MID-BOARD & PANEL OPTICS

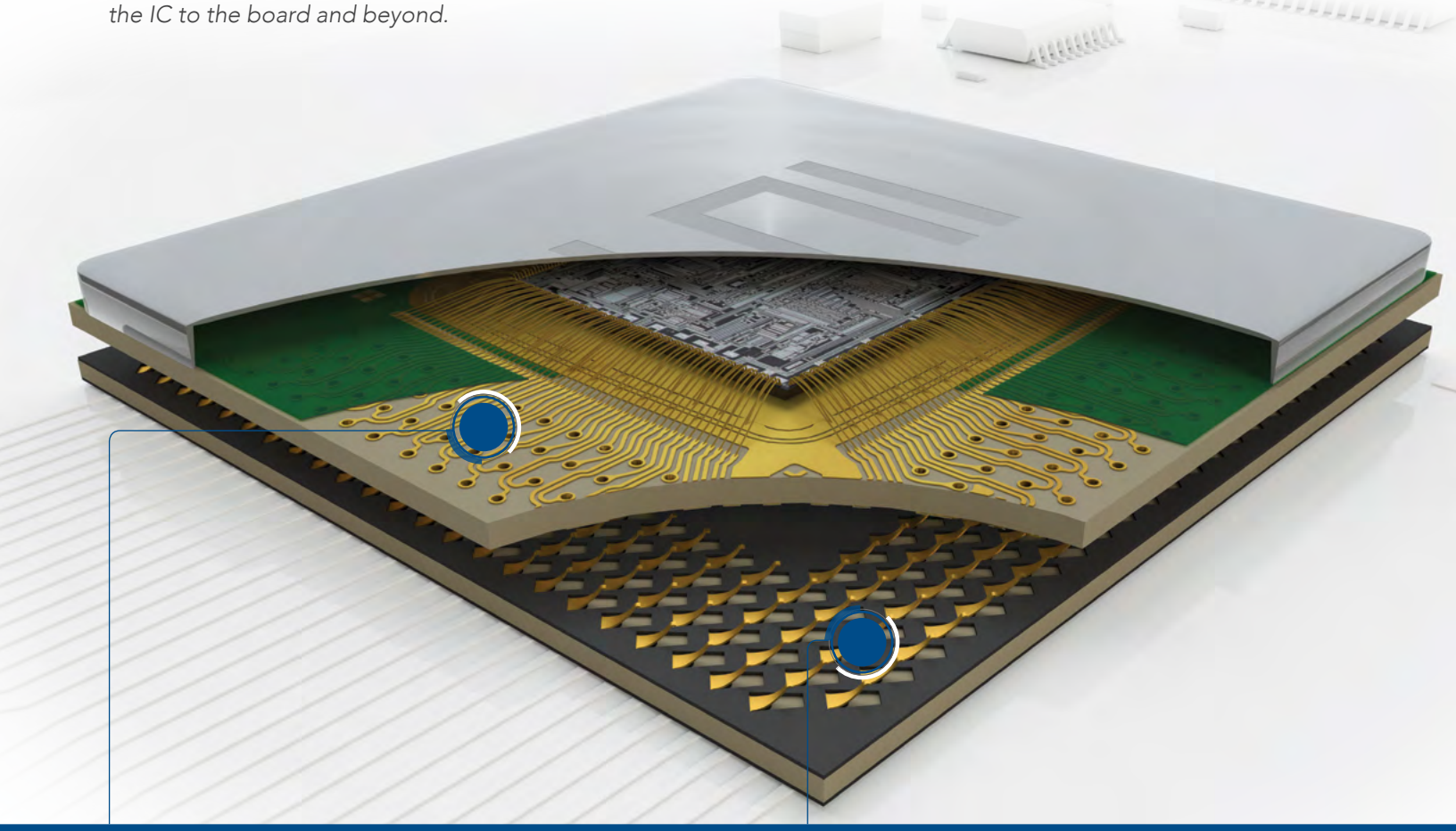
Patented signal integrity-optimized optical systems designed to ensure maximum density at minimum cost, while offering an easy path to 56 Gbps.

High-density, low profile systems designed to optimize signal integrity in high-performance board-to-board, IC-to-board and cable-to-board applications.

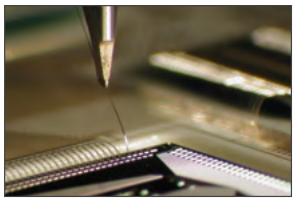
HIGH-SPEED MEZZANINE

IC PACKAGING
SYSTEM OPTIMIZATION

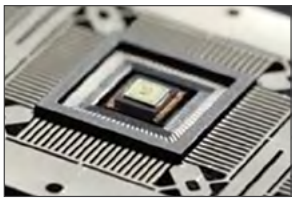
A unique blend of unmatched high-performance interconnect, Signal Integrity and IC Packaging expertise positions Samtec to provide full channel system support, effectively streamlining, and thereby optimizing, the signal path - from the IC to the board and beyond.



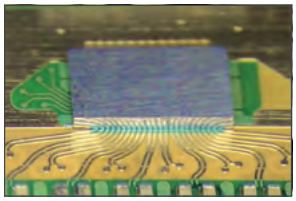
SAMTEC MICROELECTRONICS GROUP
Advanced IC packaging expertise and capabilities



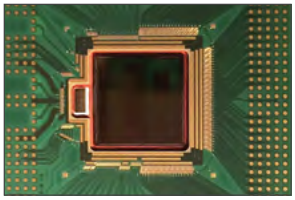
Ultra-fine pitch, ultra-low profile ball bond and wedge bond



Stacked die and multi-chip module design + manufacturing expertise



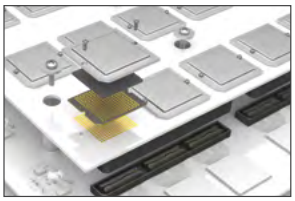
Flip chip accuracy to +/- 3 microns; capillary and jet underfill



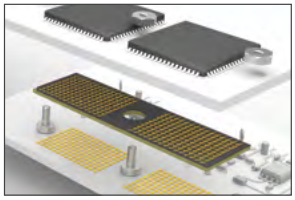
High-speed, high accuracy die placement (to +/- 3 microns)

ADVANCED INTERCONNECT DESIGN
Interconnect systems designed for IC-to-Board applications

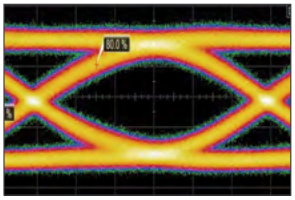
In-house IC, optics + interconnect manufacturing for design flexibility



Cost-saving design strategies and product solutions



Highly customizable micro interposers optimize IC-to-Board applications



Interconnect + IC expertise ensures full system optimization

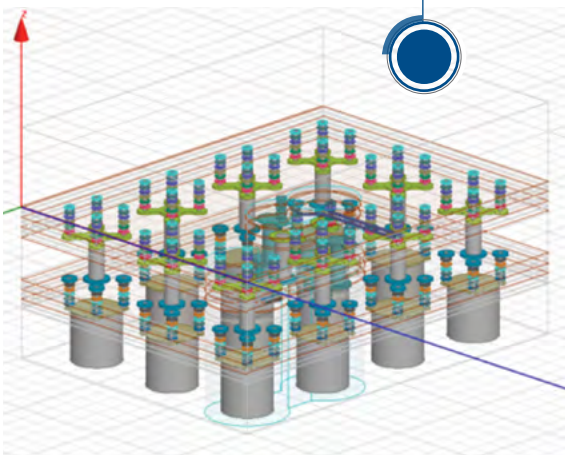
IC PACKAGING: PRACTICAL APPLICATIONS

Advanced semiconductor packaging design and analysis expertise enables IC application optimization

Samtec provides assistance in advanced IC package design, including structural analysis, signal and power integrity optimization, thermal management and material characterization.

Samtec Microelectronics Group and Teraspeed® Consulting offer development partnerships for the entire product life cycle, including complete program support from concept through the design phase, into small prototype builds, through to full production.

- Packaging engineers work directly with customers to resolve packaging needs, providing design and application assistance
- Signal integrity and power integrity design
- Temperature rise and distribution analysis and modeling
- IR thermography, thermal characterization and performance testing
- Package characterization, high-speed modeling and simulation
- Fully custom, advanced IC package and substrate design
- Expertise in designs operating at 56 Gbps, as well as up to 100 Gbps, provides for complete high-speed designs without complex and expensive redesigns
- Full electrical modeling of the signal chain from the die, into the substrate, through the package, and into the board
- Materials expertise and relationships with suppliers specializing in qualified and cutting-edge materials for solutions to unique design challenges



Novel differential SerDes package design cell developed with the IC packaging and signal integrity expertise of the engineers at Teraspeed® Consulting.

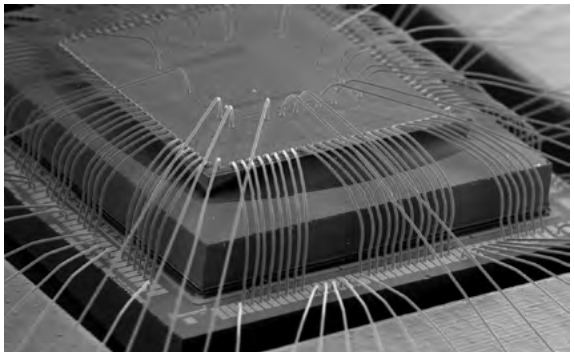
Visit SamtecMicroelectronics.com or email SME@samtec.com for more information.

CUSTOM 3D PACKAGING APPLICATIONS

Samtec Microelectronics Group has experience with the necessary processes to ensure a thinner, more space efficient package by incorporating 2.5D and 3D package technologies.

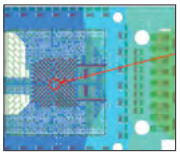
- Die and wafers handling down to 20 µm
- Wire bonding to complex overhanging die
- Low loop wire bonding
- Mixed technology, flip chip and wirebond, die stacking
- Flow over wire materials

Contact SME@samtec.com to discuss your application.

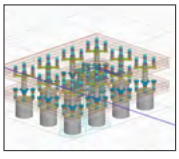


Samtec provides the highest level of engineering support for even the most complex applications.

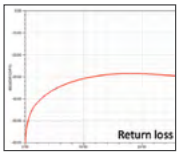
REFERENCE + SUPPORT DATA | APPENDIX A, p. 26



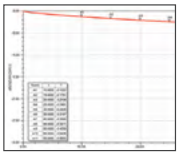
POWER DELIVERY ANALYSIS
(Appendix A, p. 26, Fig. A1)



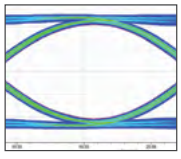
SERDES PACKAGE CELL MODELING
(Appendix A, p. 26, Fig. A2)



RETURN LOSS MEASUREMENTS
(Appendix A, p. 26, Fig. A3)



FLAT INSERTION LOSS TO 56 GHz
(Appendix A, p. 26, Fig. A4)



EYE OF PACKAGE TRACE
(Appendix A, p. 26, Fig. A5)

SAMTEC.COM

ADVANCED IC PACKAGING

Samtec Microelectronics Group has an extensive offering of advanced package design and assembly capabilities as well as the ability to assist in choosing the best technology and materials for your specific application, helping to save valuable design and engineering time.

COMPLEX PACKAGE ASSEMBLY

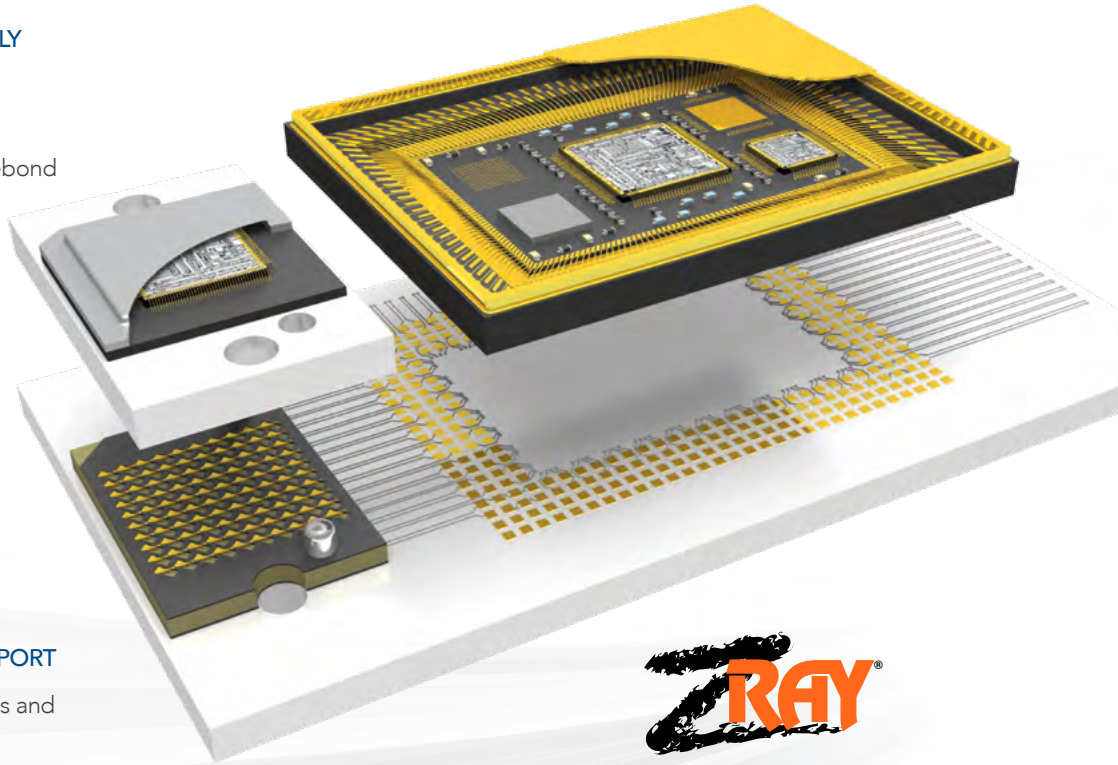
- Flip chip and underfill
- Precision die attach
- Low profile and fine pitch wirebond
- Dam, encapsulation and lid attach
- Stacked and custom die

SUBSTRATE DESIGN & MANUFACTURING

- PCB design with signal integrity support
- Integration of interposers with substrates
- Multi-chip modules
- Ceramics and organics

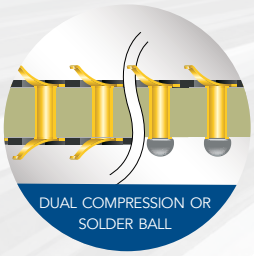
ADVANCED PACKAGING SUPPORT

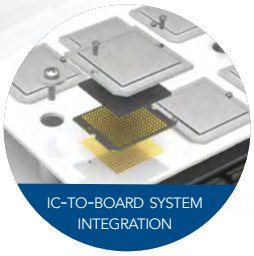
- SI-enabled layouts for 28 Gbps and 56 Gbps systems
- Advanced design of OC-48, XAUI and OC-192 packages operating at speeds to 40 Gbps
- Package characterization, I/O buffer sizing and design kits



Z-RAY® ULTRA LOW PROFILE INTERPOSERS

- Ideal for board-to-board, cable-to-board and complex IC-to-board applications
- Dual compression BeCu contacts
- One piece design on 0.80 mm or 1.00 mm pitch grid
- High speed performance up to 28 Gbps and 56 Gbps with a migration path to 100 Gbps
- Low profile 1 mm body height
- Low 25 g normal force with .008" (0.20 mm) contact deflection
- Ultra flexible, with a variety of standard and custom configurations, including dual compression, solder ball and an array of sizes and shapes





ZA8/ZA8H Series	ZA1/ZA1H Series	Custom Capabilities
0.80 mm pitch	1.00 mm pitch	> 0.80 mm
1 mm stack height		0.30 mm to 4 mm stack heights
100 - 400 pins		3,000+ pins
Screw Down Holes, Alignment Holes		
Performance to 28 Gbps (ZAX Series) / 56 Gbps (ZAXH Series)		Latches, Thermal Spreaders, Quick-Release Spring Constraints
Single Layer FR4		Multi-layer FR4 (e.g., Pitch Spreaders)

INDUSTRY-SPECIFIC APPLICATIONS

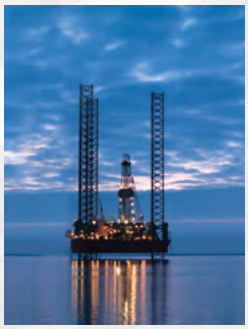
Aerospace, Military and Space

- Robust, high-reliability solutions
- AS9100 certification in process
- ITAR compliant
- Hermetic sealing
- Durable packages, custom footprints and lids
- Package design shrink (additional function in a significantly smaller footprint)

Broadcast Video

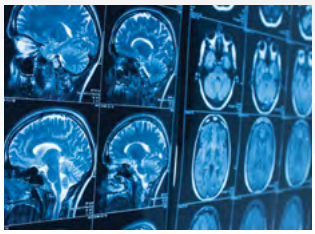
- Package design shrink (small package and/or footprint requirements)
- MEMS integration
- Custom lids
- High end projectors
- Contained signal integrity for higher performance (smaller trace lengths, less expensive PCB materials, lower layer count boards)

Oil and Gas Markets



- Downhole rigging, pipe inspection robots
- High temperature range products
- Custom packages
- Hermetic sealing with lids
- Package design shrink (small package and/or footprint requirements)

Medical, Healthcare & Industrial Sensors

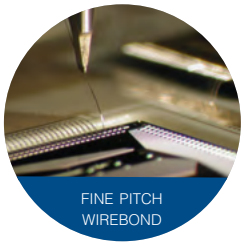


- Small handheld devices and implantable products requiring custom packaging (e.g. endoscopes, ocular implants, etc.)
- Throw-away applications
- Hermetic sealing
- Package design shrink (small package and/or footprint requirements)
- MEMS integration
- Custom lids and mounts (optics, fluidics, etc.)

