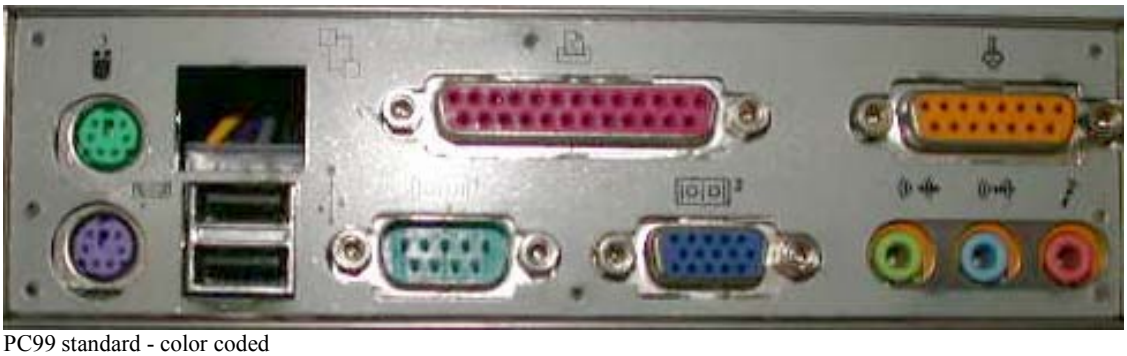
Agel, Shadi (ID# 984-1414)
Bunyaphriruang, Pongsakorn (ID# 022-2076)
Chang, Chih-Chung (ID# 015-7480)
Chia,Winnie (ID# 025-7473)

USB 2.0 VS FireWire

Shadi Agel
Pongsakorn Bunyaphriruang
Chih-Chung Chang
Winnie Chia

When the personal computer was introduced to the market for the first time, the configuration of the PC was a real mystery to computer users. Users did not understand why they had to have a different connector for each device and the differences between a mouse port, printer port, game port or a SCSI port. The cables to be connected to these ports were even more confusing. The different number of pins (male and female) made it even harder to know which cable went with what port. The manufacturers were developing technologies that were aiming at realizing immediate profits without giving consideration to compatibility and simplicity issues. To make these ports more user-friendly, the external connections and the cables were eventually color coded by PC manufacturers to eliminate any possibility of plugging the connector to the wrong port. After the PC99 standard regulated the color-coding for each port, computer users became less intimidated to plug the cable to the right port by themselves.



PC99 standard - color coded

New back panel for motherboard (no ps/2, com port, printer port)

The drastic drop in computer components that made computers more affordable to most families and the introduction of the Internet as a necessity created a vast market hungry for computers and peripherals that are more powerful and less complicated. Faster data transmission ports became a necessity because of the need to transmit huge files and it pushed the development of transmission ports to new boundaries. In response, Intel and its partners invented the USB port to accommodate the needs of the computer manufactures and the consumers alike. In the following report, we are going to review why computer manufactures changed from the old connection port to the USB port, the transition to the IEEE 1394 and the USB 2.0 standard, and the future of high-speed connectors.

USB Technology Considerations

As the technology improved, more and more external devices required faster data transmission ports to handle the faster peripherals. For the computer industry, the various connectors and cables became a costly financial and logistical burden. In 1999, a printer cable only yielded only a few cents per cable in profit. Configuring and connecting printers, scanners and their bulky cables to the correct ports and installing their drivers created a great dilemma for computer users regardless of their degree of computer sophistication. Computers and their peripherals became obsolete quicker than they could be made because they could not handle the fast development of processors and peripherals. The drastic drop in computer prices made them more disposable and less attractive to upgrade. Users and manufacturers were taking chances about what to include or exclude in their systems. Something had to be done to make peripherals more compatible and computer systems more versatile and less complex.

USB Development

The USB (Universal Serial Bus) standard was introduced in 1995 in an attempt to replace the multitude of connectors common on personal computers. Since the introduction of the IBM PC in 1983, computers came equipped with serial, parallel, keyboard, mouse, SCSI and Ethernet ports. Intel Corporation along with other development partners set sail on the invention of USB. The USB standard allows peripheral devices — items being plugged into the computer — to be self-configuring. This allows the user to plug in a USB device and lay the burden of installing the proper drivers to support the installed hardware on the operating system. USB promises to one day make adding new devices truly plug and play.

