Apple ProRes

White Paper
January 2020

Contents

Introduction

Apple ProRes is one of the most popular codecs in professional post-production. The ProRes family of video codecs has made it both possible and affordable to edit full-frame, 10-bit, 4:2:2 and 4:4:4:4 high-definition (HD), 2K, 4K, 5K, and larger video sources with multistream performance in Final Cut Pro X. This white paper provides in-depth information about the ProRes family of codecs, including technical specifications and performance metrics.

For information about Apple ProRes RAW, which brings to raw video the same great performance, quality, and ease of use that ProRes has brought to conventional video, see the Apple ProRes RAW White Paper.

Authorized Apple ProRes Implementations

Apple ProRes is a codec technology developed for high-quality, high-performance editing in Final Cut Pro X. Apple has licensed ProRes to select companies for use in specific products and workflows.

In some instances, unauthorized codec implementations have been used in third-party software and hardware products. Using any unauthorized implementation (like the FFmpeg and derivative implementations) may lead to decoding errors, performance degradation, incompatibility, and instability.

For a list of all authorized ProRes licensees and developers, and for licensing information, go to support.apple.com/kb/HT5959. If you're using or considering purchasing a product that encodes or decodes ProRes, and that product is not on this list, contact Apple at ProRes@apple.com.

Apple ProRes Family Overview

Apple ProRes codecs provide an unparalleled combination of multistream, real-time editing performance, impressive image quality, and reduced storage rates. ProRes codecs take full advantage of multicore processing and feature fast, reduced-resolution decoding modes. All ProRes codecs support any frame size (including SD, HD, 2K, 4K, 5K, and larger) at full resolution. The data rates vary based on codec type, image content, frame size, and frame rate.

As a variable bit rate (VBR) codec technology, ProRes uses fewer bits on simple frames that would not benefit from encoding at a higher data rate. All ProRes codecs are frame-independent (or “intra-frame”) codecs, meaning that each frame is encoded and decoded independently of any other frame. This technique provides the greatest editing performance and flexibility.

A variety of cameras can now capture and record a wider gamut of color values when working in log or raw formats. You can preserve a wider color gamut by recording with the ProRes LOG setting on certain cameras such as the ARRI ALEXA or transcoding from the RED® camera’s REDCODE® RAW format. Final Cut Pro 10.3 or later can process color in wide color gamut and output ProRes files in the Rec. 2020, DCI-P3, or D65-P3 color space. This results in deeper colors and more detail, with richer red and green areas of the image.

With Final Cut Pro 10.3 or later, you can also export ProRes files inside an MXF metadata wrapper instead of exporting .mov files. This makes the exported video file compatible with a wide range of playback systems that rely on the MXF standard for broadcast and archiving.

Apple ProRes includes the following formats:

Apple ProRes 4444 XQ: The highest-quality version of ProRes for 4:4:4:4 image sources (including alpha channels), with a very high data rate to preserve the detail in high-dynamic-range imagery generated by today's highest-quality digital image sensors. Apple ProRes 4444 XQ preserves dynamic ranges several times greater than the dynamic range of Rec. 709 imagery—even against the rigors of extreme visual effects processing, in which tone-scale blacks or highlights are stretched significantly. Like standard Apple ProRes 4444, this codec supports up to 12 bits per image channel and up to 16 bits for the alpha channel. Apple ProRes 4444 XQ features a target data rate of approximately 500 Mbps for 4:4:4 sources at 1920 x 1080 and 29.97 fps.

Note: Apple ProRes 4444 XQ requires OS X 10.8 Mountain Lion or later.

Apple ProRes 4444: An extremely high-quality version of ProRes for 4:4:4:4 image sources (including alpha channels). This codec features full-resolution, mastering-quality 4:4:4:4 RGBA color and visual fidelity that is perceptually indistinguishable from the original material. Apple ProRes 4444 is a high-quality solution for storing and exchanging motion graphics and composites, with excellent multigeneration performance and a mathematically lossless alpha channel up to 16 bits. This codec features a remarkably low data rate compared to uncompressed 4:4:4 HD, with a target data rate of approximately 330 Mbps for 4:4:4 sources at 1920 x 1080 and 29.97 fps. It also offers direct encoding of, and decoding to, both RGB and $Y'C_BC_R$ pixel formats.

Apple ProRes 422 HQ: A higher-data-rate version of Apple ProRes 422 that preserves visual quality at the same high level as Apple ProRes 4444, but for 4:2:2 image sources. With widespread adoption across the video post-production industry, Apple ProRes 422 HQ offers visually lossless preservation of the highest-quality professional HD video that a single-link HD-SDI signal can carry. This codec supports full-width, 4:2:2 video sources at 10-bit pixel depths, while remaining visually lossless through many generations of decoding and re-encoding. The target data rate of Apple ProRes 422 HQ is approximately 220 Mbps at 1920 x 1080 and 29.97 fps.

Apple ProRes 422: A high-quality compressed codec offering nearly all the benefits of Apple ProRes 422 HQ, but at 66 percent of the data rate for even better multistream, real-time editing performance. The target data rate of Apple ProRes 422 is approximately 147 Mbps at 1920 x 1080 and 29.97 fps.