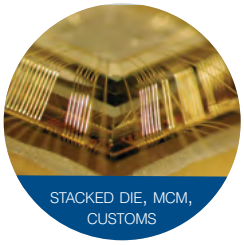
IN-HOUSE EXPERTISE | COMPLEX PACKAGE ASSEMBLY

In-house R&D and manufacturing

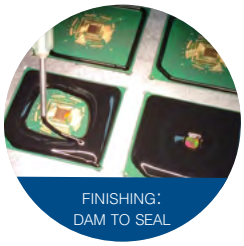
Custom designs for organics, ceramics, silicon, etc.



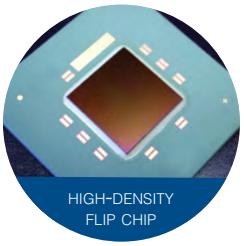
Ultra-fine pitch, ultra-low profile ball bond and wedge bond



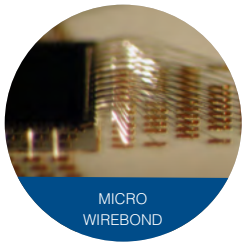
Ultra low loops (<1.5x dia); cantilevered die stacks



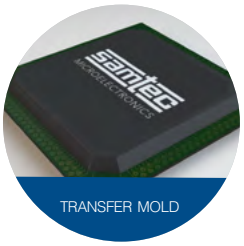
Encapsulation, laser/ink marking, lid attach and hermetic sealing



Bumps down to 25 µm diameter on 50 µm pitch with 350 µm die spacing



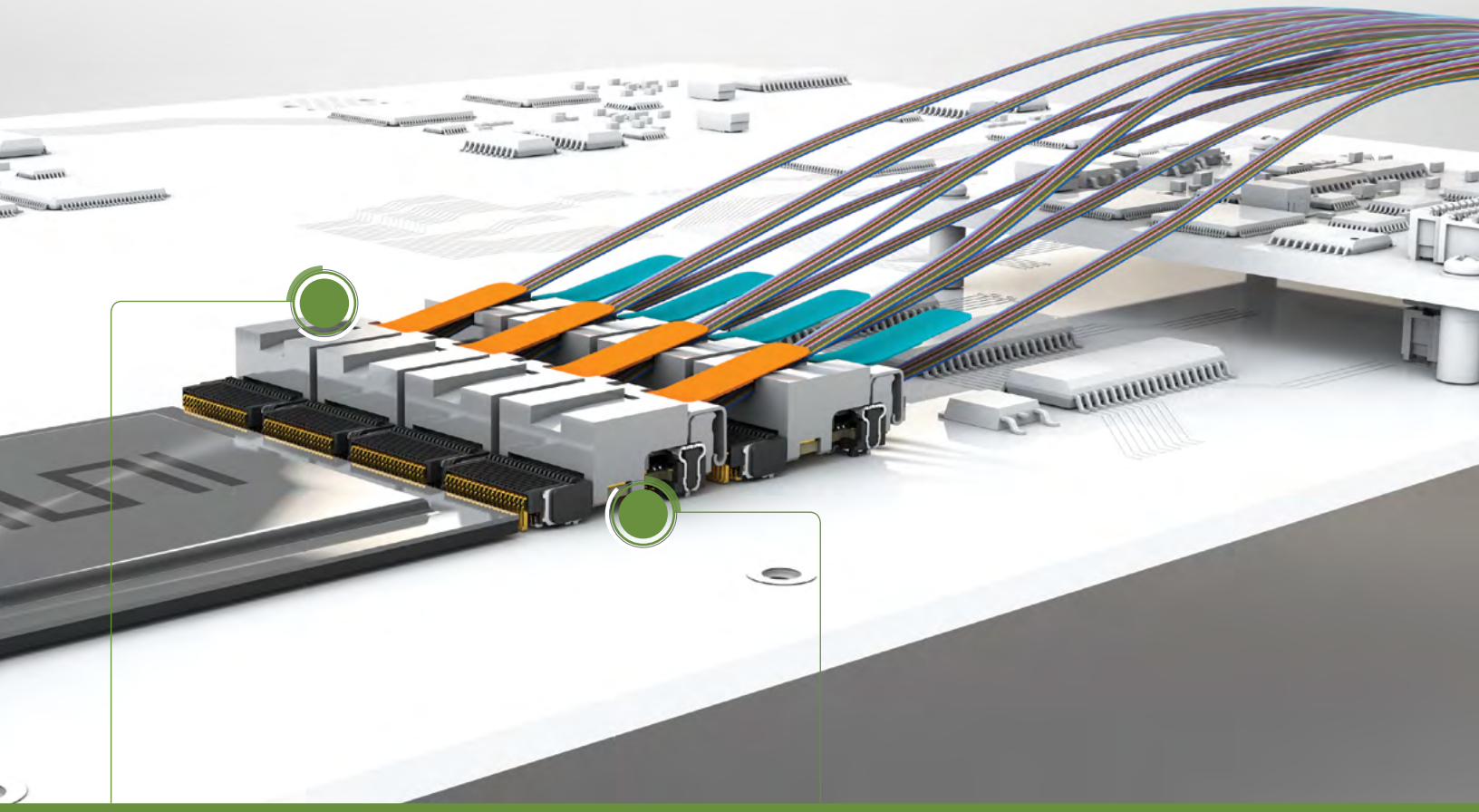
Pitches down to 25 µm on 20 µm pad with complex multi-tiered wirebonds



Capabilities to support a variety of order volumes and cost-levels

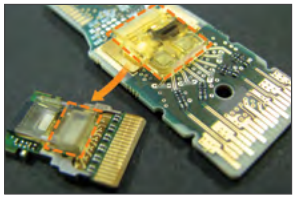
MID-BOARD + PANEL OPTICS
SYSTEM OPTIMIZATION

Samtec's optical and signal integrity expertise enables systems designed to ensure maximum density, cost and performance optimization, while offering an easy path to 56 Gbps and beyond.

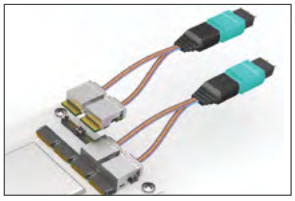


SAMTEC OPTICAL GROUP
Advanced design, development and application support

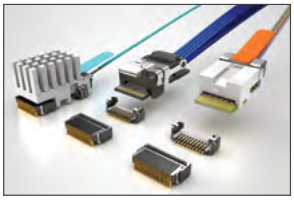
ADVANCED INTERCONNECT DESIGN
Future-proof designs for today's data rates and beyond



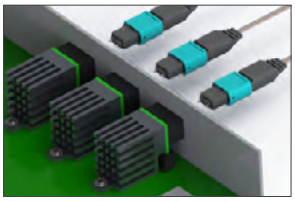
High-performance micro optical engine design + manufacturing



Integration of advanced products with patented technologies

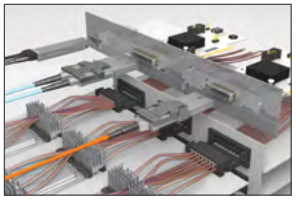


Future-proof connector designs offer easy migration path to 56+ Gbps

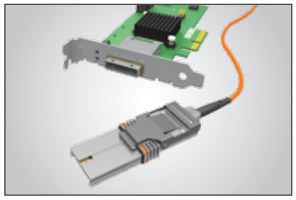


Innovative solutions for optical applications

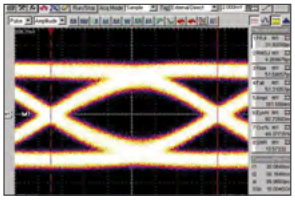
Application-specific solutions for high-performance systems



Active optical assemblies + high-density ganged passive systems



Support for industry-standard optical systems



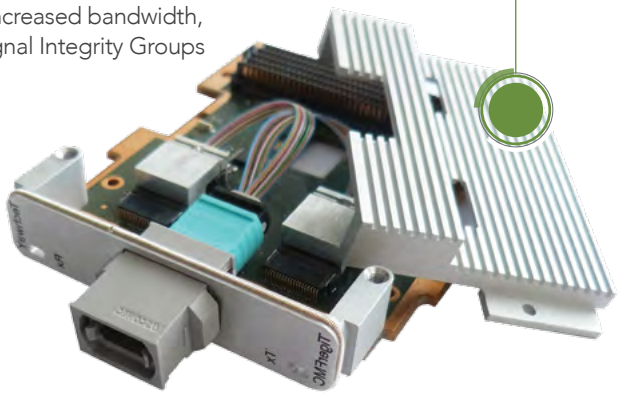
Full system Signal / Power Integrity analysis and design

OPTICAL SOLUTIONS FOR HIGH-PERFORMANCE MID-BOARD SYSTEMS

Samtec provides full channel support for growing demands for increased bandwidth, performance and density, via the expertise of our Optical and Signal Integrity Groups and Teraspeed® Consulting, including:

- In-house optics design, engineering and application expertise and support
- Full channel and electrical-to-optical simulation, signal integrity and connectivity analysis
- High-speed routing and layout assistance, including breakout region recommendations to streamline the design process
- Extensive test and measurement capabilities
- Power delivery / power integrity expertise
- Assistance from consulting review to full turn-key design

Contact optics@samtec.com to discuss your specific application.



TechWaY TigerFMC, a VITA 57.1 compliant mezzanine card integrates Samtec's FireFly™ with 10 full duplex, 10 Gbps optical links, for 200 Gbps aggregate bandwidth.

OPTICAL SOLUTIONS FOR ADVANCED + EMBEDDED SYSTEMS

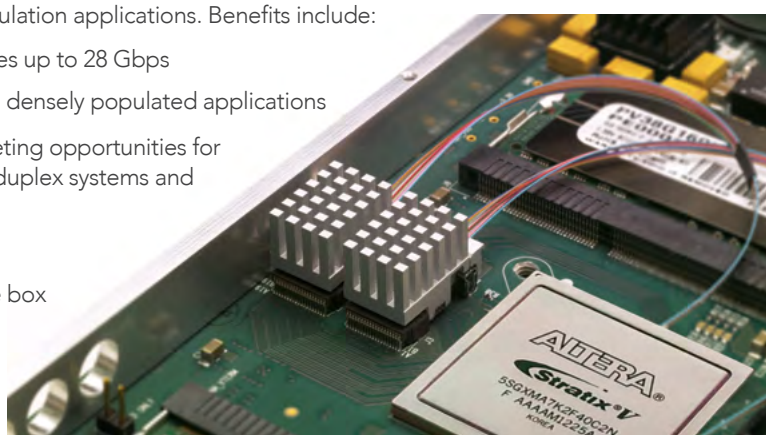
Samtec's FireFly™ optical micro flyover system is a robust solution for the high data rate demands of silicon development, high-performance computing, simulation and emulation applications. Benefits include:

- simplified design and board routing at data rates up to 28 Gbps
- a micro footprint ideal for small form factor and densely populated applications

Samtec also offers co-development and co-marketing opportunities for high data rate systems. FireFly™ x12 simplex and duplex systems and x4 duplex systems have recently been used:

- as a mid-board optics flyover solution
- as a fast-path I/O via MTP® to go outside of the box
- to create embedded optics for rugged environments
- as a flyover optical backplane incorporating a standard VITA 66.4 interconnect solution

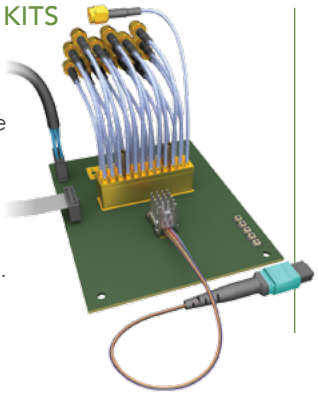
Contact sig@samtec.com to discuss your high-performance application needs.



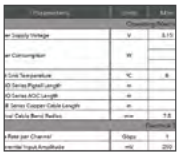
Samtec Optical Group and Teraspeed® Consulting collaboration with Guzik on Guzik's Fiber Optics-to-PCIe® Bridge Card incorporates Samtec's FireFly™ technology, which enables evolving markets to take advantage of the latest optical technology.

FIREFLY™ EVALUATION KITS

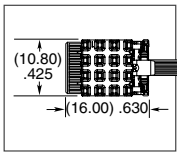
Samtec offers evaluation kits rated up to 28 Gbps, that allow designers real-time evaluation of an actively running FireFly™ system — in your lab, with your inputs. For additional information contact FireFly@samtec.com.



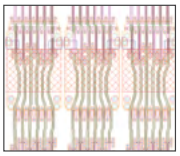
REFERENCE + SUPPORT DATA | APPENDIX B, p. 29



FIREFLY™ OPTICAL SPECIFICATIONS
(Appendix B, p. 29, Fig. B5)



FIREFLY™ MECHANICAL SPECIFICATIONS
(Appendix B, p. 29, Fig. B6)



FIREFLY™ PCB LAYOUT RECOMMENDATIONS
(Appendix B, p. 29, Fig. B7)

MID-BOARD + PANEL OPTICS

Samtec Optical Group provides complete design, engineering and application support for high-performance optical engines, active optical assemblies and high-density ganged passive optical panel solutions. Contact optics@samtec.com for additional details.

