Technologies & Trends, Influencing the Connector Industry

Keeping pace with the semiconductor industry and Moore's Law

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As the twentieth century draws to a close, we are ever mindful of the vast technological advances which were realized during the last half of this century; more so than during any other period. The sciences and the humanities have kept their respective disciplines separate, albeit on converging paths; and one may debate which spawned the evolutionary trends in technology that have become increasingly intrusive. Perhaps, a welcomed intrusion as one reflects upon the impact technology has had on our industrial environment, communications, computers, transportation, medical research, and the quality of life.

To a degree, we are involved in this technological march by virtue of our industry participation and as practitioner's of innumerable disciplines which support the markets mentioned above. As such, it is timely that we take stock of our accomplishments, and insure that our goals and objectives are compatible with those emerging technologies and trends that will surely influence our industry.

It would be extremely difficult to identify a contemporary technology that has had a more dramatic, pervasive, and beneficial influence on our culture than microelectronics. The extent and sophistication of the spectacular scientific and engineering advances that are at our fingertips today are neither entirely recognized or fully appreciated by those outside the field. Semiconductors continually evolve toward more complex integration by incorporating more functions within the IC Package perimeter, either by increasing gate density, hybridization, or multilayering. Before founding Intel Corporation in 1968, Gordon Moore hypothesized that "relative to chip density, the number of transistors on a chip would double every 2 years". Up to our present time, his theory continues to be accurate, and has come to be known as *Moore's Law*. As the interconnect requirements increase at the chip level, a domino effect takes place in order to satisfy all other interconnection needs within the system. *Physical Interconnections* adheres to the following *Hierarchy*: On-Chip, VLSI Monolithic Functions, Chip-to-Board, Interchip Circuitry, Board-to-Board, and Rack-to-Rack. Simply stated, this translates into a growing demand for connectors, cable assemblies, and backpanel assemblies. From the perspective of interconnects, the two primary technological drivers in the industry today are Bandwidth and Density. The challenge facing the connector and printed board industries is to keep pace with the semiconductor industry and Moore's Law.

Interconnect manufacturers participate in markets which are dynamic and undergo change caused by technology P*ulls* and *Pushes*. This article is the first of a series in which we will identify the technology and market drivers that propel our industry. Over the next several months, we will *drill down* and examine those technologies and trends in greater detail. Finally, with an eye toward the future, we will identify and discuss the emerging technologies and external forces which will impact the future of the interconnect industry. Following are brief commentaries concerning the technologies and trends that have influenced the connector industry. These are not listed in order of importance.

EXTERNAL FORCES:

- Since 1965, the semiconductor industry has emerged as the primary catalyst for the connector industry. The semiconductor industry continually re-invents and redefines itself. This evolution has had a dramatic impact on emerging technologies and emerging markets as well as changing how connector manufacturers "go-to-market".
- The distribution channel continually expands. In 1998, distributor sales accounted for more than a third of all OEM connector sales.
- Major OEM's have deployed both manufacturing and design centers around the world. To meet service demands, primary suppliers *must* follow.
- Contract Manufacturing has carved a permanent niche for itself. Major OEM's are focusing on their core competencies and will continue to *out-source* manufacturing activities.

INTERNAL FORCES:

- Level 2 Interconnects, (device-to-board):
  Higher density demands will require from 400 to 2000 Input / Output connections located on 0.25 to 0.40 mm centerline spacing with operating frequencies ranging from 1 to 3 GHz.
- Level 3 Interconnects, (board-to-board and cable-to-board):
  Higher density demands will require, 400 to 1200 Input / Output connections, (100 real signals per inch), located on 0.40 to 1.00 mm centerline spacing with operating frequencies ranging from 250 to 500 MHz.
- Bus Architectures & Interconnect Devices:
  Bus Architectures and their electro-mechanical interfaces, are undergoing evolutionary change in response to multi-tasking demands, while providing connectivity to an ever-increasing number of peripheral devices. As the PCMCIA card revolutionized mobile PC connectivity; USB offers adaptive flexibility to the desk top environment by providing a standardized connective interface for peripheral devices, see discussion below. Additionally, on work stations, mid-range servers and high-end computing platforms, several specifications and standards have emerged which address various hardware configurations and performance criteria. Nationally recognized standards organizations, i.e., IEEE, EIA, ANSI, etc..., devote enormous amounts of time and energy bringing an array of disciplines and interests into agreement while dealing with a myriad of technical hurtles. There are also numerous working groups and committees, i.e., the PICMG & Small Form Factor consortiums, operating *outside* the auspices of the national organizations that perform similar activities. The list of hardware interfaces continues to expand as OEM's, connector makers and system developers define configurations for various platform requirements. The following discussion highlights the ongoing efforts of several technical committees that strive to answer the need for higher density and increased bandwidth interconnects.

Bus Trends:

There are two forces driving forces I/O interconnects to the next level. System designers are moving toward *Remote I/O*, and in what appears to be a departure from the traditional LAN structure, designers are developing modular *System Area Networks*, (SAN).