Apple ProRes 422 LT: A more highly compressed codec than Apple ProRes 422, with roughly 70 percent of the data rate and 30 percent smaller file sizes. This codec is perfect for environments where storage capacity and data rate are at a premium. The target data rate of Apple ProRes 422 LT is approximately 102 Mbps at 1920 x 1080 and 29.97 fps.

Apple ProRes 422 Proxy: An even more highly compressed codec than Apple ProRes 422 LT, intended for use in offline workflows that require low data rates but full-resolution video. The target data rate of Apple ProRes 422 Proxy is approximately 45 Mbps at 1920 x 1080 and 29.97 fps.

Note: Apple ProRes 4444 XQ and Apple ProRes 4444 are ideal for the exchange of motion graphics media because they are virtually lossless, and are the only ProRes codecs that support alpha channels.

Properties of Digital Images

The technical properties of digital images correspond to different aspects of image quality. For example, high-resolution HD images can carry more detail than their lower-resolution SD counterparts. 10-bit images can carry finer gradations of color, thereby avoiding the banding artifacts that can occur in 8-bit images.

The role of a codec is to preserve image quality as much as possible at a particular reduced data rate, while delivering the fastest encoding and decoding speed. The Apple ProRes family supports the three key properties of digital images that contribute to image quality—*frame size, chroma sampling,* and *sample bit depth*—while offering industry-leading performance and quality at each supported data rate. In order to appreciate the benefits of the ProRes family as a whole and to choose which family members to use in various post-production workflows, it is important to understand these three properties.

Frame Size (Full-Width Versus Partial-Width)

Many video camcorders encode and store video frames at less than the full HD widths of 1920 pixels or 1280 pixels, for 1080-line or 720-line HD formats, respectively. When such formats are displayed, they are upsampled horizontally to full HD widths, but they cannot carry the amount of detail possible with full-width HD formats.

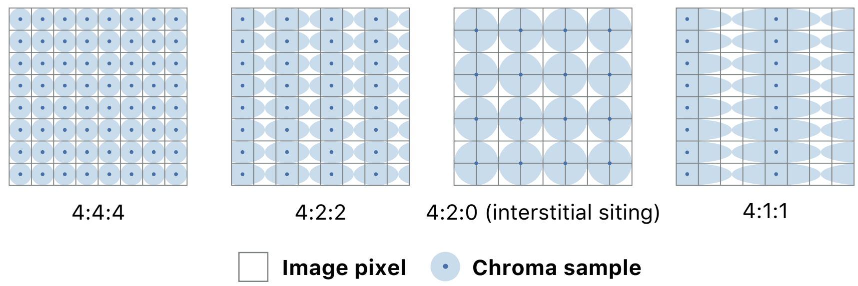
All ProRes family members can encode full-width HD video sources (sometimes called “full-raster” video sources) to preserve the maximum possible detail an HD signal can carry. ProRes codecs can also encode partial-width HD sources if desired, thereby averting potential quality and performance degradation that results from upscaling partial-width formats prior to encoding.

Chroma Sampling

Color images require three channels of information. In computer graphics, a pixel's color is typically defined by R, G, and B values. In traditional digital video, a pixel is represented by Y′, C_B, and C_R values, where Y′ is the "luma" or grayscale value and C_B and C_R contain the "chroma" or color-difference information. Because the eye is less sensitive to fine chroma detail, it is possible to average together and encode fewer C_B and C_R samples with little visible quality loss for casual viewing. This technique, known as *chroma subsampling,* has been used widely to reduce the data rate of video signals. However, excessive chroma subsampling can degrade quality for compositing, color correction, and other image-processing operations. The ProRes family handles today's popular chroma formats as follows:

- *4:4:4* is the highest-quality format for preserving chroma detail. In 4:4:4 image sources, there is no subsampling, or averaging, of chroma information. There are three unique samples, either Y′, C_B, and C_R or R, G, and B, for every pixel location. Apple ProRes 4444 XQ and Apple ProRes 4444 fully support 4:4:4 image sources, from either RGB or Y′$C_B C_R$ color spaces. The fourth "4" means that Apple ProRes 4444 XQ and Apple ProRes 4444 can also carry a unique alpha-channel sample for every pixel location. Apple ProRes 4444 XQ and Apple ProRes 4444 are intended to support 4:4:4:4 RGB+Alpha sources exported from computer graphics applications such as Motion, as well as 4:4:4 video sources from high-end devices such as dual-link HDCAM-SR.
- *4:2:2* is considered a high-quality, professional video format in which the chroma values of Y′$C_B C_R$ images are averaged together such that there is one C_B and one C_R sample, or one "C_B/C_R chroma pair," for each Y′ (luma) sample. This minimal chroma subsampling has traditionally been considered adequate for high-quality compositing and color correction, although better results can be achieved using 4:4:4 sources. 4:2:2 sources are generated by many popular higher-end video camcorder formats, including DVCPRO HD, AVC-Intra/100, and XDCAM HD422/50. All Apple ProRes 422 family members fully support the chroma resolution inherent in 4:2:2 video formats.

