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Connector Trends in Consumer Electronics

By Dr. Tamim P. Sidiki and Ir. Paul Potters, DSM Engineering Plastics

The huge global consumer electronics market, with its estimated value of \$175 billion, is a trendsetter that has a strong impact on many other industry segments. Out of a global connector market approaching \$50 billion, consumer electronics' connectors represent a total of more than 30 percent of the total connector market. Connectors provide a detachable link to electronic devices, various circuit boards, peripherals, and others. Examples include board-to-board, wire-to-board, flexible printed circuit, and memory or input/output connectors. Connectors typically use metallic contacts, a plastic insulator, and are generally enclosed in a housing.

Major trends influencing today's consumer electronics market center on size, form, and choice of material. In today's applications, product miniaturization, ease of use, diminishing carbon footprints, and wireless data access converge.

Such product trends require a respective underlying technology on the device side (e.g. GPS, solid state disks, finger print sensors, holographic storage), application and content side (e.g. 3D True-HD, data streaming), networks (e.g. Internet TV, Long Term Evolution, Cloud Computing) and wireless data transmission (W-USB, W-HDMI, W-Power, Bluetooth, RFID, and NFC).

New technologies drive new applications such as True HD TVs based on LED/OLED backlight displays, roll-able printed electronics, flash memory, touch screen technology, or data streaming as a replacement for traditional media, such as CD or DVD.

A growing focus on sustainability requirements also affects electronic products, as certain hazardous materials are banned and designers look for ways to improve carbon footprints. This impacts manufacturing processes, either by tighter processing conditions and methods, or by product changes. The halogen-free policy and higher required temperatures of lead-free soldering are well-known examples.

Architects and designers at original equipment manufacturers (OEMs) seek materials that address all of these trends. Product and system components should perfectly align with these technologies. As a consequence, connectors are also impacted. Miniaturization, high frequencies, banned materials, and high temperature requirements demand high-performance connectors with high-performance materials. Product developers and designers should be aware of the technology and product trends to select the right application. Good design solutions require an integral approach.

Product and Technology Trends

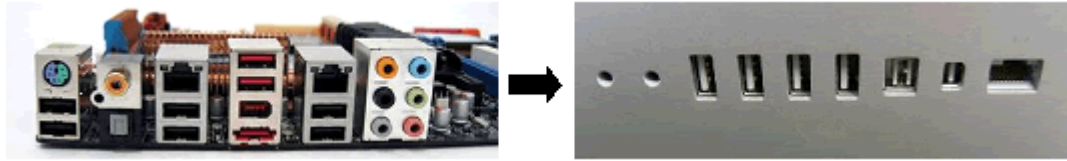
Computing, consumer, and communication (3C) are the main drivers in consumer electronics. The 3C industry is characterized by strong convergence, driven by a consumer demand for functional integration, and an application push by manufacturers to penetrate new or other market segments.

Computing

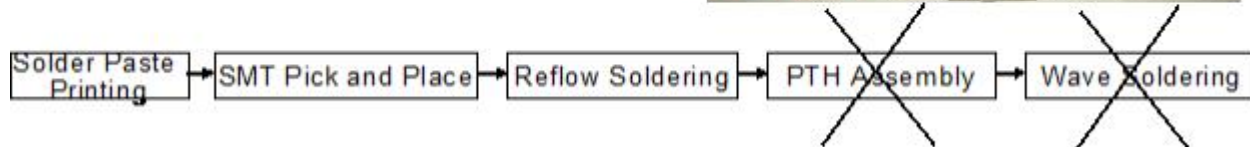
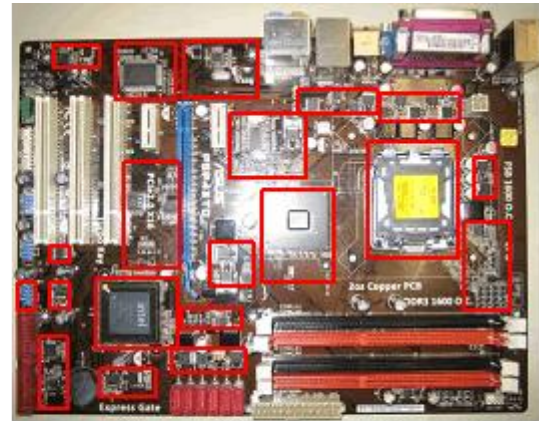
Desktop PCs will phase out. Fewer consumers desire a bulky box with lots of cables and peripherals on or under their table. In Europe's largest computing market, Germany, four times more portable PCs were sold than desktops in 2009, although only a few consumers really require portability of their computer. Notebooks, however, have significant drawbacks compared to desktops. Based on their optimization for mobility and power consumption, the display is smaller and the performance is not as good. Another step down is the netbook, but we believe that the growth of this segment, spoiled by the last downturn, will see a fast end. Netbooks have cannibalized notebooks, and have led to strong price erosion. Manufacturers will not invest in this segment once the industry has recovered, as consumers tend to prefer a high-performing notebook over a netbook, now that the price gap has narrowed.