- Remote I/O entails moving the microprocessors, memory controller, and memory as close together as possible to accommodate increased bus frequencies. System vendors must strive to separate the I/O subsystem from this microprocessor/memory complex. The key to accomplishing this separation is to create an array of point-to-point interconnections rather than using the shared bus connection, i.e., PCI and PCI-X.
- SANs are emerging as an alternative to LANs for processor-to-processor communications in server clusters, but LANs are still needed to interconnect other computers such as clients. Dedicated storage interconnects are also available to interconnect processor systems and storage systems thus creating a distributed and modular system architecture.

Two distinct industry groups were formed to address the need for a new switched-fabric, interconnect that could move the industry toward more flexible, distributed modular systems. PCI-X is expected to sustain the server industry for the next several years, however long term, a shift away from shared bus interconnects is required to support the growing need for distributed resources and SANs. The Future I/O Alliance and the Next Generation I/O Forum are developing high-bandwidth, low-cost, switched fabric architectures for consistent interconnects throughout the SAN.

Future I/O Alliance , (FIO):

Adaptec, Compaq, HP, IBM, and 3Com began work on the Future I/O specification in the third quarter of 1998 and formally announced the Future I/O initiative on January 13, 1999. A developers conference was held in February 1999 to encourage wider participation. Workgroup meetings will be scheduled and a review period is underway for feedback on the earliest stages of the specification.

Because the new PCI-X protocol will have the bandwidth to carry the I/O subsystems through the next two to three years, the Future I/O alliance will have time to optimize a standard that can revolutionize the industry and fulfill enterprise computing needs for the next generation. The Future I/O specification is expected to be functionally complete in fourth quarter, 1999, with prototypes available in 2000 and products available in 2001.

Next Generation I/O Forum, (NGIO):

The NGIO Forum is an independent organization under the guidance of a steering committee comprised of Dell, Hitachi, Intel, NEC, Siemens and Sun. The organization was formed in February, 1999. Next Generation I/O architecture is a channel-oriented, switched fabric, serial point-to-point link architecture aimed at meeting the growing needs of I/O reliability, scalability and performance on servers. Next Generation I/O introduces the use of an extremely efficient engine that is directly coupled to host memory which replaces shared buses with switched point-to-point links.

System I/O:

More recently, August 31, 1999, Compaq, Dell, Hewlett-Packard, IBM, Intel, Microsoft Corp., and Sun Microsystems announced their intent to merge the best ideas of the FIO and NGIO architectures into a uniform specification for server and peripheral manufacturers throughout the industry. System I/O will provide a common system area network fabric which supports both conventional server I/O and inter-processor communication among parallel clusters.

Emerging Technologies & Trends, Influencing the Connector Industry, Continued:

USB 1.0:

USB 1.0 offered the PC industry its first Universal Plug-N-Play peripheral interface that provided flexible interconnections with up to 127 peripherals. The bus is capable of transfer rates up to 12 Mbit/s. Peripheral devices compatible with this interface include the keyboard, mouse, joystick, digital camera, digital telephone, printer, monitor, and many others. The interface features a 4 position connector module and a mating overmolded cable assembly.

USB 2.0:

USB 2.0 was introduced at the Intel Developers conference in February 1999 and is gaining market acceptance because the bus features transfer rates of 120 and 240 Mbit/s while maintaining forward and backward compatibility with its predecessor, USB 1.0. With this type of performance, USB 2.0 is a true alternative to IEEE 1394 for many traditional PC peripherals, including printers, scanners, and digital cameras.

High Performance Serial Bus, IEEE 1394, FireWire:

The IEEE-1394 High Performance Serial Bus is a versatile, high-speed, and low-cost method of interconnecting a variety of personal computer peripherals and consumer electronics devices. The IEEE-1394 bus began life in 1986 as Apple Computer's alternative to the tangle of cables required to connect printers, modems, external fixed-disk drives, scanners, and other peripherals to PCs. The proposed standard (P1394) derived from Apple's original FireWire design, was accepted as an industry standard at the December 12, 1995 meeting of the Institute of Electrical and Electronics Engineers (IEEE) Standards Board. Characteristics of this serial interconnect device are as follows:

- Provides a direct digital link many peripherals, i.e., digital camcorders, scanners, printers, videoconferencing cameras, and fixed-disk drives. FireWire is a candidate for the "Home Network" standard initiated by VESA (Video Electronic Standards Association).
- Delivers 400 Mbit/s data rates presently with future development planned to achieve 1.6 Gbit/s.
- Uses a flexible, six-conductor cable and connectors to interconnect devices. A four-conductor version of the standard cable is used to interconnect consumer audio/video components.
- Extends Plug-and-Play features beyond the PC. When a new device is connected, FireWire automatically recognizes the device; and when disconnected, automatically reconfigures itself.

