IEEE 1394 (Firewire) versus Universal Serial Bus (USB)

ECE 422

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1.0. History

IEEE 1394 better known as Firewire introduced by Apple and Sony and USB (USB 2.0) High Speed by Wintel group are revolutionary modern buses for peripheral communication not only for computers but consumer electronics as well. Both have been rivals since the day they were introduced and both claimed to be better and faster than all the other classic bus types.

2.0 Universal Serial Bus

Universal Serial Bus (USB) was conceived in 1993 by a team from Compaq, Digital, Intel, Microsoft, NEC, IBM and Nortel. Unveiled in 1995, USB is a cross platform industry standard and offers many benefits over traditional connection methods including thinner and cheaper cables, greater expendability with the addition of a USB hub and greater speed. USB was developed around the idea that users should be able to run multiple peripherals on the computer.

USB was initial introduced as version 1.0 and later upgrade to version 1.1. USB 1.0 had a maximum data transfer rate of 1.5 Megabits per second (Mb/s) and later increased to 12 Mb/s under version 1.1. USB provides the ability to connect up to 127 devices to a single computer. In February 1999, Intel led a consortium to bring USB to faster speeds, and allowing it to compete with IEEE –1394 Firewire. This update to USB 2.0 allows USB to utilize the full range of devices including cameras and drives. USB 2.0 ramps up data transfer rate from 12 to 480 Mb/s.
### 3.0 IEEE 1394 Firewire

Firewire originally was developed by Apple Computer, Inc as a high speed, high bandwidth serial bus. While it was developed many thought it was actually too fast and some lower speed interconnects like USB would be cheaper to build. Firewire languished, and in 1995 Sony produced a DV camcorder with the tiny Firewire connector. In late 1995, Firewire was accepted as a standard by the IEEE, and since has been called IEEE 1394.

Firewire initial was introduced with several data transfer rates. The first rate was 100 Mb/s then later surpassed by 200 Mb/s. The current data rate per the IEEE standard is at 400 Mb/s. Firewire has been design to allow up to 63 devices of any of the above mention data rates to be attached to a single bus. The Firewire provides high power for the devices connected or can attach to self-powered devices. The next generation of IEEE 1394B is Firewire 800. Firewire 800 doubles the throughput and increases the maximum distance between the connectors.

### 4.0 Features

#### 4.1 USB

USB provides several features over existing data buses, first replaces all the different kinds of serial and parallel port connectors with one standardized plug and port combination. Second, USB provides the user with Hot-swapping and plug and play capability. Hot-swapping allows a user to attach or remove peripherals without restarting
the computer. The user just plugs the device(s) in and the system automatically detects
and configures the peripheral with the necessary software.

Third, USB provides two-way communications between the computer and its peripheral
devices. When the computer is turned on it queries all devices on the bus and assigns
each of them an address. The process of assigning address is called enumeration. After
the host completes the enumeration process. The computer queries the devices for the
type of data transfer it wishes to perform. For a USB device there are three types of data
transfers: Interrupt, Bulk and Isochronous. A mouse or keyboard is a device that would
use the Interrupt process, this process transfer very little data. A device like a printer
would receive blocks of data (64-byte chunks) as part of the Bulk process. A device like
a video camcorder would require a continuous data stream from the host in real time as
part of the isochronous process.

USB divides the available bandwidth into frames, and the computer controls the frames.
Frames contain 1,500 bytes, and a new frame starts every millisecond. During a frame,
isochronous and interrupt devices get a slot so they are guaranteed the bandwidth they
need. Bulk and control transfers use whatever space is left.

The computer tracks the total bandwidth used by the peripherals requesting interrupt and
isochronous data transfers. When peripherals using the interrupt and isochronous data
transfers method request more than 90 % of the 12 Mb/s bandwidth. The computer
denies the request of the peripheral(s).

Forth, USB can sense if a peripheral requires power and supplies that power it needs.
USB also allows devices with their own power supply to be connected to the bus. A USB
cable layout is present in Figure 1. This layout clearly illustrates the power lines (red +5v and brown is ground) and the data lines (blue and yellow). USB can provide 500mA to high-power devices and 100 mA to low-power devices.

