Getting Connected

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Industry standards have helped drive interoperability between computers over networks. For design engineers, picking an industry standard saves on those pesky headaches when choosing connectors and cables, but these choices can have big implications for installation and maintenance technicians down the line.

Figure 1: Next generation storage devices use high performance cascade cables like this 3M™ miniSAS External Cable Assembly, featuring metal junction shell and integral latch.

The first time a computer was connected to what we would now call a local area network (LAN) was in 1969. In the original ARPAnet just four computers were connected. The story goes that at 10.30pm on October 29 UCLA researchers tried to log into Stanford Research Institute's machine by typing "login" and promptly crashed their computer when they keyed in the letter 'g'. While computer crashes and network outages remain a feature of the networked life, the number and impact of innovations since that momentous day forty years ago has been nothing short of staggering. Email followed in 1971; telnet in 1972; FTP in 1973; and TCP/IP in 1982. The National Science Foundation's LAN, NSFnet, which gradually replaced ARPAnet and became the modern Internet, was started in 1986.

Standards for physical layer interfaces, that define electrical, mechanical and signaling transmission characteristics, have taken a little longer to emerge. Work on Ethernet started in 1973 and it has been in general use since 1980. Ethernet still uses the common-or-garden 8-position RJ-45 connector and continues to be the 800-pound gorilla in 10Base-T LANs. Small Computer System Interface (SCSI) first appeared in 1981 and is still in widespread use in the enterprise storage space with its high-density 68 position tab and receptacle connector. Universal Serial Bus (USB) took its first tentative steps when the issue 1.0 of the standard was published in January 1996 and, now in version 2.0, is still the *de facto* interface in personal computers with its 4-position connector. Infiniband, a merging of two competing standards, saw adoption among the industry's leading companies making high performance information communications technology (ICT) with the foundation of its trade association in 1999 and the publication of the first architecture standard a year later. It created yet another type of connector, the so-called multi-lane SAS or 4X (SFF8470). Serial Attached SCSI (SAS) emerged in the early 2000s and in its latest iteration, miniature multi-lane SAS or miniSAS, is delivering almost double the data rate of its predecessor in an even smaller, but again different, connector – for which read two connectors, as there is one for internal connections using 36 pins, and another for the external I/O, which uses 26 pins (figure 1).

These industry standards have greatly facilitated the growth of LANs, storage area networks (SAN) and the Internet. The great virtue of standardization is that much of the time-consuming engineering is eliminated, and with it the delays and headaches, because cables, connectors, pinouts and the electrical issues are predetermined. Unfortunately, the law of unintended consequences applies. In our connected world there are now so many standards that a major issue facing equipment designers today is picking which interface to build into their new devices. This is a particular worry when several standards may be competing in a given applications space, as is the case in LANs and SANs. How does an engineer pick, what amounts to, the winning horse? In many companies, that decision will be driven by the marketing department which, one hopes, has researched their customers' needs or made a risk assessment about emerging or immature technologies. Yet even industry standards do not stand still. Like the proverbial old soldier, old standards do not die: they merely reiterate and remerge as new and improved revisions. Continuous improvement means updates, upgrades and the problem of connecting legacy equipment. The result is a plethora of different types of leads, cascade cables, jumpers, extension cables and adapters that merely passes the headache down the line to the technicians in the data center who have to install, maintain and repair equipment over the course of the life of equipment racks, 24/7/365.25.