- *4:2:0* and *4:1:1* have the least chroma resolution of the formats mentioned here, with just one C_B/C_R chroma pair for every four luma samples. These formats are used in a variety of consumer and professional video camcorders. Depending on the quality of a camera's imaging system, 4:2:0 and 4:1:1 formats can provide excellent viewing quality. However, in compositing workflows it can be difficult to avoid visible artifacts around the edges of a composited element. HD 4:2:0 formats include HDV, XDCAM HD, and AVC-Intra/50. 4:1:1 is used in DV. All Apple ProRes 422 formats can support 4:2:0 or 4:1:1 sources if the chroma is upsampled to 4:2:2 prior to encoding.



Sample Bit Depth

The number of bits used to represent each Y′, C_B, or C_R (or R, G, or B) image sample determines the number of possible colors that can be represented at each pixel location. Sample bit depth also determines the smoothness of subtle color shading that can be represented across an image gradient, such as a sunset sky, without visible quantization or "banding" artifacts.

Traditionally, digital images have been limited to 8-bit samples. In recent years the number of professional devices and acquisition techniques supporting 10-bit and even 12-bit image samples has increased. 10-bit imagery is now often found in 4:2:2 video sources with professional digital (SDI, HD-SDI, or even HDMI) outputs. 4:2:2 video sources rarely exceed 10 bits, but a growing number of 4:4:4 image sources claim 12-bit resolution, though with sensor-derived images the least significant one or two bits may have more noise than signal. 4:4:4 sources include high-end film scanners and film-like digital cameras and can include high-end computer graphics.

Apple ProRes 4444 XQ and Apple ProRes 4444 support image sources up to 12 bits and preserve alpha sample depths up to 16 bits. All Apple ProRes 422 codecs support up to 10-bit image sources, though the best 10-bit quality is obtained with the higher-bit-rate family members—Apple ProRes 422 and Apple ProRes 422 HQ.

Note: Like Apple ProRes 4444 XQ and Apple ProRes 4444, all Apple ProRes 422 codecs can in fact accept image samples even greater than 10 bits, although such high bit depths are rarely found among 4:2:2 or 4:2:0 video sources.

Properties of Apple ProRes Codecs

Every image or video codec can be characterized by how well it behaves in three critical dimensions: compression, quality, and complexity. *Compression* means data reduction, or how many bits are required compared to the original image. For image sequences or video streams, compression means data rate, expressed in bits/sec for transmission or bytes/hour for storage. *Quality* describes how closely a compressed image resembles the original. "Fidelity" would therefore be a more accurate term, but "quality" is the term widely used. *Complexity* relates to how many arithmetic operations must be computed to compress or decompress an image frame or sequence. For software codec implementations, the lower the complexity, the greater the number of video streams that can be decoded simultaneously in real time, resulting in higher performance within post-production applications.

Every image or video codec design must make tradeoffs between these three properties. Because codecs used within professional camcorders or for professional video editing must maintain high visual quality, the tradeoff amounts to one of data rate versus performance. For example, AVCHD camcorders can produce H.264 video streams with excellent image quality at low data rates. However, the complexity of the H.264 codec is very high, resulting in lower performance for real-time video editing with multiple video streams and effects. In comparison, Apple ProRes features excellent image quality as well as low complexity, which results in better performance for real-time video editing.

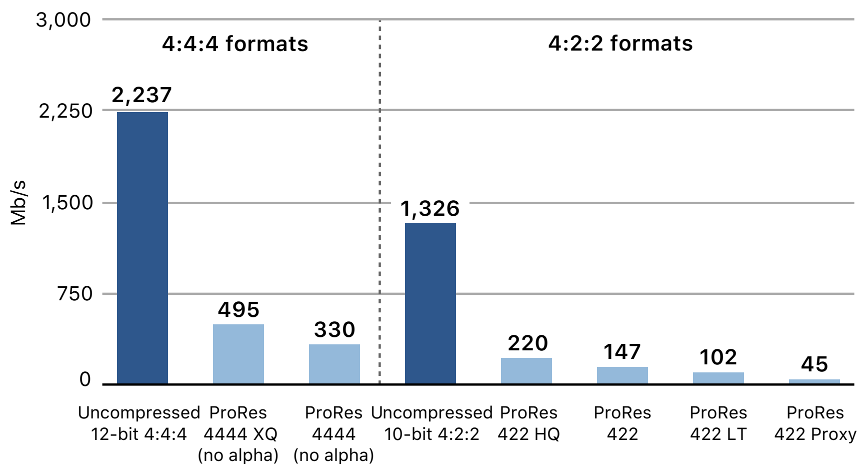
The following sections describe how the various ProRes codecs behave and compare to one another in terms of these three important codec properties: *data rate, quality,* and *performance*.

Data Rate

The ProRes family spans a broad range of data rates to support a variety of workflow and application purposes. This section describes how ProRes data rates compare to each other and to the data rates of uncompressed video. The section also illustrates how frame size and frame rate affect ProRes data rates. Finally, the text includes information on the variable bit rate (VBR) nature of the ProRes codec family.