Understanding USB

The USB connection is a serial communication standard; meaning it specifies how data flows in a series of pulses along one pair of wires. In a parallel connection, data flows along several wires at the same time, with the pulses on each wire required to be in step with those on the other wires. Serial cables are thinner, longer, and easier to handle than parallel cables. In addition, USB is a bus or "party line" where all devices on the bus share the same communications channel. These devices have the ability to identify themselves and take turns communicating with the computer. Up to 127 peripheral devices can share one USB connection, which can loop from one to the next or fan out from a central "hub" device with thin wires to each device.

The USB wire also carries a limited amount of power to the devices, which is designed to eliminate many of those power cubes we all have plugged into the wall near our computers. Finally, the USB connection is a high-speed service, which means great things can happen when dealing with an enormous tree. Up to 12 million bits of data can flow down the USB connection per second. (That's 12 Mega-bits-per-second or Mbps.) It is common knowledge that there are 8 bits in a byte, which can represent a character. Figuring a thousand characters in a page and one can imagine seeing USB moving the

equivalent of 1,000 pages of data per second. Only recently could computer serial ports handle speeds greater than 19 thousand bits per second verses 12 Mega bits per second with a USB. Of course, the more devices on a bus, the less data that particular device can receive or send in a given period of time since it has to share the time with all the other devices.

USB and Operating Systems

Windows 95 was the first operating system to utilize the plug and play feature for a computer, but it really should have been called plug and pray. Although the developers at Microsoft had the right idea when creating the plug and play feature, Windows 95 did not support the plug and play device very well, and had a tendency to crash when attempting to plug or unplug any kind of device.

Although the USB standard was introduced in 1995, the USB port did not surface on many computers until around 1998. Although the USB standard has been around since 1995, the first operating system to utilize the USB feature was Windows 98 osr2. Window Me, Windows 2000 and Windows XP (Pro and Home edition) all support USB and will activate computers that already have USB ports built in. In the computer business world, a technology with a great potential will readily be embraced. When Intel introduced USB standard, it caught the general public attention with the introduction of Apple's iMac was the first computer without a dedicated keyboard and mouse port. Instead, it featured two USB ports into which users plug the USB keyboard and mouse. In fact, the iMac's keyboard acts as a hub with additional USB connections on each side, allowing for a mouse or other low-voltage USB devices to plug into it. The use of USB ports in the iMac offered additional flexibility to users by allowing them to plug a floppy drive with great ease if they found it necessary to have one.

Today, computers from most national brands carry USB ports in addition to their traditional serial, parallel, and keyboard/mouse ports. It is only a matter of time before USB is the only type of port on new computers. If the computer does not have a built-in USB port, one can buy a PCI interface card for their Mac or PC with a minimum of 4 USB ports.

USB Applications offer Greater Expandability and Compatibility

What computer devices are using USB to connect to a personal computer? The obvious ones are the keyboard and mouse, plus connections to modems, printers, digital cameras, game pads, joysticks and storage devices. Also, there is good news for genealogists who scan many of their documents; more than 90 percent of the new scanners sold this year will connect via USB. Buying a scanner with a USB connection to digitize family photos should not only be more affordable, but also easier to operate. Since the USB has a maximum throughput of 12Mbps, a great number of new home network equipment also use USB ports because they do not need complicated steps to setup. It is easy to use and powerful and it works virtually with every peripheral. USB supports simultaneous connection of up to 127 devices by attaching peripherals through interconnected external

hubs. When a computer port fills up, users can easily attach a USB hub, which provides additional ports. In addition, USB uses one style of inexpensive cable with different connectors at both ends, so plugging the cable in incorrectly is virtually impossible.

The Problem with USB

The biggest problem with USB is that the computer will have a current limit on the USB port. Most USB devices are powered from the USB connector, and the power that each peripheral device demands is not always clear. This means that plugging several peripherals that draw power from the USB may affect the performance of some of the peripherals if one demands more power than the others.

Another problem with USB ports is its speed limit. The USB ports have only 12Mbps speed (USB version 1.1). Even an old SCSI 1 external port is faster than it (SCSI 1 external port's speed is 40Mbps). When a user tries to connect an external CD-ROM or CD-RW, scanner or a new high-resolution digital camera to a USB port, the transmission speed becomes very slow. As a result, there are still some devices that are utilizing SCSI ports to transmit the data to the computer. Finally, many USB devices run at 1.5Mbps, only a few are rated at 12Mbps.

