DigiPoints

The Digital Knowledge Handbook

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Inside

DVD, Part One

Why DVD Is Important

In some respects, DVD technology is like a mini-cable service offering on a disc. DVD discs not only can contain video programming such as TV shows and movies, but they can also include embedded menus, interactivity, parental controls, and alternate programming. Of course, the features and services available from a DVD system are limited because the system is completely self-contained. It cannot draw from a centralized network for enhancements or real-time events, nor can it enable communication with other consumers. That does not, however, change the fact that, from the consumer's perspective, DVD offers a comprehensive supplement to cable and other components of home entertainment and communications systems.

Cable technical personnel will be connecting digital set-top terminals to entertainment systems that include DVD players with various formats. Since the interconnection is fairly complex, it will be helpful to understand how DVD is supposed to work so that the cable technician can verify

operation before starting an installation, and operation in the system with newly provided cable equipment after completing an installation. It also helps to understand the similarity of DVD features to those provided by advanced interactive set-top terminals. From their experiences with DVD, our customers will be familiar with some functions that may or may not work the same on a set-top as in the DVD system. Both installers and support personnel will need to understand the differences.

This issue is Part One of a two-part series. It addresses DVD technology and features. Part Two will discuss the physical connections to other components of a home entertainment system.

Introduction to DVD

DVD (which doesn't stand for anything[1]) is the new generation of optical disc storage technology. Improvements in optical technology make the tightly packed microscopic pits that store data on an optical disc even more microscopic and even more tightly packed than a Compact Disc (CD). A DVD disc is the same size as the familiar CD—12 centimeters (about 4-1/2 inches) wide—but holds up to 25 times more and is at least nine times faster. A DVD disc is essentially a bigger (in terms of storage capability), faster CD that can hold video as well as audio and computer data. DVD covers home entertainment, computers, and business information with a single digital format that could eventually replace audio CDs, videotape, laserdisc, CD-ROM, and video game cartridges. DVD has widespread support from all major electronics companies, all major computer hardware companies, and most of the major movie and music studios, which is unprecedented and says much for its chances of continued rapid growth.

DVD is bringing a significant change in the world of video entertainment and multimedia. It is the first high-quality interactive medium to be affordable to the mass market. All of the features and conveniences that we take for granted on audio CDs, yet miss on videotape—instant rewind and fast forward, track access, digital quality, durability, and compact size—are now available for video. And DVD adds even more, such as on-screen menus, multiple audio tracks and subtitles, widescreen aspect ratio, seamless branching for multiple story lines or more than one rating, multiple simultaneous video tracks, 5.1-channel digital surround, better-than-CD stereo audio, crystal clear still frames, and various playback speeds. DVD also includes copy protection and regional management (to control in what countries the disc can be played).

DVD *is* versatile. Just as audio CD has its computer counterpart in CD-ROM, DVD has DVD-ROM, which goes far beyond CD-ROM. DVD-ROM holds from 4.4 to 16 gigabytes of data—25 times as much as a 650-megabyte CD-ROM—and sends it to the computer at least four times faster than a double-speed CD-ROM drive.

1 DVD originally stood for Digital Video Disc. Some companies wanted to change it to Digital Versatile Disc, which better describes its wide range of applications, but is a distasteful mangling of the English language. Today, the letters DVD stand in their own.

DVD-Video (DVD-V) is an application of DVD-ROM designed for playback of video and audio. The DVD-V specification defines how data is formatted and stored on a DVD disc in order to be played on an inexpensive consumer player. DVD-ROM can contain any desired digital information, but DVD-V is limited to certain data types designed for television reproduction. The DVD-V specification is proprietary to the DVD Forum,[2] but builds on existing standard formats such as MPEG-2 video, Dolby Digital audio, and DTS audio.

Digital Storage and Error Correction on DVD

Data is stored on DVD discs in the form of microscopic pits. The discs are stamped in a molding machine from molten polycarbonate, and then coated with a reflective layer. As the disc spins, the pits pass under a laser beam and are detected according to the change in intensity of the beam. These changes happen very fast (over 300,000 times per second) and create a stream of off/on bits: a digital signal. Half of the information in this signal is used to arrange (modulate) the data in sequences and patterns designed to be accurately readable as a string of pulses. About 13 percent of the remaining digital signal is extra information for correcting errors.

Errors can occur for many reasons, such as imperfections on the disc, dust, scratches, a dirty lens, and so on. A human hair is as wide as about 150 pits, so even a speck of dust or a minute air bubble can cover a large number of pits. However, the laser beam focuses past the surface of the disc, so the spot size at the surface is much larger and is hardly affected by anything smaller than a few millimeters. This is similar to the way dust on a camera lens is not visible in photographs because the dust is out of focus. As the data is read from the disc, the error correction information is separated out and checked against the remaining information. If it doesn't match, the error correction codes are used to try to correct the error.

The error correction scheme used by DVD is 10 times more powerful than on CDs. In general, it can correct glitches caused by scratches or contaminants, although it's always possible that so much of the data is corrupted that error correction fails. In this case, the player must try reading that section of the disc over again. In the worst case, such as an extremely dirty disc, the player will be unable to correctly read the data after multiple attempts. At this point, a movie player will continue on to the next section of the disc, causing a brief glitch in the picture or sound.

Layers, Sides, and Capacities

One of the clever innovations of DVD is to use layers to increase storage capacity. The laser that reads the disc can focus at two different levels, so that it can look through the first layer to read the layer beneath. The outermost layer is coated with a semi-reflective material that allows the laser to read through it when focused on the bottom layer. When the player reads a disc, it starts

2 The DVD Forum is a group of over 200 companies that define and support the DVD family. The original 10 founding companies were Hitachi, JVC, Matsushita (Panasonic), Mitsubishi, Philips (Magnavox), Pioneer, Sony, Thomson (RCA, Proscan), Time Warner, and Toshiba.

at the inside edge and moves toward the outer edge, following a spiral path. If unwound, this path would stretch 11.8 kilometers (7.3 miles), three times around the Indianapolis 500 Speedway. When the laser reaches the end of the first layer, it quickly refocuses onto the second layer and starts reading in the opposite direction—from the outer edge toward the inner edge. Refocusing happens very quickly, but on most players the video and audio pause for a fraction of a second as the player searches for the resumption point on the second layer. If the player has a large enough buffer, or if the disc is carefully designed to lower the data rate at the layer switch point (so that the buffer will take longer to empty), there is time for the laser pickup to refocus and retrack without causing a visible break.

