

Light On Board[™] Technology Overview

Implementation of High-Speed Optical Interconnects Integrated
into Semiconductor Integrated Circuit (IC) Packages

WHITE PAPER

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April 2006

Introduction

The ever increasing data rate, power consumption and transistor density within microchips is reaching a point where the integrated circuit (IC) packages that hold the microchips are becoming the limiting factor on the bandwidth. The copper-based interconnections, vias, connectors and packages on typical Printed Circuit Boards (PCB) have had difficulty keeping up with the demand for increased data rates. As such, the microchip IC package has been the focus of intense engineering over the past decade but is now reaching the physical limits of electrical technology while maintaining low-cost solutions.

Industry standard IC packages such as a Ball Grid Array (BGA) have been able to keep pace with the data rate and pin-out demands from leading edge microchip designers but are steadily facing an ever more challenging set of criteria for density and data rate in the face of growing power consumption concerns.

Light On Board[™] Breakthrough

The trend towards utilizing optical fiber in communications and networking environments has been based on the trade-off between distance and data rate. As data rates have increased, optical fiber has replaced copper wire (given the same physical distance) so that higher speed signals are not degraded. It is this trend that has inspired the work behind optics-to-the-chip; trademarked *Light On Board*[™] by Reflex Photonics.

Fundamentally, the concept of *Light On Board*[™] is to provide the IC package with multiple optical inputs and outputs without changing either the microchip fabrication or the standard assembly and test methods used by IC and PCB manufacturers. Ultra-high speed electrical signals from the microchip are immediately converted into

optical signals and passed to the outside world. Both performance and cost issues can then be addressed into the next decade by allowing the microchip to remain as an all-electrical processing unit where optical fiber is the ultimate conduit of high speed data to and from the microchip. Furthermore, since the fundamental IC package remains the same as before, all other signals to and from the chip such as control signals and voltage supply pins can remain fully electrical.

Applications

Performance is not the only improvement offered by the *Light On Board*[™] solution, immediate cost benefits are also possible. Figure 1, is an example of a contemporary "all-optical component I/O" system which moves optical data into and out of a line card. The line-card includes a microchip in a typical IC package, electrical backplane connectors, copper trace lines and 32 pluggable optical transceivers. The size, power, reliability, and overall cost of this system are all areas that must be improved to meet the growing bandwidth demands of next generation equipment. However, only marginal improvements are possible with current IC and PCB assembly techniques, while simultaneously keeping costs low.

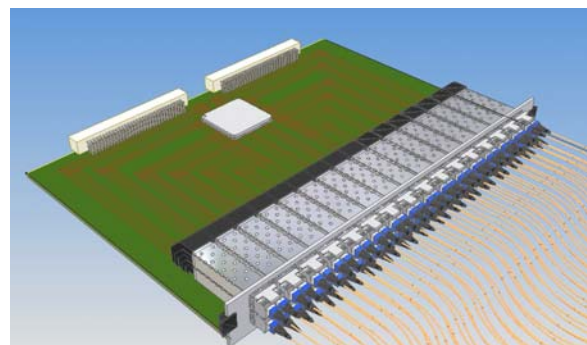


Figure 1, System line card example.

Figure 2, is an example of the same system function using the *Light On Board*[™] IC packaging technology. The most significant

difference is the complete elimination of all of the optical transceivers. Essentially, the optics has been moved directly into the IC package and integrated along side the microchip. This is foremost a large cost savings in both raw components and PCB manufacturing but also allows significant bandwidth improvements and power savings.

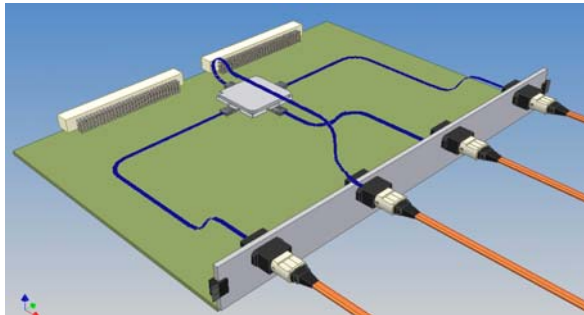


Figure 2, *Light On Board*[™] implementation example.

The line card now has a set of parallel optical fiber ribbon cables with passive optical connections at the front face plate and can be scaled in size by at least a factor of 4 allowing either smaller card sizes or more optical ports. This implementation does not affect the overall chip architecture and can still support multiple communication standards such as Fibre Channel, Ethernet, SONET/SDH and InfiniBand.