All-in-One PCs are increasingly taking a sweet spot between bulky desktops and lower performing notebooks. From Apple to Shuttle, everyone is striving for a piece of the cake in this attractive segment. A major differentiator for All-In-One PCs is the display, which is increasingly offering touch screen functionality. Touch screens come as single or multi-touch option. With the ongoing price erosion of the panels, multi-touch can be expected to become the standard.

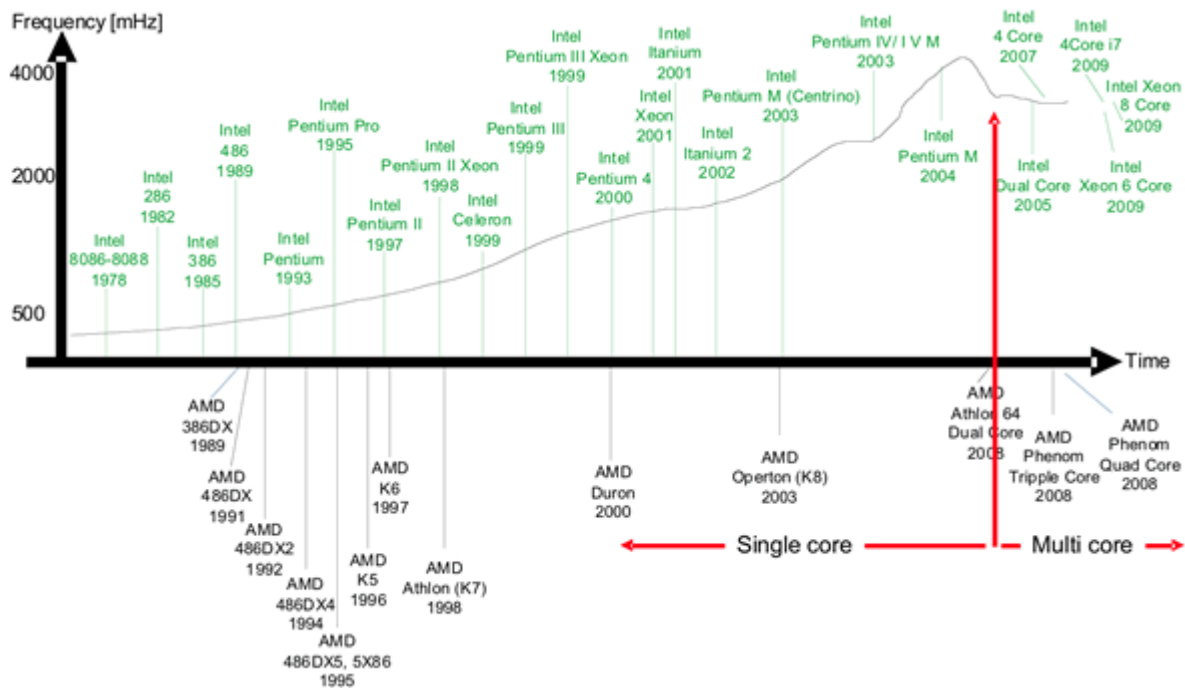
The integration of functionalities, such as mainboard, DVD recorder, power supply, cooling, and I/Os into the display frame have a significant impact on connectors.