The bar chart below shows how the data rates of the ProRes formats compare to those of uncompressed, full-width (1920 x 1080), 4:4:4 12-bit and 4:2:2 10-bit image sequences at 29.97 frames/sec. The chart shows that even the two highest-quality ProRes formats—Apple ProRes 4444 XQ and Apple ProRes 4444—offer significantly lower data rates than their uncompressed counterparts.

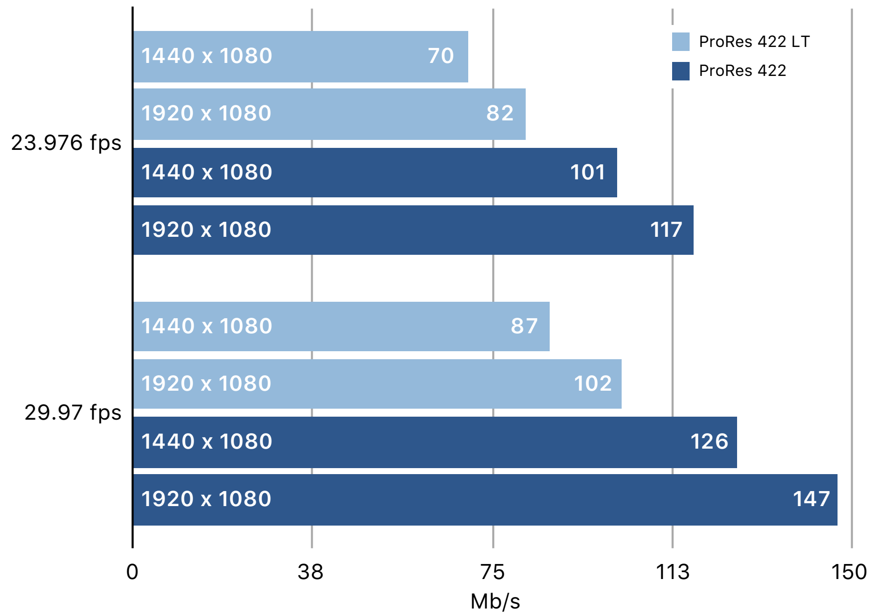
Data Rates - Uncompressed and Apple ProRes at 1920 x 1080, 29.97 fps



The data rates shown in the bar chart above are for "full-width" (1920 x 1080) HD frames at 29.97 frames/sec. The ProRes family also supports the 720p HD format at its full width (1280 x 720). In addition to full-width HD formats, ProRes codecs support three different "partial-width" HD video formats used as the recording resolutions in a number of popular HD camcorders: 1280 x 1080, 1440 x 1080, and 960 x 720.

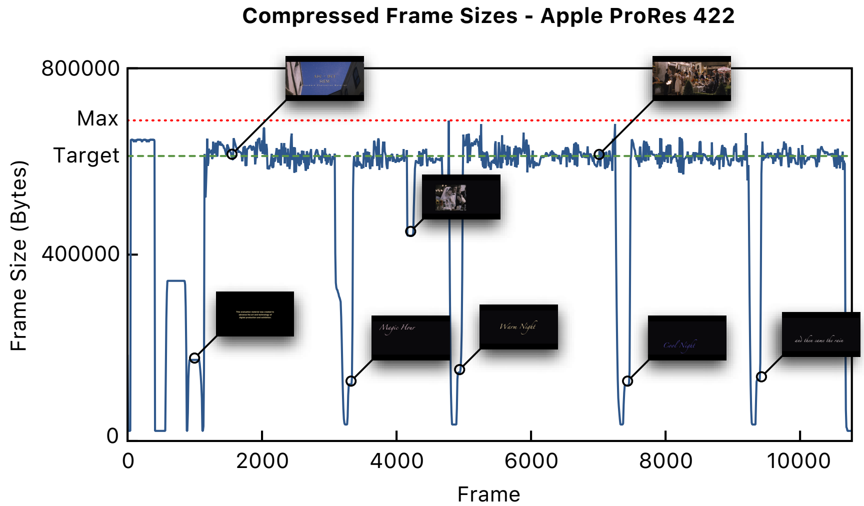
The data rate of a ProRes format is determined primarily by three key factors: ProRes codec type, encoded frame size, and frame rate. The chart below shows some examples of how varying any one of these factors changes a ProRes format's data rate. A table of data rates for a number of ProRes formats supported for real-time editing in Final Cut Pro X can be found in the appendix.

Data Rates - Apple ProRes 422 LT versus Apple ProRes 422



ProRes is a variable bit rate (VBR) video codec. This means that the number of bits used to encode each frame within a stream is not constant, but varies from one frame to the next. For a given video frame size and a given ProRes codec type, the ProRes encoder aims to achieve a "target" number of bits per frame. Multiplying this number by the frames per second of the video format being encoded results in the target data rate for a specific ProRes format.

