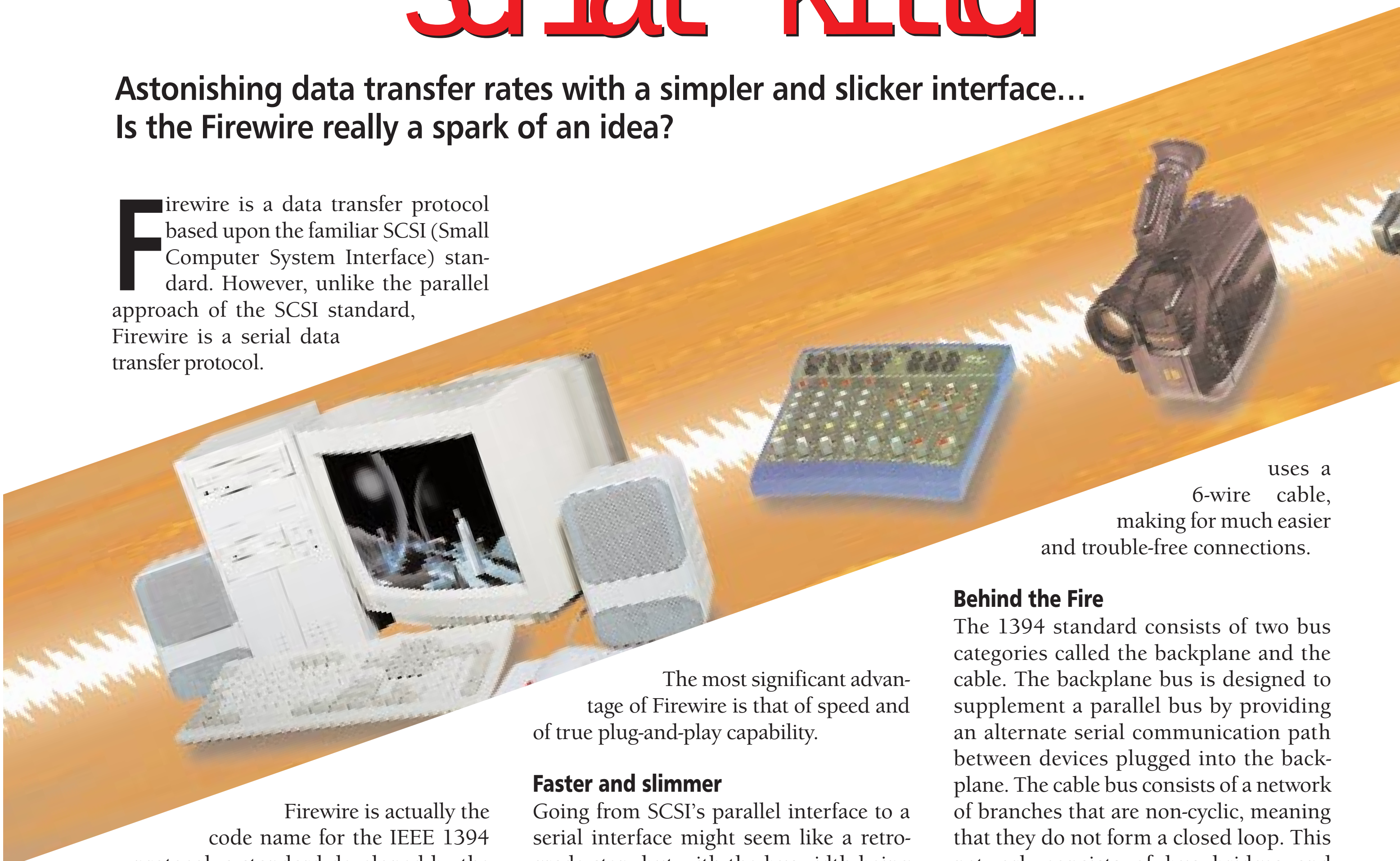
The new serial killer

Astonishing data transfer rates with a simpler and slicker interface… Is the Firewire really a spark of an idea?

Firewire is a data transfer protocol based upon the familiar SCSI (Small Computer System Interface) standard. However, unlike the parallel approach of the SCSI standard, Firewire is a serial data transfer protocol.



Firewire is actually the code name for the IEEE 1394 protocol, a standard developed by the Institute for Electrical and Electronic Engineers (IEEE) in late 1995. This protocol was born when IEEE's Microcomputer Standards Committee began a unification process for various other serial bus standards such as VME, Multibus II, and Future Bus.

