IEEE 1394 (AKA 'FireWire' & 'iLink')

Around 1986, Apple Computer Inc developed a very fast but relatively low cost serial interface for distributing digital audio and other bulk data between personal computers, and between computers and their peripherals. The new high speed serial interface was designed to replace the relatively expensive SCSI parallel interface, and Apple dubbed it *FireWire* (which is still an Apple trademark).

Firewire was so successful that other manufacturers soon began using it under licence. In 1995 Sony released its DCR-VX1000 digital video camcorder, which featured essentially the same interface for input and output of digital video. Sony dubbed the interface *iLink*, and has gradually provided the interfaces on all of its digital camcorders and VCRs. (*iLink* is a Sony trademark.)

It was soon realised that the FireWire/iLink interface was ideal not just for conveying digital video and audio, but for fast transfer of large amounts of any kind of digital data. Because of this the IEEE (Institution of Electrical and Electronics Engineers) established it in 1995 as an industry standard data interface, known as IEEE 1394-1995 — or 'IEEE 1394' for short.

Nowadays IEEE 1394 interfaces are used on a very wide range of digital equipment, both in the computer and entertainment electronics industries. They're standard on the majority of digital camcorders and VCRs, as well as on video editing workstations and advanced computer graphics systems, and will probably be standard on the new DVD-RW and DVD-RAM video recorders. They're increasingly found even inside large workstations and servers, to interface peripherals like large hard disk drives and arrays, CD-writers and scanners.

In fact it looks very much as if IEEE 1394 could well become the standard high speed interface for the coming era of digital convergence — the merging of computers, communications and entertainment technology.

Note that although there are some similarities between IEEE 1394 and the USB, there are quite a few differences. USB is slower and essentially designed for networks with a single host (the PC), whereas IEEE 1394 can be used for peer-to-peer communication. A digital camcorder can stream video and audio data to both a digital VCR and a DVD-RAM recorder simultaneously via an IEEE 1394 network, for example, with no need for assistance from a PC or other network controller device (after it has been allocated an isochronous channel for the transfer — see later).

Fast & powerful

IEEE 1394 can transmit data at three rates: 98.304, 196.608 and 393.216Mb/s (megabits per second), which are usually rounded to 100Mb/s, 200Mb/s and 400Mb/s — and officially labelled 'S100', 'S200' and 'S400' respectively. As you can see even the lowest rate is nearly 10 times that of USB.

Most consumer equipment like digital camcorders, VCRs and DVD-RAM recorders use the S100 rate, which is more than capable of handling a compressed video-and-audio data stream. The majority of PCI/IEEE 1394 interface adaptor cards for PCs will also support S200, while some can also support S400.

Like USB, IEEE 1394 is designed to allow 'hot swapping'. Devices can be connected and/or disconnected without turning off the power or resetting, etc. The device which is performing the bus manager role constantly monitors bus status, and reconfigures it dynamically whenever nodes are added or disconnected.

Data is transferred on the IEEE 1394 bus in addressed packets, and is transaction-based. The transfers can be *asynchronous* or *isochronous*. Asynchronous transfers are used mainly for bus configuration, setting up transfers and handshaking, but are also used for bulk data transfer to and from hard disk drives, etc. Isochronous transfers are used for transporting time-sensitive data like digital video and audio.

IEEE 1394 data packets have a 64-bit address header, which is divided into a 10-bit network address, a 6-bit node address and the remaining 48 bits for data (or mode control) memory addresses at the receiving node. This gives IEEE 1394 the ability to address 1023 networks of 63 nodes, each with up to 281TB (terabytes) of data addresses.

In practical terms this tends to mean up to 63 devices can be hooked up via IEEE 1394 cables as a network, with each device able to have tens or even hundreds of

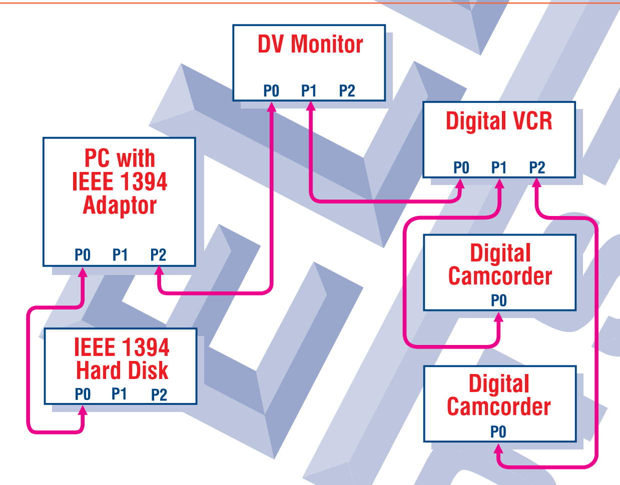


Fig.1: A fairly typical IEEE 1394 network used in a digital video editing studio. The PC would generally take the role of bus manager and isochronous resource manager.