Although ProRes is a VBR codec, the variability is usually small. The actual data rate is usually close to the target data rate. For a given ProRes format, there is also a maximum number of bits per frame that is never exceeded. This maximum is approximately 10 percent more than the target number of bits per frame. The graph below plots the actual number of bits used per frame in an example ProRes video sequence.



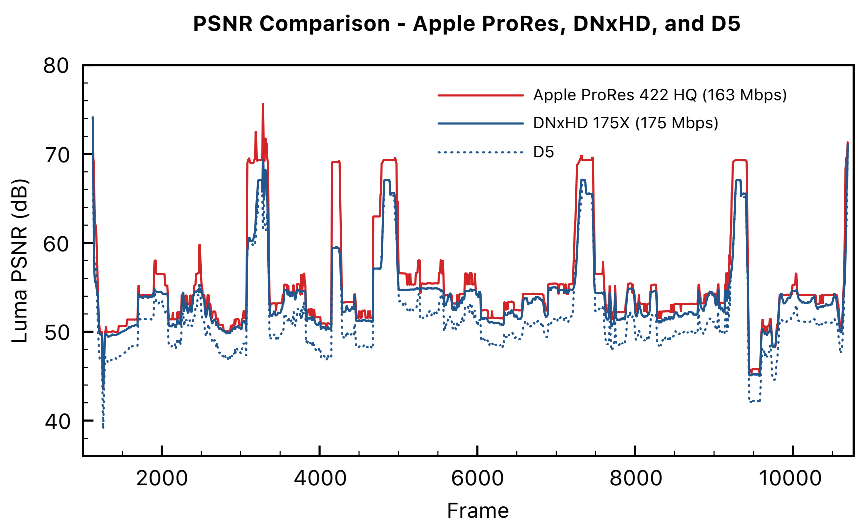
Sequence depicted is ASC/DCI Standard Evaluation Material (StEM) Mini-Movie at 1920 x 1080.

Note that for this particular sequence of over 10,000 frames, only one frame uses the maximum number of bits and most frames are clustered within a few percent of the target. However, many frames use significantly fewer bits than the target. This is because ProRes encoders add bits to a frame only if doing so will produce a better match to the original image. Beyond a certain point, simple image frames, such as an all-black frame with a few words of text, incur no quality benefit if more bits are added. ProRes encoders do not waste bits on any frame if adding more will not improve the fidelity.

Quality

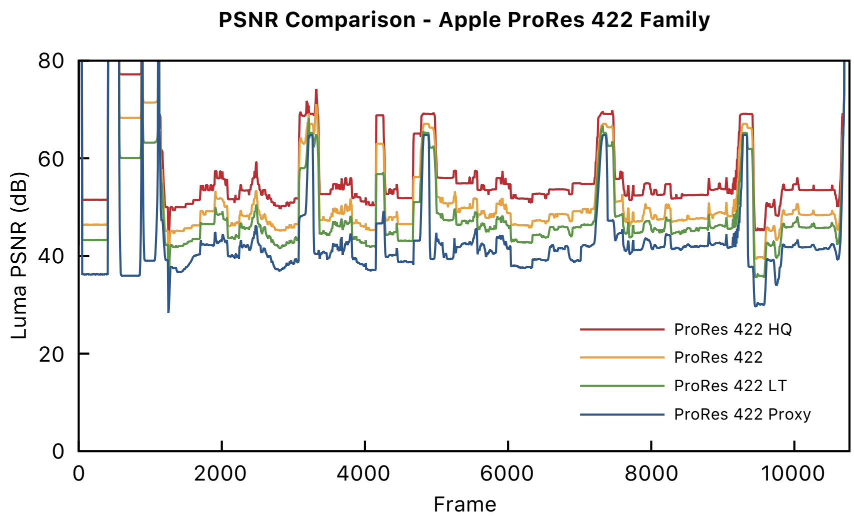
Although the ability to produce high-quality output is a key attribute of image and video codecs, it is quality preservation—or fidelity—that is the actual goal of a codec. Imagery often goes through many stages of processing prior to ProRes encoding, and these stages may add visible flaws, or "artifacts," to the images. If an image sequence has visible artifacts to begin with, ProRes will perfectly preserve these artifacts, which can make viewers mistakenly think such flaws are caused by the ProRes codec itself. The goal of every ProRes family member is to perfectly preserve the quality of the original image source, be it good or bad.

The quality-preserving capability of the various ProRes codecs can be expressed in both quantitative and qualitative terms. In the field of image and video compression, the most widely used quantitative measure of image fidelity is peak signal-to-noise ratio (PSNR). PSNR is a measure of how closely a compressed image (after being decompressed) matches the original image handed to the encoder. The higher the PSNR value, the more closely the encoded image matches the original. The graph below plots the PSNR value for each image frame in a test sequence for three different codecs: Apple ProRes 422 HQ, Avid DNxHD, and Panasonic D5.