Firewire is similar to the standard that was used all along by Apple Computer. Intended to be a replacement for the SCSI bus, it is a standard feature of Macintosh and PowerMac computers and is also used in a variety of high-end digital applications such as consumer audio/video device control and signal routing, home networking, nonlinear digital video editing and 32-channel (or more) digital audio mixing.

The most significant advantage of Firewire is that of speed and of true plug-and-play capability.

Faster and slimmer

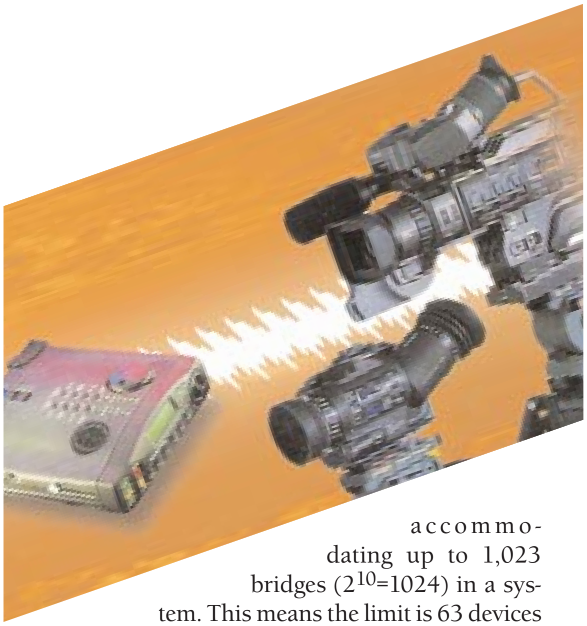
Going from SCSI's parallel interface to a serial interface might seem like a retrograde step, but with the buswidth being inversely proportional to the frequency, the Firewire being a serial cable, hence, much thinner than parallel cables, allows for much greater bus frequencies. The 20 MHz of Ultra SCSI is close to the top end of what is achievable using the old style bus.

Firewire trades the width of the original SCSI bus in favour of a dramatic increase in bus frequency. Since only a single data line must be managed, it is possible to increase its speed from the 20 MHz maximum of Ultra SCSI, to 400 MHz or even higher. Ultimately, speeds of over 1 GHz will be possible. Furthermore, the serial connection is much simpler than the large, cumbersome SCSI connections. Instead of a 68-wire SCSI cable, Firewire uses a 6-wire cable, making for much easier and trouble-free connections.

Behind the Fire

The 1394 standard consists of two bus categories called the backplane and the cable. The backplane bus is designed to supplement a parallel bus by providing an alternate serial communication path between devices plugged into the backplane. The cable bus consists of a network of branches that are non-cyclic, meaning that they do not form a closed loop. This network consists of bus bridges and devices also known as nodes. The system uses a 16-bit addressing system, providing over 65,000 nodes or devices in a system (2^{16}=65,536). Up to 16 cable connections are allowed between nodes; hence the term 'finite branches'.

The bus bridge serves to connect buses of similar or different types, for example, a 1394-to-PCI interface within a PC constitutes a bus bridge. This ordinarily serves as the root device and provides bus mastering (controller) capabilities. A bus bridge also would be used to interconnect a 1394 cable and a 1394 backplane bus. The Node IDs are 6-bit, allowing up to 63 nodes (2^6=64) to be connected to a single bus bridge, whereas the Bus IDs use a ten-bit system



accommodating up to 1,023 bridges (2^{10}=1024) in a system. This means the limit is 63 devices connected to a conventional 1394 adapter card in a PC.

Each node usually has three connectors, although the standard provides for 1 to 27 connectors per physical layer of the device. Up to 16 nodes can be daisy-chained through the connectors with standard cables up to 4.5 metres in length. This gives a total standard cable length of 72 metres. Higher-quality 'fatter' cables permit longer interconnections between the devices. Additional devices can be connected in a leaf-node configuration, as shown in Figure 1. Physical addresses are assigned when the bridge is powered up or when the bus is reset. Additionally, these addresses are also assigned whenever a node is added or removed from the system, either by physical connection or disconnection or power up/power down. Unlike in the SCSI standard, no device ID switches are required and hot plugging of nodes is supported. Thus, like USB, IEEE 1394 truly qualifies as a plug-and-play bus.