Emergence of USB 2.0

A team from seven industry-leading companies, four members of the original USB core team (Compaq, Intel, Microsoft and NEC) and three new members (Hewlett Packard, Lucent and Philips) collectively developed USB 2.0. Together they developed the specification for the much faster USB 2.0. Their aim was to provide a bus that would provide manufacturers with the ability to connect to high performance peripherals at the lowest cost possible. As with the original USB, the group decided not to charge any royalties for the patent to promote faster and wider acceptance. This second generation bus uses the same cables and connectors used with the original USB. The final specifications for USB 2.0 were released in the winter of 2000 and the first products for USB 2.0 hit the market in spring 2001.

The final USB 2.0 specification was released on April 27, 2000. It was developed with the aim to handle higher data rates while still allowing low-and full-speed devices on the same bus. USB 2.0 was also designed to make automatic devise detection and installation a seamless operation, making plug-and-play a truly plug-and-play capability.

The original USB 1.1 supported data speed of 12 Mbps, USB 2.0 supports data speed of up to 480 Mbps, which is 40 times faster than the original. Naturally, USB 2.0 expanded the market for USB devices, including hubs and other higher bandwidth peripherals, such as digital image design and web publishing.

While the original USB refers today to the 1.5 Mbps (low) and 12 Mbps (full), USB 2.0 specifications covers 480 Mbps as well as 1.5 Mbps and 12 Mbps. The bus speed depends on how busy the bus is, as well as on the type of transfer being used. For now, USB 2.0 is about the same speed of IEEE 1394a (FireWire) which offers 400 Mbps and is in development to increase this speed to 3.2 Gbps. IEEE 1394 will be explored in more detail later on in this paper.

Today USB is everywhere in the U.S. retail market. Almost 100% of the scanners, digital cameras, external floppy drives, external CD-RW, digital cameras and Ink Jet printers require USB ports.

Intel's specifications for USB 2.0 define an architecture that is fully compatible with USB 1.1 and 2.0 devices and hubs. It can even run USB 1.1 devices with existing USB 1.1 software drivers. The architecture is also highly optimized and, therefore, consumes minimum CPU overhead. In addition, existing USB 1.1 devices connect to USB 1.1 controllers, thus leaving all of the high-speed bandwidth free for USB 2.0 high-speed devices. With this flexibility, USB 2.0 will deliver the final push to making serial and parallel ports obsolete in the near future.

High-Speed USB is both forward and backward compatible with the original USB, thus providing seamless transition process for the user and allowing smooth transition to the faster peripherals. USB 2.0 uses a low cost host-centric connection model based on the best solution to connect PCs with higher functionality peripherals. Since 1996, the Windows operating Systems have been equipped with USB drivers for a variety of video and DVD applications.

History of IEEE 1394

Originally, audio and video were limited to specific products such as VCRs, TVs and DVD's until computers encompassed similar capabilities and functions. Performance of the computer is determined by the speed of the CPU, main memory, and the peripheral devices. The faster CPU and the faster memory access time require the faster data transfer rate between CPU and I/O devices that connected to the computer. Connection between the I/O devices and the computer has a different data transfer rate depending on the type of I/O module. For example, the mouse and keyboard need lower data transfer rates than a printer or a scanner. Data can be transferred in parallel or serial mode. Length of the cable, the quality of the data and the transfer medium are the factors used to determine the transmission type.

IEEE 1394 was designed to be a universal interconnect. It eliminated the need for many I/O connectors. The resulting port integrated and consolidated the circuit board space and

was used to connect a variety of the consumer electronics devices and PC. This technology was developed under the 1394 Trade Association, formed in 1994. The Association defines how the technology is implemented in specific applications, such as HDTV's, VCR's, etc.

IEEE 1394 is otherwise known as FireWire. Apple Inc. was the first company to develop and implement the FireWire port in all its computers. Because Mac systems mainly use the GUI, graphic user interface which require more accuracy and high quality of the graphic, audio, and video. Mac end users are mainly graphic designers, moviemakers, animators, etc.

