

## **1394-FireWire-i.LINK: Fast, Reliable, Proven Ideal for all Audio and Video Connectivity**

*-- New 1394b Version Provides New Benefits and Performance as IEEE 1394 Emerges as the Home Network and Automotive Backbone Technology --*

The arrival of the digital age has created a complex web of technologies, audio systems, and video products with broad appeal to consumers and users worldwide. The ability to take still or moving pictures, edit them, and ship them out via the Internet using a personal computer and a modem line is compelling. So is the ability to download a full, feature length movie onto a small hard drive, then upload it again for viewing on a large, high definition television panel. There are many other business and consumer applications just emerging – along with others not yet conceived.

The key technology for this digital traffic is the IEEE 1394 multimedia bus, the most reliable, cost-effective, and efficient way to move audio and video data. Known commercially as FireWire in the computer community and as i.LINK among most consumer electronics providers in Japan, IEEE 1394 has been designed for transporting and networking multiple types of digital data between users and systems, simply and with a quality that users expect. It also has been constructed to move data to or through systems that are busy with other tasks and applications – without disruptions. As the digital revolution continues, this kind of performance enables huge new and exiting opportunities in and for networks populated with every conceivable digital consumer and computer device from storage to printing to display products.

As a comprehensive example: a 1394 network at present can include a personal computer, digital TV, digital set-top box, printer, DVD player, external disk drive, and camcorder. Because 1394 has been built to support up to 63 nodes in one network, it can easily handle requirements of all of these products and systems at the same time. Also, multiple 1394 networks can be connected together, so -- theoretically -- more than 1,000 systems can communicate together in a super network, which is still just an idea. But it will not be long in arriving.

### ***Complex Network Application Enabled by IEEE 1394***

Transporting digital data is a relatively straightforward process. But, specific applications and user requirements can make it more complex. For example, a network must manage data in situations where a set-top box is streaming a program to a Digital TV at the same time channels can be changed. Now, at the same time the streaming and channel changing occurs, a user needs to output another program to DVHS for recording, while taking part in an Internet session on his or her PC. Add a camcorder connected to the PC for video editing and it makes up a complex network scenario. With IEEE 1394, it can all be done at the same time, efficiently.

## ***Overview of the 1394 Structure***

IEEE 1394 provides the common rules of operation required to create this in an orderly fashion. The technology is constructed -- and can be envisioned -- in layers. Generally, these layers include the cable and connectors mechanical physical layer; the electrical physical layer, in which signaling specifications and networking rules are detailed; the link layer, which formats or manipulates transported data for easier use by the application; and the protocol/application layer, which includes higher level system guidelines/ interfaces that bring the data, the end system design, and the application together. Figure 1 illustrates the layers.

To illustrate the 1394 'map,' consider a national highway system. The cable and connector represent the road and its traffic lanes. The rules of the road are reflected in the physical and link layers, while the target applications are represented by various users of the road -- commercial goods transporters, family vehicles, nationwide commercial busing transportation, military equipment convoys, and others. It is a complex web governed by basic regulations and a set of mutual understandings that keep traffic 'moving' reliably and efficiently.

Like the highway driver, 1394 applications share a subset of rules, yet there are elements of the standards and application specifications for which they are unconcerned or unaware. Car drivers don't exit for truck weigh stations, for example, and bridge clearances are designed so that military vehicles can safely traverse intersections (a fact some car drivers may not realize). Cars, trucks, and military equipment use the same highway, are guided by speed limits, and use identical passing guidelines. This is essentially the way the 1394 protocol stack operates. It is efficient, and does not demand that all elements understand all the activity that takes place at the same time.

## ***1394 Technology and the Consumer***

For the user and consumer, 1394 has been designed to simplify the many technical issues involved as data is streamed for viewing on a DTV. The user makes random inputs. The network configuration may be changed at any time by adding or deleting new applications. Different types of content are involved, all with their own characteristics, including Internet protocol (IP) from the web; MPEG data for DTV; digital video (DV) data from the camcorder; content-sensitive information like pay-per-view movies; and non-content sensitive data such as still image transfer from a camera.

In addition to these technical issues, there are user considerations, focused on guaranteed delivery and service quality. For example, how long it takes to change from one channel to another, or whether the stream will be disturbed when reconfiguring for a new application, possibly interrupting a viewer who's watching a movie.