MID-BOARD ACTIVE OPTICAL FLYOVERS

- FireFly™ future-proof high-performance micro flyovers
- x4 and x12 simplex or duplex transceiver systems
- 14 Gbps and 28 Gbps (in development) per channel
- Extended temperature system (-40 °C to +85 °C)
- Rugged, easy on-board interconnects
- Variety of standard integrated heat sinks

PCIe® ACTIVE OPTICAL CABLE

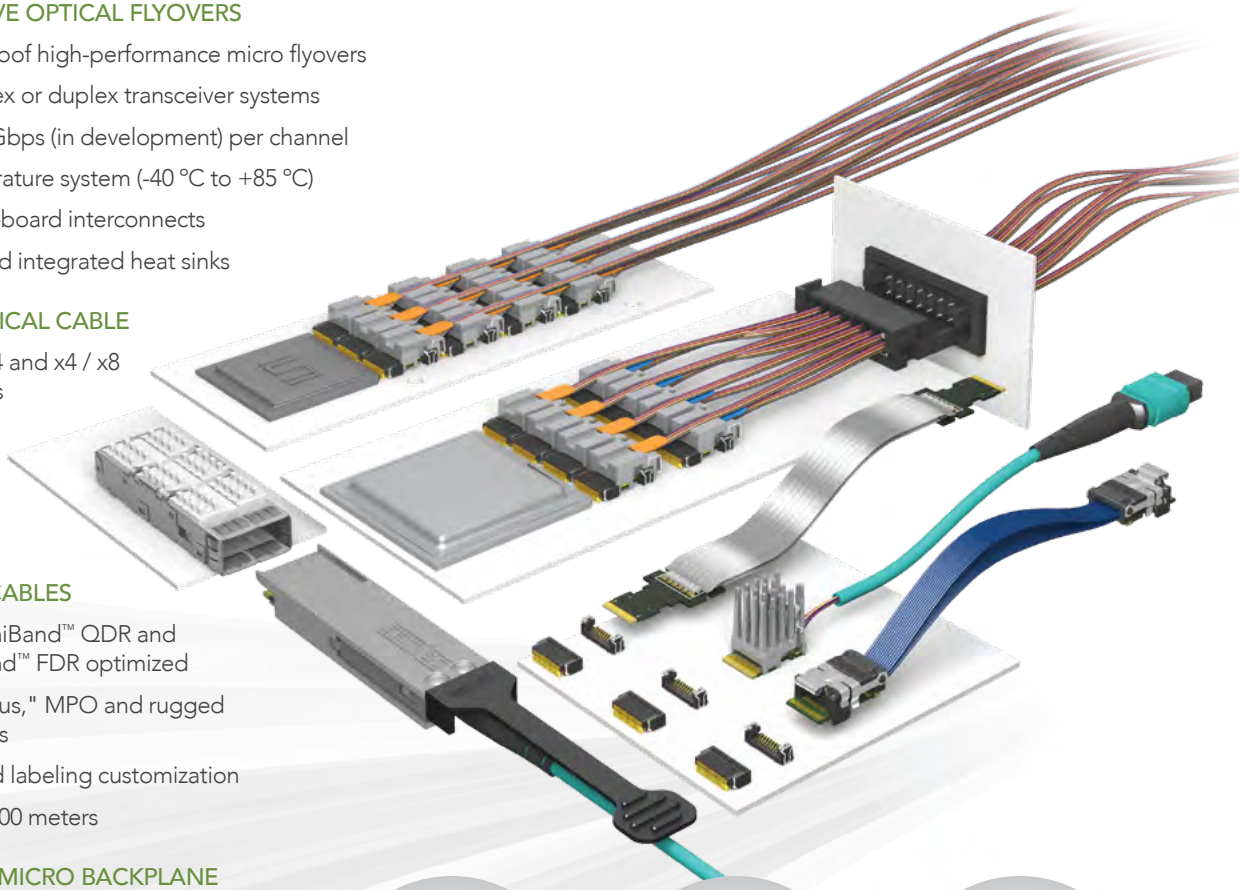
- Gen3 x8, Gen3 x4 and x4 / x8 conversion cables
- Full AOCs and pigtailed cables
- Distances up to 100 meters

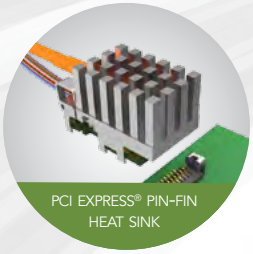
QSFP PIGTAILED CABLES

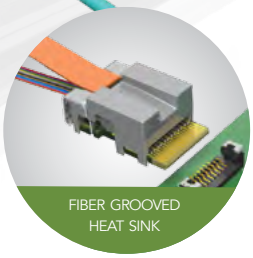
- 40 Gbps and InfiniBand™ QDR and 56 Gbps InfiniBand™ FDR optimized
- Quad LC "Octopus," MPO and rugged connector options
- Memory map and labeling customization
- Distances up to 100 meters

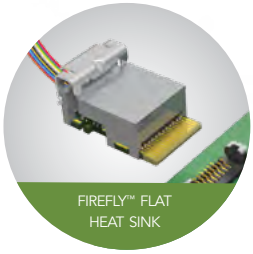
PASSIVE OPTICAL MICRO BACKPLANE

- Ganged MT ferrule optical couplers
- Panel and backplane half AOC terminations to any industry standard passive interface
- MT/MTP®/LC/MXC passive terminations
- Optical patch cable and adaptor system




PCI EXPRESS® PIN-FIN HEAT SINK


FIBER GROOVED HEAT SINK


FIREFLY™ FLAT HEAT SINK

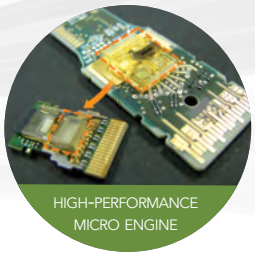
ECUO Series	UEC5/UCC8 Series	PCIEO Series	QSFPO Series
FireFly™ Micro Flyover	FireFly™ Micro Flyover	PCIe®	QSFP+
OM3 Optical Fiber	Two-piece interconnect system	OM2 or OM3 Optical Fiber	OM2 or OM3 Optical Fiber
0.50 mm pitch	UEC5: 0.50 mm pitch UCC8: 0.80 mm pitch	0.80 mm pitch	0.80 mm pitch
28 Gbps	28 Gbps	8 GT/s	56 Gbps
Mates: UEC5/UCC8	Mates: ECUO	Mates: PCIEA	Mates: QSFP8

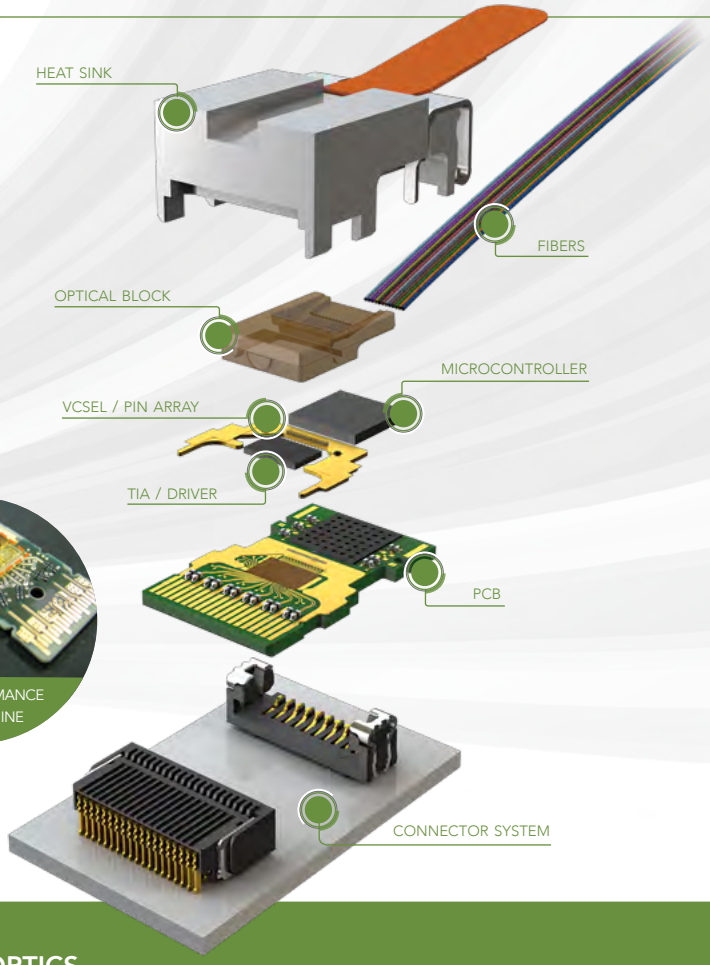
*PCIe® and PCI Express® are registered trademarks of PCI-SIG®. MTP® is a registered trademark and MXC is a trademark of US Conec Ltd.
The UEC5 and UCC8 connectors were designed to work specifically with the FireFly™ flyover system. They were not designed for use with mating cards other than those used with FireFly™. Please see samtec.com/edgecard or contact CustomerEngineeringSupport@samtec.com for other edge card options.

PATENTED OPTICAL ENGINE TECHNOLOGY

- 850 nm VCSEL / PIN technology
  - · Standard compatible with Ethernet, InfiniBand™ and Fibre Channel
  - · Integrated AC coupling capacitors
  - · Industry standard two-wire interface
  - · Class 1 laser output
- x12 simplex or duplex transceiver systems
- x4 simplex and duplex systems also available
- 14 Gbps and 28 Gbps (in development)
- Last step fiber and heat sink attach
  - · Convective and conductive heat sink options
  - · Variety of optical terminations
  - · Custom heat sink and fiber pigtail possible
- FireFly™ qualification criteria: Telcordia GR-468

For additional information, please contact optics@samtec.com or visit samtec.com/optics.

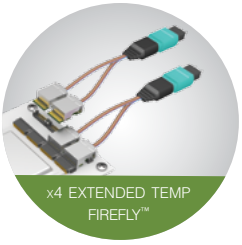




TECHNOLOGY ROADMAP | MID-BOARD + PANEL OPTICS

28+ Gbps x12 simplex optical FireFly™

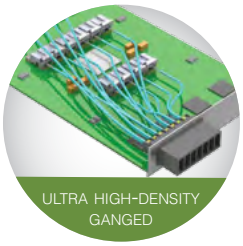
14 & 28+ Gbps x4 duplex optical FireFly™



x4 duplex system for -40 °C to +85 °C

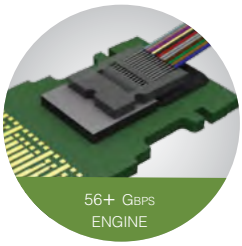
16 Gbps simplex optical FireFly™

FireFly™ with PCI Express® Interoperability



Ganged panel and backplane MXC optical connectors for 35% more space savings

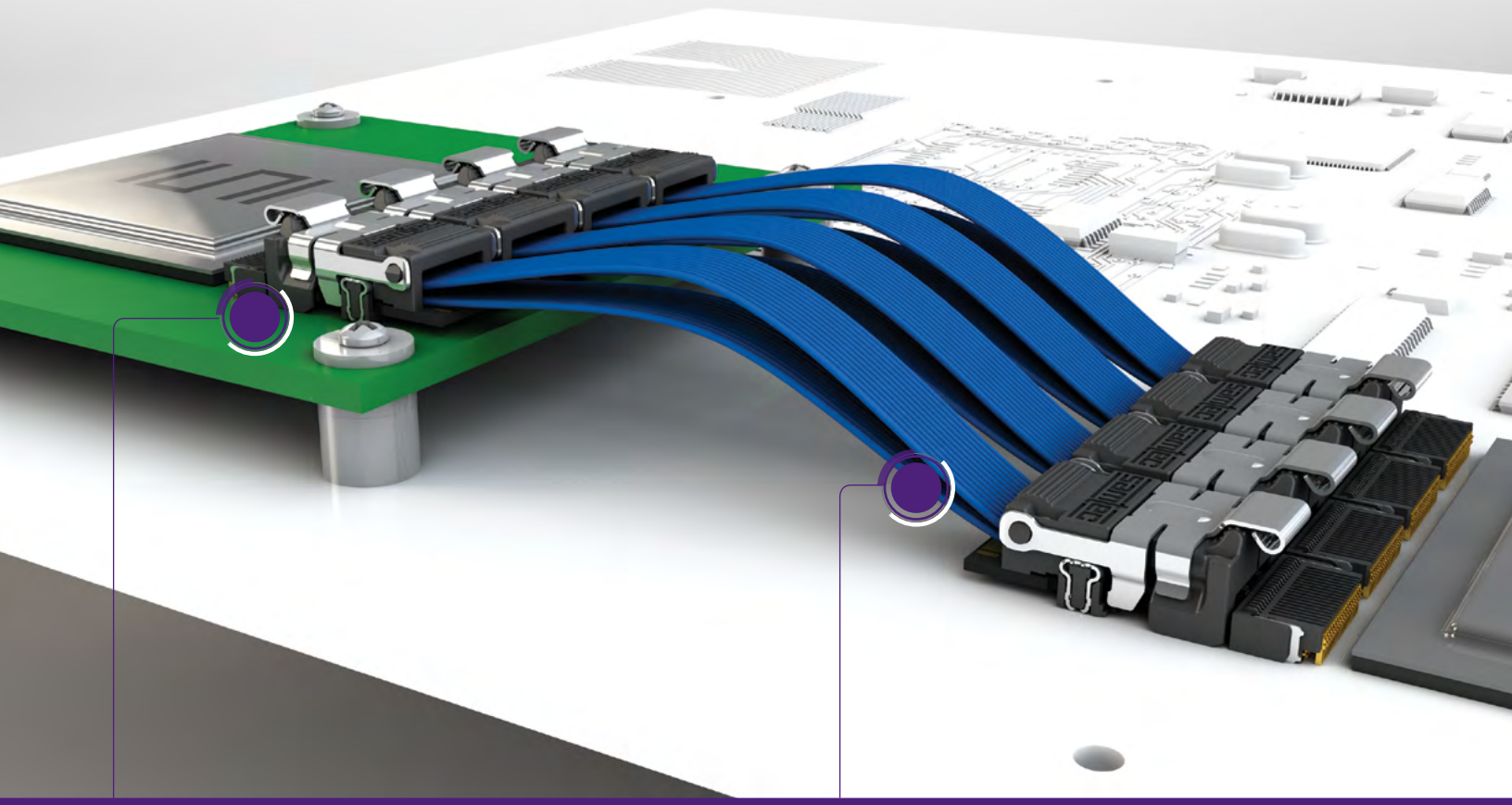
Robust latch and pluggable connector (in development)



Silicon Photonics Single Mode (in development)

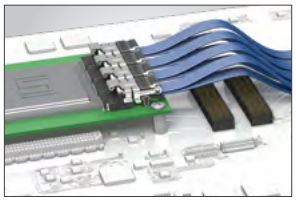
TWINAX FLYOVER
SYSTEM OPTIMIZATION

Samtec's high-speed ultra low skew twinax cable technology is designed specifically for the smallest, most dense 28 Gbps performance systems. Twinax flyovers enable maximum density, while meeting the signal integrity data rate requirements of today, and beyond.



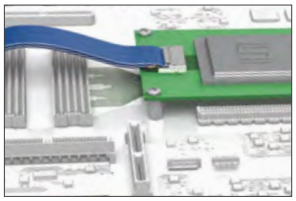
ADVANCED INTERCONNECT DESIGN

Future-proof designs optimize performance now + beyond

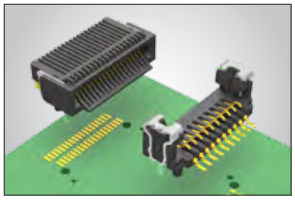


Data "flies" over the PCB, simplifying layout & enhancing signal integrity

Future-proof designs for easy migration to optical systems



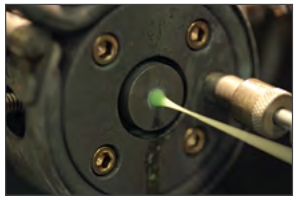
Micro footprint designs for ultra high-density systems



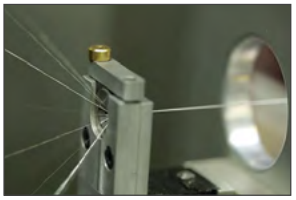
Rugged, two-piece connector system supports 28 Gbps data rates

HIGH-SPEED CABLE PLANT

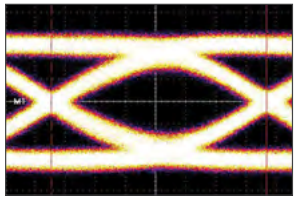
In-house R&D / manufacturing of high-speed cable systems



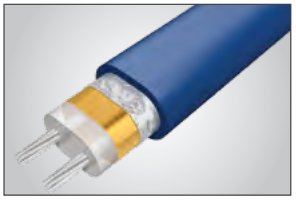
Precision extruded micro coax and twinax cables



Extreme flexibility for high-speed / high-density cable design



Full system signal integrity analysis and optimization



Co-extruded twinax provides ultra low skew advantage

FLYOVERS: PRACTICAL APPLICATIONS

Significantly reduce complex routing challenges of 28+ Gbps systems with the incorporation of flyover designs

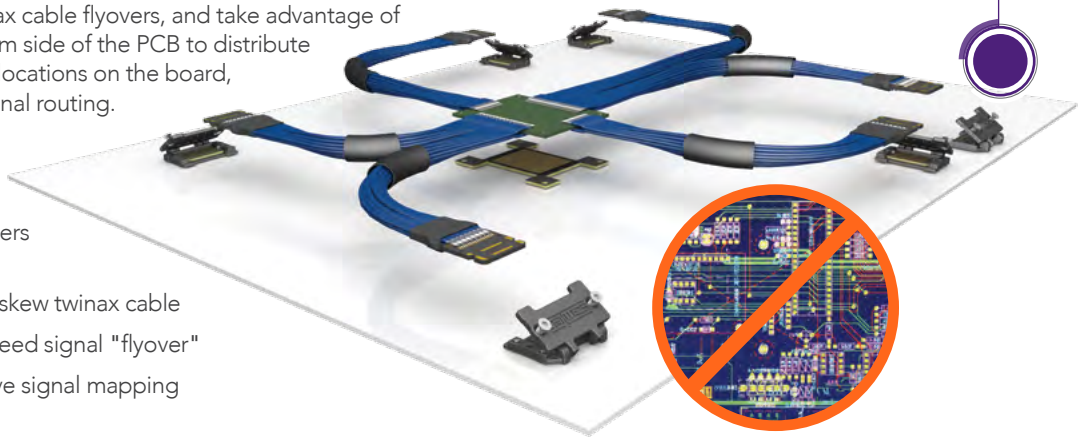
Demands for increased signal reach and density at speeds of 28+ Gbps have made high-speed signal routing, and finding the optimal way to get from "Point A" to "Point B," a complex and often seemingly impossible task.