The DVD standard does not actually require compatibility with existing CDs. However, manufacturers recognize the vital importance of backward-compatibility. The difficult part is that the pits on a CD are at a different level than that of a DVD. (See Figure 1.) In essence, a DVD player must be able to focus a laser at three different distances, one for each layer of information.[3] There are various solutions to this problem, including using lenses that switch in and out and holographic lenses that are actually focused at more than one distance simultaneously.

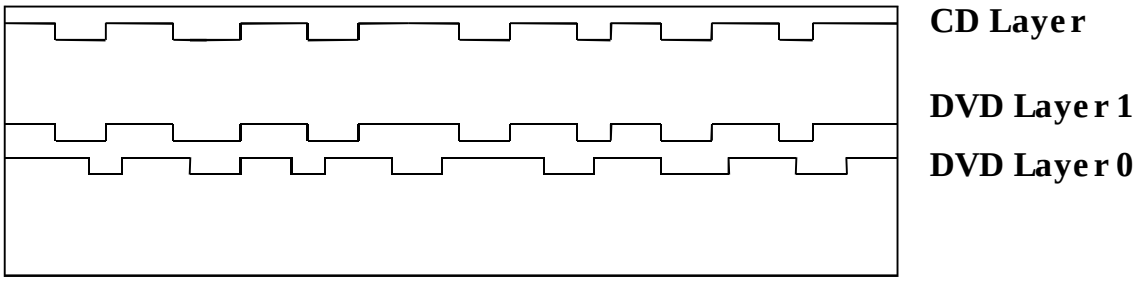

Figure 1: DVD and CD Disc Layers

The remaining task of being CD-compatible merely requires another chip or two for reading CD-format data. Since the data on a CD can be read by any DVD system, conceivably any CD format could be supported. Interpreting the data is another matter. The CD “family” is quite large and includes some odd formats, not all of which fit well with DVD. (See Table 1.) Most manufacturers choose to support only the most common or easy-to-support versions. Enhanced CD and Video CD, for example, are easy to support with existing hardware. Others, such as CD-i and Photo CD, require additional hardware and interfaces, so they are not commonly supported. DVD-ROM drives will support more CD formats than DVD-V players, partly because some are

3 An additional difficulty is that recordable CDs (CD-R discs) do not properly reflect the 635- to 650-nm wavelength laser required for DVD. DVD-ROM drives intended to read recordable CDs include a second 780-nm laser.

designed for computer applications, and partly because specialized CD systems can be simulated with computer software.

Family Member	Application
Audio CD	Optical storage of audio information, typically music, as digital PCM data; also known as Compact Disc Digital Audio.
CD Plus (Enhanced CD)	Optical storage of computer software in addition to music, resulting in a CD that can be played in a music player or read by a computer.
CD-ROM	Compact Disc Read Only Memory; Computer software storage.
CD-R	CD that can be recorded once using a dye-sublimation technology.
CD-RW	Rewriteable CD.
CD-i	CD designed for use with a TV set-top computer to provide interactive entertainment, such as video games.
Photo CD	Storage of photographic images.
CDV	Combination of laserdisc and CD that places CD audio at the beginning of a disc and laserdisc format video on the remainder of the disc.
Video CD	Storage of MPEG-1 video and audio.

Table 1: Prominent CD Family Members

There are two sizes of DVD discs: 12 cm (4.7 inches) and 8 cm (3.1 inches). Both are 1.2 mm thick. These are the same diameters and thickness as used for CDs, but DVDs are made of two 0.6-mm substrates glued together. This makes them more rigid than CDs so they spin with less wobble and can be tracked more reliably by the laser. A DVD can be single-sided or double-sided. A single-sided disc is a stamped substrate bonded to a blank substrate. A double-sided disc is two stamped substrates bonded back to back. Each side can have one or two layers of DVD data. This is part of what gives DVD its enormous storage capacity. A double-sided, dual-layer disc has data stored on four separate planes.

A single-sided, single-layer DVD holds 4.38 gigabytes of data,[4] seven times more than a CD-ROM, which typically holds 650 megabytes. A double-sided, dual-layer DVD holds 15.9 gigabytes, which is 25 times what a CD-ROM holds. (See Table 2.)

Type	Sides	Layers/ Side	Data[1]	Approx. Playing Time[2]
DVD-5	1 side	1 layer	4.38 gigabytes (4.70 billion bytes)	2-1/4 hours
DVD-9	1 side	2 layers	7.95 gigabytes (8.54 billion bytes)	4 hours
DVD-10	2 sides	1 layer	8.75 gigabytes (9.40 billion bytes)	4-1/2 hours
DVD-14	2 sides	mixed[3]	12.33 gigabytes (13.24 billion bytes)	4-1/2 hours
DVD-18	2 sides	2 layers	15.90 gigabytes (17.08 billion bytes)	8 hours

1. Data capacities are shown as reference values in gigabytes, followed by billions of bytes. Actual capacities can be slightly larger if the track pitch is reduced. Please see body text footnote four for an explanation.

2. Assuming an average aggregate data rate near 4.7 Mbps. Actual playing times can be much longer or shorter.

3. One layer on one side, two layers on the other side.

Table 2: DVD Disc Capacities

4 There is an unfortunate confusion of units of measurement in the DVD world and beyond. For example, a single-layer DVD holds 4.7 billion bytes (G bytes), not 4.7 gigabytes (GB). It only holds 4.38 gigabytes.The problem is that the prefixes “kilo,” “mega,” and “giga” generally represent multiples of 1000 (10^3, 10^6, and 10^9), but when used in the computer world to measure bytes they generally represent multiples of 1024 (2^{10}, 2^{20}, and 2^{30}). Both Microsoft Windows and Mac OS list volume capacities in “true” megabytes and gigabytes, not millions and billions of bytes. Most DVD figures are based on multiples of 1000, in spite of using notation such as GB and KB that traditionally has been based on 1024.In 1999, the IEC produced new prefixes for binary multiples: kibibytes (KiB), mebibytes (MiB), gibibytes (GiB), and so on. These prefixes may never catch on, or they may cause even more confusion, but they are a valiant effort to solve the problem. The big strike against them is that they sound a bit silly.

DVD Video Formats

MPEG-2 Video

DVD-V uses a restricted version of the MPEG-2 standard for compressed digital video, either constant bit rate (CBR) or variable bit rate (VBR). The maximum video bit rate is 9.8 Mbps. The average bit rate is 3.5 Mbps, but depends entirely on the length, quality, amount of audio, etc. Picture dimensions are usually recorded as 720 x 480 pixels (NTSC) or 720 x 576 pixels (PAL). Using the traditional television measurement of "lines of horizontal resolution," DVD can theoretically produce 540 lines on a standard TV and 405 on a widescreen TV. In practice, most DVD players provide about 500 lines because of low-pass filtering in the player to reduce interlace artifacts. For comparison, VHS has about 230 (172 widescreen) lines and laserdiscs have about 425 (318 widescreen) lines.