High Performance Serial Device Bay, IEEE 1394-b:

Compaq Computer Corporation, Intel Corporation and Microsoft Corporation have joined forces in the development of this technology. Device Bay is an open architecture which defines an industry specification that enables adding and upgrading peripheral devices without opening the chassis and without turning off or rebooting the PC. Device Bay also enables peripheral devices to be easily swapped between platforms and can be used for a variety of devices, such as: Readable and writeable CD and DVD drives, Smart card readers, Satellite television decoders, High-speed digital modems and network cards, Hard drives, High-capacity removable media drives, and Audio processors. Intel chip sets are currently being sampled in the laboratory and Microsoft announced that its Windows 98 Second Edition supports this technology. Device Bay uses two standard industry interfaces; IEEE 1394 High Performance Serial Bus and Universal Serial Bus (USB). All peripherals in use today can be designed to utilize one of these interfaces, with three exceptions. Because of bus bandwidth limitations, memory, CPUs, and video cards must still be attached to the motherboard.

Emerging Technologies & Trends, Influencing the Connector Industry, Continued:

Intelligent Peripheral Interface, (IPI):

IPI is an IBM System 38/AS-400 bus interface. It is a high-speed hard disk interconnect interface used on minis and mainframes and transfers data in the 10 to 25 MBytes/second range. FC, SCSI, and HIPPI described below are IPI interconnects.

HIPPI 6400-PH, Physical Layer Interface:

The T11.1 Committee specifies a point-to-point, full-duplex, interface for reliable transmission of data at 6400 Mbit/s, per direction, over distances of up to 1 km. Characteristics of a HIPPI-6400-PH physical-layer include:

- User data transfer bandwidth of 6400 Mbit/s (800 MByte/second);
- A full-duplex link capable of full-bandwidth transfers in both directions simultaneously;
- An ac coupled parallel electrical interface for driving parallel copper cable up to 40 meters;
- A parallel electrical interface for driving a local optical interface for distances up to 1 kilometer.

SCSI (Small Computer System Interface):

Over the last 13 years, this I/O family has become an official industry standard. SCSI has grown and evolved to keep pace with the demands of the most sophisticated systems. The standard recognizes virtually every peripheral type and takes advantage of newer hardware and more intelligent controllers. The data path has been widened and transfer speeds have been increased to keep pace with system requirements. Current and planned performance enhancements will insure that SCSI remains a viable bus architecture in the future. Following are several examples:

- **SCSI Parallel interface (SPI):**
  SPI includes data rates up to 20 MBytes/second.
- **Ultra SCSI, (FAST-20)**
  Ultra SCSI doubles the data rate of SPI to 40 MBytes/second.
- **Ultra2 SCSI, SPI-2, (FAST-40):**
  Ultra2 SCSI doubles the data rate Ultra SCSI to 80 MBytes/second.
- **Ultra3 SCSI, SPI-3, (FAST-80DT):**
  Ultra3 SCSI doubles the data rate of Ultra2 SCSI to 160 MBytes/second.

SCA-2 (Single Connector Attachment):

The SCA-2 provides a means for directly attaching disk drives to printed circuit boards and answers the industry's need for a connector that will expand the SCSI interface, while being flexible enough to simplify the installation and interconnection of a myriad of peripheral devices. The connector is under the control of the following industry specifications:

- SFF-8451 (Small Form Factor Committee), and
- EIA PN-3651 (Electronic Industries Association).

Electro-mechanical features which enhance this components function include:

- Sequential contact engagement permits first-make-last-break connections for hot swapping.
- Mechanical features to provide positive orientation and polarization of mated connectors.
- Blind-mate docking for direct engagement of disk drives to backpanels.

Emerging Technologies & Trends, Influencing the Connector Industry, Continued:

Gigabit Ethernet, IEEE 802.3z:

Gigabit Ethernet provides 1 Gbit/second bandwidth for campus networks at a lower cost than other technologies of comparable speed, i.e., Fiber Distributed Data Interface (FDDI), and Asynchronous Transfer Mode (ATM). It offers a natural upgrade path for current Ethernet installations and leverages existing hardware installations. Gigabit Ethernet is fast becoming the technology of choice for intranet installations. In the past, it was thought that video might require a different networking technology designed specifically for multimedia. However, it is possible to mix voice, data and video over Ethernet by employing a combination of the following:

- Increase bandwidth via Fast Ethernet and Gigabit Ethernet and enhanced by LAN switching;
- Utilize Resource Reservation Protocol (RSVP), to manage bandwidth on demand;
- Apply IEEE 802.1P and 802.1Q, to provide LAN specific information within the network;
- Apply advanced video compression methods such as MPEG-2.

These technologies and protocols combine to make Gigabit Ethernet an extremely attractive solution for the delivery of video and multimedia traffic. Continuous improvements over time have afforded this technology a ever increasing installed base. Regarding cost versus performance comparisons, this technology has managed to thwart the general acceptance and installation of FDDI via ATM, except in those instances where optical media is mandated due to the transmission environment.