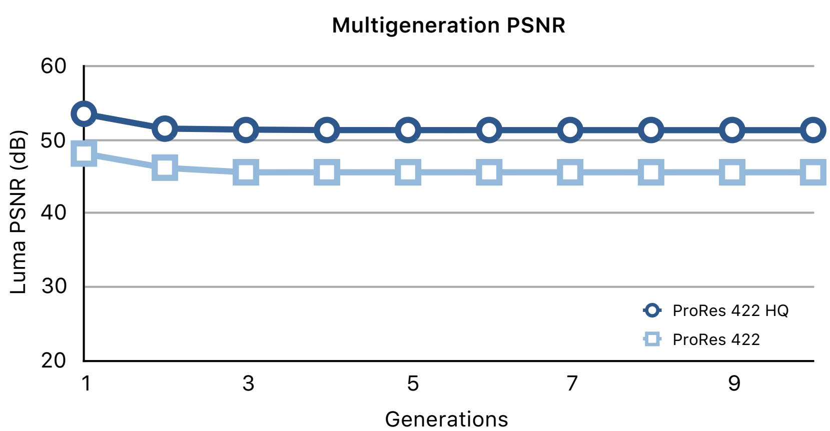
Measured using ASC/DCI Standard Evaluation Material (StEM) Mini-Movie at 1920 x 1080.

The next graph shows the same sequence plotted for each Apple ProRes 422 codec. As the graph shows, there is a difference in PSNR between one family member and the next. These differences correspond to the comparative data rates of the Apple ProRes 422 codecs. PSNR for Apple ProRes 422 HQ is 15–20 dB higher than that for Apple ProRes 422 Proxy, but the Apple ProRes 422 HQ stream has nearly five times the data rate of the Apple ProRes 422 Proxy stream. The benefit of higher fidelity comes at the cost of larger file sizes, so it's important to select the ProRes family member according to your workflow requirements.



Measured using ASC/DCI Standard Evaluation Material (StEM) Mini-Movie at 1920 x 1080.

In addition to indicating visual fidelity, the difference in PSNR values also denotes headroom. For example, if you were to view the original sequence used in the graph above, and then view the Apple ProRes 422 HQ and Apple ProRes 422 encoded versions of the same stream, all three would look visually identical. However, the higher PSNR value for Apple ProRes 422 HQ indicates greater quality headroom. This increased headroom means that an image sequence can be decoded and re-encoded over multiple generations and still look visually identical to the original, as shown in the graph below.



Because PSNR is not a perfect measure of compressed image fidelity—there is no particular PSNR number that can absolutely guarantee that a compressed image will have no visible difference from the original—it's useful to have some qualitative description of expected image quality for each ProRes codec type. Note that in the table below, the qualitative description for Apple ProRes 4444 (without an alpha channel) is identical to that for Apple ProRes 422 HQ. This is because Apple ProRes 4444, though its target bit rate is 50 percent higher than that of Apple ProRes 422 HQ, uses extra bits to encode the greater number of chroma samples in 4:4:4 at the same high quality headroom ensured by Apple ProRes 422 HQ for 4:2:2 sources.

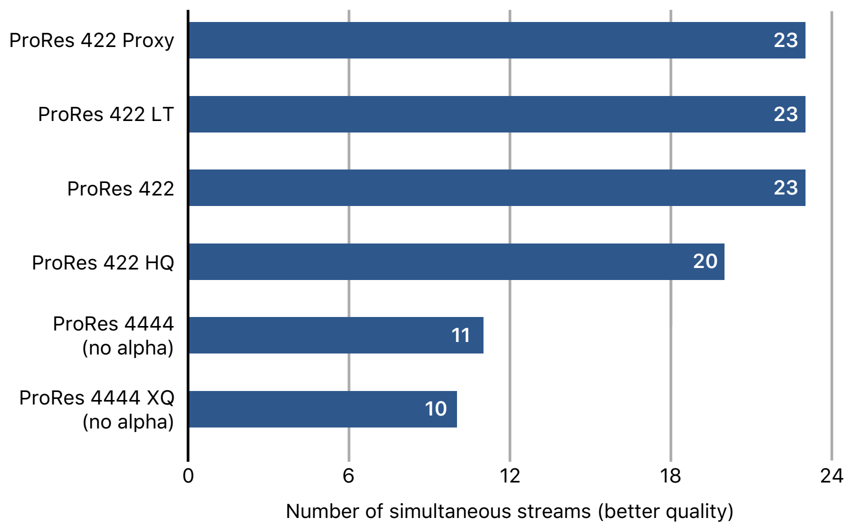
Apple ProRes codec	Visible differences (1st gen.)	Quality headroom
ProRes 4444 XQ	Virtually never	Very high, excellent for multi-gen. finishing and camera originals
ProRes 4444	Virtually never	Very high, excellent for multi-gen. finishing
ProRes 422 HQ	Virtually never	Very high, excellent for multi-gen. finishing
ProRes 422	Very rare	High, very good for most multi-gen. workflows
ProRes 422 LT	Rare	Good for some multi-gen. workflows
ProRes 422 Proxy	Subtle for high-detail images	OK, intended for first-gen. viewing and editing