Since the digital signal gives higher quality result for transferring data than analog transmission, IEEE 1394 was developed to satisfy specific consumer needs. An analog signal has to be converted to a digital signal before and after transmission by using the Digital Audio Converter or DAC in order to produce sound on the speakers. The A/V cable is used to connect the VCR or DVD player to TV. The S-video cable is used to transfer the better quality of the image and leaves the audio signal to be transferred over A/V or a digital coaxial cable.

FireWire Features

FireWire cable has an important feature in that the cable itself provides power supply to its device. By using the 6-pin cable, the device does not need an extra power supply cable. The device will get the power from the computer. FireWire uses isochronous data transmission that transfers data as a packet in digital form, which provides higher quality and greater reliability. FireWire is best used in computers for transferring streaming video and audio because of its very high data transfer rate.

FireWire will replace the traditional A/V cable in the near future because of the increasing use of home networking. With FireWire, all audiovisual and electronic products in a house can be connected to each other and inter-communicate. It will facilitate connecting the stereo system to the computer, the VCR, the DVD player and the HDTV. The data or signals will be sent in high-quality digital form. In the past, audio and video signals were transmitted in analog form. The environment and the length of the cable easily distorted analog signals. Even when the digital coaxial cable was developed to transfer the data in digital form, there were some limitations. The major downside was the signal conversion from digital to analog or vice versa. Another weakness was that the A/V cable needed three lines: one for video signal and two for the left and right audio channels. Furthermore, the S-video cable was developed to transfer the video signal in digital form, but it still needed other cables for the audio signal.

Nowadays, FireWire technology is the standard for transferring data from digital cameras or camcorders directly to the computer in order to edit, save, or transmit over the network or the Internet. FireWire makes connection between computers and peripheral devices easier and satisfies consumer needs. FireWire is also used for connecting the computer

with the external hard drives or storage devices that require more data reliability, accuracy, and easy access.

FireWire bus provided a great advantage over its rival the SCSI bus which required connecting devices serially (daisy-chain) with a termination point. FireWire did not need a termination point. SCSI also required from the user to assign IDs for each device in order to prevent conflict among devices. FireWire can be connected in multiple configurations and automatically assigns the ID for each device connected to the bus.

FireWire can send a combination of digital signals, including audio, video, MIDI, and the control commands. This distinguishes the FireWire from other systems which transmit only a single signal type. Digital Video camera use DV format that exceed the quality of S-VHS. DV format gives very high resolution, bright with excellent depth and contrast image. It is stored in digital form, so it can be copied repeatedly without loss. IEEE 1394 has the protocol that can transfer DV signal data to the PC and give the exact digital copy from the original source.

IEEE 1394 / USB Comparison

The topology of IEEE 1394 is known as a tree topology. Any device can be connected to any other device, so long as there are no loops. An IEEE 1394 network can support up to 63 devices. The devices can be hot swapped. If a device is added or removed, the bus will reset, reconfigure, and continue operation. If the bus is broken, the two pieces will reset, reconfigure and resume operation as 2 independent busses. IEEE 1394 also offers peer-to-peer connectivity, so peripherals can talk to one another without intervention from the PC.

In contrast, USB has what is known as a star-tiered topology, where the PC acts as the host. Each device is connected to a hub, which provides sockets and power and acts as a repeater. Hubs can be either self-powered or bus powered. They can also be cascaded. USB topology supports up to 127 devices. The peripheral USB 2.0 bus appeared last year. Unfortunately, Intel didn't integrate it in its new chipsets, and thus, prevented its popularization. NEC, however, released a single-chip solution for expansion cards with the USB 2.0 support. Some main-board manufacturers turned to those chips to integrate USB 2.0 in their boards. Unfortunately, there were too few such main-boards in the market; and it turned out that there were much more devices able to work with the USB 2.0 bus than the controllers.

These directly competing buses are very close in their technical characteristics, though each has its own features. Following are the characteristics of USB 2.0 and FireWire (IEEE 1394):

USB 2.0

1. 1.5 Mbps, 12Mbps, 480 Mbps supported.
2. USB controller is required to control the bus and data transfer.
3. Cable up to 5m.
4. Up to 127 devices supported.
5. Power supply to external devices is 500 mA/5V (max).
6. Full compatibility with USB 1.1 devices.

FireWire (IEEE 1394)

1. 100 Mbps, 200Mbps, 400 Mbps supported.
2. Works without control, devices communicate peer-to-peer.
3. Cable up to 4.5m.
4. Up to 63 devices supported.
5. Power supply to external devices is 1.25A/12V (max).
6. The only computer bus used in digital video cameras.

