

TECHNICAL NOTE

Distributing digital video to multiple computers

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Video is an effective teaching tool, and live video microscopy is especially helpful in teaching dissection techniques and the anatomy of small neural structures. Digital video equipment is more affordable now and allows easy conversion from older analog video devices. I here describe a simple technique for bringing digital video from one camera to all of the computers in a single room. This

technique allows students to view and record the video from a single camera on a microscope.

Key words: digital video (DV); FireWire; IEEE1394; i.Link; mega bits per second (Mbps); peer-to-peer networking; Macintosh computer

To send video from one camera on a microscope to many computers one must connect the camera and computers to a network that is fast enough to carry the large amount of information in a digital video (DV) signal. "FireWire" cables are typically used to transfer DV signals because of their ability to carry large amounts of data in a short time. I here describe how to create a FireWire network to bring DV signals to many computers.

In my neurobiology teaching laboratory, I use a FireWire network to demonstrate dissection techniques and to teach neuroanatomy. It is often easier to see small or translucent structures in video than in a still image. Live video allows one to respond to questions and be more interactive with students, in contrast to using pre-recorded movies.

Since most teaching laboratories are equipped with computers, this method of bringing video to students is more cost effective than purchasing additional video projectors or large plasma screen displays.

Background of IEEE1394

A network consists at minimum of a DV source, such as a digital camcorder, or digital video converter box, and several computers connected with "FireWire" cables. "Firewire" is a trademark term for the IEEE1394 [1] standard for this form of communication between computers and/or peripherals such as hard drives and video cameras. This standard was formalized by the Institute of Electrical and Electronics Engineers. Apple Computer [2] created a trademarked symbol (Figure 1), and they license the 1394 Trade Association [3] to use it in marketing 1394 devices and cables. The Sony Corporation created their own symbol, but both symbols refer to the same 1394 standards.

There are two major kinds of FireWire now [4], IEEE1394a (FireWire 400) and IEEE1394b (FireWire 800). FireWire 400 can transfer data at a theoretical maximum of 400 Mbps (mega bits per second), and is more common in today's computers because it was invented first. A FireWire cable is collection of four or six parallel wires that carry electrical signals to and from a "bus", which is a collection of input/output connections that work together in a device, usually collected into a plug. This bus has

enough bandwidth to carry the large amounts of data found in a digital video signal. FireWire 400 cables are usually limited to a length of 4.5 meters. After that, the signal is too weak for reliable communication. FireWire 800 is newer, and uses nine wires instead of four or six, so it can send more information in a shorter time, and over a longer distance. I will focus on FireWire 400 because it is more common. All concepts described here may be applied to FireWire 800, but some limitations, such as cable length, will not be as severe.

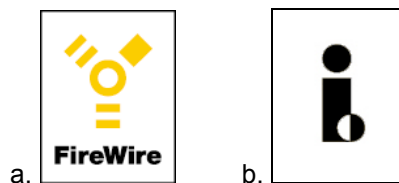


Figure 1 Symbols that represent the IEEE1394 standard. These symbols will help you identify products that are compatible with computers and cameras that use this standard. The FireWire symbol on the left (a) is a trademark of the Apple Corporation. The i.Link symbol on the right (b) is a trademark of Sony Corporation.

FireWire has several useful features [2]. It is "hot-pluggable", so one does not have to shut down a computer or peripheral to unplug it from the FireWire bus. It provides up to 45 W of power from the computer to a peripheral, so peripherals do not require a separate power supply. It uses "peer-to-peer" connectivity, so communication between devices is two-way and they automatically configure and work together immediately.

One important difference between digital and analog video is that digital video (DV) signals are bi-directional in the cables that connect video sources (cameras) and video displays and recorders (computers). This enables computers to automatically respond to the presence of a DV signal, and to also control a digital video camera.

How to assemble a network

The video signal can originate from any camera that has an output bus. Many laboratories have a microscope with

a camera attached to a trinocular or to an eyepiece. These cameras often have an analog output jack such as "composite video" or "S-video" (a.k.a. "Y-C" video). The composite video jack is the one that is found on most VCRs and uses the same RCA-style plug found on stereos. It is often color-coded yellow. This video signal is of relatively lower quality than that from S-video, but S-video cables are a little harder to find sometimes, and more expensive. Alternatively, a digital C-mount camera can be installed on a microscope, eliminating the need for conversion from analog to digital video. These cameras are now available from The Imaging Source [5].