Not only can Samtec assist with complex PCB layout and routing recommendations via Teraspeed® Consulting and our Signal Integrity Group, we can help significantly reduce or eliminate these challenges by combining our revolutionary flyover technology with unique interconnect solutions designed for high-speed, high-density applications.

BACKSIDE INTERCONNECT ULTRA HIGH-SPEED LOW SKEW TWINAX FABRIC

Customized assemblies leverage Samtec's 28 Gbps ultra micro interposers and ultra low skew twinax cable flyovers, and take advantage of real estate on the bottom side of the PCB to distribute critical data to multiple locations on the board, eliminating complex signal routing.

- Interconnect system: Z-Ray® ultra high-density, ultra low profile micro interposers
- High-speed cabling: Eye Speed® ultra low skew twinax cable
- BGA-to-BGA high-speed signal "flyover"
- Customizable selective signal mapping

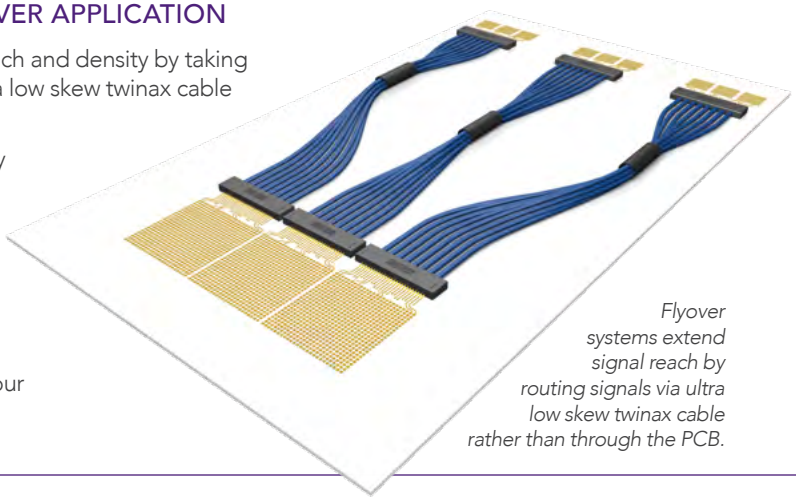


SURFACE MOUNT DIRECT ATTACH FLYOVER APPLICATION

Samtec's flyover concept can help extend signal reach and density by taking advantage of the benefits of routing signals via ultra low skew twinax cable versus through the PCB.

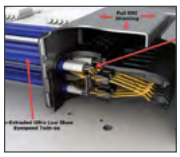
- Ultra low skew Eye Speed® twinax cable is directly soldered to the high-performance chassis card
- Extended reach compared to PCB trace routing enables flexibility of module placement
- Chip-to-chip data transmission
- Simplifies PCB routing

Contact sig@samtec.com to discuss solutions for your specific routing challenges.

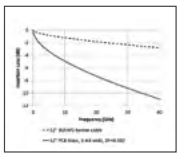


Flyover systems extend signal reach by routing signals via ultra low skew twinax cable rather than through the PCB.

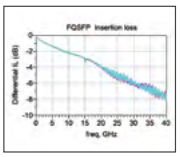
REFERENCE + SUPPORT DATA | APPENDIX B, pp. 28-29



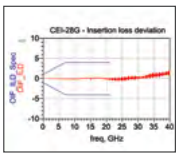
MECHANICAL ANATOMY OF FQSFP
(Appendix B, p. 28, Fig. B1)



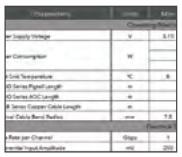
FQSFP INSERTION LOSS COMPARISON
(Appendix B, p. 28, Fig. B2)



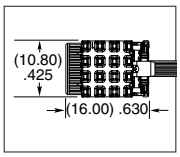
FQSFP ASSEMBLY PERFORMANCE
(Appendix B, p. 28, Fig. B3)



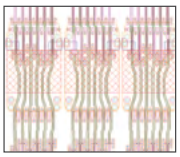
OIF-CEI-3.1 PERFORMANCE
(Appendix B, p. 28, Fig. B4)



FIREFLY™ ELECTRICAL SPECIFICATIONS
(Appendix B, p. 29, Fig. B5)



FIREFLY™ MECHANICAL SPECIFICATIONS
(Appendix B, p. 29, Fig. B6)



FIREFLY™ PCB LAYOUT RECOMMENDATIONS
(Appendix B, p. 29, Fig. B7)

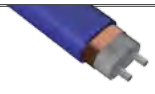
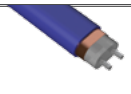
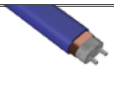
HIGH-SPEED TWINAX FLYOVER SYSTEMS

FIREFLY™ COAX & TWINAX FLYOVERS

- Performance up to 28 Gbps
- x12 systems on 36 AWG ultra low skew twinax ribbon cable
- x4 bidirectional system with passive equalized 34 AWG ultra low skew twinax ribbon cable provides a performance boost or enables longer cable lengths
- x4 bidirectional system (in development) with active equalized 100 Ω 34 AWG ultra low skew twinax ribbon cable provides greater performance boost or enables even longer cable lengths and offers relatively low power consumption
- Large variety of end two connector termination options
- Pin compatible with optical FireFly™

DIRECT ATTACH FLYOVER QSFP SYSTEM

- Addresses the large loss issues associated with the circuit card PCB traces in 28 Gbps QSFP systems
- Allows the receiver to be remotely located, providing more flexibility in system architecture and more control over thermal cooling
- 28 Gbps high-speed performance
- No re-timers are required resulting in reduced costs and power consumption
- Reduced PCB costs due to lower layer counts and increased material options
- High-speed signals via Eye Speed® 30 AWG 100 Ω ultra low skew twinax cable enables inherently lower attenuation
- Backward compatible with all QSFP cable assemblies
- Variety of end two options available

		30 AWG 100 Ω	32 AWG 100 Ω	34 AWG 100 Ω	36 AWG 100 Ω
Eye Speed® Ultra Low Skew Twinax Cable					
Performance (Gbps) IL -3dB	0.25 m	36	28	28	27.4
	1.00 m	10	8	5	3.4
Density / Flexibility		Good	Better	Best	Best
Samtec Assemblies (Series)		FQSFP, DCC 2.0	DCC, HDLSP, EPLSP, SEAC	ZRDP, ECUE (x4)	ECUE (x12), Flyunder DCC

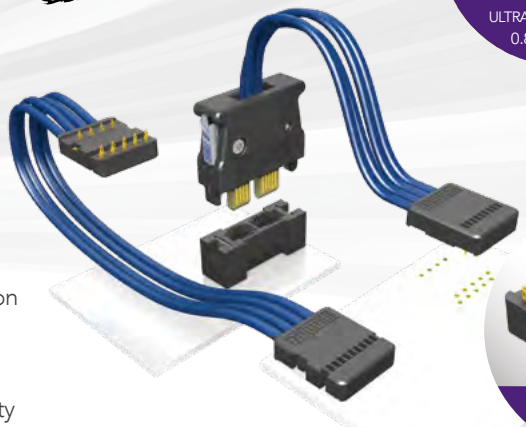
Z-RAY® ULTRA LOW PROFILE HIGH-SPEED CABLE ASSEMBLY

- 0.80 mm pitch micro interposer
- 8 or 16 high-speed differential pairs
- Eye Speed® 100 Ω 34 AWG ultra low skew twinax ribbon cable
- Designed for high-speed, high-density, micro pitch applications
- Overall profile < 4.00 mm
- Performance up to 28 Gbps

ULTRA HIGH-DENSITY 0.80 MM PITCH

DIRECT CONNECT CABLE SYSTEMS

- Cost-effective ultra low skew twinax cable solution
- 2.00 mm (.0787") pitch
- Eye Speed® 100 Ω 32 AWG ultra low skew twinax cable
- Stitched ground pins for improved signal integrity and easy routing
- High retention, low cost, one-time press-fit termination directly to the PCB
- Performance meets SAS-4, PCIe® Gen 4 and beyond
- Choice of End 2 options for increased design flexibility




HIGH RELIABILITY PRESS-FIT TAILS

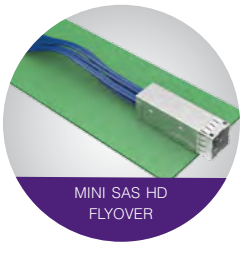
TECHNOLOGY ROADMAP | TWINAX FLYOVER SYSTEMS


TWINAX FIREFLY™ x4 & x12

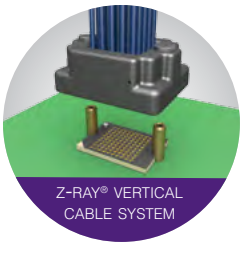
x4 and x12 twinax with up to 28 Gbps performance


EQUALIZED TWINAX FIREFLY™

x4 and x12 with passive or active equalization


MINI SAS HD FLYOVER

Press-fit cable to Mini SAS HD with 4 bidirectional channels to 12 Gbps


Z-RAY® VERTICAL CABLE SYSTEM

26+ Gbps high-density, space-saving assembly


PRESS-FIT DCC

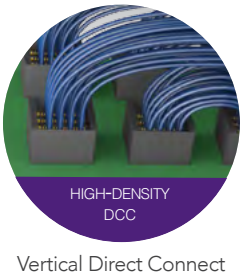
28+ Gbps Direct Connect Cable meets SAS-4, PCIe® Gen 4 & beyond


SURFACE MOUNT DCC

32+ Gbps designed for chip-to-chip high-speed signal traffic


CABLE MOUNT DCC

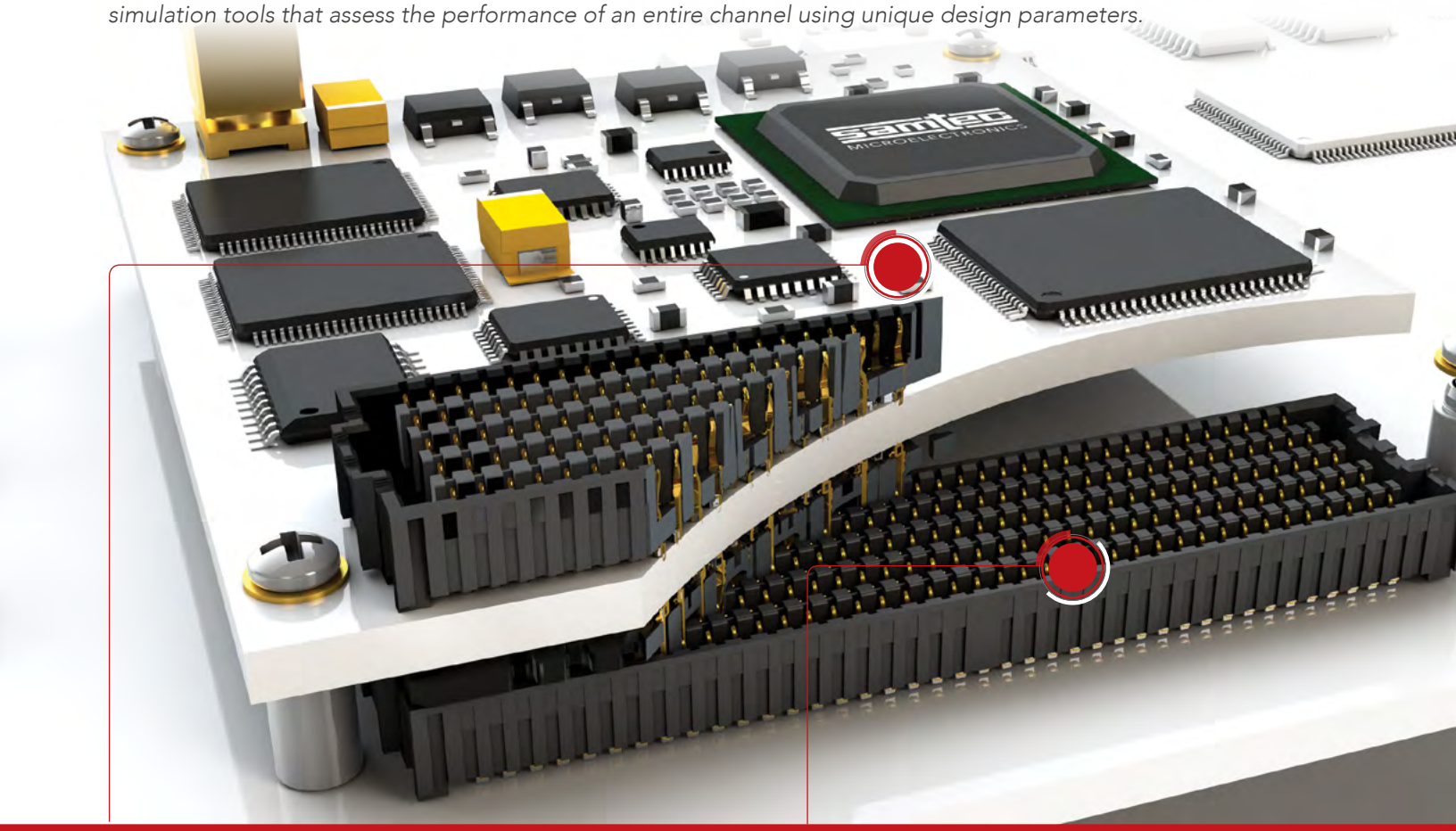
32+ Gbps chip-to-chip high-speed signal applications with mate/unmate capabilities


HIGH-DENSITY DCC

Vertical Direct Connect Cable for high channel count flyover applications

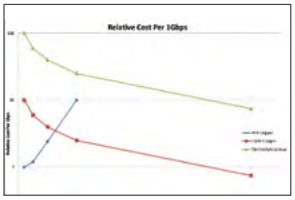
HIGH-SPEED MEZZANINE SYSTEM OPTIMIZATION

The integration of Samtec's Technology Centers enables a unique level of expertise in mezzanine system optimization, from signal integrity design and analysis, layout and routing optimization strategies, to revolutionary point-to-point simulation tools that assess the performance of an entire channel using unique design parameters.