Each bus has its advantages and disadvantages. The maximum speeds are almost equal. And each bus has already occupied a certain market niche.

Speed:
USB offers speeds ranging from 1 Mbps to 480 Mbps. In contrast, the current IEEE specification 1394 offers speeds starting at 100 Mbps and going up to 400 Mbps. P 1394b will start at 800 Mbps and is defining speeds of up to 3200 Mbps.

Application:
IEEE 1394 and USB are complimentary technologies. USB is a small and medium bandwidth connection for telephony products, digital still cameras, monitors, keyboards, mice, and other similar I/O devices. In contrast, IEEE 1394 is a high-speed bus designed for digital video cameras, DVD players, mass storage devices, and other peripherals that require greater bandwidth.

Cost:
USB2.0 is around $3 in OEM (Original Equipment Manufacturer) quantities. It is a very low-cost interconnected technology. Low-speed USB implementations for devices such as mice and keyboards typically cost less than $1 in OEM quantities, and even the medium-speed implementations for devices like scanners and modems are in the $1-2 range in OEM quantities. Due to relatively lower volumes and higher complexity, IEEE 1394 implementations are currently in the $9 range. This cost is expected to decrease as volume builds over the next few years.

Comparison Summary:

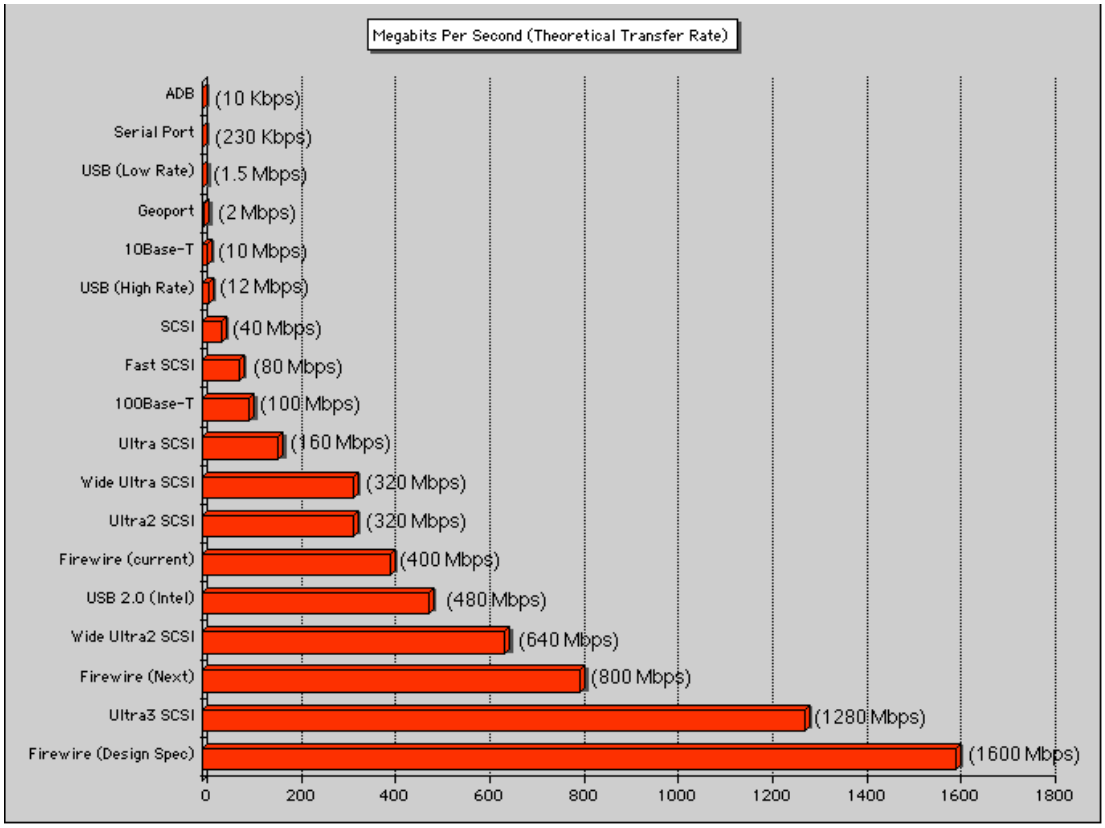
USB and IEEE 1394 (FireWire) technologies are easy to use and compliment each other in terms of performance and cost and give a choice between high performance and high cost.