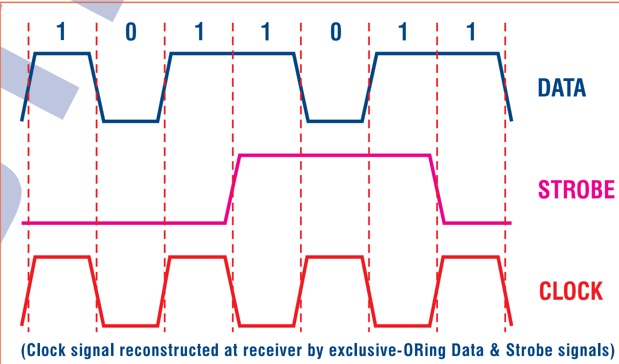


Fig.2: How the DS coding works. The Strobe signal is produced at the transmitting port, by exclsuive-ORing the Data and Clock. Then at the receiving end the Clock is reconstructed by exclusive-ORing the Data and Strobe signals.

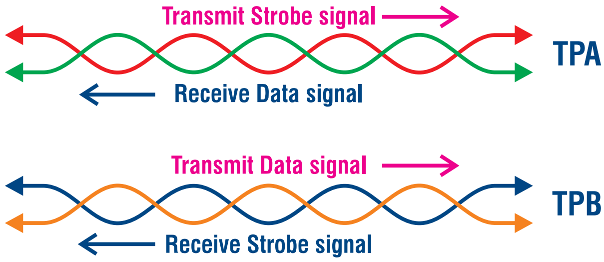


Fig.3: The Strobe and Data signals are sent along the IEEE 1394 bus via two shielded twisted-wire pairs, TPA and TPB.

gigabytes of memory — and plenty of room for more!

Typically devices have three IEEE 1394 ports, but they can have up to 27. This allows networks to be as simple as a DV camcorder connected to a digital VCR, or more complicated like the setup shown in Fig.1. As you can see this shows a 'tree' topology, taking advantage of the ability of each device to act as a bus repeater or 'mini hub'.

One device on the bus acts as *bus manager*, and can also act as *isochronous resource manager*. The latter allocates bus bandwidth for isochronous data transfers when devices request them. When there's a PC in the network, it usually performs the roles of bus manager and isochronous resource manager.

As the IEEE 1394 bus uses time-domain multiplexing (TDM), the isochronous resource manager allocates each isochronous transfer a 'channel' consisting of so many 'bandwidth allocation units' (i.e., a guaranteed proportion of the total time slots). A bandwidth allocation unit is 20.3ns, so there are 6144 of them in a IEEE 1394 'basic cycle' of 125us. However 25us of every cycle is always reserved for asynchronous control data transfers, so a maximum of 4195 units is available for isochronous transfers. Typically a stream from a DV camcorder to a PC or digital VCR might need to be allocated a channel of say 1800 bandwidth units, for about 30Mb/s.

Only one data packet can occur every basic cycle for a particular isochronous transfer channel, using that channel's allocated bandwidth units. However multiple isochronous transfers can take place at the same time, providing there's enough bandwidth available. The transfers can even be at different rates — say one at S100 and another at S200. If there isn't enough bandwidth available when a device requests it, it waits until the bandwidth does become available.

Asynchronous transfers can have multiple data packets per basic cycle, within the 25us reserved for this type of signalling.

Data-Strobe coding

All data is sent along the IEEE 1394 bus in serial four byte (32-bit) words, called *quadlets*. And the quadlets are encoded together with their clock signal onto two NRZ (non return to zero) bus signals, using a technique known as Data-Strobe (DS) coding. This improves transmission reliability by ensuring that only one of the two signals changes in each data bit period.

Fig.2 shows how DS coding works. The top waveform shows the Data bits being sent, while the bottom waveform shows the Clock signal. At the transmitting node these two are fed to an exclusive-OR gate to generate the Strobe signal, shown in the centre. It's this signal and the Data signal which are sent along the bus, and as you can see there's only one change in the pair every bit period.

At the receiving device, though, the Data and Strobe signals are again fed to an exclusive-OR gate. The output of this gate effectively reconstructs the Clock signal again, with its timing still accurately locked to the Data. The DS coding therefore avoids the need for IEEE 1394 receivers to have a PLL (phase-locked loop).

Twisted pairs

The IEEE 1394 Data and Strobe signals are sent on cables with two separately shielded twisted-wire pairs, called TPA (twisted pair A) and TPB (twisted pair B). Transfers in one direction have the Strobe signal on TPA and the Data signal on TPB, while those in the opposite direction have the Data signal on TPA and the Strobe signal on TPB. Fig.3 shows the idea.

There are two different kinds of IEEE 1394 cable, with matching connectors. The primary type of cable has not only the two separately shielded wire pairs TPA and TPB, but also two DC power conductors — the negative being grounded. A cross-section of this type of cable is shown in Fig.4, and as you can see there's also an outer shield and sleeve.

The IEEE 1394 standard allows nodes to be supplied with DC power via the two power conductors. The power can be supplied at a voltage between 8V and 33V, and the current can be up to 1.5 amps.