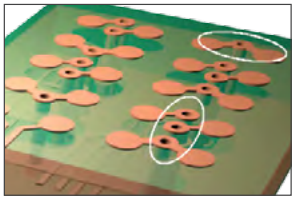


TERASPEED® CONSULTING

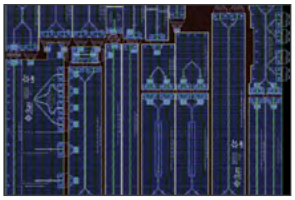
Advanced support for full system + cost optimization



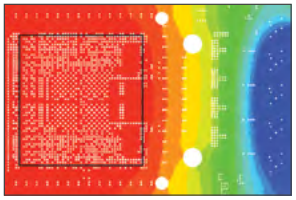
Full channel cost and performance analysis



Advanced break out region support, including Differential Vias™ for arrays



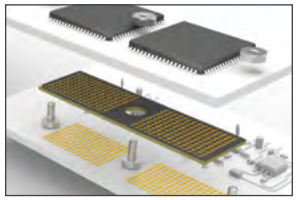
Modeling, simulation, measurement methodology development



Power delivery and thermal management assistance

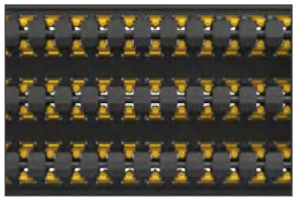
ADVANCED INTERCONNECT DESIGN

Systems engineered for maximum density + performance

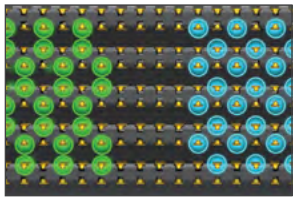


Design flexibility with ultra low profile high-density micro interposers

Innovative solutions for high-performance applications



High-density and space-saving designs



High-density open-pin-field arrays with maximum routing flexibility

MEZZANINE SYSTEMS: PRACTICAL APPLICATIONS

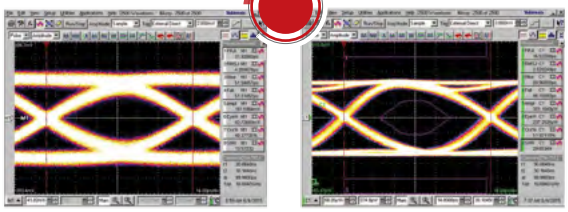
Signal integrity expertise enables full channel optimization of high-performance mezzanine systems

SerDes DESIGN APPLICATIONS

Samtec offers unparalleled support for SerDes applications via the expertise of Teraspeed® Consulting, which includes:

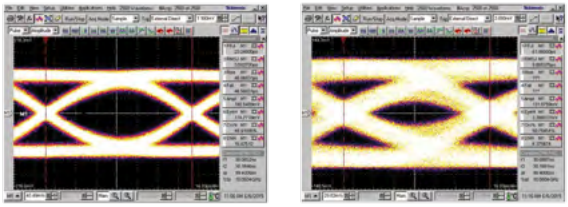
- Optimization of connectivity between the mezzanine connector and the main board
- Full channel analysis and measurement (channel loss, reflection loss and crosstalk noise)
- Full system validation: signal integrity analysis, specification compliance, performance and power management modeling
- Material selection and trace design to optimize SerDes channels
- Advanced breakout region layout and routing assistance:
  - Tri-Planar™ Transmission Lines — high-density routing of differential signals with less impedance and lower loss than microstrip
  - Differential Vias™ — provide better signal integrity at high data rates over traditional high-density array designs

ELECTRICAL OPTICAL



With Teraspeed® Consulting involvement

ELECTRICAL OPTICAL

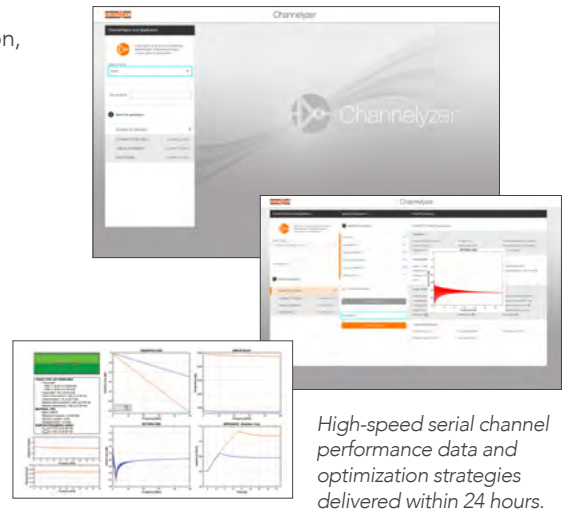


Without Teraspeed® Consulting involvement

CHANNELYZER™ ONLINE FULL CHANNEL SIMULATION AND ANALYSIS

Samtec's Channelyzer™ delivers high-speed serial channel performance data and optimization strategies within 24 hours. Leveraging user-defined system inputs, this easy-to-use tool provides the necessary data to reinforce channel confidence. Features of Channelyzer™ include:

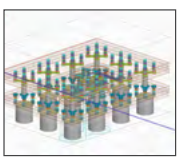
- Channel modeling defined by package model, connector selection, PCB material, trace type and length and other system variables
- Produces results for standards (IEEE 802.3bj 100GBASE-KR4, OIF CEI-28G-SR, OIF CEI-28G-MR and OIF CEI-25G-LR) and transceivers at varying equalization levels and data rates
- Generates individual receiver performance data per user-defined Tx/Rx assignments
- Channelyzer™ reporting details include:
  - Channel overview and strategies for improved performance
  - Differential impedance, insertion loss, return loss, PSXT
  - Voltage bathtub curves
  - COM as a function of BER
  - Probability density eye summary



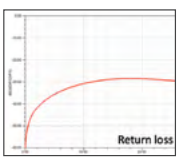
High-speed serial channel performance data and optimization strategies delivered within 24 hours.

Simulate and analyze your high-speed serial channel at samtec.com/channelyzer.

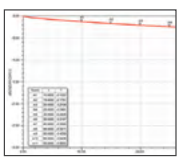
REFERENCE + SUPPORT DATA | APPENDIX A pp. 26-27 + APPENDIX C p. 31



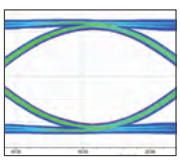
SerDes PACKAGE CELL MODELING
(Appendix A, p. 26, Fig. A2)



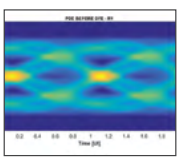
RETURN LOSS MEASUREMENTS
(Appendix A, p. 26, Fig. A3)



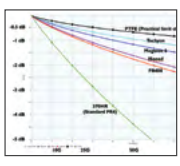
FLAT INSERTION LOSS TO 56 GHz
(Appendix A, p. 26, Fig. A4)



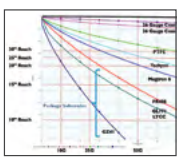
EYE OF PACKAGE TRACE
(Appendix A, p. 26, Fig. A5)



CHANNELYZER™ EXAMPLE DATA
(Appendix A, p. 27, Fig. C6)



PCB MATERIAL LOSS RANGE
(Appendix C, p. 31, Fig. C4)

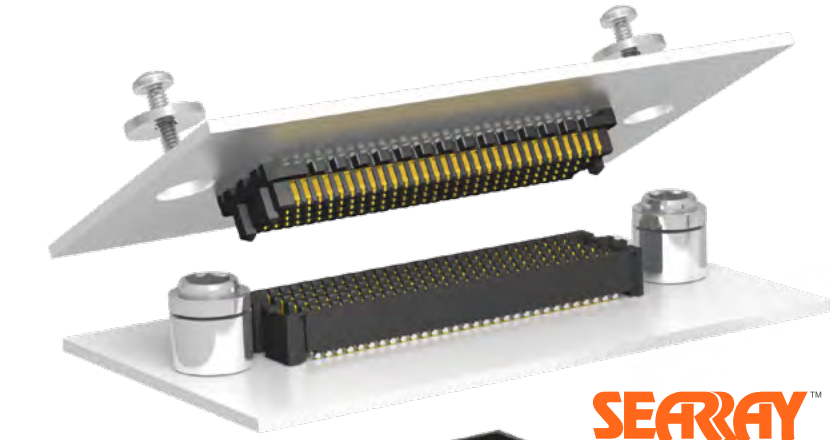


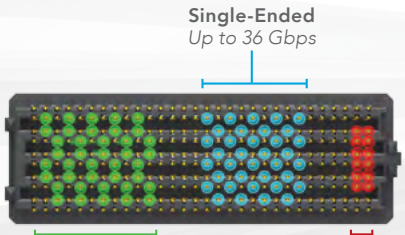
INTERCONNECT REACH COMPARISON
(Appendix C, p. 31, Fig. C5)

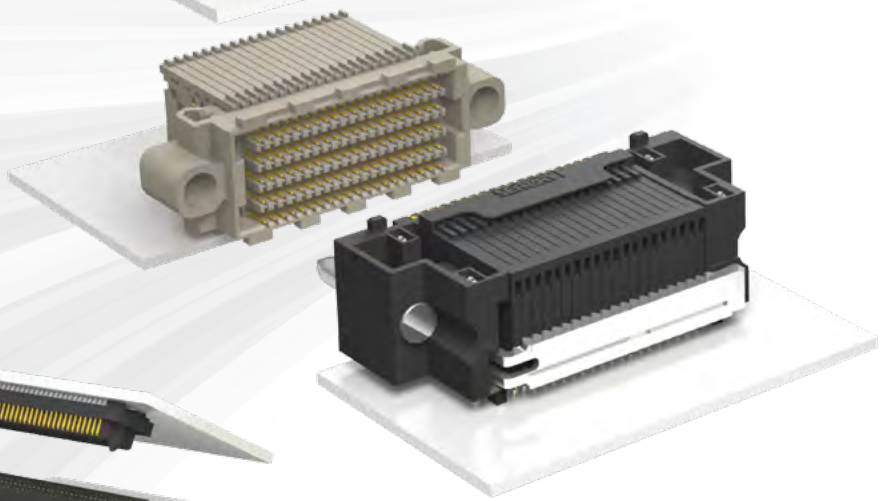
HIGH-DENSITY ARRAYS + MICRO INTERPOSERS

SEARAY™ OPEN-PIN-FIELD ARRAYS

- .050" (1.27 mm) pitch grid for maximum routing flexibility
- Up to 500 I/Os in open-pin-field design
- Performance up to 36 Gbps
- Rugged Edge Rate® contact system less prone to damage when "zippered" during unmating
- Solder on each tail for ease of processing (tin-lead or lead-free)
- Standard stack heights from 7 mm to 40 mm
- Optional guide posts for blind mating
- 85 Ω tuned and press-fit tails available
- VITA 47, VITA 57, VITA 57.4
- IPC-A-610F and IPC J-STD-001F Class 3 solder joint
- For additional information, visit samtec.com/searay

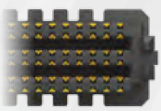






SEARAY™ 0.80 mm ULTRA HIGH-DENSITY ARRAYS

- 0.80 mm pitch grid
- Up to 50% board space savings
- Performance: Up to 17.5 GHz / 35 Gbps
- Rugged Edge Rate® contact system
- 7 mm and 10 mm stack heights
- Vertical and right-angle
- High pin count 960 I/Os in development

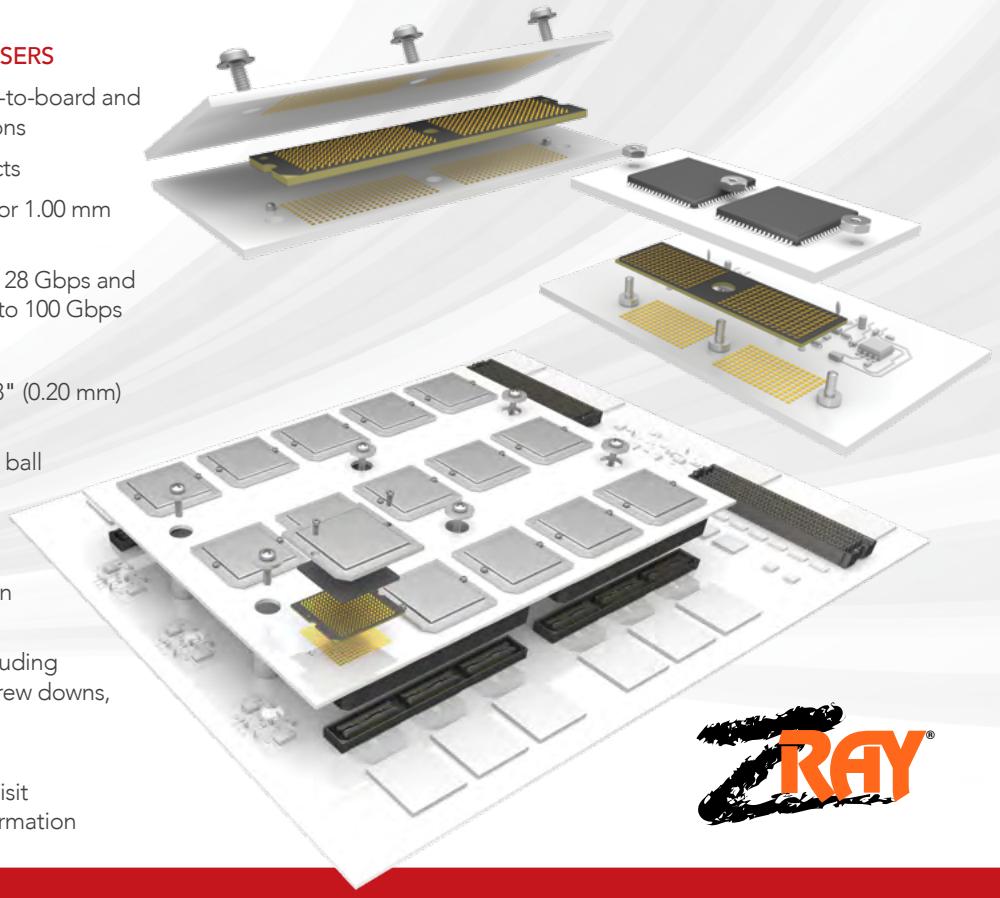


1.27 mm SEARAY™

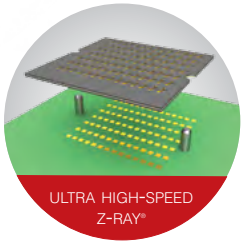
0.80 mm SEARAY™

Z-RAY® ULTRA MICRO INTERPOSERS

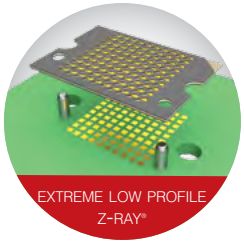
- Ideal for board-to-board, cable-to-board and complex IC-to-board applications
- Dual compression BeCu contacts
- One piece design on 0.80 mm or 1.00 mm pitch grid
- High speed performance up to 28 Gbps and 56 Gbps with a migration path to 100 Gbps
- Low profile 1 mm body height
- Low 25 g normal force with .008" (0.20 mm) contact deflection
- Single compression with solder ball
- Ultra flexible, with a variety of standard and custom configurations, including dual compression, solder ball, and an array of sizes and shapes
- Choice of fastener options, including application specific designs, screw downs, quick install (easy on/off) and thermal spreaders
- Contact zray@samtec.com or visit samtec.com/zray for more information



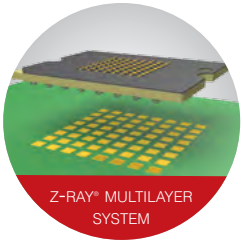
TECHNOLOGY ROADMAP | HIGH-DENSITY ARRAYS + MICRO INTERPOSERS



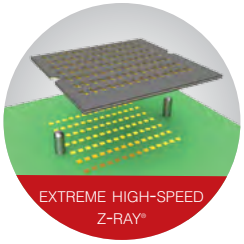
56 Gbps performance with migration path to 100 Gbps



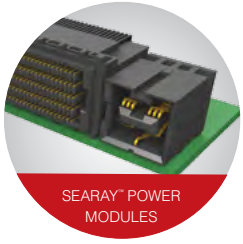
0.30 mm stack height interposer with Kapton core



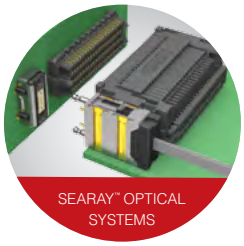
Pitch spreaders and other embedded interconnect circuitry



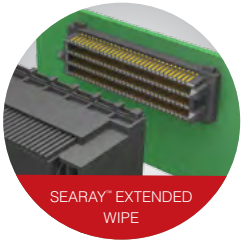
112 Gbps performance system



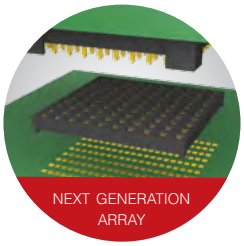
Add-on modules for up to 20 A with 1.27 mm & 0.80 mm pitch grid SEARAY™



Right-angle array with integrated optics to support VITA 74



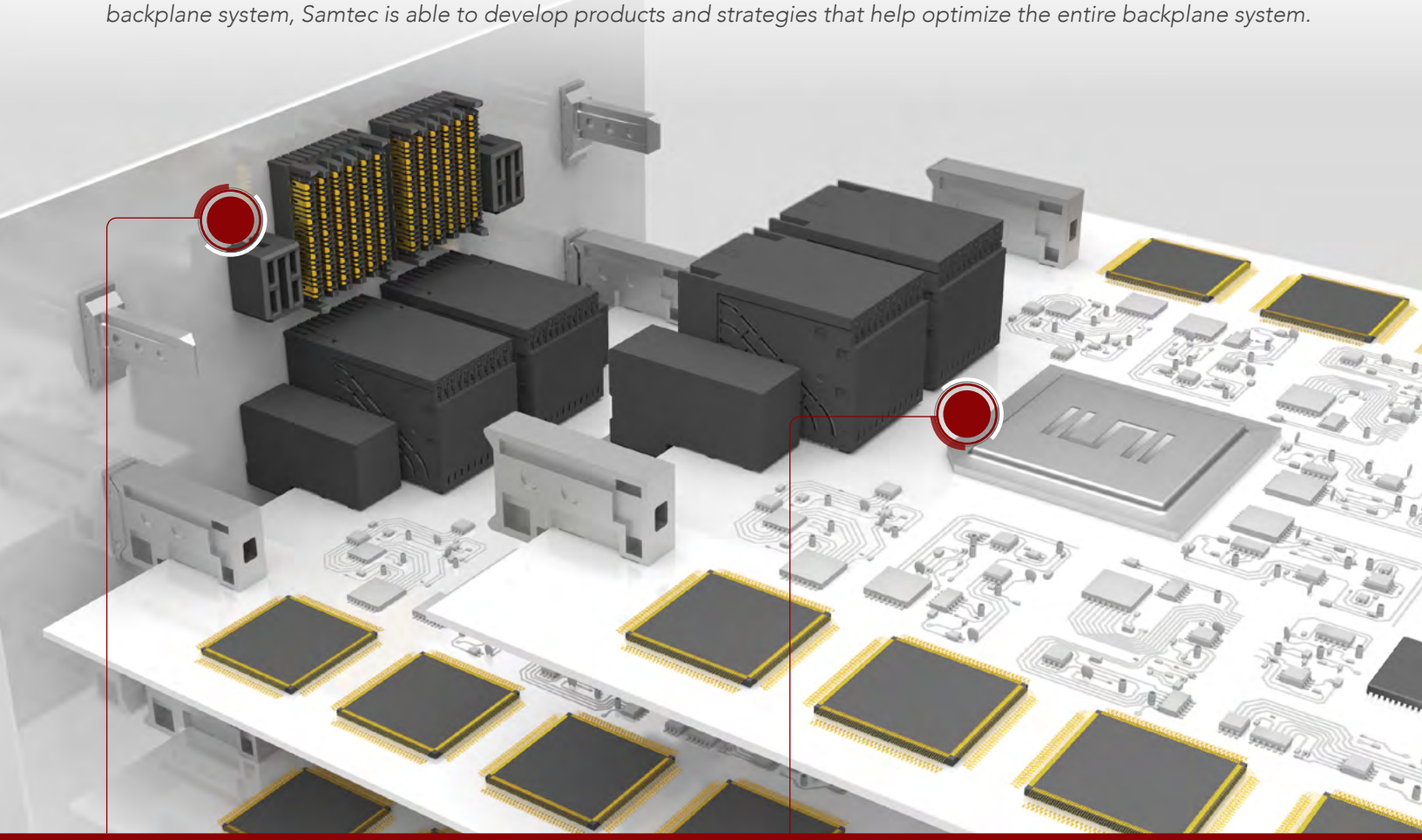
Right-angle & vertical arrays with 2.00 mm extended contact wipe



Higher speed arrays achieved with PCB routing and design strategies to reach 56 Gbps

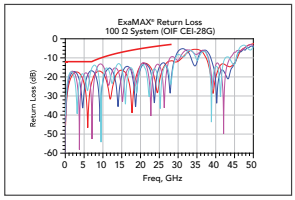
HIGH-SPEED BACKPLANE SYSTEM OPTIMIZATION

By evaluating cost and performance, along with how components operate in the context of the complete high-speed backplane system, Samtec is able to develop products and strategies that help optimize the entire backplane system.