Anamorphic Widescreen

DVD is specially designed to support widescreen displays with a 16:9 aspect ratio (1.78), while being compatible with existing 4:3 displays. Since the recorded NTSC resolution is 720 x 480 pixels, the image is designed to hold video shaped for a 1.33 x 1 rectangle. The challenge in supporting a widescreen format is to fit a 1.78 x 1 rectangle into the same space. This problem, of course, has been faced for years by anyone attempting to put widescreen movies on television. The most common solution, apart from hacking off parts of the picture, is to letterbox. That is, make the two shapes equal in the horizontal dimension, then matte over the gap left at the top and bottom. The problem with this approach is that a large portion of the picture area is wasted in storing nothing but black. When a 1.78 picture is letterboxed before being digitized for MPEG-2 encoding, only 259,200 pixels are active out of 345,600. This doesn't matter when the picture is displayed unchanged on a standard 1.33 TV, but when the TV has a true widescreen display, the stored format must be expanded to fit back into the 1.78 widescreen TV.

DVD's solution to this problem is to modify the widescreen video image by anamorphic processing before encoding. Instead of matching the width and blacking out the gap, anamorphic deformation matches the height and squeezes horizontally to also fit the width. Because the picture fills the available space, 33 percent more pixels can be used to store active picture. Anamorphosis causes no problems with line doublers and other video scalers, which simply replicate the scan lines before they are stretched out by the widescreen display.

Another challenge must be met when movies, rather than TV video, are recorded onto a DVD disc. Most movies are not in 1.78 aspect ratio. Those in common use today are 1.66, 1.85 ("flat"), and 2.4 ("scope"). Two processes are employed to make various movie-shaped pegs fit TV-shaped holes: letterbox and pan & scan. Pan & scan formatting is almost exclusively used to adapt movies for a 1.33 display, while letterboxing is used for both 1.33 and 1.78 display.[5]

Once the video is formatted to 1.33 or 1.78 form, it's encoded and stored on the disc. DVD players have four playback modes, one for 1.33 video and three for anamorphic 1.78 video:

- full frame (1.33 video for 1.33 display)
- auto letterbox (1.78 video for 1.33 display)
- auto pan & scan (1.78 video for 1.33 display)
- widescreen (1.78 video for 1.78 display)

Video stored in 1.33 format is not changed by the player. It will appear normally on a standard 1.33 display. Widescreen display systems will either enlarge it or add mattes to the sides. Alternatively, video stored in 1.33 form may have been formatted for widescreen with letterboxing or a pan & scan format before being transferred to DVD. All formatting done to the video prior to it being stored on the disc is transparent to the front end of the player, which merely reads the pits.

Anamorphic video is intended for widescreen equipment, which stretches the video back out to its original width. Alternatively, many new 1.33 TVs can reduce the vertical scanning range to restore the proper 1.78 aspect ratio without losing resolution. The setup options of DVD players allow the viewer to indicate whether he or she has a 1.78 or 1.33 TV. In the case of a 1.33 TV, a second option lets the viewer specify a preference for how the player will reformat anamorphic video: auto letterbox or auto pan & scan. Since no movies released to date on DVD provide the information needed for auto pan & scan, in reality there are only two choices.

One choice is to lie to the player and tell it you have a widescreen TV when you don't. The anamorphic video is then shown unchanged, causing everything and everyone in the picture to look tall and skinny. That leaves the second option, automatic letterbox.

In automatic letterbox mode, the player generates black bars at the top and bottom of the display picture (60 lines each for NTSC, 72 for PAL). This leaves 3/4 of the height remaining, creating a shorter, but wider, rectangle, which just happens to be 1.78 x 1. In order to fit this shorter rectangle, the anamorphic picture is squeezed vertically using a *letterbox filter* that combines every four lines into three, reducing the vertical resolution from 480 scan lines to 360.

In cases where wider film content was already letterboxed to 1.78 before being encoded for DVD, the mattes generated by the player sit above and below the "burned in" mattes to seamlessly create thicker mattes that are the same size as if the video had been letterboxed

5 Unlike letterboxing, pan & scan is a dynamic editing process that essentially chooses from scene to scene the part of the picture that should be displayed in the aspect window.

directly for 1.33. The vertical squeezing of the letterbox filter in the player exactly compensates for the original horizontal squeezing of the anamorphic process so that the movie is shown in its proper proportions and in its full width. Some DVD players have better letterbox filters than others, using weighted averaging to combine lines (scaling four lines into three or merging the boundary lines) rather than simply dropping one out of every four lines.

NTSC vs. PAL

DVD-V has the same NTSC vs. PAL problem as videotape and laserdisc. The MPEG video on DVD is stored in digital format, but it is formatted for one of two mutually incompatible television systems: 525/60 (NTSC) or 625/50 (PAL/SECAM). There are three differences between discs intended for playback on different systems: picture size/pixel aspect ratio (720 x 480 vs. 720 x 576), display frame rate (29.97 vs. 25), and surround audio (Dolby Digital vs. MPEG). Video from film is usually stored at 24 frames/second, but is preformatted for one of the two display rates. Movies formatted for PAL display are usually sped up by 4 percent, so the audio must be adjusted accordingly before being encoded. All PAL DVD players can play Dolby Digital audio tracks, but no NTSC players can play MPEG audio tracks.

Some players will only play NTSC discs, some players will only play PAL discs, and some will play both. All DVD players sold in PAL countries play both. These *multi-standard* players partially convert NTSC to a 60-Hz PAL (4.43 NTSC) signal, which requires a PAL TV that can handle 60-Hz signals. Most modern PAL TVs can handle this kind of signal. A few multi-standard PAL players output true 3.58 NTSC from 525/60 NTSC discs, which requires an NTSC TV or a multi-standard TV. Some players have a switch to choose between 60-Hz PAL and NTSC output when playing NTSC discs. In 1999, Samsung and others released *standards-converting* players that convert from a 525/60 NTSC disc to standard PAL output. Proper standards conversion requires expensive hardware to handle scaling, temporal conversion, and object motion analysis. Because the quality of conversion in DVD players is poor, using pseudo-PAL output with a compatible TV provides a better picture. A very small number of NTSC players can play PAL discs.