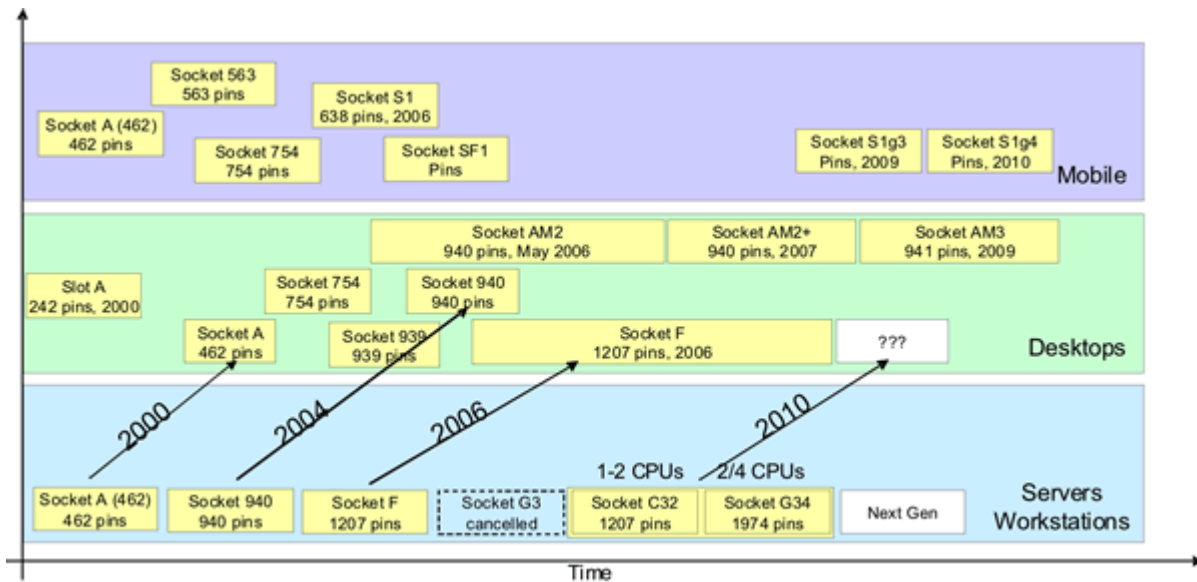
While traditional desktops have a broad variety of bulky I/Os, All-in-One PCs compromise on external I/Os. A condensed amount of external I/O with less vertical stacking enables a cost-optimized board assembly. Desktop PCBs combine reflow soldering of SMT components such as ICs and wave soldering of PTH sockets, e.g. DDR. Pin-in-paste soldering basically allows using a PTH socket design combined with reflow soldering process. As such, the mechanical robustness of PTH sockets will be maintained, as opposed to transferring the socket to SMT design. Wave soldering, including the manual PTH assembly stage, can then be omitted as an entire assembly step, leading to an immediate cost reduction.



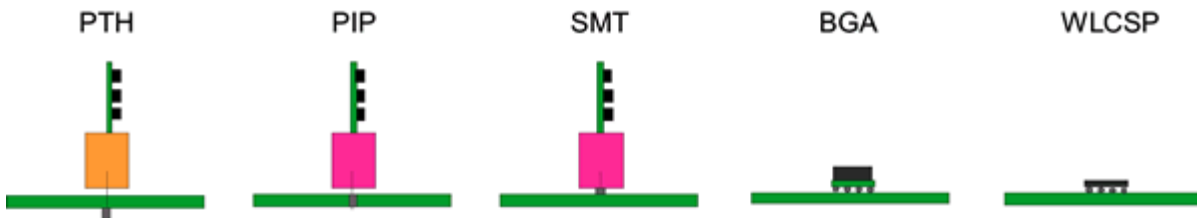
Another trend, the technical evolution of core components like the CPU socket, has a crucial role in connector design, as well. The race in CPU performance is the main indicator for powerful solutions, increased performance, and integrated technology. Until 2005, the continuous frequency increase at Intel and AMD was mainly driven by transistor gate shrinkage. For a further increase of performance, it turned out to be viable to modify CPU architecture and go from single core, with ever-shrinking transistors, to multi-core technology with parallel processing.



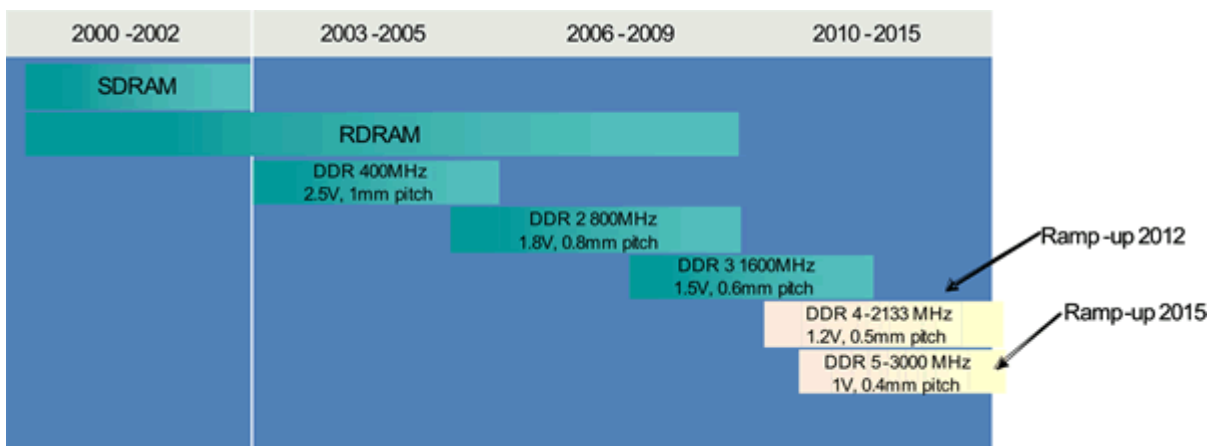
Therefore, this step has led to an even higher number of pins in CPU sockets. A growing pin number will influence board design, as it has a direct impact on board termination. In general, the more pins and the smaller the pitch, the more difficult PTH design becomes.