Performance

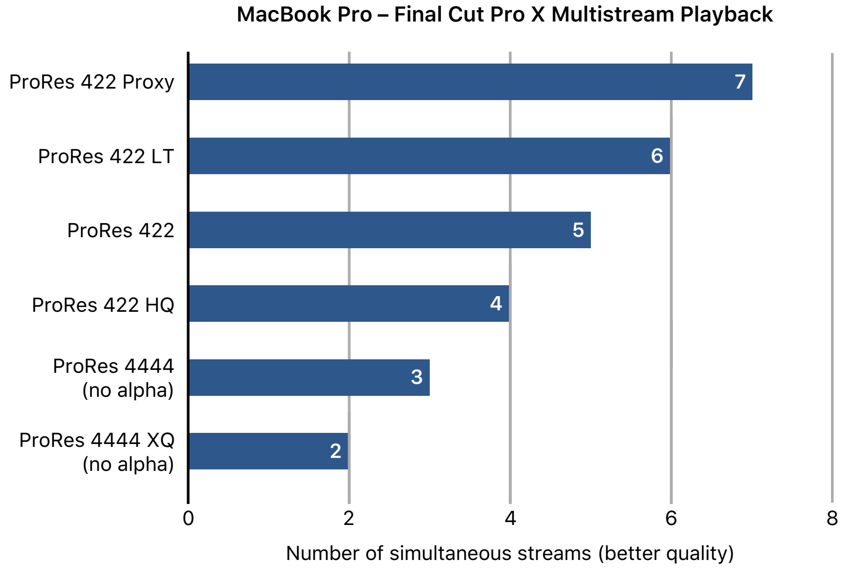
The ProRes family of codecs is designed for speed, and high speed of both encoding and decoding is essential to avoid workflow bottlenecks.

Fast decoding is especially critical for multistream, real-time playback in Final Cut Pro X. The ProRes codec family performs exceptionally well in this regard. For each Apple ProRes codec type, the following charts show the number of full-quality 4K streams that can be played back simultaneously in real time on a Mac Pro and a MacBook Pro computer. In practice, of course, you may not often need to play back ten, twenty, or more streams simultaneously, but these charts give an idea of how much processing time will be available for real-time titling, effects, and so on when just one, two, or three streams are being used.

Mac Pro – Final Cut Pro X Multistream Playback

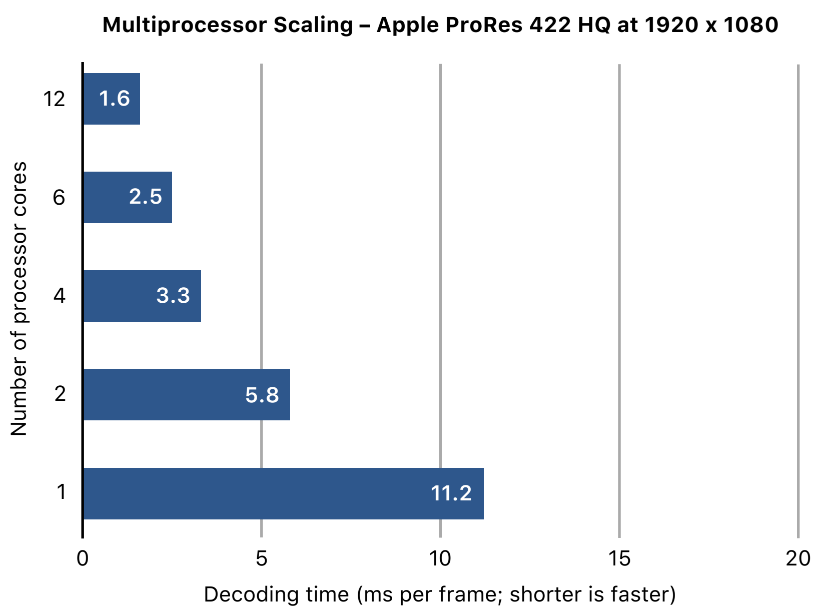


Testing conducted by Apple in December 2019 on preproduction 2.5GHz 28-core Intel Xeon W-based Mac Pro systems with 384GB of RAM and dual AMD Radeon Pro Vega II graphics with Infinity Fabric Link and 32GB of HBM2 each, configured with Afterburner and a 4TB SSD. Tested on macOS Catalina with Final Cut Pro 10.4.7, using 90-second picture-in-picture projects with 23 streams of Apple ProRes 422 Proxy video, 23 streams of Apple ProRes 422 LT video, 23 streams of Apple ProRes 422 video, 20 streams of Apple ProRes 422 HQ video, 11 streams of Apple ProRes 4444 video, and 10 streams of Apple ProRes 4444 XQ video, all at 4096 x 2160 resolution and 23.98 frames per second. Performance may vary based on system configuration, media type, and other factors.