Fibre Channel, (FC):

In the Datacomm industry, data transfer rates resulting from the networking of high performance computers is a bottleneck. Faster CPU's and sophisticated peripheral devices, in addition to client/server distributed architectures have compounded the performance gap which exists between workstations; as distance between LAN nodes continually increases. Fibre Channel provides a means to negate this bottleneck. It offers a switched protocol which provides a network bandwidth of approximately 1 terabit per second. FC is capable of transmitting data at rates up to 1 Gbit/sec, in full duplex mode, simultaneously. It is also able to transmit existing protocols, i.e., IP, SCSI, HIPPI, and IPI over both copper cable and optical fiber. It is interesting to note that the 40 position SCA-2, described earlier, is specified for high speed Fibre Channel drive applications over copper media.

PICMG & Compact PCI:

The PICMG, (PCI Industrial Computer Manufacturers Group), is a consortium of over 450 companies who collaboratively develop specifications that adapt PCI technology for use in industrial and telecommunications computing applications. PICMG Specifications include CompactPCI, *(cPCI)*, for Eurocard, rackmount applications and PCI/ISA for passive backplane, standard format cards. This groups purpose is to offer industrial equipment suppliers common specifications, thereby increasing availability and reducing the costs of industrial PCI standard-based products.

CompactPCI is an adaptation of the *Peripheral Component Interconnect (PCI) Specification* for industrial and/or embedded applications requiring a more robust mechanical form factor than desktop PCI. CompactPCI uses industry standard mechanical components and high performance connector technologies to provide an optimized system intended for rugged applications. It provides a system that is electrically compatible with the PCI Specification, allowing low cost PCI components to be utilized in a mechanical form factor suited for rugged environments. *cPCI* specifies using the 2 mm Hard Metric connector system supported by the IEC-1076-4 Standard, (ref. Bishop Report Type 2).

VITA, VME International Trade Association, (VME, and VME64x):

VITA was accredited as an ANSI standards development organization in June of 1993. Standards activities take place in either study groups or task groups. Within the VME Standards Organization, (VSO), no one individual holds the authority to decide what technology may or may not become a standard. This authority belongs solely to the membership. VME bus is an *open architecture* and the following list summarizes its' most popular applications:

- Industrial controls: factory automation, robotics, injection molding machines, automotive body assembly and painting, sawmill controls, metal working, steel manufacturing, cardboard cutters and many others.
- Military: battlefield command & control systems, ground and flight radar control systems, tank and gun controls, communications, avionics and many others.
- Aerospace: avionics, fly-by-wire control systems, in-flight video servers, spacecraft experiment control, missile countdown sequencers, and many others. In 1998 the Mars Pathfinder used a VME bus computer to control spacecraft operation on the planet Mars.
- Transportation: railway controls, smart highway systems and light-rail transit systems.
- Telecom: advanced intelligent node (AIN) switch gear, cellular telephone base stations, satellite up-link and down-links and telephone switches including routers and servers.
- Simulation: aircraft flight, earthquake, metal fatigue and various military simulation systems.
- Medical: CATSCAN imaging, MRI imaging and various acoustical systems.
- High Energy Physics: particle accelerators, particle detectors.

PCI-X bus:

Compaq, Hewlett-Packard, and IBM proposed the PCI-X bus protocol to the PCI Special Interest Group (SIG) during the second half of 1998. PCI-X is a backward compatible high performance extension of the PCI local bus that addresses the increased input/output requirements of high-bandwidth applications such as Gigabit Ethernet, Fibre Channel, Ultra3 SCSI and graphics. PCI-X supports 32-bit and 64-bit operations at frequencies up to 133 MHz, allowing performance capability of up to 1066 MBytes/second data throughput. It is expected that the evolutionary enhancements made to the PCI bus will satisfy I/O performance demands for the next two or three years, and will remain broadly supported for years after that. The initial application of PCI-X is expected to be in server and workstation products with additional applications in embedded systems and data communication environments. Based on the PCI-X initiative, Compaq, HP, and IBM have joined with Adaptec and 3Com forming the Future I/O alliance to develop a longer-term solution for I/O. The Future I/O interconnect will be based on a point-to-point, switched-fabric interconnect and will provide high-speed, low pin-count solutions.

Mezzanine Cards offer great flexibility and upgrade capabilities to Single Board Computer (SBC) manufacturers and users alike. The cards provide a means of bus expansion by adding additional or specialized I/O to the main processor board. There are presently three leading mezzanine technologies available: PMC, PC•MIP and IndustryPack; with PMC being the most popular. PCI Bus is a very fast expansion interface (no wait-states) with a large installed base, and is an ideal choice for use with a mezzanine system. The IEEE's CMC (Common Mezzanine Card) standard defines mezzanine card size, and the locations of the 64-pin low profile connectors which are used. The PMC standard is under the control of IEEE P1386.1.