Light On Board[™] Technology

Light On Board[™] technology is designed to augment IC packages with optical interconnects without changing the microchip, the IC package or the PCB manufacturing methodology. The *Light On Board*[™] technology continues to respect all aspects of IC packaging and board assembly such as package size, footprint, solder-reflow and microchip interconnections since it is extremely important not to disrupt the processes developed by IC and PCB manufacturers. *Light on Board*[™] technology does this by introducing pre-aligned

optical-to-electrical (or electrical-to-optical) modules into standard IC packages. These pre-aligned modules are called *LightABLE*[™] Optical Sub-Assemblies (OSA) and an example is shown in Figure 3. The OSA is a compact, encapsulated, thin module that can be pick-and-placed into the IC package along side the microchip. The distance between the microchip and the *LightABLE*[™] OSA is on the order of millimeters so ultra-high speed electrical signals from the microchip can be immediately converted into optical signals.

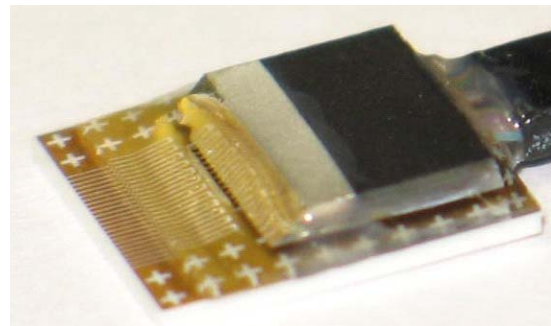


Figure 3, *LightABLE*[™] Optical Sub-Assembly.

Furthermore, because of the fidelity of optical signals and their immunity to crosstalk and electro-magnetic effects, the rate at which electrical power is consumed on the microchip is reduced for data rates above 1-Gb/s relative to “electrical-only” power consumption. The reason is that an optical signal requires far less signal conditioning and signal correction (fewer transistors overall) than equivalent electrical signaling methods. This allows much lower cost per gigabit per second per watt.

Light On Board[™] IC Package

The optically enabled IC package is identical in basic size, footprint, and assembly methodology as any other large

style IC package and is based on JEDEC standards for high-density packages.

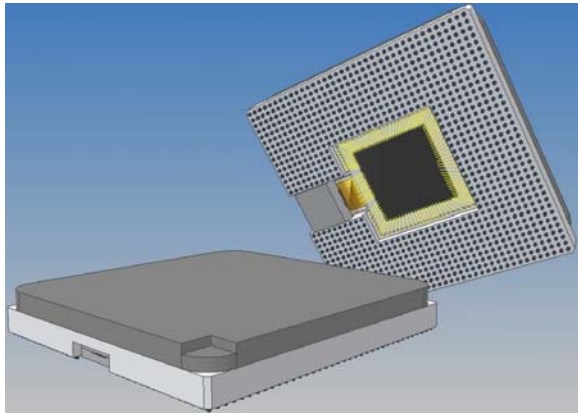


Figure 4, Optically Enabled BGA IC Package

The optically enabled IC package shown in Figure 4 is an example of a 40-mm x 40-mm cavity-down ceramic Ball-Grid Array (BGA) package with 1010 solder balls. This figure shows the exposed inner cavity where the microchip is placed (i.e.: without the typical encapsulation and cover in place). The OSA is shown directly beside the microchip with its optical port directed towards the side of the IC package. The microchip is connected to both the package and the OSA via standard wirebond interconnects, so the package offers both electrical and optical data pathways. The standard profile and layout of the package implies that the package can be easily assembled onto standard PCBs. Clearly, there are many other package styles that can be optically enabled. Different chip interconnect methods such as controlled collapse chip connect (C4) of the microchip and other cavity orientations can be addressed as well.

Summary

Reflex Photonics has developed a novel optically enabled IC package that offers both high speed electrical and optical interfaces by integrating the patented *LightABLE™* Optical Sub-Assembly into

standard IC packages. This new *Light On Board™* strategy “light-enables” IC packages without impacting the current model for IC and PCB manufacturing while at the same time providing more cost effective solutions for ever growing bandwidth requirements.

The *Light On Board™* optical package offers four key advantages:

- Lower overall system cost
- Increased density
- Increased signal fidelity
- Lower overall power consumption

Reflex Photonics technology will enable next generation computing and switching applications and presents a compelling choice for commercial implementation for multiple high-speed inputs and outputs. The *Light On Board™* platform merges the communications abilities of optics with the computing of silicon in a cost effective manner like never before.

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