Computer DVD players are often able to process both formats. Most DVD PC software and hardware can play both NTSC and PAL video and both Dolby Digital and MPEG audio. Some PCs can only display the converted video on the computer monitor, but others can output it as a video signal for a TV.

Progressive Scan vs. Interlaced Scan

There are basically two ways to display video: *interlaced scan* or *progressive scan.* Progressive scan, used in computer monitors and digital television, displays all the horizontal lines of a picture at one time, as a single frame. Interlaced scan, used in standard television formats NTSC, PAL, and SECAM, displays only half of the horizontal lines at a time. (The first field, containing all the odd-numbered lines, is displayed, followed by the second field, containing all the even-numbered lines.) Interlacing relies on the *persistence of vision* characteristic of our eyes, as

well as the phosphor persistence of the TV tube to blur the fields together into a seemingly single picture. The advantage of interlaced video is that a high refresh rate (50 or 60 Hz) can be achieved with only half the amount of data. The disadvantage is that the horizontal resolution is essentially cut in half because the video must be filtered to avoid flicker and other artifacts.

DVD is specifically designed to be displayed on interlaced-scan displays, which covers 99.9 percent of the TVs in use. However, most DVD content comes from film, which is inherently progressive. To make film content work in interlaced form, the video from each film frame is split into two video fields—240 lines in one field, and 240 lines in the other—and encoded as separate fields in the MPEG-2 stream. Another complication is that film runs at 24 frames/second, while TV runs at 30 frames (60 fields) per second for NTSC or 25 frames (50 fields) per second for PAL and SECAM. For PAL/SECAM display, the simple solution is to show the film frames at 25/second, which is a 4 percent speedup, and speed up the audio to match. For NTSC display, the solution is to spread 24 frames across 60 fields by alternating the display of the first film frame for two video fields and the next film frame for three video fields. This is called 2-3 pulldown. The sequence works as shown below, where A–D represent film frames; A1, A2, B1, etc. represent the dissection of each film frame into two video fields; and 1–5 represent the final video frames.

Film frames:	A		B		C		D		
Video fields:	A1	A2	B1	B2	B1	C2	C1	D2	D1	D2
Video frames:	1		2		3		4		5	

Table 3: 2-3 Pulldown

For MPEG-2 encoding, repeated fields (B2 and D2) are not actually stored twice. Instead, a flag is set to tell the decoder to repeat the field. There is also a flag to indicate when a frame is progressive (that the two fields come from the same instant in time).

The difference between frames and field rates causes some problems. Some film frames are shown for a longer period of time than others, causing *judder*, or jerkiness, that shows up especially in smooth pans. Also, if you freeze the video on the third or fourth video frame when there is motion in the picture you will see two separate images combined in a flickering mess. Most DVD players avoid the second problem, although some allow you to freeze on flicker-frames. (This is the purpose of the frame/field still option in the player's setup menu.)

Since most DVD players are hooked up to interlaced TVs, there's not much that can be done about these artifacts from film conversion. In the case of 24 frames per second (fps) source, the encoder embeds MPEG-2 *repeat_first_field* flags into the video stream to make the decoder either perform 2-3 pulldown for 60 Hz (59.94) displays or 2-2 pulldown (with 4 percent speedup) for 50 Hz displays. In other words, the player doesn't really "know" what the encoded rate is. It

simply follows the MPEG-2 encoder's instructions to produce the predetermined display rate of 25 fps or 29.97 fps.

The first progressive-scan DVD players were released in the fall of 1999. It is also possible to buy an external *line multiplier* to convert the output of a standard DVD player to progressive scanning. All DVD computers are also progressive players, since the video must be displayed on a progressive monitor. A progressive-scan DVD player converts the interlaced (480i) video from DVD into progressive (480p) format for connection to a progressive display (31.5 KHz or higher). Progressive players work with all standard DVD titles, but look best with film source. They provide a significant increase in vertical resolution, for a more detailed and film-like picture.

Features

Menus and Interactivity

Almost every DVD includes on-screen menus. Some discs automatically begin playing the movie, while others go straight to the main menu. Menus are used to select from multiple programs, choose different versions of program content, navigate through multilevel or interactive programs, activate features of the player or the current disc, and more.

For example, a movie disc may have a main menu from which you can choose to watch the movie, view a trailer, watch a "making of" featurette, or peruse production stills. There may also be another menu from which you can choose to hear the regular sound track, foreign language sound track, or director's commentary. Selecting the supplemental information option from the main menu may bring up another menu with options such as production stills, script pages, storyboards, and outtakes.

Menus are especially useful on DVDs designed for equipment calibration. The *Video Essentials* and *AVIA* discs, which are excellent tools for testing the video and audio of a home theater system, contain literally hundreds of test sequences and still frames that can be quickly accessed via menus.

Disabling of Features

A potentially confusing DVD feature is UOP disabling (user operations disabling). The producer of a disc can choose to disable certain functions, such as pause, skip, fast forward, and so on, at any point on the disc. This is commonly used to lock the viewer into the FBI warning at the beginning of a disc. Some players briefly display an on-screen notice or icon when a disabled operation is attempted.

Subpictures and Closed Captions

Video can be supplemented with one of 32 subpicture tracks for subtitles, captions, and more. Unlike existing closed captioning or teletext systems, DVD subpictures are graphics that can fill the screen. The graphics can appear anywhere on the screen and can create text in any alphabet or symbology. Subpictures can be karaoke song lyrics complete with bouncing balls, Klingon subtitles, Monday Night Football-style motion diagrams, pointers and arrows, highlights and overlays, animated silhouettes, and much more. Subpictures are limited to a few colors at a time but the graphics and colors can change with every frame, which means subpictures can be used for simple animation and special effects.

Seamless Branching

A major drawback of almost every previous video format, including laserdiscs, Video CD, and even computer-based video such as QuickTime, is that any attempt to switch to another part of the video causes a break in play. DVD-V can finally achieve completely seamless branching. For example, a DVD can contain additional director's cut scenes for a movie, but jump right over them without a break to recreate the original theatrical version.

This opens up endless possibilities for mix-and-match variety. At the start of a movie the viewer could choose to see the extended director's cut, alternate ending number four, and the punk rock club scene rather than the jazz club scene. The player would jump around the disc indistinguishably stitching scenes together. It's even possible for a disc to tell the player to randomly select alternate sequences so the experience will be different every time.

A by-product of seamless branching is a feature for viewing scenes from different angles. A movie could be filmed with multiple cameras so the viewer can switch at will between up to nine different viewpoints. A classic sports event on DVD could let the viewer have complete control over instant replays.