Emerging Technologies & Trends, Influencing the Connector Industry, Continued:

Connector Trends, Board-to-Board & Cable-to-Board Interconnects:

As witnessed by the previous discussion, the need for high performance Level 3 connectors is dramatically accelerating. The challenge facing the connector and printed board industries is to keep pace with the semiconductor industry and Moore's Law. Manufacturers of supercomputers, high-end workstations & servers, telecom, datacomm & wireless systems are demanding connectors that adhere to stringent electrical performance criteria. It should also be noted that the notebook computer continually narrows the performance gap between it and the desk top computer. As such, both of these platforms have imposed increasingly demanding standards upon interconnect devices as system speeds and functionality are augmented. Typical system demands being imposed on connector, pwb, and cable manufacturers include the following:

- Operating Frequency range: 500-800MHz, and Rise time range: 60-120 picoseconds (ps),
- Data Transfer Rates: ≤ 580 Mbits/second, and Cross Talk maximum: 2 % near-end & 5% far-end.

To address these performance issues effectively, interconnect devices must incorporate suitable attributes which address geometry constraints (size, coding, keying), density (pin count, grid pattern), and signal fidelity (impedance control, grounding, shielding, hot-swap). Not to mention the ever present *least applied cost"* of the connector as a board/cable installed unit. Additionally, the list of drivers which continually influence interconnect performance remains dynamic:

- Migration from ISA to PCI to System I/O bus,
- Bus architectures moving from 66MHz to 100MHz to 133MHz to XXX MHz,
- Logic voltage declining from 5.0V to 3.3V with 1.0V on the drawing board,
- Contact pitch: reduced 0.100 inch to 2.0mm to 1.0mm to 0.5mm, & 0.3mm in development,
- Connector type: one-piece cardedge shifting to two-piece, separable modular connectors,
- Pin Count *Real Signals*: 10s of contacts per inch to 100s of contacts per inch,
- Signal Transmission Mode: Single-Ended changing to Differential Pairs,
- High performance dielectric materials require new manufacturing processes be developed, and
- High performance alloys continually push mechanical, electrical, & thermal functional limits.

Category 6 and Category 7 Cables:

No doubt these cables and their connector systems were topics of discussion at the BICSI (Business Industry Consulting Service International) Conference held in Nevada this past August. These cables differ in construction and bandwidth capability. As compared to *Cat 6* cable, *Cat 7* is "fully shielded" with individually screened twisted pairs, and an overall shield. This composition provides excellent signal fidelity at high data rates, however, it also results in a larger outside diameter which is considerably less flexible than *Cat 6*. Traditional pathway guidelines (commonly used with *Cat 6* cable) must be modified to provide additional termination space and larger bend radii. Other differences are centered around the connector interface. To meet industry specifications, *Cat 7* connectors must provide crosstalk isolation of ≥ 60 dB between all twisted pairs at 600 MHz. Compared to connectors used with *Cat 6* cable, equivalent crosstalk isolation values must be ≥ 40 dB between all twisted pairs at 250 MHz. *Cat 7* may become the conduit of choice for technology leaders whose applications require robust, high speed, and highly reliable media. Typical applications would include installations which require minimal radiated emissions, financial, insurance, medical, and other information sensitive organizations. Certain educational research facilities and government offices will also have applications for the "fully shielded" *Cat 7* system.

Connector Trends, Board-to-Board & Cable-to-Board Interconnects, continued:

Small Form Factor Fiber Optic Connectors:
No discussion of cable transmission media would be complete without mention of the advancements made in multimode and singlemode fiber optic cables and connector systems during the past 2 years. Resulting from the introduction of new connector technologies these interconnects are now considered to be a cost effective alternative to copper wire systems. As compared with the traditional SC fiber optic connectors, these *small form factor* (sff) connectors perform equivalently, are roughly half the size, provide greater port density, can be terminated with or without ferrules, operate in either singlemode or multimode states, and are approximately 1/7th the cost of SC connectors. A number of standards bodies, (IEEE, IEC, EIA, TIA, Fibre Channel, and the ATM Forum), have benchmarked these sff connectors for high speed network environments. Based on the industry standard RJ-45 port interface, these sff connectors provide a familiar envelope to packaging engineers and system technicians which makes it convenient for fiber to coexist with legacy copper within the network and at the wall outlet. Most network installations employ a hybrid system which utilizes both copper and fiber media to satisfy specific performance needs and address bottleneck issues. However, these new sff connectors may create the ground-swell necessary to finally make the often touted FTTD (fiber to the desk) a reality once and for all.

The *degrees-of-freedom* associated with the manufacture of various interconnect media have been greatly reduced as the electrical parameters affecting digital signal transmissions became the dominant factor to increasing system throughput. The key to satisfying these criteria will require backpanel, connector, and cable manufacturers to jointly develop their products in order to arrive at a mutually compatible, high-speed, digital signal interface which is differentially, (LVDS), driven.