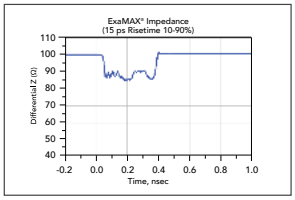


ADVANCED INTERCONNECT DESIGN

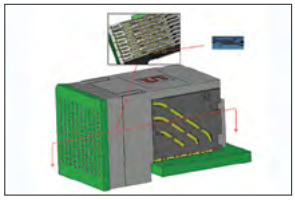
Systems engineered for maximum density + performance



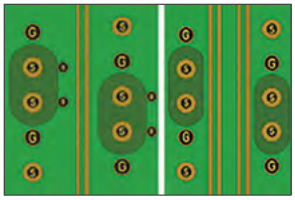
Targeted performance for return loss compliance in 85 Ω & 100 Ω systems



Future-proof design for easy migration to 56 Gbps systems



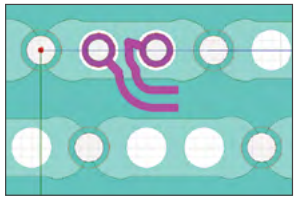
Unique contact geometry results in lowest mating force on the market



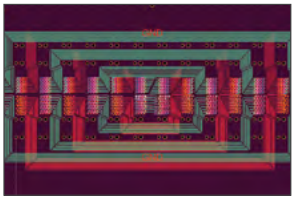
Single track routing on 2.00 mm pitch; single or double track on 3.00 mm pitch

TERASPEED® CONSULTING

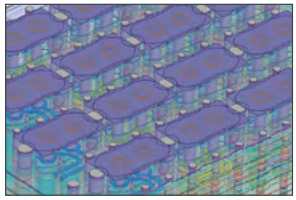
Advanced support for full system + cost optimization



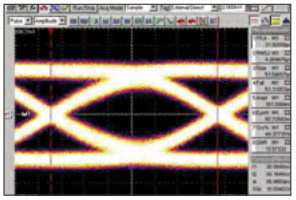
PCB layout and trace routing strategies for optimized performance



Design assistance from consulting review to full turn-key design



PCB materials expertise for optimized cost and performance



Full system Signal / Power Integrity analysis and design

BACKPLANE SYSTEMS: PRACTICAL APPLICATIONS

Comprehensive engineering approach + backplane expertise enables full system optimization

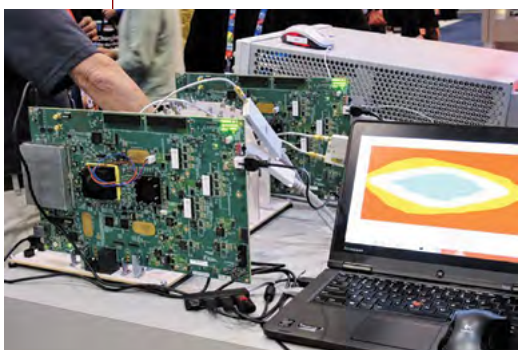
The expertise of Samtec's Technology Centers enables high-speed backplane systems optimized for both the performance and cost of the entire backplane system.

- Extensive backplane and platform R&D experience, including design, layout, PCB materials and high-speed interconnects
- Assistance ranging from consulting review to full turn-key design

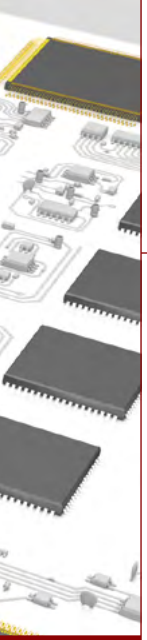
Our comprehensive engineering approach integrates design, simulation, test and development services that help optimize high-speed backplane systems, including:

- Modeling, simulation and measurement methodology development
- Advanced signal and power integrity engineering
- Full channel analysis, optimization and design
- High bandwidth full-wave S-Parameter model extraction along the entire signal chain

*ExaMAX® is a trademark of FCI.



Teraspeed® Consulting demonstration of a 28 Gbps backplane system attaching two Xilinx VCU109 Evaluation Boards across Samtec's ExaMAX® backplane connectors. The demo leveraged advanced design optimization techniques that minimize insertion loss, return loss and crosstalk, while utilizing advanced PCB materials. Photo courtesy of Xilinx.



COST-SAVING HIGH-PERFORMANCE CABLE BACKPLANE SYSTEM

Combining the electrical and mechanical benefits of the ExaMAX® interconnect system with the materials and routing expertise of Teraspeed® Consulting has allowed Samtec to develop a high-speed backplane system concept that optimizes both cost and performance. The system:

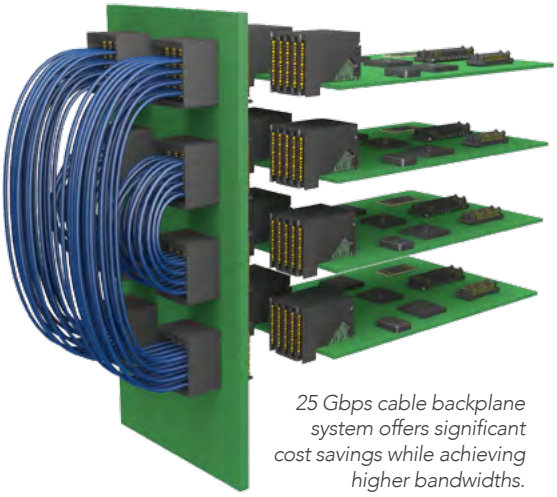
- fully leverages cost-effective, traditional PCB materials
- simplifies PCB layout and reduces layer count
- provides for expanded bandwidths with use of cable vs. PCB routing

The result is a reduction of approximately 25% the cost of a traditional backplane system.

25 Gbps CABLE BACKPLANE SYSTEM OPTIMIZATION

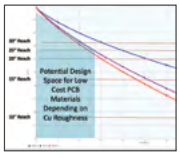
(16 Slot Backplane with Fourteen (14) 400G Redundant Cables)

	Low-loss PCB	FR-4 + Cables	Total Savings
SYSTEM COST	$1390 (1 backplane panel + connectors)	$1395 to $1091 (for various cable architectures)	0% to 21%

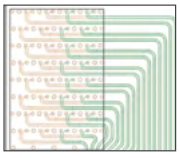


25 Gbps cable backplane system offers significant cost savings while achieving higher bandwidths.

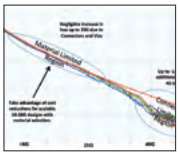
REFERENCE + SUPPORT DATA | APPENDIX C, pp. 30-31



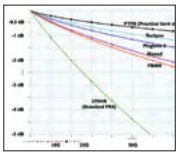
POTENTIAL DESIGN SPACE COMPARISON
(Appendix C, p. 30, Fig. C1)



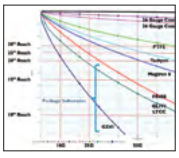
HIGH-DENSITY ROUTING
(Appendix C, p. 30, Fig. C2)



MTRL VS CONNECTOR CONTRIBUTION
(Appendix C, p. 30, Fig. C3)



PCB MATERIAL LOSS RANGE
(Appendix C, p. 30, Fig. C4)



INTERCONNECT REACH COMPARISON
(Appendix C, p. 31, Fig. C5)

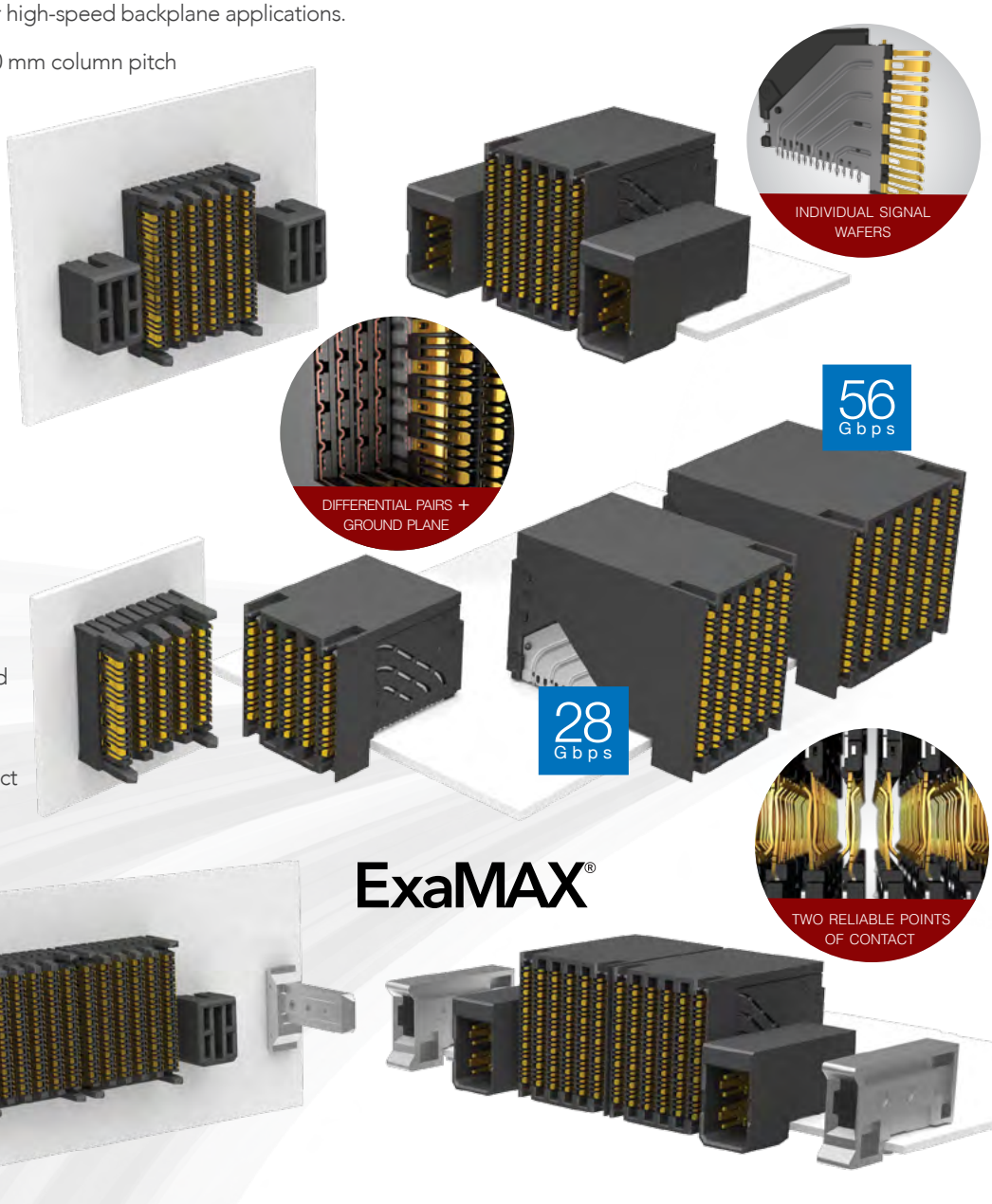
SAMTEC.COM

HIGH-SPEED BACKPLANE & MICRO BACKPLANE

ExaMAX® HIGH-SPEED BACKPLANE SYSTEMS

A future-proof 28 Gbps performance design offers an easy migration path to 56 Gbps. With a choice of 28 Gbps performance on a 2.00 mm column pitch, or 56 Gbps performance on a 3.00 mm column pitch, designers have the option of optimizing density or minimizing board layer count for high-speed backplane applications.

- 28 Gbps performance on 2.00 mm column pitch
- 56 Gbps performance on 3.00 mm column pitch (in design)
- Engineered for 92 Ω impedance; addresses both 85 Ω and 100 Ω applications
- Exceeds OIF CEI-28G-LR specification for 25 Gbps standards
- Contact system achieves two reliable points of contact, even when subjected to angled mating
- 2.40 mm contact wipe
- Individual signal wafers with staggered, differential pairs
- One-piece, embossed ground structure reduces crosstalk
- Lowest mating force on the market: 0.36 N max per contact
- Stub free mating
- Press-fit termination



Column Pitch	Performance	Impedance	Contact Wipe	I/Os	Mating / Unmating Force (per contact)	Normal Force
2.00 mm **3.00 mm** (in development)	28 Gbps (2.00 mm pitch) **56 Gbps** (3.00 mm pitch)	92 Ω (addresses 85 Ω & 100 Ω applications)	2.40+ mm mating surface area	72 pair design (6 pair x 12 column) **40 pair design** (4 pair x 10 column)	0.36 N maximum 0.12 N minimum	30 g (end of life)

*ExaMAX® is a trademark of FCI.

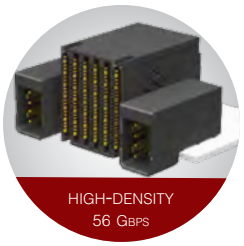
HIGH-DENSITY MICRO BACKPLANE SYSTEMS

- .050" (1.27 mm) pitch grid for maximum routing flexibility
- Up to 500 single-ended I/Os or 125 differential pairs
- Ultra high-density 0.80 mm pitch uses 50% less board real estate than standard SEARAY™ 1.27 mm pitch array
- Right-angle arrays optimized for reduced skew and impedance mismatch
- Lower insertion/extraction forces versus typical array products
- Performance up to 36 Gbps
- Up to 500 I/Os in open-pin-field design
- Vertical, right-angle, press-fit
- VITA 47, VITA 57, VITA 57.4
- Solder on each tail for ease of processing
- Rugged Edge Rate® contact system can be "zippered" during unmating

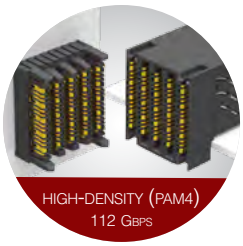
For additional information, visit samtec.com/searay.