Figure 1 STRUCTURE OF A FIREWIRE NETWORK

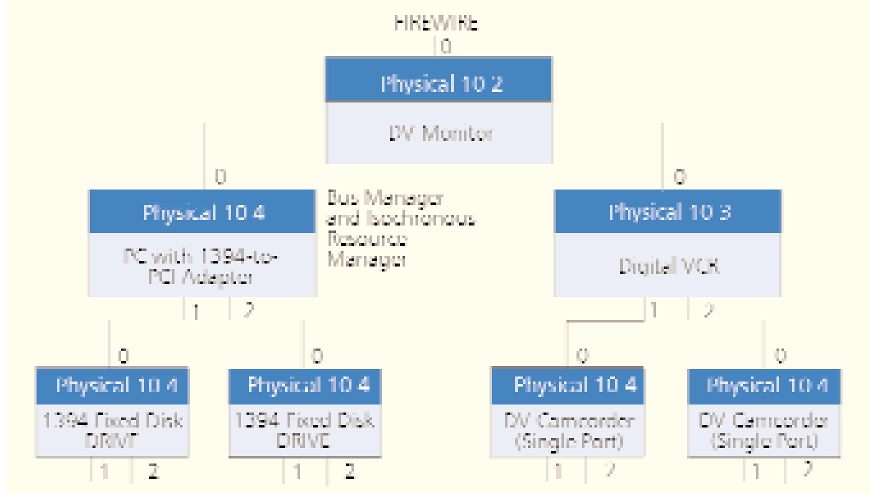
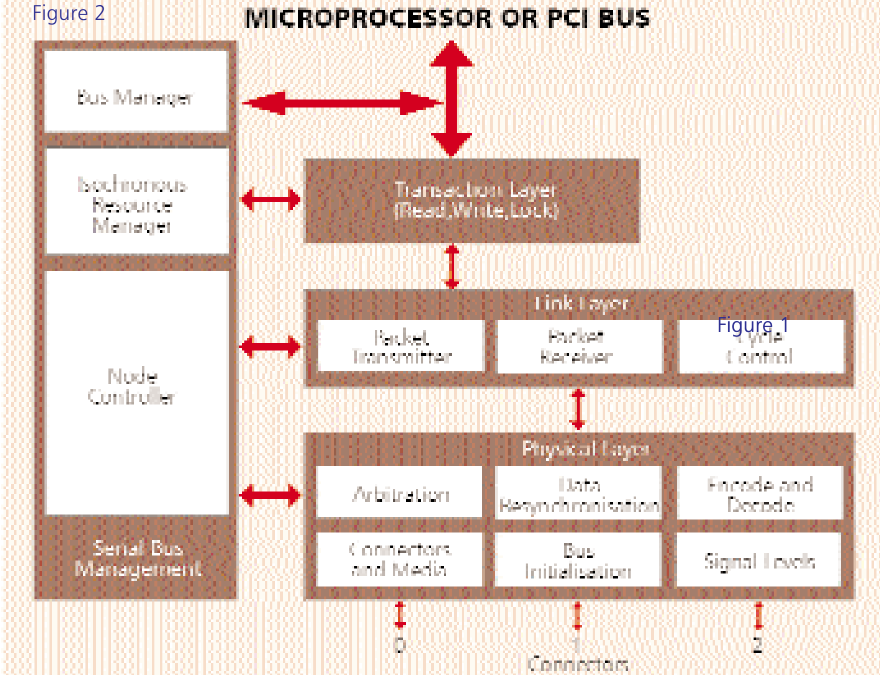


Figure 2 MICROPROCESSOR OR PCI BUS



The 1394 cable standard defines three signalling rates: 98.304-, 196.608- and 393.216-Mbps. These rates are rounded off to 100, 200, and 400 Mbps respectively and are referred to in the 1394 standard as S100, S200 and S400. Consumer digital video devices use S100 speeds, but most 1394 PC adapter cards available today support the S200 rate.

The slowest active node ordinarily governs the signalling rate for the entire bus. However, if a bus master (controller) implements a Topology Map and a Speed Map for specific node pairs, the bus can support multiple signalling speeds between individual pairs.

The three stacked layers shown in Figure 2 implement the 1394 protocol. Their functions are listed below:

Transaction layer: This layer implements the request-response protocol and is required to conform to the ISO/IEC 13213:1994 standard. Conformance to ISO/ IEC 13213:1994 minimises the circuitry required by 1394 ICs to connect with standard parallel buses.

Link layer: This supplies an acknowledged datagram to the transaction layer. A datagram is a one-way transfer of data with a request for confirmation. The link layer handles all packet transmission and reception responsibilities, plus the provision of cycle control for isochronous channels.

Physical layer: The physical layer provides the initialisation and arbitration services necessary to assure that only one node at a time is sending data, and to translate the serial bus data stream and signal levels to those required by the link layer. Isolation may be implemented between the physical layer and the link layer. With isolation, the bus conductors power the chip resulting in the implementation of the physical layer.