The following discussion summarizes various automotive industry consortia that are involved in the process of standardizing common electrical interconnects among various manufacturers. These initiatives are driven by the need to reduce connector cost and complexity, while improving reliability, quality and serviceability. By their participation and contributions, these groups insure that their ongoing research remains aligned with USCARs Partnership for a New Generation of Vehicles (PNGV), which will speed the development of vehicles that are even cleaner, more fuel efficient and more easily recyclable than today's vehicles. As advanced technologies are applied to automobiles, connectors will be influenced by electrical, mechanical, environmental, and cost considerations.

EWCAP, Electrical Wiring Component Applications Partnership:
The United States Council for Automotive Research (USCAR) is the umbrella organization of Daimler Chrysler, Ford and General Motors, which was formed in 1992 to further strengthen the technology base of the domestic auto industry through cooperative, pre-competitive research. Under its sponsorship EWCAP, the Electrical Wiring Component Applications Partnership was formed in June of 1994. EWCAPs goals were to encourage cooperative research and development including the joint sharing of technologies to develop common electrical connection systems as follows:

- To develop common designs for electrical connectors to reduce costs and complexity,
- To establish common families of best-in-class connection systems,
- To establish a standard "footprint" for electrical components common to all partners, and
- To develop industry-wide, test specifications and design guidelines for electrical components.

Emerging Technologies & Trends, Influencing the Connector Industry, Continued:

Bluetooth Technology:

Bluetooth is the codename of a specification for small form factor, low-cost, short range radio links between mobile PCs, mobile phones and other portable devices. The Bluetooth Special Interest Group is an industry group consisting of Ericsson, IBM, Intel, Nokia and Toshiba who are driving development of the technology and bringing it to market. Bluetooth will provide an easier way for mobile computing and communications devices to communicate with one another and connect to the Internet at high speeds without the need for wires or cables. Bluetooth technology will also simplify synchronization of mobile computers, mobile phones and handheld devices.

CAN, Controller Area Networking:

CAN protocol effectively eases automotive electronics networking. Without networking, connecting the electronic modules in a modern automobile results in bulky, complex, and difficult-to-install wiring harnesses. Using a serial bus, such as the CAN, simplifies wiring, reduces the number of data sensors, and implements extra functions at no additional cost. A modern car needs serial networking to connect its various electronic modules. Cars contain three networks that operate separately, but share information: comfort and convenience; body electronics and diagnostics; and power train, antilock brakes, and vehicle dynamics. CAN simplifies wiring, adds functions for little extra cost, and improves car on-board diagnostics. As a result of the application of this serial interface, the number of connectors within the wiring harness and the number of contact positions per connector will decrease as compared to the traditional parallel connection scheme.

NAHSC, National Automated Highway System Consortium:

In 1995, the US government quietly introduced the NAHSC, thereby formalizing an organized effort to automate our roadways. Comprising universities, automobile companies, and regional traffic agencies, the consortium has developed an impressive set of scenarios that should ultimately lead to hands-free operation of automobiles. Manufacturers have demonstrated these technologies on actual roadways. Moreover, the systems should improve safety as well as traffic congestion, pollution, and fuel-consumption problems.

The Automated Highway System (AHS) is a broad label for a variety of techniques that seek to address widespread problems that current vehicles cause. AHS includes both in-car, computer-based control systems and additions to the highway infrastructure. In-car systems rely on vision-, magnetic-, and radar-based sense elements for input to computer-controlled steering, acceleration, and braking. Infrastructure enhancements include magnetic and visual cues placed along roadways. The connector opportunities for infrastructure applications will require extremely robust, high reliability and environmentally stable devices capable of transmitting digital signals. Additionally, connectors for on-board systems will remain similar to those currently used in digital signal paths. Vehicle Systems under development encompass the following:

- Smart-highway technologies, including adaptive-cruise-control and collision-warning systems,
- Vision-, radar-, and laser-based sensors to allow automated cars to navigate existing roadways,
- Magnetic elements embedded in roadways to control on-board systems & lane selection, and
- Multi-car Automated Highway System fleets generate fuel and emission savings and significantly increase the capacity of freeway lanes.

Emerging Technologies & Trends, Influencing the Connector Industry, Continued:

The Automated Highway System (AHS), continued:
Additional development efforts are underway which promise to bring a new generation of automated and occupant initiated, interactive features to the automotive environment:

- Automakers will move to the controller-area-network (CAN) standard by 2002 or 2003 models which will increase the number and functionality of on-board systems,
- The Automotive Multimedia Interface Collaboration is developing an open gateway to connect with on-board vehicle networks to enable data sharing between systems,
- The Intelligent Transportation Systems Data Bus (IDB) will access on-board network systems to provide automated, real-time vehicle diagnostics, and
- IDB will connect navigation, driver-warning, communications, and stereo systems seamlessly. Additionally, wireless internet connections will allow WWW information to be accessed on-demand, i.e., headline, financial, and sports news, audio books, music, and videos.