Figure 1: Inside a USB Cable

Fifth, USB can allocate to a device up to a maximum of 6 megabits per second (Mbps) of bandwidth, which was initial fast enough for the vast majority of peripheral devices that most people want to connect to their machines. To avoid confusion in connecting a peripheral to the computer, USB connectors are constructed with two different ends. The “A” connector shown in Figure 2 connects to the computer. The USB standard calls the connector “upstream”.

Figure 2: An USB “A” connector

The “B” connector shown in Figure 3 connects to the device; the standard calls this connector “downstream”. By using different connectors on the upstream and
downstream end, it is impossible to ever get confused -- if you connect any USB cable's "B" connector into a device, you know that it will work. Similarly, you can plug any "A" connector into any "A" socket and know that it will work.

Figure 3: An USB “B” connector

Computer systems currently on the market come with at least two USB ports. By adding a printer and scanner to the system, one can easily use up both ports. If one wanted to add another peripheral to the system, you would have to swap out one for the other. To alleviate this problem, hubs have been developed to enable the system to add multiple devices. USB is a hub based architecture, each device must be connected into a hub rather than daisy chained from one device to another. Remember the USB standard allows 127 devices to be connected to the network. A typical USB hub looks like this, Figure 4.
Figure 4: Four port USB HUB

A hub typically has four ports; the newer hubs can have many more ports. Not only are hubs super multiple ports, but also there are also powered and unpowered hubs versions.
4.2 Firewire

IEEE 1394 standard known as Firewire possess several features over existing data buses as well, first with Hot-swapping and plug and play capabilities the same as USB. The second, Scaleable Architecture allows peripherals with different data transfer rates of 100, 200, 400 Mb/s to be connected to the same bus. Third, Flexible Topology, devices can be daisy chained and the devices can branch to perform true peer to peer communication as in Figure 5.

Figure 5: Peripherals Daisy-chained on Firewire Bus

Peer to Peer communication allows peripherals to transfer data without going through the host system. Firewire like USB establishes two-way communications between the computer and its peripheral devices. Firewire also like USB performs the process of enumeration with its peripherals. The enumeration procedure is part of Firewire protocol process. Firewire protocol dictates the data is contained as an information packet in IEEE 1394 and is based on the IEEE 1212 spec. Each packet is 64-bit: 10-bit Bus ID to identify where the data is from, 6-bit physical ID to ID which device sent the data, and a 48-bit storage area. Fourth, Firewire has a very complex serial bus protocol for data transfer. Firewire protocol is defined as three ISO layers: the Physical Layer, the Link
Layer, and the Transaction Layer, plus a Serial Bus Management process that connects to all three layers as shown in Figure 6.

![Bus Protocol ISO Layers Diagram](image)

**Figure 6: Bus Protocol ISO Layers**

The Physical Layer connects to the 1394 connector and the other layers connect to the application. The Physical Layer provides the electrical and mechanical connection between the 1394 device and the 1394 cable. Besides the actual data transmission and reception tasks, the Physical Layer provides arbitration to insure all devices have fair access to the bus. The Link Layer provides data packet delivery service for the two types of packet delivery: asynchronous and isochronous. As mentioned before, asynchronous is the conventional transmit-acknowledgment protocol and isochronous is a real-time guaranteed-bandwidth protocol for just-in-time delivery of information.
The Transaction Layer supports the asynchronous protocol write, read, and lock commands. A write sends data from the originator to the receiver and a read returns the data to the originator. Lock combines the function of the write and read commands by producing a round trip routing of data between sender and receiver including processing by the receiver. Serial Bus Management provides overall configuration control of the serial bus in the form of optimizing arbitration timing, guarantee of adequate electrical power for all devices on the bus, assignment of which 1394 device is the cycle master, assignment of isochronous channel ID, and basic notification of errors. Bus management is built upon IEEE 1212 standard register architecture. To transmit data, a 1394 device first requests control of the physical layer. With asynchronous transport, the address of both the sender and the receiver is transmitted followed by the actual packet data. Once the receiver accepts the packet, a packet acknowledgment is returned to the original sender. To improve throughput, the sender may continue transmission until 64 transactions are outstanding. If a negative acknowledgment should be returned, error recovery is initiated. With isochronous transport, the sender requests an isochronous channel with a specific bandwidth. Isochronous channel IDs are transmitted followed by the packet data. The receiver monitors the incoming data's channel ID and accepts only data with the specified ID. User applications are responsible for determining how many isochronous channels are needed and their required bandwidth. Although up to 64 isochronous channels may be defined, this Figure 7 shows 2 channels.
**Figure 7: Time Slot Allocation.**