Back to Basics

Connectors and cables are vitally important components that are often the last thing to be considered in new equipment designs. They connect one sub-assembly to another and one device to another. They are the one group of components customers regularly handle during a lifetime of using your product. With that in mind, there are several attributes that should be considered when evaluating different interconnects:

- **Suitability for Intended Application**: the needs of a user of a handheld computer differ to those of an IT manager running a supercomputer. The design of connectors and cables should reflect the differences. These include size, weight, ease of connect and disconnect, ruggedization and ease of replacement or repair. Most standards bodies, such as ANSI, IEEE or IEC, will have given consideration to these factors when evaluating choices before settling on one design for inclusion in the final publication. Where an industry standard does not exist, there may yet be a *de facto* standard, established by a leading manufacturer or consortium. To encourage interoperability, some organizations host 'plug fests' where participating manufacturers can attach their devices to other manufacturers' and identify bugs that require fixing.
- **Form Factors and Industry Standards**: as we have seen, there are many industry standards and picking the right one for your design calls for both technical and business judgment. Not all standards explicitly define all aspects required of connectors and cables: the document may set out dimensions and pin assignments but omit the precise details of contact design or latching. In this situation, it is prudent to consider the products sold by the leading manufacturers and review their technical literature for similarities and differences and to consult with customers about use expectations. Standards committees are always looking at ways to extend the reach of their specifications or their suitability for new applications. They are continuously reviewing new technologies so it is important you are aware of the current status (proposal, development, spec release, productization) since the details can and do change.
  If you intend to tweak the standard to suit your product platform, such as changing the wiring configuration, there may be consequences for interoperability with devices that do fully comply with the extant standard, and you may be limited in compliance claims you can make for your product.
- **Cable Construction and Electrical Performance**: cable comes in a bewildering selection of styles and constructions, not to mention gauges and colors. Round, flat, shielded and unshielded, ground plane, twisted pair, ribbon and discrete wire cables offer different flexibility, durability and electrical performance characteristics. Review manufacturer's technical specs to compare shielding effectiveness, skew, impedance, attenuation and cross talk to find the best combination for your equipment.
  Flat cable, such as 3M™ Flat Ribbon Cable, 3365 Series, is attractive because it is cost effective and easy to use. Unfortunately, common unshielded flat ribbon cable is not well suited for high-speed differential signaling except for very short runs. For low voltage differential signaling (LVDS) applications, use balanced cables such as twisted pair, which are usually better for noise reduction and signal quality, than unbalanced cables, such as ribbon or multi-conductor cables. Balanced cables tend to generate less EMI than unbalanced. This is due to field canceling effects. Balanced cables also tend to pick up electromagnetic radiation as common-mode (not differential-mode) noise, which is rejected by the receiver.
  Shielded ribbon cable, such as 3M™ Pleated Foil Covered or 'PFC' Cable, is particularly well suited for high-speed differential signaling. The 3M™ PFC Cable, 93101 Series offers a skew of less than 100 picoseconds per meter when terminated in balanced mode, with a ground wire on either side of each signal pair. This makes it ideal for applications that demand accuracy at high speeds, such as data transfer between servers and storage devices. It can be terminated to the popular 3M™ Mini Delta Ribbon Plug Connector for a complete end-to-end shielded I/O solution.
- **Shielding**: applications have different shielding requirements and the end use for your device and the final country where it will be sold determines the requirements. These may be driven by a national government body, such as the Federal Communications

Commission (FCC) in the USA, or the European Commission (EC) and authorized agencies in its member states. Compliance to these regulations and directives is 'mission critical'. Properly designed shielded input/output (I/O) connectors and cables should be a key part of a strategy and program for electromagnetic compatibility (EMC), helping to reduce susceptibility to, and improve immunity from, EMI/RFI. Download any technical specs the component maker posts on its website or call and request to see a hardcopy and include them in your technical construction file.

Pay attention to the construction and quality of braid and foil shields in cables to ensure the wire bundle is adequately covered (ideally it should be 360° coverage).

Examine junction shells for potential hotspots: metal shells should completely cover the cable/connector interface, while plastic or molded shells should contain an inner metal or foil wrap.

On the mating side, consider the design of the protective metal face or shell. Well designed components will drain away electrostatic discharge (ESD) before the connector contacts wipe, protecting the sensitive circuits of the equipment.