MID Technology, (molded interconnect device) will certainly have an impact on the connector industry as hybridization and miniaturization of electrical components continues. MIDs provide a powerful combination of benefits to manufactures and user alike;

- Integrates mechanical & electrical functions into a single component,
- Reduces package complexity, size and weight,
- Reduces part count via feature integration, and
- Reduces assembly complexity, skill level and labor.

MIDs are three dimensional injection molded parts with plated circuitry conforming to the surfaces of the part. These devices replace components such as discrete wiring, metal stampings, and flexible circuits in automotive, medical, appliance, computer, telecommunications, and other applications.

ADDITIONAL TECHNOLOGY TRENDS:
By virtue of the trickle down theory, the following technology drivers will influence the Level 3 and PWB interconnect industry over the next 1 to 3 years.

- **The Microprocessor Wars:**
  The processors which will define the next generation of high-end computing systems have recently made headlines. Based on the industries IA-64 architecture, these 64 bit microprocessors will offer considerable throughput improvements.
  - ⇒ At its Developers Forum, Intel introduced working samples of its *Merced* silicon complete with L2 cache encased in a cartridge. Intel claims that *Merced* will be faster than the Pentium III, and predicts that its clock speed will be approximately 800 MHz.
  - ⇒ Sun Microsystems IA-64 processor called *Ultrasparc III* will debut shortly. Its expected performance will be around 600 MHz; a somewhat slower clock that Intel’s *Merced.* However, Sun claims the scalability and multiprocessing capabilities of its newest processor will outpace the competition.

ADDITIONAL TECHNOLOGY TRENDS:

- **The Microprocessor Wars, continued:**
  - ⇒ Apple Computer has also introduced its new *G4* PowerPC family which uses Motorola's *MPC 7400* processor. This chip family will be produced with clock speeds of 350, 400, 450, and 500 MHz.
  - ⇒ Compaq's next generation Alpha processor, *EV-7* is scheduled to be introduced in December. It's intended to support clock speeds over 1 GHz, and will include 1.5 Mbytes of L2 cache, a 6 GByte/sec Rambus memory controller, a 3 GByte/sec I/O interface and a direct processor-to-processor interface.

- **Hard Disk Drives:**
  - ⇒ Manufacturers are under pressures to reduce size, increase speed, and increase capacity.
    - There's no stopping the upward movement in average disk drive capacities. Drives in the 3 to 5 gigabyte range held the lead in 1998 shipments, but the market's appetite for more capacity goes up every year. In 1999, leadership has already moved up to the 5-10 gigabyte group, with 40-80 gigabyte drives forecasted to be 2002's leading product group.
    - HDD sizes in order of most to least installed include 3.5, 2.5, 5.25, and 1.8 inch diameters.
    - Spin speeds have increased from 3600 rpm, to 4800, and 7200 rpm presently; with 10,000 and 15,000 rpm projected for the next generation of HDD.
  - ⇒ The typical SCSI & SCA-2 connector interface will be pushed beyond their limits trying to keep pace with HDD technology. RAID systems will impose different requirements on the interconnect as the connector becomes the bottleneck to data storage and retrieval.

- **Hard Metric Connector Systems:**
  - ⇒ The growing trend continues regarding the use of 2mm pin and socket connectors as the major interconnect in pcb to backpanel packaging schemes.
  - ⇒ The technological drivers of increased I/O density and higher bandwidth have been satisfied by the introduction of 8 and 10 row connector modules which employ internal ground pins or shields, and in some cases, an interstitial grid pattern to minimize signal degradation.
  - ⇒ Connectors have become more *digitally oriented* as dielectric materials, conductor geometry, shape, and placement are designed specifically to be compatible with Coaxial, RF, and Differential signal transmissions resident in today's pwb circuitry.

- **The Battle for the Last Mile:**
  - ⇒ A battle is being waged to control broadband service deployment, (high-bandwidth Internet access), into America's homes, and whoever wins could control much of the Internet pie. ISPs and phone companies have claimed that cable companies like TCI and Time Warner Cable are monopolizing high-speed Net access in the *Local Loop*.
  - ⇒ Competing technologies include xDSL, ISDN, Cable Modems, and Satellite Systems. Transmission media includes twisted pair copper wire, fiber optic cable, or hybrid fiber-coax lines running between the premise and the local loop pedestal and the Central Office Switch or Cable Company. Due to the lack of cost effective *upstream* transmissions, satellite systems are not considered to be a strong player in this arena. However, *Wireless Local Loop* over frame relay may become an economically acceptable alternative to cable.