This feature presents a major paradigm shift that could be as significant as the way sound changed motion pictures. The storytelling opportunities are fascinating to contemplate. Imagine a movie about a love triangle, which can be watched from the point of view of each main character; a murder mystery with multiple solutions; or a scene that can be played at different times of day, different seasons, or different points in time. Music videos can include shots of each performer, allowing viewers to focus on their current favorites or to pick up instrumental techniques. Classic sports videos can be designed so that armchair quarterbacks have complete control over camera angles and instant replay shots. Exercise videos might allow viewers to choose their preferred viewpoints. Instructional videos can provide close-ups, detail shots, and picture insets containing supplemental information. The options are endlessly diverse and merely require new tools and new approaches to filmmaking and video production.

The disadvantage of this feature is that each camera angle requires that additional footage be created and stored on the disc. A program with three camera angles available the entire time can only be one-third as long.

Parents can lock a movie rating into their DVD player with a password so that it won't play objectionable pieces or even entire discs. Studios can release multiple-ratings versions of a movie on a single disc. The seamless branching feature will automatically select the appropriately rated versions of scenes or skip over scenes as necessary, with no visible pause or break. However, given the additional work required to create such discs, there may not be much enthusiasm or return on investment for producing them.

Multiple Audio Tracks

The DVD-V standard provides for up to eight sound tracks to support multiple languages and supplemental audio. Each of these audio tracks can include surround sound with 5.1 channels of discrete audio. Audio tracks are used for audio commentary from directors and actors, musical sound tracks without lyrics, foreign language audio dubs, production notes, simplified dialog for children, and so on.

Most DVD players allow the owner to select a preferred language so that the appropriate menus, language track, and subtitle track can be automatically selected when available. In many cases, the selection also determines the language used for the player's on-screen display.

Discs containing 525/60 (NTSC) video must use PCM or Dolby Digital on at least one track. Discs containing 625/50 (PAL/SECAM) video must use PCM or MPEG audio or Dolby Digital on at least one track. Additional tracks may be in any format.

PCM Audio

Linear PCM is uncompressed (lossless) digital audio, the same format used on CDs and studio digital masters.[6] For DVD-V it can be sampled at 48 or 96 KHz with 16, 20, or 24 bits/sample. (Audio CD is limited to 44.1 KHz at 16 bits.) DVD-Audio (DVD-A) adds 192 KHz sampling, as well as a family of sample rates based on CD audio: 44.1, 88.2, and 176.4 KHz. DVD-V allows one to eight channels of PCM audio; DVD-A allows only six, but has more flexibility in mixing and matching tracks for multichannel surround.

It is generally felt that the 96 dB dynamic range of 16 bits or even the 120 dB range of 20 bits combined with a frequency response of around 22,000 Hz from 48 KHz sampling is adequate for high-fidelity sound reproduction. However, additional bits and higher sampling rates are useful in studio work, noise shaping, advanced digital processing, and three-dimensional sound field reproduction. DVD players are required to support all the variations of PCM, but some of them may subsample 96 KHz down to 48 KHz, and some may not use all 20 or 24 bits. The signal provided on the digital output for external digital-to-analog converters may be limited to less than 96 KHz and less than 24 bits.

6 The details of audio compression, including the distinctions between lossy and lossless compression, are covered in *DigiPoints, Volume One*, by Justin J. Junkus and Michael Sawyer.

Dolby Digital Audio

Dolby Digital (formerly known as AC-3) is multi-channel digital audio, lossy encoded from PCM masters with a sample rate of 48 KHz at up to 24 bits. The bitrate is 64 Kbps to 448 Kbps, with 384 being the normal rate for 5.1 channels and 192 being the normal rate for two channels. Dolby Digital is the format used for audio tracks on almost all DVDs.

DTS Audio

Digital Theater Systems Digital Surround is an optional 5.1-channel digital audio format, using lossy compression from PCM at 48 KHz at up to 24 bits. The data rate is from 64 Kbps to 1,536 Kbps (the DTS Coherent Acoustics format supports up to 4,096 Kbps as well as variable data rate for lossless compression). A typical data rate on DVD is 1,536 Kbps, which is claimed to provide better sound reproduction, but leaves less room for video data than Dolby Digital.

The DVD specification has always included DTS, but all players made before mid-1998, and many since then, ignore DTS tracks. DTS-compatible players carry an official "DTS Digital Out" logo. All DVD players can play DTS audio CDs.

THX

THX (Tomlinson Holman Experiment) is not an audio format. It is a certification and quality control program that applies to sound systems and acoustics in theaters, home equipment, and digital mastering processes. The THX Digital Mastering program uses a patented process to track video quality through the multiple video generations needed to make a final format disc or tape. THX also covers the setup of video monitors to ensure that the filmmaker is seeing a precise rendition of what is on tape before approval of the master, and other steps along the way.

Compatibility with Other Digital Disc Formats

Audio CD

All DVD players read mass-produced audio CDs. On the other hand, you can't play a DVD in a CD player. (The pits are smaller, the tracks are closer together, the data layer is a different distance from the surface, the modulation is different, the error correction coding is new, etc.)

CD-R is a different story. Many DVD players can't read CD-Rs. The problem is that CD-Rs are "invisible" to the DVD laser wavelength because the dye used in CD-Rs doesn't reflect the beam. The common solution is to use two lasers at different wavelengths: one for reading DVDs and the other for reading CDs and CD-Rs. CD-Rewritable discs, which can't be read by most CD players, are more compatible with DVD players, since CD-RW does not have the "invisibility" problem of CD-R.

Video CD

About half of the DVD players available support the Video CD standard, since any MPEG-2 decoder can also decode MPEG-1 from a Video CD. All DVD-ROM computers can play Video CDs (with the right software). Standard VCD players can't play DVDs.

Super Video CD (SVCD) is an enhancement to Video CD that was developed in China. So far, no DVD players outside of China can play SVCDs. SVCD players can't play DVDs, since the players are based on CD drives.

Laserdisc

Standard DVD players will not play laserdiscs, and you can't play a DVD disc on any standard laserdisc player. Laserdisc uses analog video, and DVD uses digital video. They are very different formats. However, Pioneer produces combo players that play laserdiscs and DVDs (and also CDVs and audio CDs).