Linking Up

Standard bus interconnections are made with a 6-conductor cable containing two separately-shielded twisted pair transmission lines for signalling, two power conductors, and an overall shield. The two twisted pairs are crossed in each cable assembly to create a transmit-receive connection. The power conductors (8 to 40 volts, 1.5 Amps max) supply power to the physical layer in isolated devices. Galvanic isolation is effected by transformer or capacitative coupling. Transformer coupling provides 500 volts and the lower-cost capacitative coupling offers 60 volts of isolation with respect to ground.

The 1394 standard provides a flexible bus management system that allows connectivity between a wide range of devices. These devices need not include a PC or other bus controller. Bus management involves the following services:

TECH-TALK: ISOCHRONOUS DATA TRANSFER

Isochronous data transport is how the 1394 bus transfers data, providing the guaranteed bandwidth and latency required for high-speed data transfer over multiple channels. It consists of a resource manager and includes a register called the Bandwidth Available register that specifies the remaining bandwidth available to all nodes with isochronous capability. On bus reset or when an isochronous node is added to the bus, the node requests a bandwidth allocation. As an example, a digital video device would request approximately 30 Mbps of bandwidth, time code, and packet overhead. Bandwidth is measured in bandwidth allocation units. A unit is about 20 nanoseconds, that is, the time required to send one data quadlet at 1,600 Mbps, called the S1600 data rate. A quadlet is a 32-bit word; all bus data is transmitted in quadlets.

For example, in a 100-Mbps system, a digital video device would request about 1,800 units; in a 200-Mbps system, about 900 units would be sufficient. If adequate bandwidth is not available, the requesting device is expected to repeat its request periodically.

The isochronous resource manager assigns a channel number (0 to 63) to nodes that request isochronous bandwidth based on values in the manager s Channels Available register. The assigned channel number identifies all isochronous packets. When a node does not require isochronous resources, it is expected to release its bandwidth and channel number.

A cycle master, a device that broadcasts cycle start packets, is required for isochronous operation. An isochronous resource manager supports isochronous nodes, if any are present in the system. This is required for digital video and digital audio applications. On bus reset, the structure of the bus is determined, node IDs (physical addresses) are assigned to each node, and arbitration for cycle master, isochronous resource manager, and bus master nodes occur. During the one-second delay that occurs after reset, isochronous resources that had been allocated before the reset are reallocated. Any resources that are not reclaimed will become available for future use. After this delay, new resources may be allocated.

CATEGORY	USB	FIREWIRE
Chipset	Using an electric signal, a USB peripheral tells the physical interface, or PHY a specialised set of chips and connectors to send data at either 1.5 Mbps or 12 Mbps.	Its physical interface (PHY) enables Firewire to attach multiple Firewire devices to the same PC. PHYs provide for transfer rates of 100 Mbps, 200 Mbps and 400 Mbps.
Data Flow devices	USB uses one of three types of data transfer: unbroken flow of data, an occasional signal, or a bulk load of bits.	As with USB, data and commands are broadcast to all based on whether the peripherals need an interface among themselves without the CPU intervening.
Topology	Up to 127 peripherals connect to a single USB interface through daisy-chained hubs, specialised connectors that repeat and amplify signals.	A Firewire network can support up to 63 peripherals. Each PHY has up to 27 ports; more can be daisy-chained to other Firewire peripherals.
Cabling	Signals to and from peripherals travel along a four-wire cable. One wire sends power to the peripherals, another wire provides grounding, and the two remaining wires carry data.	Six-wire cables carry signals among the PC and the Firewire peripherals. Two wires provide power and grounding, and the other four communicate bits and carry requests and instructions among the devices and the PC.
Pros	Overcomes the limitation of having only four serial ports on a PC. Adds less than $1 to the manufacturing cost of a PC.	Fast enough to transfer any type of data. Overcomes serial port limitations.
Cons	Few peripherals have USB ports.	So far, few Firewire peripherals are available. Standards are still being reworked. Adds more to the manufacturing cost of a PC $15 than USB.

Which One?

With Firewire having close similarities to the USB (Universal Serial Bus) standard, what are the advantages of using one over the other? The immediate advantage: Speed. However, IEEE 1394 loses out in the number of devices that can be connected to it. (*See table*)

All Fired Up

For devices like digital cameras and video recorders that are becoming affordable and cheaper, Firewire promises sufficient speed and connectivity. With the advantages of SCSI's speed and USB's ease of connectivity, this standard could well become the standard of the future. However, this depends solely on whether there will be enough peripherals available to support it.

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