The bus is configured to send a start of frame timing indicator in the form of a timing gap. This is followed by the time slots for isochronous channels #1 and #2. What time remains may be used for any pending asynchronous transmission. Since the slots for each of the isochronous channels have been established, the bus can guarantee their bandwidth and thus their successful delivery. Fifth, cable and connector interface design is reduced in size an important feature in consumer electronics. Figure 8 show a cross section of cable and the relative size of the four and six pin connectors.

**Figure 8**: IEEE 1394 six-wire cable
Firewire per the standard is capable of providing power to the peripheral from 8Vdc to 40Vdc at up to 1.5 amps.
5.0 Conclusion

The major difference between USB and Firewire is that Firewire is designed to work devices requiring high bandwidths. Such devices are video camcorders and audio equipment. Both buses share number of common characteristics and differ in some other ways. Table 1 shows a summary of the characteristics:

<table>
<thead>
<tr>
<th></th>
<th>Firewire</th>
<th>USB</th>
<th>USB 2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Transfer Rate</td>
<td>400 Mb/s</td>
<td>12 Mb/s</td>
<td>480 Mb/s</td>
</tr>
<tr>
<td>Number of devices</td>
<td>63</td>
<td>127</td>
<td>127</td>
</tr>
<tr>
<td>Plug and play</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hot pluggable</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Isochronous devices</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Bus Power</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Bus Termination</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Bus Type</td>
<td>Serial</td>
<td>Serial</td>
<td>Serial</td>
</tr>
<tr>
<td>Cable Type</td>
<td>Twisted pair (6 wires, 2 power, 2 twisted pair sets)</td>
<td>Twisted pair (4 wires, 2 power, 1 twisted pair sets)</td>
<td>Twisted pair (4 wires, 2 power, 1 twisted pair sets)</td>
</tr>
<tr>
<td>Networkable</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Network Topology</td>
<td>Daisy Chain</td>
<td>Hub</td>
<td>Hub</td>
</tr>
</tbody>
</table>

Table 1: Summary of Firewire vs. USB

As you can see, the two are remarkably alike. Implementing Firewire costs a little more than USB, which led to the adoption of USB as the standard for connecting most peripherals that do not require a high-speed bus. If one observes the Table above USB 2.0 has 80kb/s more bandwidth than Firewire. In recent studies not present in this paper USB 2.0 has increase in operational overhead, therefore reducing its effective Bandwidth below that of Firewire.

In conclusion, depending upon your requirements both buses are good to use. However, if your need is for high-bandwidth then Firewire is the only choice. USB is very good for non-Isochronous devices, such as printers, mouses and keyboards.
References

How USB port Works, by Marshall Brain

USB, by Patrick Koehler

USB 2.0 versus Firewire, by Dennis Sellers

Firewire, by Apple Inc.

How Firewire Works, by Jeff Tyson
## USB versus FireWire

<table>
<thead>
<tr>
<th>Version</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB 1.1</td>
<td>12 Mbps</td>
</tr>
<tr>
<td>FireWire 400</td>
<td>400 Mbps</td>
</tr>
<tr>
<td>USB 2.0</td>
<td>480 Mbps</td>
</tr>
<tr>
<td>FireWire 800</td>
<td>800 Mbps</td>
</tr>
</tbody>
</table>

Due to the speed and efficiencies of FireWire 800, in many cases the effective bandwidth is more than twice that of USB 2.0.