The AMD roadmap of CPU sockets shows the evolution of different socket generations and the amount of pins involved. In each of the segments, there is an increase of pins. The correlation between servers and desktops is striking. Approximately every four years a new socket, which has been introduced in the higher-end server segment, is adopted by desktops. The newly launched G34 socket, with 1907 pins, has such a high pin count that the typical two additional copper layers that AMD board design requires over Intel board design enforces an all-SMT board design. Otherwise routing of the socket cannot be done in a proper way. Based on historic trends and an expectation that consumers, and especially the gaming community, will ask for growing performance, we can expect that in a few years, SMT design of DDR sockets may find its way into desktops, too. We should not expect that all connectors and sockets will be transferred to SMT termination, but a transition of such a fundamental socket like DDR will make PiP very attractive for the remaining sockets. Hence, reflow soldering may see stronger growth in the future. This move already occurred with mobile phones and notebook/netbook PCs, and is now starting in servers. Interestingly, other industry segments, such as appliance or medical, start the implementation of SMT or PiP design practices in order to further improve total cost.



For some products, such as All-in-One PCs, the traditional wave-soldered through-a-hole pin connector will evolve to pin-in-paste design suitable for reflow soldering with through-hole pins. Higher temperature resistance of the socket will be required, specifically of the insulation plastics. In the next generation, or for other products, pins are replaced by surface mount legs. Then, BGA is directly applied to an interposer containing the die. The connector is purged, and the material is changed to silicon, epoxy, and FR4. A final step could be that the pads are printed directly onto silicon WLCSPs (Wafer Level Chip Scale Package). The solder balls interconnect the pads with the PCB. The package is reduced to a size slightly larger than the silicon die, and the actual die size will be entirely ball limited.



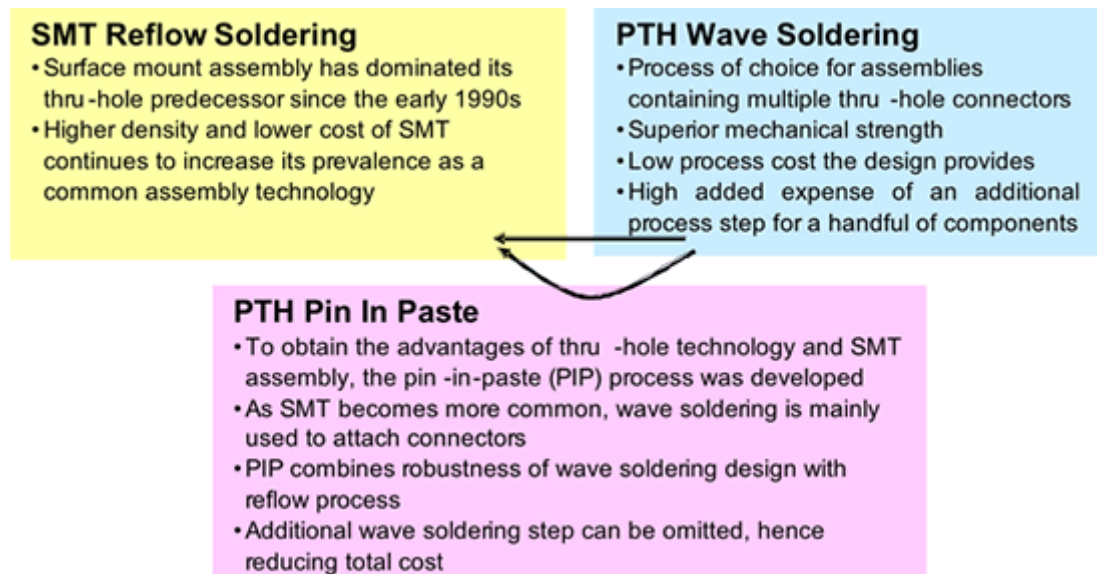
The evolution of DDR technology is a key driver for the related socket design change.