After connecting the analog video camera to an output cable, convert the analog video signal to a digital video (DV) signal. This can be accomplished by using a device specifically designed for this conversion or by many DV camcorders that have "pass-through" capability.

The dedicated devices can be a stand-alone box, or a PCI card one can install inside a desktop computer. The camera, box, or card will accept analog video into one jack, and emit digital video from a FireWire bus. And stand-alone converter box can be found by searching for "DV converter" and can cost as little as \$150. The capture card that is installed in the PCI slot inside a desktop computer can be less than \$100. Some brands include Formac [6], Datavideo [7], Pinnacle [8], Canopus [9] and Plexor [10].

Alternatively, one could use a camcorder that has pass-through capabilities, meaning it accepts analog video such as composite or S-video, and converts it immediate to DV coming out a FireWire port. DV camcorders with this capability cost as little as \$300, and have the advantage of being used as a camcorder when not being used with the analog camera on the microscope. The DCR-TRV series of cameras by Sony [11] have this capability and work well (I used a DCR-TRV330). You might also find a camcorder with a broken tape transport for much less money. Although it won't record to tape, its pass-through ability should be intact.

In either case, one can also add an analog microphone to the input of the converter. This sound signal could be one's voice as one describes a dissection technique, or the audio monitor of recorded action potentials. One could also bypass the microphone (and room noise) by sending the output of an electrophysiology amplifier directly into the analog sound input. The DV converter creates a digital audio signal in addition to a video signal that will be carried in the same FireWire cable to all of the computers in the network. Recording this DV signal to the hard drive is one simple way to synchronize video of behavior with electrophysiology data. If one does use a microphone, one may need to reduce the volume on nearby speakers to reduced feedback.

At this point, one can use a FireWire cable to transfer the DV signal from the converter to a computer that has a FireWire port. There are two kinds of FireWire ports, four-pin and six-pin. The four-pin ports do not carry power, and the six-pin ports carry power than can be used to run an external hard drive. Both kinds carry data in the same way. If the computer came with FireWire built-in, then the ports are usually six-pin. Most camcorders run on battery

or require an external power source, so they have a four-pin FireWire jack.

Once the FireWire cable connects the DV signal source to the computer, then the computer can display video on the screen, or record DV on to the hard drive. To do so, one requires video acquisition software such as iMovie. iMovie is free with all Macintosh computers, and all Windows computers now come with a similar product. Although iMovie works well with one camera and one computer, I have found that it is prone to instability when used in a network of eight computers accessing one camera. Instead of iMovie, I use a shareware program called BTV [12]. This program costs \$20 per copy, or \$400 for an unlimited site license. It allows you to view and record DV onto your hard drive. BTV also has many useful features that allow one to resize the video window, manipulate picture quality, and save movies. BTVPro has additional features for editing movies and costs \$40 per copy. The time-lapse feature of BTVPro could be used to make movies of slowly-moving growth cones.

Many Macintosh computers have two FireWire ports, and this can allow one to create a 'daisy-chain' network. A daisy-chain configuration involves the DV going from the camera, to one port of first computer, and then out of the other port on the first computer, to the second computer. This chain can be extended to at least 63 computers. The computers in the chain can even be turned off without breaking the chain, but any disconnection of the cables will cut off the DV source from the computers on the other side of the break. Theoretically, each computer could be separated by 4.5 m cables, but some computers do not have sufficient power to send the signal that far, and some FireWire cables are less efficient than others. I have listed in the references a vendor that I know sells high-quality cables [13]. If the video network is to be permanent, then one would likely want the cables to run under the floor, and this often requires more than 4.5 m of cable between computers. This problem can be solved using "repeaters" at the end of each cable to boost the signal.

Repeaters are small boxes with two FireWire jacks and a power jack. With a repeater connecting each 4.5 m cable, one should be able to extend the length indefinitely. But each repeater needs to receive DC power from its AC adapter, so one may need to run AC power under the floor with extension cords. Repeaters can be found from Orange Micro [14], MacAlly [15], or Unibrain [16], among others, for around \$30.

