

Cost-effectively Designing for 10Gbit and Beyond in the MAN

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As high-speed optical networking technologies migrate outward from core transport applications into metro area network (MAN) environments, designers are facing a shifting set of new challenges in order to meet the stringent economic considerations for MAN implementations. In general, the business feasibility model for initially moving to 10 Gbps OC-192 and then onward to 40 Gbps OC-768 calls for achieving successive 4x bandwidth increases with no less 3x cost increases. However, the successful achievement of these goals can require a significantly different emphasis depending upon the link distances and port densities that must be supported. Although many of the 40 Gbps design challenges are similar for all environments, it is much too simplistic and inefficient to merely replicate core-oriented designs directly into MAN deployments.

For example, the long-haul distances and high per-channel traffic concentrations in core transport environments mean that tight dispersion management and large Wavelength Division Multiplexing (WDM) channels are important performance considerations. In order to minimize error rates over longer distance links, techniques such as dispersion compensation, return-to-zero (RZ) modulation schemes and forward error correction (FEC) algorithms are increasingly required, especially for higher bandwidths. On the other hand, in MAN environments with large numbers of individual Dense Wavelength Division Multiplexing (DWDM) channels carrying complex heterogeneous traffic over relatively shorter distances, the key design considerations shift away from achieving longer distances and become more focused on minimizing per-channel costs and power consumption.

With the introduction of low power Lithium Niobate Mach Zender and electro-absorption modulators (EAM) it is now possible to combine the modulator and laser functions within a single device. This can greatly reduce overall space and power requirements, while delivering reliable performance at OC-192 and OC-768 speeds along with precision tunability to 1.5-micron wavelength increments.

In addition, since the driver voltage requirements for Lithium Niobate modulators and EAMs have been reduced, there is no longer a need to rely on exotic compound III-V processes such as Gallium Arsenide (GaAs) or Indium Phosphide (InP) for the drive electronics. EAMs and Lithium Niobate Modulators can be very efficiently driven with highly-integrated monolithic devices that are implemented in Silicon Germanium (SiGe).

SiGe processes are identical to mainstream bulk bipolar silicon processes, with the exception that the base layer receives a graded germanium doping that allows tailoring of

the energy bands to create a pseudopotential in the base. This radically reduces the base transit time, thereby increasing the maximum gain frequency. Because SiGe is inherently a silicon-based process that can fully leverage mainstream semiconductor fabrication technologies, it provides a solid foundation for integrating high-speed driver circuitry and support logic on the same die.

As shown in Figure 1, a complete OC-768 transceiver can be efficiently implemented with a minimal number of chips by using a SiGe-based modulator driver, transimpedance amplifier and Multiplexer/Demultiplexer (Mux/Demux), in conjunction with a CMOS-based framer.

(Insert Figure 1 – OC-768 chip set)

SiGe's high performance capabilities and inherent integration flexibility are especially useful in the Mux and Demux devices by enabling a smooth transition from 16-bit streams at 2.5 Gbps to/from a single 40 Gbps stream, all within a single semiconductor device. In comparison, typical GaAs/InP approaches require several multiplexing stages. These stages include multiplexing the 2.5 Gbps lines into 4 streams at 10 Gbps and then multiplexing the 10 Gbps streams within the GaAs/InP device.

The bottom line is that a significant cost and power penalty must be paid every time that the inter-device signals are brought out to 50-ohm traces at the board level. The intelligent use of SiGe-based chip-level integration not only minimizes the number of devices and reduces overall power requirements, it also eliminates the need for inefficient "glue" logic typically used to implement interfaces between segmented components.

By eliminating the need for low-level custom glue logic, these highly-integrated devices also enable system designers to derive maximum leverage from industry standard electrical interface definitions, such as the Optical Networking Forum's SFI-5 standard for SERDES-to-Framer interfaces and SPI-5 for upstream packet interfaces. In effect, the integrated components become standards-based building blocks that can be used to both minimize time-to-market design cycles.

In addition, because SiGe offers a 10 to 100 times greater yield in transistor count than GaAs or InP, it also makes it possible to integrate the 2.5 Gbps DLL-based I/O macros and the skew compensation logic that is required to support the low pin count (16 pins operating at 2.5 Gbps) SERDES-to-Framer interface. Framers for OC-768 applications also need to support FEC functions as well as emerging digital wrapper features. Both FEC and digital wrapper technologies are now becoming increasingly important features for maintaining reliable performance in high-speed heterogeneous environments without reducing the span length when migrating to the next speed grade. This integration capability will be a key enabling factor for effectively migrating 10 Gbps and 40 Gbps into the MAN.

To support widening demands for the high-volume deployment of 10 Gbps and 40 Gbps MAN applications, semiconductor level integration, yield and production cost efficiency

have now become critical factors for competitive success. By leveraging proven mainstream semiconductor processes, such as SiGe and CMOS in conjunction with efficient electroabsorptive modulation lasers, next generation system designs can deliver the robust 10 Gbps and 40 Gbps performance in combination with the high-port densities and low costs required to support complex heterogeneous MAN environments.