Divx

Divx was a pay-per-view variation of DVD marketed by Digital Video Express. Divx discs sold for $4.50. Once inserted into a Divx player the disc was viewable for the next 48 hours, after which it cost $3.25 to unlock it for another 48 hours. A Divx DVD player had to be hooked up to a phone line so it could call an 800 number to transmit billing information. In June 1999, less than a year after initial product trials, Digital Video Express announced that it was closing down.

How DVD Affects the Job Responsibilities of Cable Personnel

With the increasing number of digital terminal devices, cable telecommunications installation and support has become more than simply connecting components together and turning on the TV for the customer to verify that the job has been done correctly. Increasingly, there is an overlap of functions that can be provided by various consumer devices, and cable's customers are going to ask cable personnel how to sort out the options. As this issue of *DigiPoints* illustrated, DVD equipment can determine output formats of video information, affecting the way the TV displays DVD files. Some of those formats are the same as, or similar to, those of digital TVs. It will be easy for cable customers to become confused as they switch between pictures originating in a DVD player, from local broadcast, and from a digital set-top terminal. In addition to data format, each of these devices can be the source of a unique menu, with similar, but different, options.

Part of the solution will be a thorough understanding of how to interconnect the various components of a home entertainment system. That part will be discussed in further detail in the

next issue of *DigiPoints*. In addition, however, cable installers and support personnel must increasingly become consumer trainers, especially immediately after adding any new service. This issue has provided an overview of DVD technology to help relate its features to those found in other digital terminal devices. Armed with that understanding, cable's technical and support personnel can help the customer sort out the options for digital terminals attached to a cable network.

Learning Just Enough to Be Dangerous: Glossary

2-2 pulldown – The process of transferring 24-frames-per-second film to video by repeating each film frame as two video fields. When 24-fps film is transferred via 2-2 pulldown to 25-fps 625/50 (PAL) video, the film runs 4 percent faster than normal.

2-3 pulldown – The process of transferring 24-frames-per-second film to video by repeating one film frame as three fields, then the next film frame as two fields.

3-2 pulldown – An uncommon variation of 2-3 pulldown where the first film frame is repeated for three fields instead of two. Most people mean 2-3 pulldown when they say 3-2 pulldown.

525/60 – The scanning system of 525 lines per frame and 60 interlaced fields (30 frames) per second. Used by the NTSC television standard.

625/50 – The scanning system of 625 lines per frame and 50 interlaced fields (25 frames) per second. Used by PAL and SECAM television standards.

AC-3 – The former name of the Dolby Digital audio-coding system that is still technically referred to as AC-3 in standards documents.

Artifact – An unnatural effect not present in the original video or audio, produced by an external agent or action. Artifacts can be caused by many factors, including digital compression, film-to-video transfer, transmission errors, data readout errors, electrical interference, analog signal noise, and analog signal crosstalk. Most artifacts attributed to the digital compression of DVD are in fact from other sources. Digital compression artifacts will always occur in the same place and in the same way. Possible MPEG artifacts are mosquitoes, blocking, and video noise.

Aspect ratio – The width-to-height ratio of an image. A 4:3 aspect ratio means the horizontal size is a third again wider than the vertical size. The standard NTSC television ratio is 4:3 (or 1.33:1). The widescreen DVD and HTDV aspect ratio is 16:9 (or 1.78:1). Common film aspect ratios are 1.85:1 and 2.35:1.

CGMS – Copy Guard Management System. A method of preventing copies or controlling the number of sequential copies allowed. CGMS/A is added to an analog signal (such as line 21 of NTSC). CGMS/D is added to a digital signal, such as IEEE 1394.

Chapter – In DVD-V, a division of a title. Technically called a part of title (PTT).

Chroma/chrominance (C) –The color component (hue and saturation) of light, independent of luminance. Technically, chroma refers to the common nonlinear signal, while chrominance refers to a linear signal.

Closed Captions – Text captions for video that are not normally visible, as opposed to open captions, which are a permanent part of the picture. In the United States, the official NTSC

Closed Caption standard requires that all TVs larger than 13 inches include circuitry to decode and display caption information stored on line 21 of the video signal. DVD-V can provide closed caption data, but the subpicture format is preferred for its versatility.

Component video – A video system containing three separate color component signals, either red/green/blue (RGB) or chroma/color difference (YC_bC_r, YP_bP_r, YUV), in analog or digital form. The MPEG-2 encoding system used by DVD is based on color-difference component digital video. Very few televisions have component video inputs.

Composite video – An analog video signal in which the luma and chroma components are combined (by frequency multiplexing), along with sync and burst. Also called CVBS. Most televisions and VCRs have composite video connectors that are usually colored yellow.

Compression – The process of removing redundancies in digital data to reduce the amount that must be stored or transmitted. Lossless compression removes only enough redundancy so that the original data can be recreated exactly as it was. Lossy compression sacrifices additional data to achieve greater compression.

CVBS – Composite video baseband signal. Standard composite video signal.

Decoder – 1) A circuit that decodes compressed audio or video, taking an encoded input stream and producing output such as audio or video. DVD players use the decoders to recreate information that was compressed by systems such as MPEG-2 and Dolby Digital; 2) a circuit that converts composite video to component video or matrixed audio to multiple channels.

Discrete surround sound – Audio in which each channel is stored and transmitted separate from and independent of other channels. Multiple independent channels directed to loudspeakers in front of and behind the listener allow precise control of the soundfield in order to generate localized sounds and simulate moving sound sources.

Dolby Digital – A perceptual coding system for audio, developed by Dolby Laboratories and accepted as an international standard. Dolby Digital is the most common means of encoding audio for DVD-V.

Dolby Pro Logic – The technique (or the circuit that applies the technique) of extracting surround audio channels from a matrix-encoded audio signal. Dolby Pro Logic is a decoding technique only, but is often mistakenly used to refer to Dolby Surround audio encoding.

Dolby Surround – The standard for matrix encoding surround-sound channels in a stereo signal by applying a set of defined mathematical functions when combining center and surround channels with left and right channels. The center and surround channels can then be extracted by a decoder such as a Dolby Pro Logic circuit that applies the inverse of the mathematical functions. A Dolby Surround decoder extracts surround channels, while a Dolby Pro Logic decoder uses additional processing to create a center channel. The process is essentially independent of the recording or transmission format.

Downmix – To convert a multichannel audio track into a two-channel stereo track by combining the channels with the Dolby Surround process. All DVD players are required to provide downmixed audio output from Dolby Digital audio tracks.

DTS – Digital Theater Sound. A perceptual audio-coding system developed for theaters. A competitor to Dolby Digital and an optional audio track format for DVD-V and DVD-A.