- Reduced voltages require less contact resistance
- Crosstalk concerns drive signal/ground ratio to 1:1, creating demand for higher density/larger contact count

As a consequence, SMT board termination will emerge. The shorter length of SMT pins directly leads to less EMI and better signal integrity, as the corresponding length of a dipole antenna will become shorter and its EMI transceiving capability will diminish as well. This effect will be eliminated once the socket is fully transformed into BGA (Ball Grid Array) or WLCSP design.

SMT vs. PTH Connector Design

Advantages SMT	Disadvantages SMT
<ul style="list-style-type: none"> • Smaller parts • Higher density layout • Cheaper PCBs (no holes to drill) • Improved shock and vibration characteristics • Improved frequency response • Easier soldering (difficult to heat holes in multilayer boards) • Easier to shield from EMI / RFI • Easier to automate manufacturing • Only one soldering process 	<ul style="list-style-type: none"> • More heat generated • Small clearance makes cleaning difficult • Visual inspection difficult • Good joint formation important for mechanical reliability of assembly • Harder to handle assembly • Lower mechanical strength vs wave soldering • Greater number of different materials to match CTE's

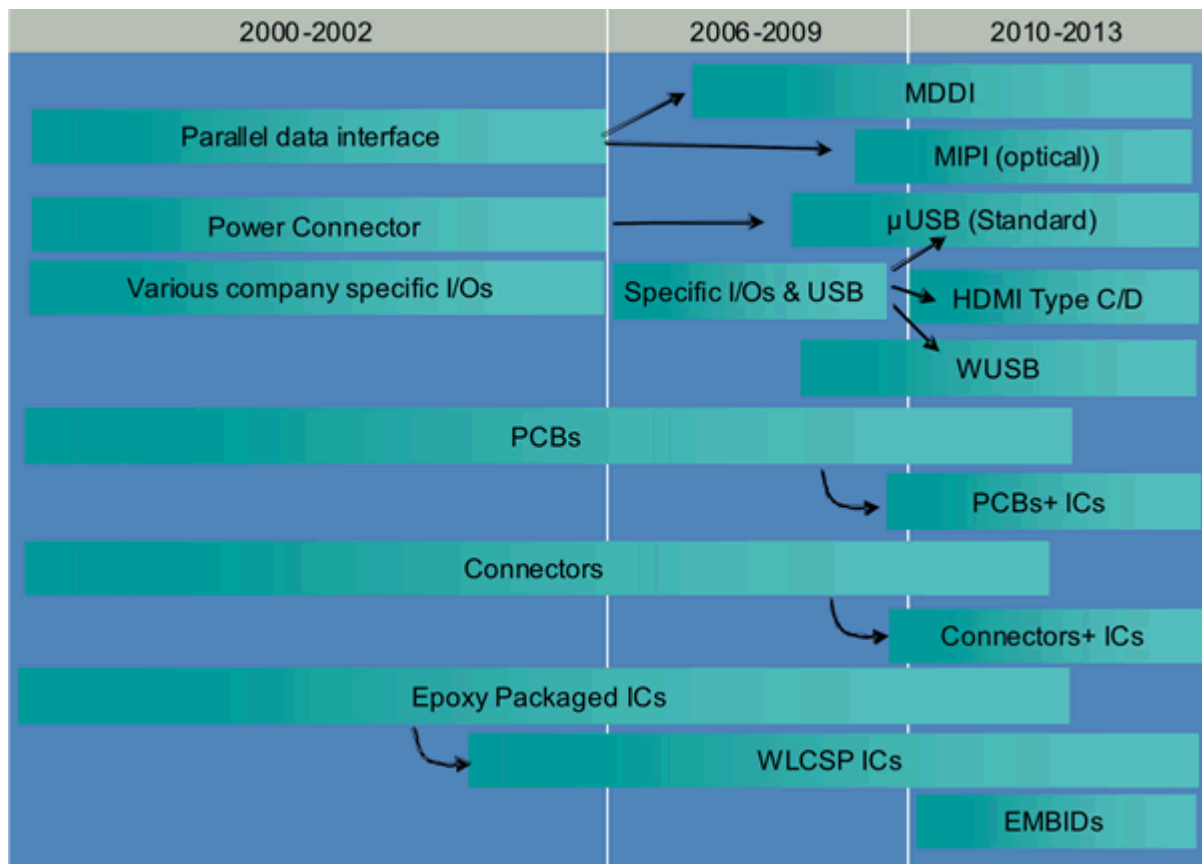


Communication

With the current transitions to LTE (Long Term Evolution) networks of the fourth generation, mobile Internet access is expected to replace wired access. Bandwidth and speed will be large enough to support the growing demand of a mobile community for content and permanent access. In mobile phones, HD content, high bandwidth, high resolution touch screens, OLED displays, various integrated functionalities such as GPS, radio, TV, high-resolution cameras, video conferencing, various motion sensors, LED lamps, or beamers, will become standard.