- **Contact Design**: connectors broadly divide into two types based on the design of the wiping contacts: pin/socket and ribbon-style. The best known pin/socket connector is the D Subminiature or D Sub invented by ITT Cannon in 1952. It is still used for RS 232 serial communications, for connecting analog VGA monitors and parallel port devices designed to meet IEEE 1284-A. A round profile pin wipes against a socket contact formed of bent metal making a complete circuit. In its half pitch iteration it was adopted as the SCSI-2 and SCSI-3 connector. However, in .050" pitch and smaller, the pins become fragile and more prone to breakage. For this reason, most high density I/O connectors are of the ribbon-style design. The 3M™ Mini Delta Ribbon plug and receptacle connectors are emblematic of this type of connector (figure 2). The precise geometries of the pre-loaded ribbon contacts ensure reliable connection, even in miniature sub-1mm versions, while the supporting insulator reduces the risk of damage during insertion and withdrawal.

  Consideration should be given to contact platings. Gold is widely used as a plating material to protect the copper alloy contact from wear or damage owing to oxidation in use. Gold also reduces the insertion/withdrawal forces. Higher gold plating levels (typically 30µ" or higher) are preferred for high value electronic ICT equipment expected to see long service life, whereas selective plating (typically 10µ" or lower) is better suited to short life consumer electronic devices.
- **Latching and Mechanical Fixtures**: the application will drive the type of mechanical fixtures you provide. In high vibration environments, such as factories, thumbscrews are recommended. In contrast, in central office or data center environments, where air conditioning and engineered flooring is found, latches may suffice, such as the simple lever found on RJ-45 connectors or the squeeze latch found on many ribbon-style I/O connectors.

  Where thumbscrews are used, the industry standard may specify mechanical hardware down to thread size. Bear in mind that different regions of the world have preferences for one size over another: a case in point, in Japan and Asia Pacific markets, M2.6 threads are favored, while in Europe and North America, M2.5 is preferred and M2.6 parts are hard to find. If your equipment is sold overseas, consider how your customers will find replacement parts if they lose or damage them.
- **Repair and Replacement**: manufacturers typically include a power cord with new equipment. Recognizing the need to connect new and older generation equipment, some also ship an adapter with the box. Cables for connecting the new device with the host, peer or peripheral devices are usually not included because a 'one-size-all' approach does not work – the original equipment manufacturer is unlikely to know how far apart different devices are from each other in the final installation. Do you include a 3 foot or a

30 foot long cable, a 1.5 meter or a 15 meter long cable? Consequently, consideration should be given to aftermarket programs to ensure the right design and quality of cable assemblies are available to system integrators and equipment installers from their distribution partner of choice, be it a cataloguer, or a main street box retailer; or direct from your own company as part of an OEM accessories program. Whichever route you choose, remember to include your recommendations and the ordering information in your customer documentation.

If this includes an option for 'do-it-yourself' field assembly, consider recommending which components and tools customers should use, or offer a kit of parts, as well as clear instructions on how to put them together. That will reduce the number of incoming calls to your tech service helpline.

Buy Wisely

How one device or sub-assembly is connected to another is critical to ICT equipment design. Fail to consider cable construction, and electrical signals may be degraded by the time they reach the receiver and the machine may not work as intended. Select the best cable construction for your equipment and your system will live up to the claims made of it in your literature. Fail to consider connector design and your technical helpline might be inundated by irate technicians having to diagnose the source of intermittents or repair broken contacts in leads. Pick the right connector and accessories, and your customers can enjoy years of service from their investment in your products. Considering intended use, current form factors and industry standards, cable construction and electrical performance, shielding, connector contact design and mechanical aspects, and anticipating repair and replacement issues, will best equip you to make informed connectivity choices.

There is one last point: don't buy the cheapest product. Shaving a few cents off the cost of a plug connector or buying a low cost cable might seem smart, but if a breakage leads to a service call request from a key customer resulting in installation of a replacement device that takes a unit in a data center off line, the true cost will dwarf any savings. Buy wisely. As in all things, you get what you pay for.

Figure 2: Many design engineers prefer ribbon-style contacts for high density, high performance I/O applications, exemplified by this 3M™ Mini Delta Ribbon Cable Assembly.

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