The Following table compares USB 2.0 with FireWire:

	USB 2.0	**IEEE 1394 (FireWire)**
Maximum number of connected devices.	127	63
Hot-swap?	Yes	Yes
Plug-and-play?	Yes	Yes
Cable length between devices.	5m	4.5m
Data Transfer rate (Mb/s)	480m	100/200/400
PC/Mac	Yes/Yes	Yes/Yes
Embedded power line	Yes	Yes-6pin/ No-4pin
Topology	Peer to Peer	Peer to Peer
Applications	Keyboard, Mouse, Joystick, Monitor, Hub, Audio, Scanner, Digital Camera	DVD high-speed, Camera, Cam Recorder, Storage, Printer, Scanner Device
Relative Cost	Low	High

The following table is summary of pros and cons of the two technologies:

	USB 2.0	**FireWire (IEEE 1394)**
Pros	Highly affordable partly based on the simplicity of the chipset. Highly versatile. Supported by both Microsoft in Window 98 and Apple (through the iMac) No royalty charges.	High transfer rate makes it ideal for streaming video, hard drives and other high-bandwidth data. Supported by both Micro Soft (Windows 98) and Apple Computer. Share peripherals. Windows 2000/ Windows ME/ Windows XP support.
Cons	Slow; however, expect higher rates to be developed as the technology progresses. Cannot share peripherals. Not supported by Windows XP without proper drivers.	Only supports 63 devices. There is fighting amongst companies such as Texas Instruments and Apple over a standard. Expensive. The added speed comes at an economic cost. Users have to pay Apple.



Meeting the needs for the future:

As expected after 2001, USB 2.0 dramatically increased its capacity to 480 Mbps, which challenges FireWire (IEEE 1394) as the serial interface of the future. Tomorrow's PC will have a need for low-cost, low-bandwidth devices like mice, keyboards, and modems. USB provides a good fit for these devices. Tomorrow's PC will also need a high-speed interface for connecting to high-speed printers, hard drives, and camcorders. IEEE 1394 is the technology that will allow these devices to interoperate with the PC. Both USB and IEEE 1394 will coexist on the future PC platforms to meet a wide range of growing peripheral interconnectivity needs.

In general, USB provides slower speed which is usually applied to keyboards, mice, and printers. FireWire provides faster speed; therefore, it is applied to most of the external storage devices such as scanners, hard drives, CD ROMs, DVD-RWs, and CD-RWs. Intel will introduce InfiniBand to try to take over the external storage market of USB 2.0 and IEEE 1394 (FireWire) such as hard drives, DVD recorders, cam recorders, etc.

The future of USB 2.0 will be InfiniBand, under development by Intel and introduced to the market in the next 5 years. The next generation of FireWire is IEEE 1394b. The IEEE 1394b standard covers such elements as cables and connectors for gigabit signaling; detection and resolution of physical loops in bus topology; circuit design for transmitting 8b/10b encoded signals; extension of the PHY/link interface for higher data rates over

either an 8-bit parallel or bit-serial bus; protocols to encode bus arbitration signals as symbols; protocols for signals speed negotiation between peer devices; and testing and compliance procedures for gigabit connections.

Conclusion:

Does this mean that FireWire will "win" the interface war with USB? No, that is because there is no need for a winner. Most industry analysts expect FireWire and USB to coexist peacefully in future computers. Small FireWire and USB connectors will replace the crowd of connectors found on the back of today's PCs. One can reserve USB for low-bandwidth peripherals (mice, keyboards, modems), and use FireWire to connect to the new generation of high-bandwidth computer and consumer-electronics products. Although the USB 2.0 is speedier than the FireWire, the latter beats it when used in high-speed storage devices. Probably, future products will unveil and use the full potential of the USB 2.0 bus. If we take only the storage devices sphere, the optimal solution would be a combo USB 2.0/FireWire-IDE bridge. In this case a user would get the maximum flexibility when choosing the ways of connection of data storage devices.

Whether it is USB 2.0, or IEEE 1394, or infiniBand, the main idea of these products was originally created to standardize external connectors. However, neither product can replace another because of their different characteristics and application. Each product has its own unique function.

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