To enable such applications, technology is evolving fast. Optical interconnects, wireless I/Os, standardized power supplies, and new lower-power and higher-bandwidth interface technologies will ripple down from high-end smart phones to simple, affordable versions to meet all ends of the market.

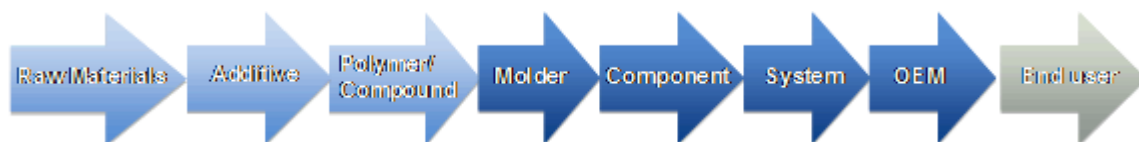
New interface technologies such as MIPI (Mobile Industry Processor interface) will lead to a growing portion of optical data transmission between the PCB and the LCD panel, reducing the number of wires or the impact of EMI, and hence, opening space for more functionality and better performance.



Sustainability

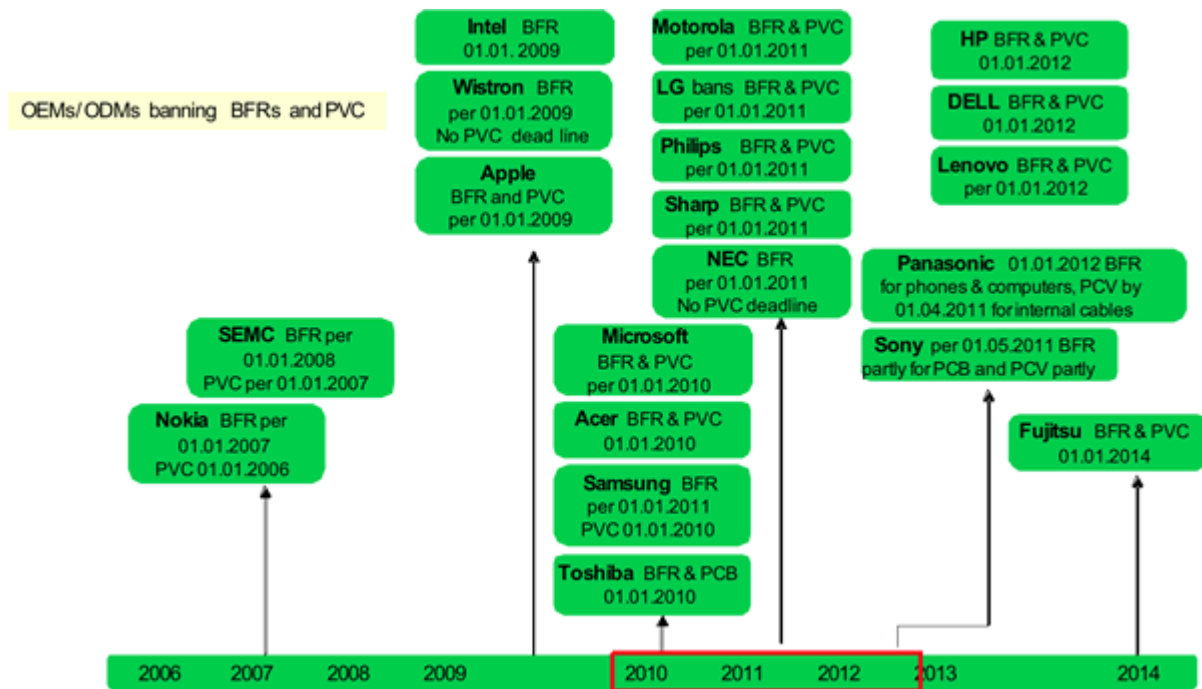
Several trends affect the products and systems designed by OEMs. Primarily, sustainability is an important direction. Eco-design in electronics is not limited to avoiding banned materials as defined in governmental regulations. The total life cycle of the product should be assessed, with a focus on hazardous materials (REACH, ROHS), carbon emissions, energy and water use, recycling, use of rare earth metals and minerals, and more. Both the product content and the related industrial processes, from mining to production to user to waste process, have to be included. This might yet be complex and abstract, but the results of the calculation methods will become more and more decisive.