DTV – Digital television. In general, any system that encodes video and audio in digital form. In specific, the Digital Television System proposed by ATSC or the digital TV standard proposed by the Digital TV Team founded by Microsoft, Intel, and Compaq.

DVD-Audio (DVD-A) – The audio-only format of DVD. Just becoming available in late 1999.

DVD-ROM – The base format of DVD. ROM stands for read-only memory, referring to the fact that standard DVD-ROM and DVD-V discs can't be recorded on by the end user. A DVD-ROM can store essentially any form of digital data.

DVD-Video (DVD-V) – A standard for storing and reproducing audio and video on DVD-ROM discs based on MPEG video, Dolby Digital and MPEG audio, and other proprietary data formats.

Dynamic range – The difference between the loudest and softest sound in an audio signal. The dynamic range of digital audio is determined by the sample size. Increasing the sample size does not allow louder sounds; it increases the resolution of the signal, thus allowing softer sounds to be separated from the noise floor (and allowing more amplification with less distortion).

Dynamic range compression (DRC)– A technique of reducing the range between loud and soft sounds in order to make dialogue more audible. Used in the downmix process of multichannel DVD sound tracks.

Error-correction code (ECC) – Additional information added to data to allow errors to be detected and possibly corrected.

Field – A set of alternating scan lines in an interlaced video picture. A frame is made of a top (odd) field and a bottom (even) field.

Frame – The piece of a video signal containing the spatial detail of one complete image; the entire set of scan lines. In an interlaced system, a frame contains two fields.

Frame doubler – A video processor that increases the frame rate (display rate) in order to create a smoother-looking video display. Compare to line doubler.

IEEE 1394 (FireWire) – A standard for transmission of digital data between external peripherals, including consumer audio and video devices. Based on the original FireWire design by Apple Computer.

Interlaced scanning – A video scanning system in which alternating lines are transmitted, so that half a picture is displayed each time the scanning beam moves down the screen. An interlaced frame is made of two fields.

i.Link – Trademarked Sony name for IEEE 1394.

Letterbox – The process or form of video where black horizontal mattes are added to the top and bottom of the display area in order to create a frame in which to display video using an aspect ratio different than that of the display. The letterbox method preserves the entire video picture, as opposed to pan & scan. DVD-V players can automatically letterbox a widescreen picture for display on a standard 4:3 TV.

Line doubler – A video processor that doubles the number of lines in the scanning system in order to create a display with scan lines that are less visible. Some line doublers convert from interlaced to progressive scan.

Lines of horizontal resolution – A common but subjective measurement of the resolution of an analog video system, measured in half-cycles per picture height. Each cycle is a pair of lines, one black and one white. Sometimes abbreviated as TVL. The measurement is usually made by viewing a test pattern to determine where the black and white lines blur into gray. The resolution of VHS video is commonly gauged at 240 lines of horizontal resolution, broadcast video at 330, laserdisc at 425, and DVD at 500 to 540. Because the measurement is relative to picture height, the aspect ratio must be taken into account when determining the number of vertical units (roughly equivalent to pixels) that can be displayed across the width of the display. For example, an aspect ratio of 1.33 multiplied by 540 gives 720 pixels.

Lossless compression – Compression techniques that allow the original data to be recreated without loss. DVD-A uses MLP.

Lossy compression – Compression techniques that achieve very high compression ratios by permanently removing data while preserving as much significant information as possible. Lossy compression includes perceptual coding techniques that attempt to limit the data loss to that which is least likely to be noticed by human perception.

Luma/luminance (Y) – The brightness component of a color video image (also called the grayscale, monochrome, or black-and-white component). Technically, luma refers to the common nonlinear signal, while luminance refers to a linear signal.

Macrovision – An antitaping process that modifies a signal so that it appears unchanged on most televisions but is distorted and unwatchable when played back from a videotape recording. Macrovision takes advantage of characteristics of AGC circuits and burst decoder circuits in VCRs to interfere with the recording process.

MLP (Meridian Lossless Packing) – A lossless compression technique (used by DVD-A) that removes redundancy from PCM audio signals to achieve a compression ratio of about 2:1 while allowing the signal to be perfectly recreated by the MLP decoder.

Motion vector – A two-dimensional spatial vector used for MPEG motion compensation to provide an offset from the encoded position of a block in a reference (I or P) picture to the predicted position (in a P or B picture).

MPEG – Moving Pictures Expert Group. An international committee that developed the MPEG family of audio and video compression systems.

MPEG audio – Audio compressed according to the MPEG perceptual encoding system. MPEG-1 audio provides two channels, which can be in Dolby Surround format. MPEG-2 audio adds data to provide discrete multichannel audio. Stereo MPEG audio is the mandatory audio compression system for 625/50 (PAL/SECAM) DVD-V.

MPEG video – Video compressed according to the MPEG encoding system. MPEG-1 is typically used for low data rate video such as on a Video CD. MPEG-2 is used for higher-quality video, especially interlaced video, such as on DVD or HDTV.

Multiangle – A DVD-V program containing multiple angles allowing different views of a scene to be selected during playback.

Multichannel – Multiple channels of audio, usually containing different signals for different speakers in order to create a surround-sound effect.

Multilanguage – A DVD-V program containing sound tracks and subtitle tracks for more than one language.

NTSC – National Television Systems Committee. A committee organized by the Electronic Industries Association (EIA) that developed commercial television broadcast standards for the United States. NTSC refers to the composite color-encoding system. The 525/59.94 scanning system (with a 3.58-MHz color subcarrier) is identified by the letter M, and is often incorrectly referred to as NTSC.

NTSC-4.43 – A variation of NTSC where a 525/59.94 signal is encoded using the PAL subcarrier frequency and chroma modulation. Also called 60-Hz PAL.

PAL – Phase Alternate Line. A video standard used in Europe and other parts of the world for composite color encoding. Various versions of PAL use different scanning systems and color subcarrier frequencies (identified with letters B, D, G, H, I, M, and N), the most common being 625 lines at 50 fields per second, with a color subcarrier of 4.43 MHz.

Pan & scan – The technique of reframing a picture to conform to a different aspect ratio by cropping parts of the picture. DVD-V players can automatically create a 1.33 pan & scan version from widescreen video by using a horizontal offset encoded with the video.

Parental management – An optional feature of DVD-V that prohibits programs from being viewed or substitutes different scenes within a program depending on the parental level set in the

player. Parental control requires that parental levels and additional material (if necessary) be encoded on the disc.

PCM – An uncompressed, digitally coded representation of an analog signal. The waveform is sampled at regular intervals and a series of pulses in coded form (usually quantized) are generated to represent the amplitude.