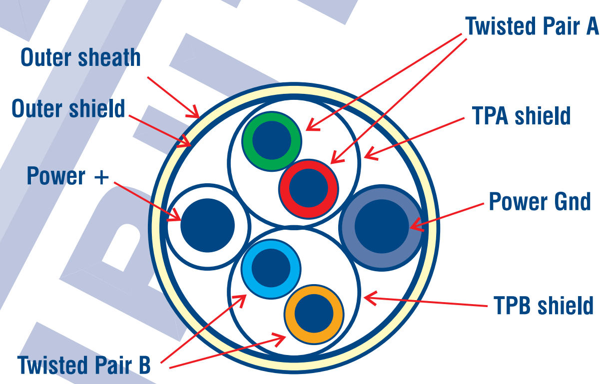


Fig.4: The primary type of IEEE 1394 cable has a pair of power conductors as well as the two shielded signal pairs TPA and TPB.

The type of cable shown in Fig.4 is used for most 'mainstream' IEEE 1394 applications, such as interfacing large hard disk arrays to DV editing workstations.

The second type of cable used for IEEE 1394 has only the two shielded twisted pairs TPA and TPB, and can therefore only be used for signal transfer. This is the type of cable first used in Sony's iLink, and is now commonly used for digital video applications. Most DV camcorders and VCRs use this type of cable.

Due to the high speed at which IEEE 1394 works, cables between device nodes should be no longer than 5m long to limit signal attenuation. There should also be no more than 16 cable 'hops' separating any two nodes in an IEEE 1394 network.

Connectors

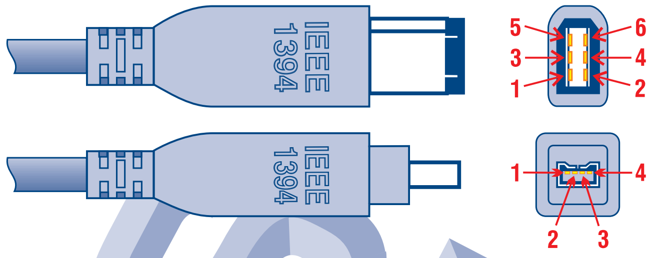
Just as there are two types of cable, there are two types of IEEE 1394 connector to match. Not surprisingly one type provides six connections and the other only four. Both of the plugs are shown in Fig.5, together with their pinouts. The corresponding sockets and their pinouts are complementary, of course.

As you can see both plugs are polarised and fairly compact. But the inserting section of the primary 6-pin plug is much larger (11.3 x 6.2mm) than that of the 4-pin plug, which is very small indeed (6.45 x 3.5mm). The larger plug is polarised by a pair of chamfers at one narrow end, while the smaller one has an indent in the centre of one side.

Normally all devices with IEEE 1394 ports are fitted with sockets, and the cables have plugs at each end. Adapter cables are available to allow data transfer between devices with 6-pin and 4-pin sockets, with appropriate plugs at each end. (There are also short adaptor cables with a plug and a socket, to mate with a standard like-to-like cable.)

NOTE that in all standard IEEE 1394 cables, the connections to the two signal 'twisted pairs' are transposed between the two ends. That is, in a 6-pin to 6-pin cable pins 4 and 3 at each end connect to pins 6 and 5 at the other, respectively. Similarly in a 4-pin to 4-pin cable pins 2 and 1 at each end connect to pins 4 and 3 at the other, respectively.

Because of their complex construction and the small size and precision of their connectors, IEEE 1394 cables can be quite expensive. Because of this and the tiny size of the 4-pin connectors in particular, they should be treated with care to ensure that they provide reliable communication at the fast data rates involved.



IEEE 1394 PLUG PINOUTS

Signal	6-pin Plug Pin	4-pin Plug Pin
Power +	1	–
Power Gnd	2	–
TPB –	3	1
TPB +	4	2
TPA –	5	3
TPA +	6	4

Fig.5: The two different types of IEEE 1394 plug, and their basic pin connections. But note that the TPA and TPB connections are transposed in all standard IEEE 1394 cables.

IEEE 1394/FireWire Cables stocked by Electus

A range of standard IEEE 1394/Firewire/i.Link cables are now stocked by Electus Distribution stores and authorised dealers. Here's a quick rundown on the cables available and their catalogue numbers:

4-pin to 4-pin Cables

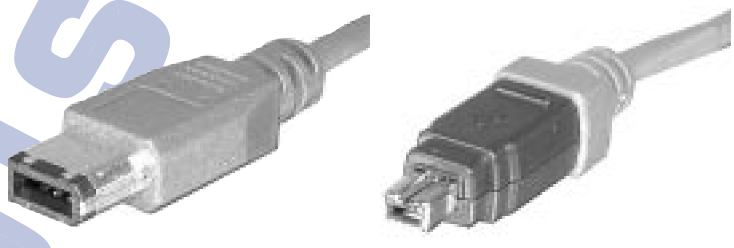
2m long — Cat No. WC-7640
5m long — Cat No. WC-7641

6-pin to 6-pin Cables

2m long — Cat No. WC-7644
5m long — Cat No. WC-7645

6-pin to 4-pin Cables

2m long — Cat No. WC-7647
5m long — Cat No. WC-7648



For more information, please refer to the latest Electus Distribution Catalogue or visit www.electusdistribution.com.au