Cooperation across the value chain is required to understand and properly align the measures to be taken. The relations must exceed the traditional first line interactions between supplier and customer. Typically, non-governmental organizations (NGOs) and standardization committees are already active across the whole chain. These are the stakeholders with an increasing influence. Media exposure of Greenpeace activities can be highly influential in determining and lobbying power of third parties.



Organizations like iNEMI (International Electronics Manufacturing Initiative) forecast and accelerate developments in the electronic manufacturing industry by interaction with all value chain partners. The leadership of such partners is key for a sustainable future.

While NGOs such as Greenpeace have pushed to ban brominated halogen flame retardants (BFRs) and PVC (polyvinylchlorid) in consumer electronics, leading OEMs are now actively picking up on this crusade, and we can expect more OEMs to position themselves as a company with a green image. The chart shows company announcements where BFRs and PVCs will be banned in new product developments.



Miniaturization

Miniaturization is an ongoing technology driver. The market requires smaller products with more functionality. The connectors, often the larger components on the printed circuit boards, are reduced in contact pitch. Traditional press-fit or wave solder contact technologies have their limitations in size reduction. Together, with the pressure to reduce total applied costs, a further focus on surface mount processes can be observed.

In miniaturization, thickness is reduced, and is sometimes called Thinnovation. Flat designs are in televisions, mobile phones, monitors, and laptops. In connectors, new developments are often much lower in height than their predecessor. Also, low profile versions of existing interconnection solutions are developed.

The examples in consumer electronics are clear. USB moved to mini-USB to micro-USB. From 2011 onwards, micro-USB becomes the standard mobile phone power and data connector in Europe.

The situation is similar in SD card readers and HDMI. FPC shows pitch reductions from 0.8mm to 0.5mm to 0.3mm to even 0.15mm. Within SATA, slim versions and micro-SATA have been developed. These are just a few examples of a bouquet of such transitions.

Conversion

Miniaturization does not only include pitch and height reduction. An interesting option is conversion. Not only sizes change, but also shape and functionality. Numerous examples are available. The parallel printer connection has become USB, and both DVI and SCART are replaced by HDMI. Within computing, the number of bulky external connectors is reduced by conversion into integrated smaller solutions, as such outmoded connectors get completely eliminated. This also happens by further use of wireless connection technologies like Bluetooth, Near Field Communication (NFC), RFID, W-USB, and W-HDMI.



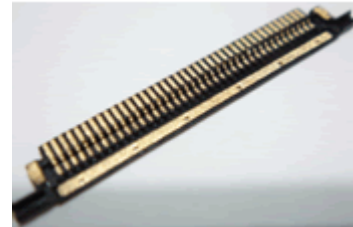
In some cases conversion is leading to revolutionary changes. With MIPI, the medium for data will transfer from copper-based electronic interconnects to optical interconnects based on IR or near IR wavelengths of 850nm VCSELS (Vertical-Cavity Surface-Emitting Laser). It will eliminate parallel interface connectors in the displays of mobile phones and also replace the majority of LVDS (Low Voltage Differential Signal) connectors. The optical links offer high mechanical flexibility, less space consumption, full rotation of displays, higher functional integration through the hinges because of only one optical fiber, high bus speed at better signal integrity, and a significant reduction of EMI (electro magnetic interference). The potential comfort of selling features on electronic devices will attract eager consumers.

Integration

Another aspect of miniaturization is the integration of elements into one component. Examples are integration of passive components such as resistors or capacitors into PCBs; integration of ICs, filters, or LEDs into added-value connectors; or the integration of multiple ICs, mechanical elements, or magnetics into one package. These might be cable connectors or I/O connectors, like single- and multiport USBs, HDMI, and μ USB. The driver for such aggressive integration is mainly the mobile phone industry, where real estate is at a premium and one of the targets of most designers is reduction of the component size. OEM companies like Samsung and Nokia, connector manufacturers like Tyco, chip manufacturers like NXP Semiconductors, and PCB manufacturers like Inberr, are among the global leaders that have such commercial products available on the market in 2010. These integration concepts move some design complexity and responsibility from OEMs to their component suppliers.