First, general architectural concepts included in the 1394 standard govern data flow. A key differentiator for 1394 compared with other buses is that the data flow between 1394 nodes is segmented into asynchronous and isochronous channels. Asynchronous channels

are used for command and control functions of the bus as well as transfer of bulk data (ie. IP files) between applications of the network. Isochronous channels are targeted at streaming audio and streaming video. Data streaming must be reliable and well organized so they assure user satisfaction; out of order data packets can destroy a viewing experiences quickly. The channels have been designed to ensure bandwidth and stability throughout any of the numerous scenarios that might occur. 1394 is one of the only interfaces that provides both isochronous *and* asynchronous capabilities.

This leads to another key concept: 1394 is “plug and play”, meaning the network continues to operate as devices are connected or detached. Also, 1394 is peer-to-peer, which means, in effect, that the intelligence for using the network is present in each node/system. As a result, users need not worry about the order in which systems are connected. They are not burdened by the need to complete complex network setups for addressing or configuration. So, 1394 delivers a high-speed network capable of connecting a wide range of diverse equipment with a minimum of complexity.

There are legal issues, too. Movie studios insist on control over their content to prevent illegal pirating and unauthorized commercial use -- especially when an unreleased or first-run film in initial distribution is involved. These concerns must be measured against the increasing number of consumers who want the right to duplicate, or copy, content for personal use.

Authors and editors of the 1394 standard have resolved these issues, using complex but reliable data flow, bus arbitration, and copy protection guarantees encompassed in the Digital Transmission Content Protection (DTCP) or ‘5C’ protocols. Defined by a leading group of technology companies from three continents, the copy protection scheme has been endorsed by many leading US studios and is becoming accepted as a highly reliable system designed to protect content from illegal re-use.

### ***1394 Interoperability***

Interoperability involves the correct and proper functioning of systems that share applications, and to offer one network for the increasing number of complex applications that can be linked through 1394. Generally, each application has its own requirements so there are specific protocols and guidelines created to support each.

For example in 1394, there are protocols in place to support the AV transmission of sensitive content (i.e., first-run movies). These include IEC 61883 for AV streaming and DTCP for copy protection of the content. When two nodes are discovered on the network, they first use 1394 network specifications. Once they find that they share an application, they utilize the necessary rules and guidelines for transmitting data.

If no application is shared between two systems nothing will occur. It's important to note that the network will still be maintained and that nodes will continue network communication, but no application data will be shared. An example: a DTV connected to a printer. Nothing will occur if the DTV is speaking IEC61883 and DTCP while the printer is looking for SBP3. This represents the proper functioning of the 1394 bus.

### *1394 Continues to Evolve*

The 1394 bus in its 1394-1995 and 1394a versions provides speeds of 400 Megabits/second over distances of 4.5 meters. These performance capabilities that have led to 1394's design into almost all high end camcorders and digital cameras, along with a long list of hard disk drives, printers, scanners, and other peripherals. Almost all new notebook PCs and many desktop versions also are now 1394-enabled. Some typical bandwidths for application are as follows: MPEG-2 for DTV requires, on average, 8 Mbps; typical IP transfer rates range between one and five Mbps; digital video in camcorders uses 25 Mbps; and high definition DTV requires approximately 20 Mbps. As a result, IEEE 1394a offers a high bandwidth network that can support many applications concurrently. North American analysts estimate that by the end of 2001, more than 60 million products worldwide were equipped with 1394. Projections now are for that number to reach 100 million – including PCs, DTVs, printers, drives and other products – by 2003.

Nor is the standard static. The 1394b version, detailed below, is ready for prime designs now, creating the basis for a comprehensive home network and enabling the base 1394 technology to expand into the automotive and wireless markets.

1394b technology builds on the strengths of 1394a and adds critical new capabilities, notably; added bandwidth – to 800 Megabits/second all the way, eventually, to 3.2 Gigabits/second. It incorporates networking capabilities over distances of 100 meters over CAT-5 and plastic optical fiber. It also improves overall network efficiency. These new features have been created with 1394a compatibility in mind, while maintaining the vital architectural characteristics of plug and play (PnP), peer-to-peer connectivity, and isochronous channels. This will keep 1394 in line with bandwidth demands currently required by CE, PC and peripheral applications, and ahead of competing standards.

For a 1394 network in the home, 1394 had to enable transmission past the 4.5-meter length originally set by 1394a. This is accomplished by 1394b, which also serves a variety of home network demands and potential requirements through a set of specifications for a multitude of cables. These include unshielded twisted pair CAT-5 cable; plastic optical fiber (POF); hard polymer clad fiber (HPCF) also known as glass optical fiber (GOF); and shielded twisted pair (STP). Each cable/ interconnect type is specified for specific lengths and associated data rates.