TECHNOLOGY ROADMAP | HIGH-SPEED BACKPLANE + MICRO BACKPLANE SYSTEMS

Up to 8 pair per column, 3.00 mm pitch

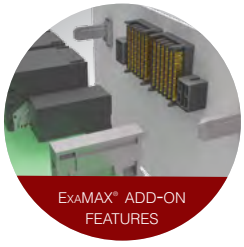


High-density 56 Gbps (NRZ) Backplane System

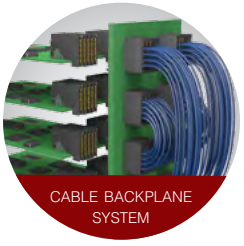


High-density 112 Gbps (PAM4) backplane system

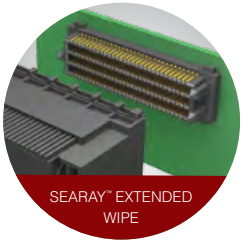
Eliminates mid-plane, decreases cost and layer counts



Power modules, alignment hardware, advanced mating



Backplane cable solutions designed to reduce board layers and costs



Right-angle and vertical arrays with 2.00 mm extended contact wipe

Right-angle array with integrated optics to support VITA 74

APPENDIX A: IC PACKAGING + CHANNELYZER™

Samtec offers advanced research and development in package layout, structural analysis, signal integrity and power integrity optimization, and material characterization, and can assist with the design of any package, whether it is a tough DDR 3/4 design, or a high-performance next-generation 56 Gbps channel.

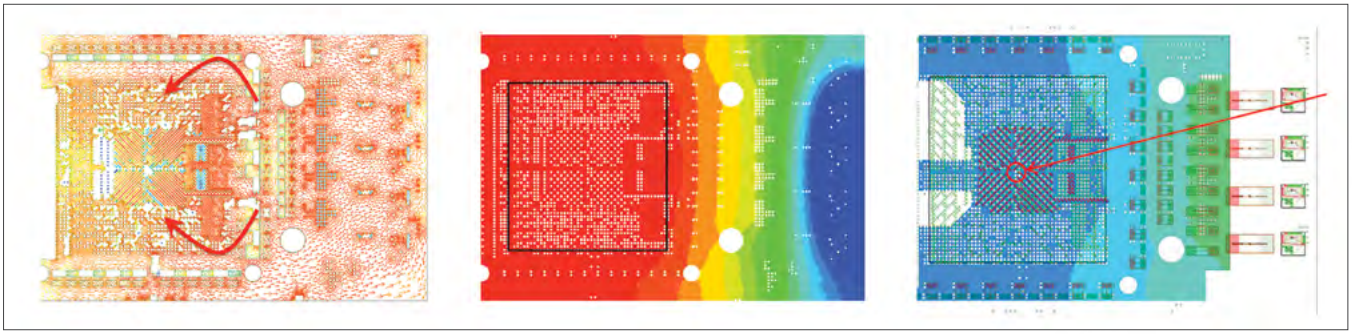


Figure A1: Power Delivery Network (PDN) Analysis

Teraspeed® Consulting helps ensure system performance and reliability by analyzing and modeling the entire system in real time under specific conditions.

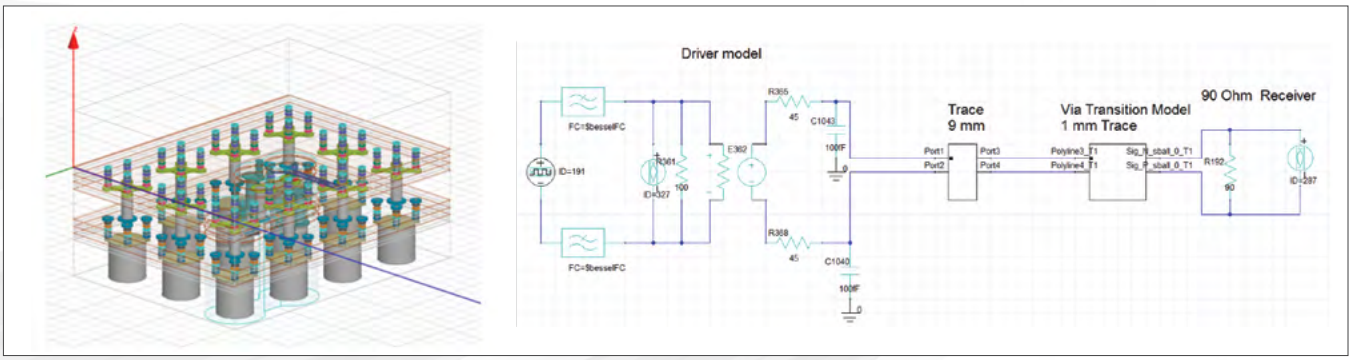


Figure A2: Novel Differential SerDes Package Design Cell Model

Package trace-to-ball transitions are no longer the performance limit: GZ-41 material enables 56 Gbps NRZ, 112 Gbps PAM4, and 112 Gbps NRZ.

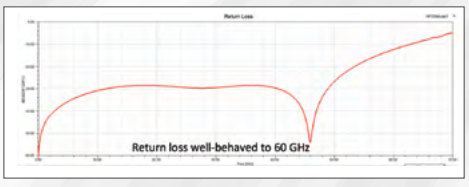


Figure A3: Return Loss Margin for 112 Gbps NRZ Using Standard Organic Buildup Process

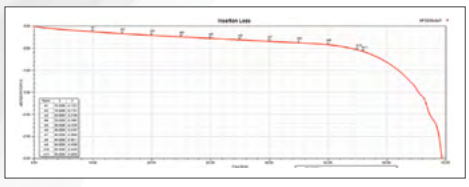


Figure A4: Flat Insertion Loss to 56 GHz

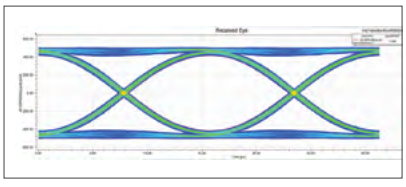


Figure A5: Eye of 10 mm Package Trace with Via / Ball Transition to PCB

Samtec's Channelyzer™ delivers high-speed serial channel performance data and optimization strategies within 24 hours. Leveraging user-defined system inputs, this easy-to-use tool provides the necessary data to reinforce channel confidence.

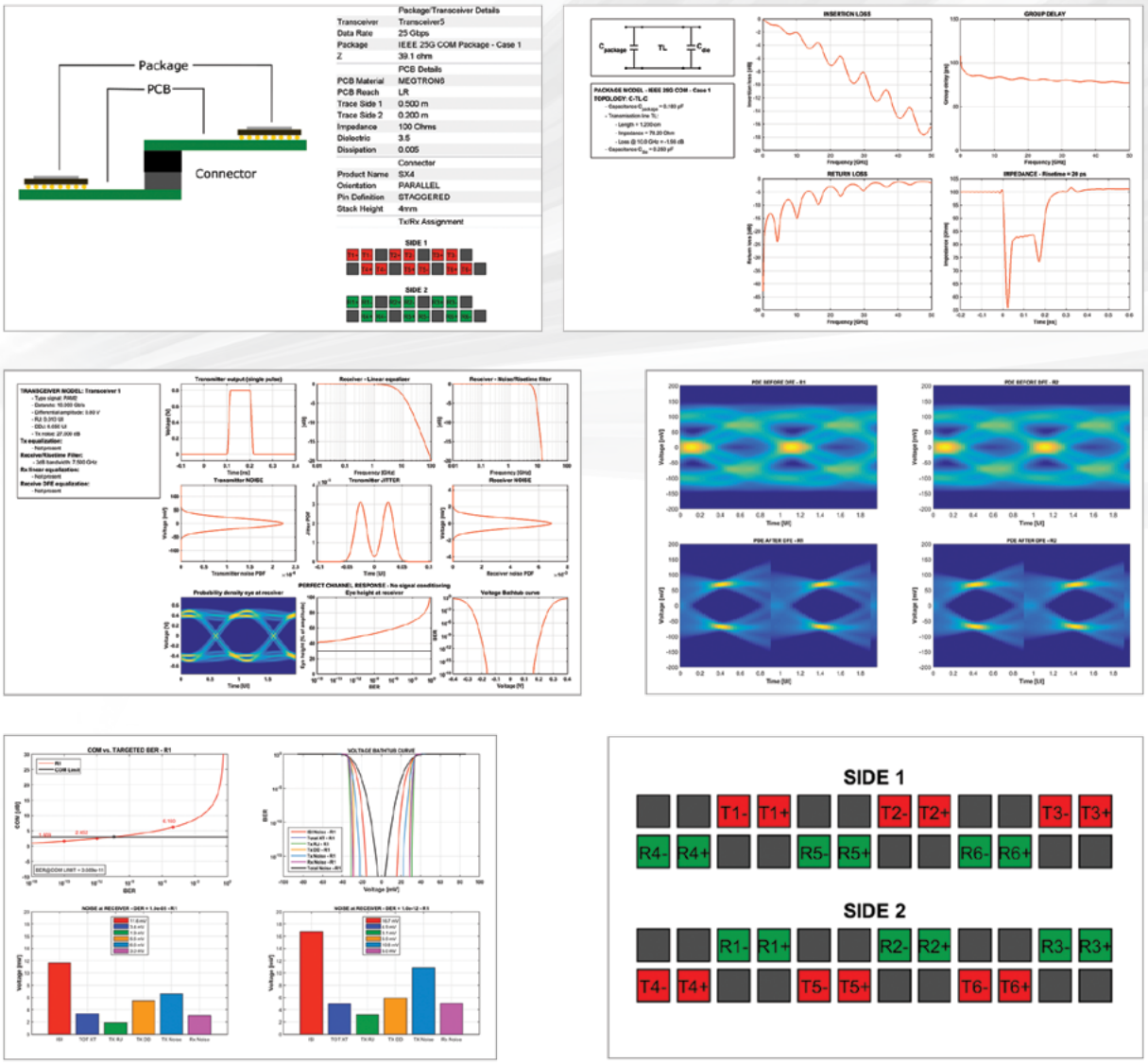


Figure A6: Channelyzer™ reporting includes channel overview and strategies for improved performance, differential impedance, insertion loss, return loss and PSXT, voltage bathtub curves, COM as a function of BER, as well as probability density eye summaries. Visit samtec.com/channelyzer to learn more.

APPENDIX B: TWINAX + OPTICAL FLYOVERS

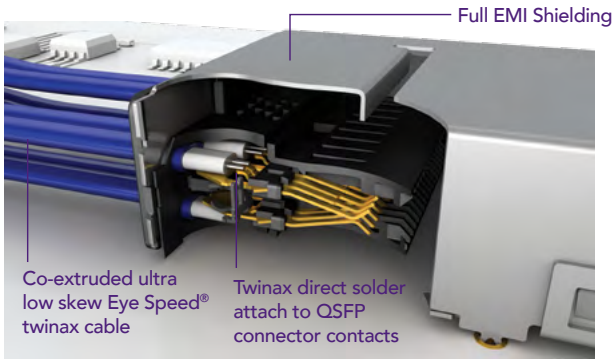


Figure B1: Mechanical Anatomy of Samtec FQSFP

The direct attach ultra low skew twinax flyover QSFP allows the receiver to be remotely located allowing for more flexibility in system architecture.

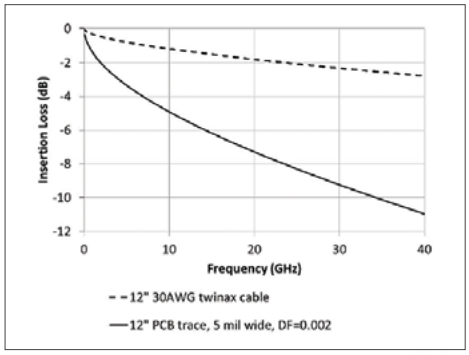


Figure B2: Insertion Loss Comparison of Twinax vs. PCB Traces

The low loss associated with twinax cable in comparison to PCB traces allows the SerDes to be located much further from the front panel, providing options for the mechanical architecture of the switch.

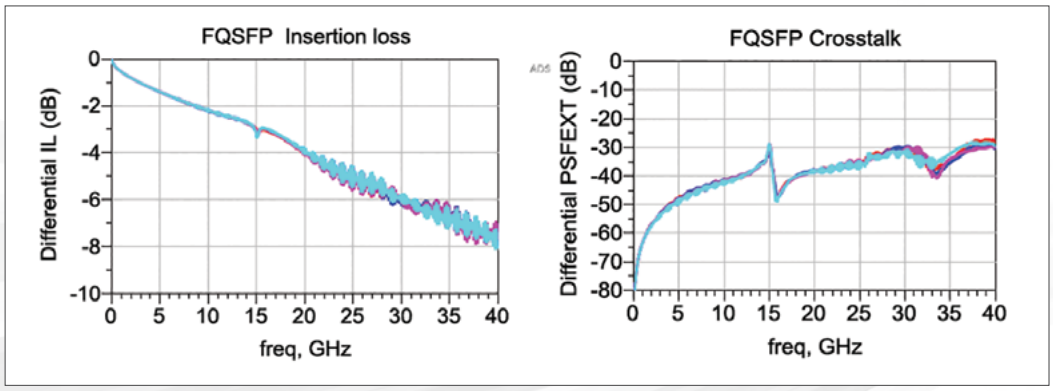


Figure B3: 18-inch FQSFP Cable Assembly Performance

Use of the ultra low skew twinax cable results in a resonance free insertion loss profile to 40 GHz for an 18-in FQSFP assembly as shown above. A 20 GHz connector and PCB termination effects add reflection loss to the cable attenuation profile.

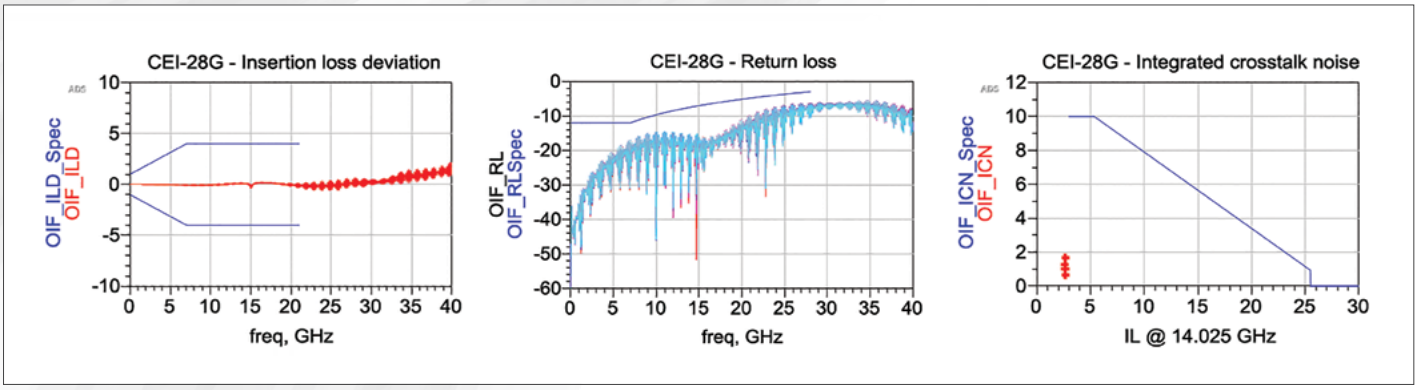


Figure B4: FQSFP Performance in Comparison to OIF-CEI-3.1 Requirements

Insertion loss deviation, return loss and integrated crosstalk noise for FQSFP in comparison with the requirements of OIF-CEI-3.1 shows that FQSFP has the signal integrity performance required to support 28 Gbps NRZ data streams.

Parameters	Units	Min.	Typical	Max.	Notes
Operating/Mechanical Specifications					
Power Supply Voltage	V	3.15	3.3	3.45	
Power Consumption	W		0.7	1.5	Transmitter for the x12 FireFly™
			0.8	2.15	Receiver for the x12 FireFly™
			1.1	2	x4 Duplex
Heat Sink Temperature	°C	0		70	
ECUO Series Pigtail Length	m			9.9	FireFly™-to-optical connector
ECUO Series AOC Length	m			9.9	
ECUE Series Copper Cable Length	m			1.5	
Optical Cable Bend Radius	mm	7.5			
Electrical Specifications					
Data Rate per Channel	Gbps	1		14.1	
Differential Input Amplitude	mV	250		1600	x12 FireFly™
Differential Output Amplitude	mV	250		760	x12 FireFly™
Optical Specifications					
Center Wavelength	nm	840		860	
Transmitter RMS Spectral Width	nm			0.65	
Transmitter RIN	dB/Hz			-128	
Average Optical Power	dBm	-7.6		2.4	
Optical Modulation Amplitude	dBm	-5.6		3	
Average Power at Receiver Input (each lane)	dBm	-9.5		2.4	
Stressed Receiver Sensitivity	dBm			-5.4	Following IEEE 802.3ae requirement

Figure B5: FireFly™ Micro Flyover System™ Electrical & Optical Specifications

All connectorized cables use OM3 fiber. Links of up to 100 m on OM3 are supported assuming that there is a maximum of 1.5 dB loss in the link.