With Laser Direct Structuring (LDS), a new type of Molded Interconnect Device (MID), the PCB and a connector can be integrated into one component. For this technology, LDS compounds have been developed in various low and high temperature plastics. Such compounds can be molded in any possible structure and can then be exposed to a laser beam in all three dimensions. During this direct laser writing, chemical activation through ablation of the exposed polymer surface prepares for proper adhesion of copper in a standard electroless plating process. The created structures can act as electrical connections over a 3D-shaped element, omitting one- or two-dimensional PCBs. Soldering of mechanical contact interfaces is possible, and also through-hole vias can be realized. The design freedom will allow developers to create more advanced electronic applications.

While LDS technology picked up many years ago, most of the commercial applications are limited to mobile phone and notebook antennas; some automotive applications, such as the integration of simple PCBs within the steering wheel; hearing aids; and other limited examples. One of the main reasons for the slow growth has been the rather slow speed of this serial process, the required installed base (the need of IR lasers for the structuring and access to batchwise electroless plating technology) and mechanical and processing limitations in available thermoplastic materials. With the boom of LDS mobile phone antennas, the installed base is showing fast growth. Additionally, the speed of lasers by companies such as LPKF has increased rapidly, bringing down the total cost well in the range of standard 2K molding processes. Furthermore, LDS grades of the newly introduced polyamide 4T enable access to reflow solderable plastics while overcoming previous mechanical and warpage limitations of liquid crystal polymers. In the near future, we can expect a strong growth of components realized in LDS technology. Next, commercial applications can be air cavity packages for MEMS or SiPs, sensors, RFIDs, or any other solutions where a 1- or 2-D PCB is directly realized inside the housing material. A most recent example of LDS technology is an ultra-thin LVDS connector, which is designed for the next-generation notebook. The available space of the slim displays will not be sufficient for standard connector design, enforcing an innovative replacement of connector housing and lead frame.



Impact on Plastics

Connector miniaturization, pitch size reduction, and an increased number of contacts require plastic materials that can exhibit excellent molding capabilities and high-strength characteristics. With flash memory becoming cheaper, DVDs and CDs will disappear, leading to a significant loss in the use of polycarbonate. Some elimination and miniaturization of connectors will reduce the volume demand for plastic use in housings. On the other side, new interconnection technologies require more and higher performing polymers.

Faster data transfers can be met with higher electronic frequencies. Plastics with stable dielectric properties over temperature have the lowest effect on the overall system performance level. In addition, the balance of wave solder products towards reflow soldered products is present for cost and miniaturization reasons. The lead-free soldering temperature profile requires high performing plastics. To secure good solder joints, the connector contact coplanarity must be secured during the reflow process. Liquid crystal polymers (LCPs) do not always perform well enough. Furthermore, esthetic requirements to the surface are demanding. No blistering or discoloration is allowed. Here, PPAs show lower performance, in addition to some limitations in processing. Materials, like DSM's new polyamide 4T (Stanyl® ForTii™), control warpage by combining a high HDT (Heat Distortion Temperature) with high stiffness and stable mechanical properties. Together, with good processing properties and temperature resistance, PA4T is prepared for future applications.

From an ecological point of view, the main and first trend is replacement of halogen flame retardants in polymers. Many halogen-free plastics are available, and other types are still under development. In the future, the eco-footprints and related LCAs will play an important role for the plastic materials.

Chemical companies, like DSM Engineering Plastics, are focusing their entire innovation pipeline towards sustainability and have already converted their entire product range to halogen-free flame-retardant offerings.



Dr. Tamim P. Sidiki is the global marketing manager at Stanyl ForTii at DSM Engineering Plastics, a company that creates innovative products and services in life sciences and materials sciences. He is also a member of the iNEMI environmental leadership steering committee.

Previously Sidiki held the position of innovation manager electronics at DSM Engineering Plastics where he was responsible for coordinating the conversion of DSM to halogen-free plastics. Prior to joining DSM Engineering Plastics, Sidiki worked for Philips Electronics and NXP Semiconductors in corporate purchasing and product marketing functions.

Sidiki holds a master's degree in physics and a Ph.D. in electrical engineering from the University of Wuppertal, Germany. He has published more than 20 scientific papers and has written two standard books on silicon-based nanostructures and properties of SiGe.

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Mr. Paul Potters recently became business development manager at Stanyl ForTii at DSM Engineering Plastics. Before joining DSM, he worked for 15 years at FCI, a leading connector manufacturer. As manager of product development, he led the European product development group of the electronics division. He previously held engineering and project management positions in connector development.

Potters holds a master's degree in mechanical engineering from the University of Eindhoven, and participated in a management program at the ESCP business school in Paris and Berlin. He holds more than 15 patents in connector designs.

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