Finally, as the specification has evolved, numerous applications have been completed and introduced into the marketplace. During this process there have been some valuable lessons learned. These inputs have been incorporated into 1394b to improve network efficiency, and reduce implementation complexities.

For example, arbitration control for transmission of packets has added a 1394b concept termed BOSS (Bus Owner Supervisor/Selector) so 1394b beta nodes can transmit data packets more efficiently, using less network bandwidth. From a chip design perspective, signaling has been simplified, so designs are less complex, which means improved robustness and lower cost implementations over time.

### ***Implementation of 1394b technology – new ports and connectors***

The benefits of 1394b take the technology to a higher plateau in terms of use and expandability. To achieve this outcome, the 1394 architecture was altered to navigate across the generations. Since 1394 specifications are constructed in layers, it was important that 1394b incorporate no changes above the link layer, so that an application is not dependent on any specific generation of 1394 technology, and will not require re-engineering or further design work.

To achieve this transparency, 1394b's developers created new physical constraints so the new versions are compatible with existing ones. As a result, one new port has been introduced, called a 'bilingual' port, a physical structure included in end-use equipment. New connectors also have been introduced. The first is a bilingual connector, which links physically to a bilingual port and 'speaks' either 1394a or 1394b signaling. The other is a beta connector, which connects physically to a beta-only port and 'speaks' only 1394b signaling. The addition of new connectors means there are now these cable combinations: bilingual and 1394a 6-pin; bilingual and 1394a 4-pin, and beta to beta, which will be used in future applications.

The current installed base of 1394a-equipped products is generally segmented: the 4-pin port/connector is typically used in a camcorder, and the 6-pin port/connector is used everywhere else, including personal computers, DTVs, DVDs, and set-top boxes.

This might seem complex, but the end result is easily quantified. For new equipment, designers will choose what works best for their application, which means analyzing availability, cost, distance needs, and bandwidth requirements. The result will yield the type of ports to put on the system (Bilingual or 1394a 6-pin). For the end users, the issue is simple: they must have the correct cable and/or appropriate adapters. Over time, these alternatives will converge, as equipment moves to the 'b' version of the standard.

The issue of long haul, ports, and connections also is important. The anticipated configuration consists of standard 1394b connections between the end equipment and a wall outlet, with cable-specific requirements housed in the outlet.

This means the impact of these decisions is not left to the consumer but resides with construction and contract personnel working on home building and rewiring.

### ***Competing Technologies***

The digital revolution has spawned a host of technologies for networking of digital data over the last six years as the need to support audio and video streaming has grown and the concept of home networking emerged.

Most digital networks were not specifically created for this application. As a result, the concepts of channels and the methodologies for bus arbitration are not consistent with the technical and user needs required in the example above.

For example, in most wired Ethernet systems, the basis of the network is to detect collisions of data transmissions, back off some amount of time, and then retry the transmission. Even when a data packet transmission is successful, a node/system must re-arbitrate for control of the bus, again and again and again. Although this is not an insurmountable challenge, it *is* clear that Ethernet's underlying architecture is not optimal for streaming consumer quality audio and video.

But the 1394 standard is. This technology is continually expanding while maintaining legacy compatibility— it is not a static networking technology. From its inception, IEEE 1394 has been directed at networking a variety of digital applications in a constrained user environment. The standard already offers solutions for MPEG2, DV, IP, audio, and other data types in a network that can be clustered within 4.5 meters, or widely distributed throughout a home or small office. A 1394 network can be set up by connecting equipment with the appropriate cables, with no need for address set-up. Most important, AV applications can be operated continuously without interference even if new equipment is added to the 1394 network. As more 1394-equipped products reach the market, the value of the network will continue to grow, and the 1394-FireWire-i.LINK technology will solidify its leadership as **the** digital networking standard.

###

The specifications and guidelines have been created by a consortium of participating companies that have joined together in the 1394 Trade Association, an incorporated entity with by-laws and a governing board of directors who are elected from member companies. The 1394TA is worldwide organization with approximately 170 member companies now, from all over the world and from throughout the computer and consumer electronics industries. The 1394 TA creates and revises specifications, provides venues for compliance and interoperation testing, works closely with other trade groups around the world, and markets the ongoing technical development and value propositions of 1394 technology to users, designers, engineers and other technical organizations. For more information about the 1394 Trade Association, its charter, members, meeting arrangements and organizational structure, please visit [www.1394ta.org](http://www.1394ta.org)