Since a repeater has only two ports, one for input, one for output, it can only extend a linear 'daisy-chain' network. A FireWire hub is a small box with three or more ports, but otherwise similar to the repeater. With a hub, one can create branching networks. The main advantage of a branching network is that one can disconnect any of the computers from the network, and the other computers will remain connected. Figure 2 illustrates the branching network I use. Our network uses some 10 m cables, but those are no longer sold since they are sometimes unreliable.

Many other network configurations are possible. One could use a "hub and spoke" configuration with a central

hub having up to 10 ports, so one can split the incoming signal out to 9 recipient computers. This may require longer cabling, so more repeaters may be needed. One may wish to keep the hubs above the floor to facilitate adding to the network, and especially if the floor below is a humid basement. One can then run the cables under the floor. Since 10 m cables are not available, one will likely require powered repeaters under the floor. Keep in mind that each repeater must receive power from its bulky AC adapter, and each adapter will require an AC power jack.

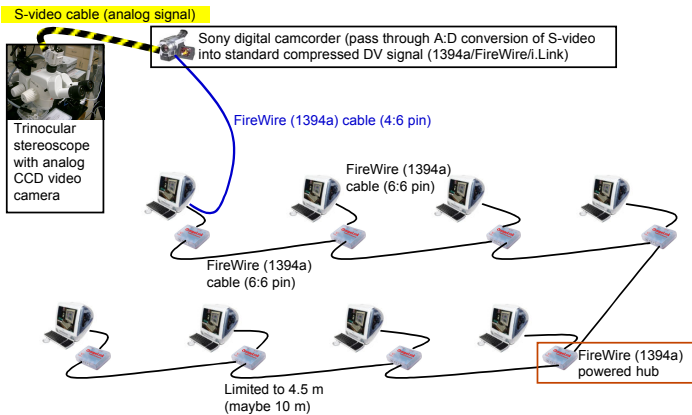


Figure 2 Example configuration. Each computer is connected to the network with 6pin/6pin FireWire400 cables that are 4.5 m or 10 m long. Our iMacs are using MacOS 9.2.2 with the video acquisition program BTVPro, and have 600 MHz PowerPC G3 processors and 384 MB of RAM. This wiring pattern has the advantage of not being broken if one computer is disconnected.

For this network one requires hubs that have at least three ports, one for input, one for output to the computer, and one for output to the rest of the network. Some hubs have up to ten ports, but no ports are dedicated to input or output. Just plug all your cables into the hub and the computers will automatically find the DV signal. The terminal computer will require only a repeater. A FireWire hub can be obtained from D-Link [17], Belkin [18], MacAlly [15], Koutech [19], CablesToGo [20], and others for \$40.

I tried to add a Windows XP notebook to my video network using a PCM-CIA card that adds one unpowered FireWire port to the computer that did not come with built-in FireWire, but that did not work, even though the notebook was capable of recording DV when the camera was connected to it exclusively. I am not sure if this is a limitation of my card, my laptop, or Windows XP.

Troubleshooting a network

Since FireWire automatically configures, there is little troubleshooting necessary. If a computer cannot detect the presence of a DV source on the network, first be sure it can detect the DV source when it is directly connected to the computer. Second, ensure that all relevant MacOS9 FireWire drivers are turned on in your system extensions. If problems remain, try using a shorter cable. If using a hub or repeater, try unplugging and replugging the cables or the power.

Other uses of the FireWire network

One can also configure any computer on the network to behave like an external hard drive, so one can use a FireWire network to exchange files across the network at 400 Mbps, which is roughly 50 MB per second. File transfer over the local area network cables used for internet access is sometimes limited to either 10 or 100 Mbps in most computers, and wireless communication is limited to 54 Mbps. To configure a Macintosh computer into an external hard drive (i.e. put the computer into "target disk mode", connect it to the FireWire network while it is shut down, and start the computer while holding down the T key. In target disk mode the screen will show a FireWire icon and will not be usable as a computer.

If one would like to transfer files without booting into target disk mode, one can purchase network software from Unibrain [16] that can allow one to send files over FireWire cables using the internet protocol. Alternatively, this capability is built into the current Macintosh operating system ("Panther", version 10.3), and is in development at Microsoft under the name Whistler.

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