Perceptual coding – Lossy compression techniques based on the study of human perception. Perceptual coding systems identify and remove information that is least likely to be missed by the average human observer.

Progressive scanning – A video scanning system that displays all lines of a frame in one pass. Contrast with interlaced scan.

Regional code – A code identifying one of the world regions for restricting DVD-V playback.

Regional management – A mandatory feature of DVD-V to restrict the playback of a disc to a specific geographical region. Each player and DVD-ROM drive includes a single regional code, and each disc side can specify in which regions it is allowed to be played. Regional coding is optional—a disc without regional codes will play in all players in all regions.

Resolution – 1) A measurement of relative detail of a digital display, typically given in pixels of width and height; 2) the ability of an imaging system to make clearly distinguishable or resolvable the details of an image. This includes spatial resolution (the clarity of a single image), temporal resolution (the clarity of a moving image or moving object), and perceived resolution (the apparent resolution of a display from the observer's point of view). Analog video is often measured as a number of lines of horizontal resolution over the number of scan lines. Digital video is typically measured as a number of horizontal pixels by vertical pixels. Film is typically measured as a number of line pairs per millimeter; 3) the relative detail of any signal, such as an audio or video signal.

RSDL – Reverse-spiral dual-layer. A dual-layer disc layout where readout begins at the center of the disc on the first layer, travels to the outer edge of the disc, then switches to the second layer and travels back toward the center. Designed for long, continuous-play programs.

Scan line – A single horizontal line traced out by the scanning system of a video display unit. 525/60 (NTSC) video has 525 scan lines, about 480 of which contain the actual picture. 625/50 (PAL/SECAM) video has 625 scan lines, about 576 of which contain the actual picture.

SECAM – *Séquential couleur avec mémoire*/sequential color with memory. A composite color standard similar to PAL, but currently used only as a transmission standard in France and a few other countries. Video is produced using the 625/50 PAL standard and is then transcoded to SECAM by the player or transmitter.

S/P DIF – Sony/Philips digital interface. A consumer version of the AES/EBU digital audio transmission standard. Most DVD players include S/P DIF coaxial digital audio connectors providing PCM and encoded digital audio output.

Subpicture – Graphic bitmap overlays used in DVD-V to create subtitles, captions, karaoke lyrics, menu highlighting effects, and so on.

Subtitle – A textual representation of the spoken audio in a video program. Subtitles are often used with foreign languages and do not serve the same purpose as captions for the hearing impaired. See subpicture.

Surround sound – A multichannel audio system with speakers in front of and behind the listener to create a surrounding envelope of sound and to simulate directional audio sources.

S-video – A video interface standard that carries separate luma and chroma signals, usually on a four-pin mini-DIN connector. Also called Y/C. The quality of s-video is significantly better than composite video since it does not require a comb filter to separate the signals, but it is not quite as good as component video.

Widescreen – A video image wider than the standard 1.33 (4:3) aspect ratio. When referring to DVD or HDTV, widescreen usually indicates a 1.78 (16:9) aspect ratio.

YUV – In the general sense, any form of color-difference video signal containing one luma and two chroma components.

Testing Your Knowledge

1. Someone complains that his DVD player won't play his homemade compilation CDs, even though he was told it would play CDs. He also wonders about the Video CD he picked up in Chinatown. What do you tell him?

2. Is video on DVD stored in progressive format or interlaced format?

3. Will a disc imported from the United Kingdom play on a U.S. player?

4. What different formats are available on a digital audio connection?

5. The video from the DVD player doesn't look as good on a widescreen TV as it should. What is the likely problem, and how do you fix it?

6. A customer only uses her VCR to play tapes and watch TV—she never records. She uses the VCR for the PIP feature on her TV. Her VCR has just broken, so she wants to know if she can replace it with a DVD player. What do you tell her?

Answers to Questions in Volume III, Issue 7

1. What are some characteristics of existing wiring systems that make them less than optimal for data distribution?

   The topologies of existing home wiring systems are not optimized for data LANs. Also, there are a number of possibilities for feedback paths from non-data devices on the wiring, which will affect transmission characteristics, such as the noise on the line. In addition, some wiring systems, such as the electrical distribution system, do not isolate each home on the distribution system. This means that data on the home network is not secure, and can be monitored by equipment in adjacent homes.

2. What is the designation for the unshielded twisted pair wiring that is specified for 100 Mbps Ethernet applications?

   Category 5 wiring.

3. What are the two grades of residential information outlets recommended by TIA/EIA 570A, and what types of information do they accommodate?

   Grade 1 provides for basic telephone and video service. The standard recommends one four-pair Category 3 or better unshielded twisted pair cable and one Series-6 cable to each information outlet.

   Grade 2 provides for enhanced voice, video, and data to the residence. The standard for Grade 2 recommends two four-pair Category 5 unshielded twisted pair (Cat 5 UTP) cables and two Series-6 coax cables. One of the Category 5 cables is for voice and the other is for data. One of the Series-6 cables is for satellite service and the other is for CATV or local programming received via a residential antenna.

4. What are the major differences between an RJ-11 jack and an RJ-45 jack?

   The proportions of the length to width of the two jack types are different.

5. What can differ between otherwise identical RJ-45 jacks?

   Both jack housings have the capability of being equipped with a different number of contacts for different applications. This is the reason that an installer who uses existing jacks as part of any network must verify that both the number of contacts and the connections to the contacts are correct for the particular application.

   Even when a particular jack has the correct number of contacts for the application, it may not be wired for that application. The RJ-45 jack, for example, can be used as a connector per EIA specification T568A, or per EIA 6000 CEBus. Each specification connects sets of twisted pair wires to different combinations of contacts.

6. How do in-home networks using existing phone wiring co-exist with voice telephone service?

   In-home networks using existing phone wiring are based on frequency division multiplexing technology that allocates all home network communications to frequencies outside the range of frequencies used by telephone services.

7. What are the two contending standards for wireless networks?

   The Home RF Working Group (HRFWG) has specified a Shared Wireless Access Protocol (SWAP), which is based on parts of the IEEE 802.11 standard for wireless networks. The other wireless standard is called Bluetooth, and was developed for low-cost short-range radio links between mobile PCs, mobile phones, cameras, portable headsets and speakers, and other portable devices.

8. What are two constraints that might limit simultaneous Internet access by multiple network devices?

   The ISP may not allow more than one device to access its services at one time per account, and the cable operator may choose to limit the number of devices that may simultaneously access the Internet to control network data traffic.

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