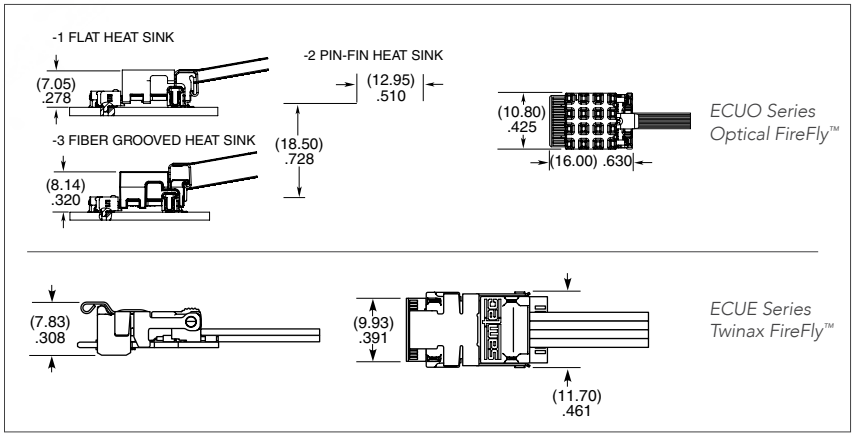


Figure B6: Mechanical Specifications of FireFly™

The micro footprint of FireFly™ Micro Flyover System™ is ideal for small form factor and densely populated applications, making it a valuable solution for both high data rate and high-density applications.

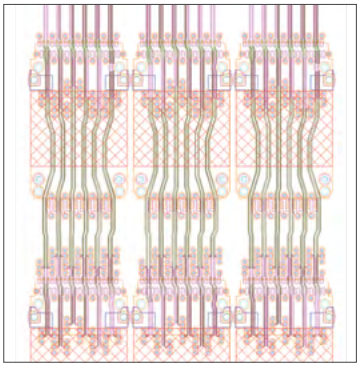


Figure B7: On-board Connector Layout Recommendations

To help streamline the design process, Samtec offers PCB layout breakout regions on demand for FireFly™ connector systems.

APPENDIX C: MATERIALS + ROUTING

Leveraging our extensive materials and trace routing expertise, our consulting team can quickly and easily help design-in the proper materials for specific systems (backplane or other high-speed systems) when using any Samtec connector, including ExaMAX®, or any other connector system, to help achieve significant cost-savings, while maintaining maximum signal integrity throughout the system. In addition, Samtec can provide low-cost design guidance and kits for application-specific ExaMAX® high-speed backplane systems.

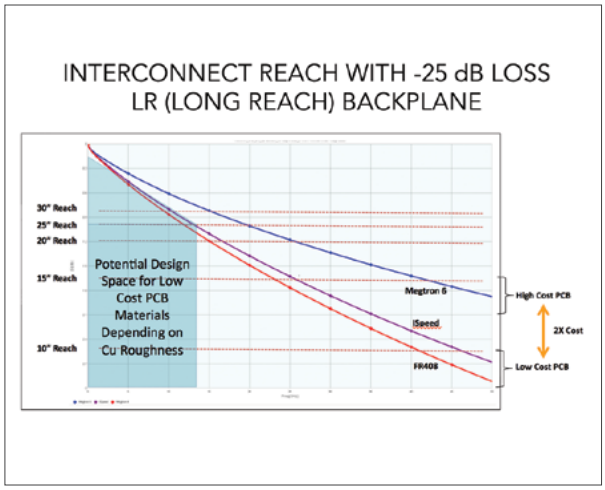


Figure C1: Interconnect Reach with -25 dB Loss LR (Long Reach) Backplane

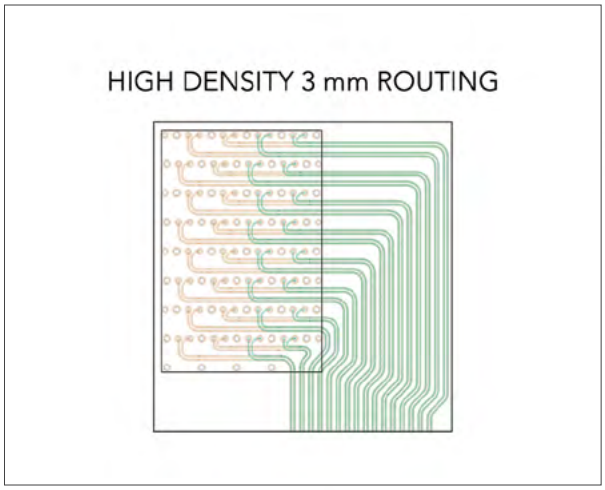


Figure C2: High-density routing with one half the routing layers: one 28 Gbps differential pair per 1.5 mm per layer (3 mm design), and one 28 Gbps pair per 2 mm (2 mm design) results in 33% higher board utilization, 50% layer count reduction and significant PCB cost savings.

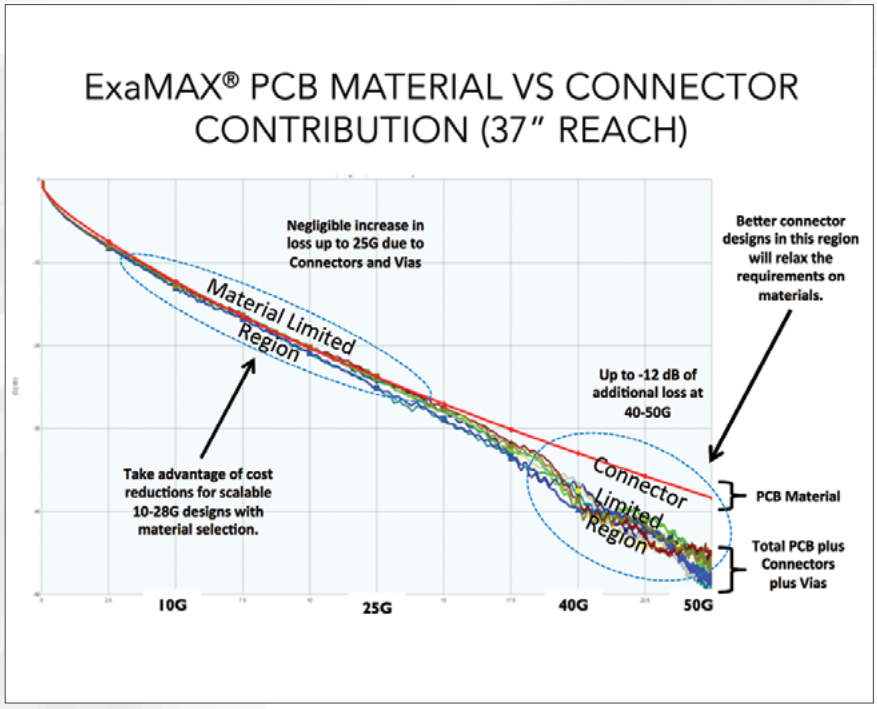


Figure C3: High-speed PCB Material with ExaMAX® High-speed Backplane vs. Connector Contribution

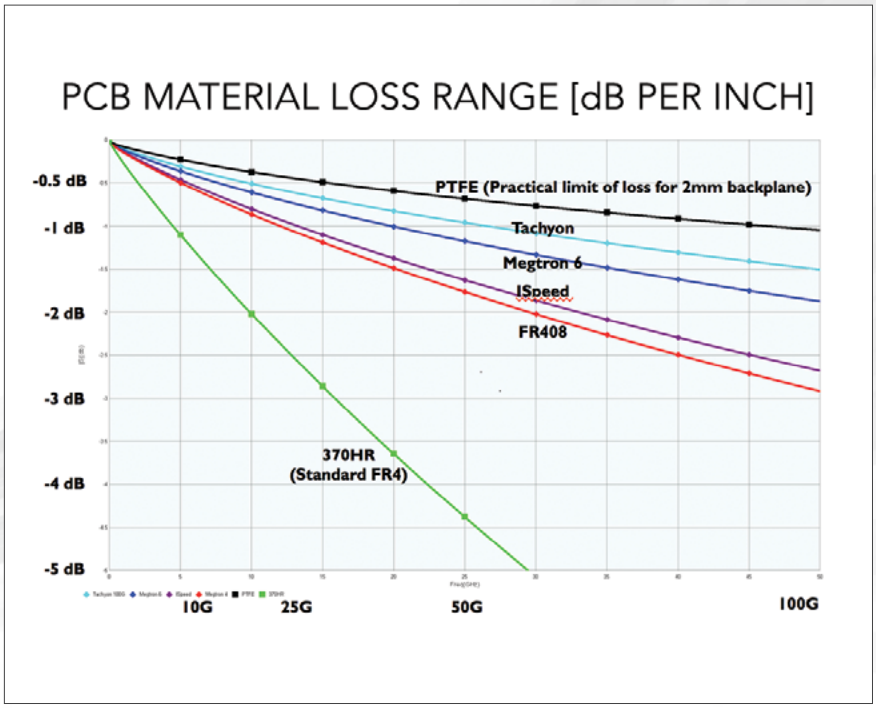


Figure C4: PCB Material Loss Range dB per Inch

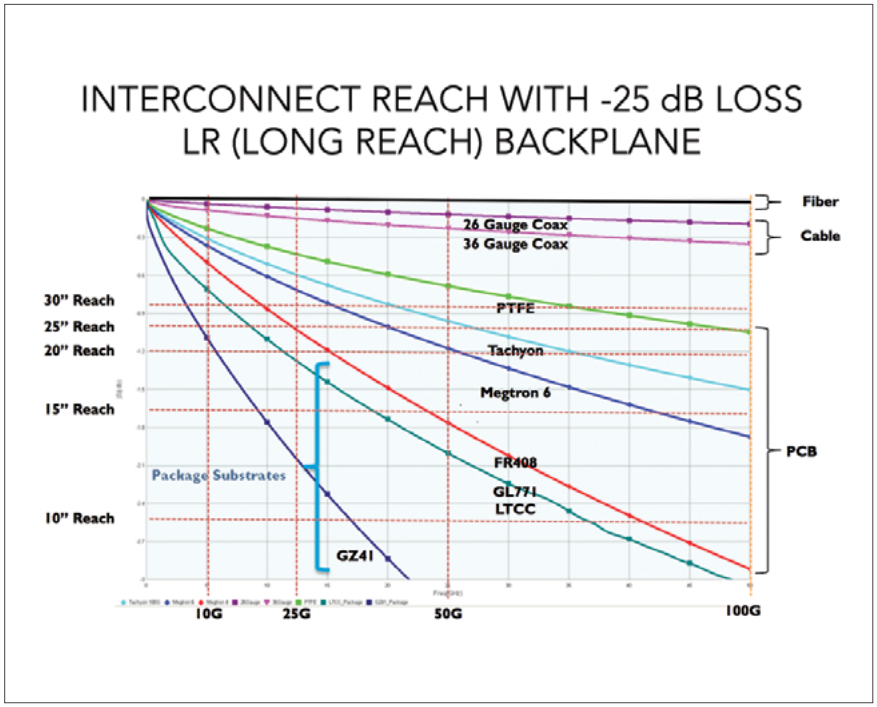


Figure C5: Interconnect Reach with -25dB Loss LR (Long Reach) Backplane

SYSTEM OPTIMIZATION
EXPERTISE + CAPABILITIES

Samtec offers unparalleled support for high-performance systems via our Signal Integrity Group and Teraspeed® Consulting, a Division of Samtec, who work together with complementary skill sets to provide system solutions from Silicon-to-Silicon.

TERASPEED® CONSULTING

Comprised of system engineers who have dedicated their careers to advancing related technologies in the domains of Silicon, board, package and systems design, this group possesses a wealth of system knowledge, experience and technical expertise, including:

- Design, development and characterization of systems, cable systems and custom products
- System product design
- Signal and power integrity optimization strategies
- Electromagnetic modeling
- Signal integrity training / system white papers
- Corporate system R & D
- Advanced semiconductor packaging design and analysis

SIGNAL INTEGRITY GROUP

Samtec's in-house team of signal integrity engineers offers an unmatched level of SI expertise and support at a local level, along with easy access to free online data, and engineer-to-engineer support for more complex applications. Samtec's Signal Integrity Group provides:

- Design, development and characterization of connectors and cable systems
- Application specific product design
- Signal integrity optimization strategies
- Electromagnetic modeling, EMI/EMC
- Application notes and white papers
- High data rate simulations
- Break out region layout and routing recommendations

Visit samtec.com or teraspeed.com for additional information.

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Samtec's Signal Integrity Group and Teraspeed® Consulting have a combined computational horsepower unparalleled in the industry. With identical High-performance Computing (HPC) systems in Silicon Valley and Harrisburg, Pennsylvania, Samtec has invested over $2 M in hardware and software, with further hardware expansion and facilities planning currently underway.

Software	Qty	Software	Qty	Software	Qty
Keysight ADS	1	Cadence® Allegro®	1	ANSYS® SIwave	4
Simberian Simbeor®	1	Tektronix® IConnect®	3	ANSYS® Cadence Allegro®	1
CST MICROWAVE STUDIO®	4	ANSYS® Q3D	1	ANSYS® Cadence APD	1
ANSYS® HFSS	7	Sigrity™ Broadband SPICE®	1	ANSYS® ALinks for EDA	2
Keysight PLTS	2	Mentor Graphics PADS 2004	1	JMP Software	4
National Instruments LABVIEW	2	MathWorks® MATLAB®	3	MathWorks® MATLAB® + Toolboxes	3
Mentor Graphics PADS 2007	3	PTC Mathcad	1	SPView	5
Synopsys Inc. HSPICE®, WaveView Analyzer	1	Agilent ADS-Samtec	1	ANSYS® Designer	4
Cadence® OrCAD® Capture	1	ANSYS® Optimetrics	2	ANSYS® 2D FEM EM Solver	1
Cadence® PSpice®	1	ANSYS® HPC Pack	5		

Hardware	Qty	Hardware	Qty
Tektronix® DSA8300 Digital Serial Analyzer Sampling Oscilloscope SN C040145	1	TG1C1-A Clock Synthesizer	1
Tektronix® DSA8300 E/O Digital Serial Analyzer Sampling Oscilloscope SN C010391	1	OPT002 for TG1C1-A	1
Tektronix® Dual 80E10B 30/40/50 GHz Sampling Module SN B020156	1	HF RF/Microwave Calibration Kits, 2.4 mm, 2.92 mm, 3.5 mm Ranges 26.5, 40.0, 50.0 GHz - (50 Ω)	4
Tektronix® Dual 80E10B 30/40/50 GHz Sampling Module SN B020157	1	LF RF/Microwave Calibration Kits, 2.4 mm, 2.92 mm, 3.5 mm Ranges 26.5, 40.0, 50.0 GHz - (50 Ω / 75 Ω)	3
Tektronix® Dual 80E04 20 GHz Sampling Module SN B010322	1	Precision Component Probe Station, XYZ motion control, 3 axis Prober Positioners	1
Tektronix® Dual 80E04 20 GHz Sampling Module SN B010782	1	40 GHz Microprobes, Dual Differential GSG 450 micron pitch	12
Tektronix® Dual 80E04 20 GHz Sampling Module SN B011387	1	40 GHz Microprobes, Single Ended GS, SG 450 micron pitch	4
Tektronix® Dual 80E04 20 GHz Sampling Module SN B023387	1	40 GHz Microprobes, Single Ended GSG 450 micron pitch	4
Tektronix® Dual 80E03 20 GHz Sampling Module SN B010213	1	40 GHz Microprobes, Dual Differential GSG 150 micron pitch	3
Agilent N5227A 4 Port PNA, 10 MHz to 67 GHz	1	40 GHz Microprobes, Single Ended GS, SG 250 micron pitch	3
Agilent N5230C 4 Port PNA, 300 kHz to 20 GHz	1	40 GHz Microprobes, Dual Differential GSG 250 micron pitch	3
Agilent 8720ES 2-Port NWA, 50 MHz to 20 GHz	1	40 GHz Microprobes, Single Ended GS, SG 250 micron pitch	1
Agilent U1732 Handheld LCR Meter	1	EMC/EMI Emissions Reverberation Chamber	1
Agilent E5071C ENA 9 kHz to 4.5 GHz	1	Agilent 8590 Spectrum Analyzer	1
Agilent E5071C ENA 9 kHz to 8.5 GHz	1	Agilent 54120B 4-channel 20 GHz TDR Oscilloscope	1
PCB12500 BERT	1	Advantest D3186 12.5 GHz Pulse Pattern Generator	1
TG5P1A TX Heads	2	Advantest D3286 12.5 GHz Bit Error Detector	1

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