ADDITIONAL TECHNOLOGY TRENDS:

- **The Battle for the Last Mile, continued:**
  ⇒ At the premise site, (residential or business), a *Set-top Box* or *Cable Modem* will provide access to broadband services on-demand. Set-top Boxes are currently available to link televisions to the Internet without the need of a separate computer. The next generation of Set-top boxes will include a programmable interface which can be accessed via a *smart card*. Cable Modems require a computer interface to access the Internet and offer significantly more function than the Set-top Box. The Multimedia Cable Network System (MCNS), comprised of TCI, Time Warner, Cox, and Comcast have formed a working group with Rogers, MediaOne, and CableLabs to develop a specification for a two-way over-cable data network. The document is titled *The Data Over Cable Service Interface Specification, (DOCSIS).* This specification will insure that compatible hardware is available from multiple sources.

- **Digital versus Analog Phone Systems:**
  ⇒ The shift from Analog to Digital systems has accelerated worldwide, and particularly in North America where analog leader Motorola, successfully kept competition at bay until its own infrastructure was ready for the changeover. Others involved in the digital build-up include Ericsson, Nokia, and Qualcomm. Digital installations are occurring worldwide as developing countries use wireless technology to expedite their communications systems. Its been projected that 50 thousand new base stations will be brought into service by the year 2006; with 26 thousand of those being built in North America alone.

- **Digital TV, (HDTV):**
  ⇒ After 8 years of deliberation, the North America Computer and Television Manufacturers Association finally reached agreement on a High Definition TV Standard. As part of that agreement, all analog TV broadcasts will be abolished by the end of the year 2006. Units will be available for this holiday season with prices ranging from $5,000 to $10,000 per TV.

- **Digital Video Disk, (DVD):**
  ⇒ Applications of this technology in optical and magnetic media will revolutionize the way video images are created, stored and retrieved.

- **Semiconductor Package Evolution:**
  ⇒ In keeping with Moore's law, the Semiconductor Industry reinvents itself every 6 – 8 months as new FABs and Packages evolve. FAB types include Small Outline Packages (SOP), Quad Flat Packs (QFP), Ball Grid Array (BGA), Super BGA (SBGA), Micro BGA (µBGA), Chip Scale Packages, (CSP), and Multi-Chip Modules (MCM). As a point of reference, BGAs contain approximately 144 interconnects, µBGAs contain as many as 500 interconnects, and CSPs contain more than 600. The next wave of chip integration will maximize the limits of size and function by creating families of monolithic devices which are composite hybrids designed and fabricated for specific applications.

<u>Emerging Technologies & Trends, Influencing the Connector Industry, Continued:</u>

<u>FUTURE TECHNOLOGIES:</u>

- **<u>Parallel Optical Interconnects:</u>**
  ⇒ This technology will revolutionize the way digital signals, (data), are moved in and between systems. The advent of the *optical pwb* at hand and the in combination with a light engine called a vertical cavity surface emitting laser, (*vcsel*), the major interconnect between the backpanel and the pcb or cable I/O will address the following issues:
    - High Bandwidth & High Data Rate Transmission,
    - Extremely Low Crosstalk at Mechanical Interface,
    - Low Attenuation and Signal Degradation,
    - Multi-Channel High Density Packaging, and
    - Insensitive to Electromagnetic Interference (EMI).

- **<u>Global Positioning System-Enabled Phones:</u>**
  ⇒ combining communications and real-time navigation.

- **<u>Micro-sized Cellular & PCS Base Stations:</u>**
  ⇒ Eliminating the down-side of wireless communications; the urban eyesore of base stations festooned with antennas.

- **<u>Pocket Travel Planner:</u>**
  ⇒ Plans routes, makes reservations, stores electronic tickets, and tracks expenses.

- **<u>Electronic Wallets:</u>**
  ⇒ Connected to banks and other financial service providers accesses accounts, documents and disperses electronic cash.

- **<u>Wireless Personal Entertainment Centers:</u>**
  ⇒ Handheld gamebox, satellite TV receiver, Internet browser, & communications device in one.

- **<u>Communicating Medical Monitors:</u>**
  ⇒ Keeps users and medical professionals apprized of patient vital signs such as heart rate, blood pressure, insulin level, etc…

-- CONCLUSION --

Technology is evolving toward interconnection systems which integrate the advantages of disparate transmission media at several packaging levels. The driving force within the semiconductor industry is the need to provide increased functionality within the perimeter of the IC Package. If one examines a typical state-of-the-art IC Package, the actual active area (die) amounts to approximately 5% of the total package size. The industry is striving to increase this to 15-20% currently with a goal of 35-50% by the year 2002. The latter is believed to be possible by implementing *multi-layering and hybridization* at the die level. It appears Silicon will prevail. As this technology moves forward, the interconnect requirements to move data off chip and off card to various parts of the system, or to other systems and peripheral devices will become increasingly more difficult to achieve. The challenge for the connector industry will be to develop future generations of Board-to-Board, Cable-to-Board, and Device-to-Board systems which meet those needs. The convergence of optical and copper transmission media is emerging as the vehicle to meet these high performance systems demands in an efficient and cost effective manner. For the foreseeable future, the backpanel, with all its' inter-dependent connections, will continue to serve as the information conduit providing flexible, high data rate transfers between devices within the system in addition to those devices which reside within external systems.