Testing conducted by Apple in December 2019 on preproduction 2.4GHz 8-core Intel Core i9-based 16-inch MacBook Pro systems with 64GB of RAM, Radeon Pro 5500M graphics with 8GB of VRAM, and a 4TB SSD. Tested on macOS Catalina with Final Cut Pro 10.4.7, using 90-second picture-in-picture projects with 7 streams of Apple ProRes 422 Proxy video, 6 streams of Apple ProRes 422 LT video, 5 streams of Apple ProRes 422 video, 4 streams of Apple ProRes 422 HQ video, 3 streams of Apple ProRes 4444 video, and 2 streams of Apple ProRes 4444 XQ video, all at 4096 x 2160 resolution and 23.98 frames per second. Performance may vary based on system configuration, media type, and other factors.

Today’s Mac notebook and desktop machines rely on multicore processing, so the speed of a fast editing decoder must scale up—meaning that decoding time per frame should decrease—as the number of processing cores increases. Many industry codec implementations “hit the wall” and do not realize further performance gains as more processors are added, but ProRes codecs continue to get faster as more cores are added, as the following chart shows.

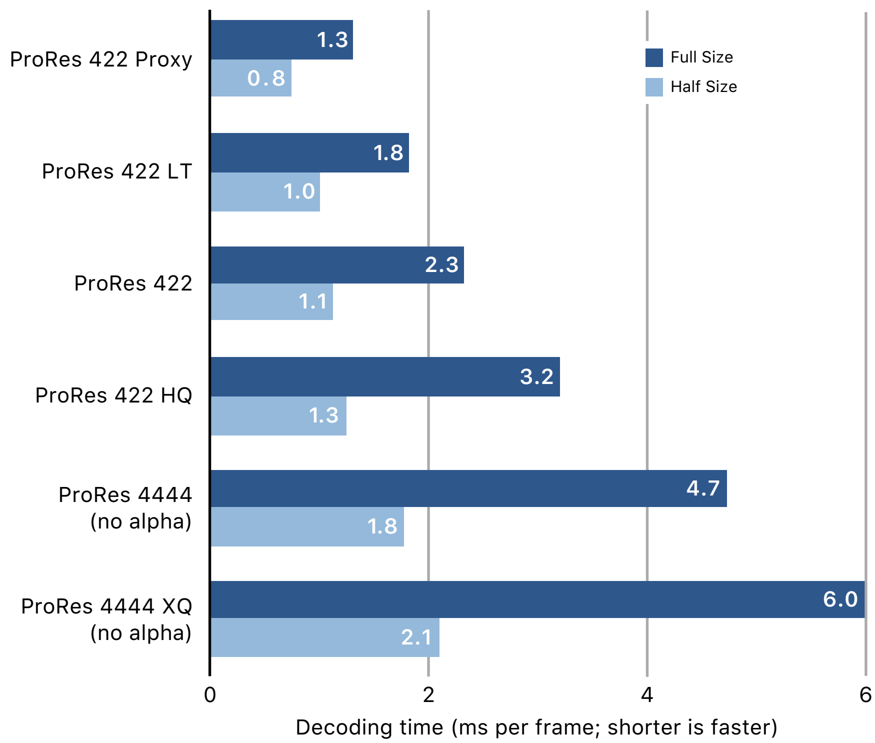


Testing conducted by Apple in May 2014 using OS X Mavericks v.10.9.2 and a Mac Pro with 2.7GHz 12-core Intel Xeon processor. Performance may vary depending on system configuration, content, and performance measurement tool use.

ProRes decoders are designed to work especially well as high-quality, high-performance editing codecs for Final Cut Pro X. Not only are they fast for decoding video at full frame size and quality, but they are even faster at decoding frames at "half-size" frame (1/2 height and 1/2 width). Especially for high-resolution formats like HD and 2K, half-size images provide plenty of onscreen detail for making editing decisions.

The chart below shows that half-size decoding is substantially faster than already-fast full-size decoding, especially for the higher-quality ProRes codecs. The faster decoding speed means more CPU time is available for decoding more streams or more real-time effects.

Reduced Resolution Decoding Speed at 1920 x 1080



Testing conducted by Apple in March 2014 using shipping 15-inch MacBook Pro with Retina display quad-core 2.6GHz units with 1TB flash storage, 16GB of RAM, NVIDIA GeForce GT 750M graphics, and OS X 10.9.2. MacBook Pro continuously monitors system thermal and power conditions, and may adjust processor speed as needed to maintain optimal system operation. Performance may vary depending on system configuration, content, and performance measurement tool use.

Although fast decoding speed is the primary factor in real-time editing performance, fast encoding speed is also important for key steps in post-production workflows. Like ProRes decoders, the ProRes family of encoders have all been built as efficient software implementations, and fast encoding is achieved through efficient use of multicore processors. Fast encoding speed is essential for some steps and important in virtually all others.

For real-time capture and ProRes encoding of baseband video signals (either analog or digital SD or HD signal sources), ProRes software encoders must be fast enough to keep up with the incoming real-time video frames. An appropriate video capture card must be used for this purpose, but otherwise no specialized encoding hardware is required to achieve real-time capture of baseband video to ProRes formats.

For file-based transcoding of video files that have been encoded with other (non-ProRes) video codecs, transcoding to ProRes entails both decoding of the starting technique and re-encoding to ProRes. The minimum total transcoding time will therefore be the sum of the time required to decode the file and the time required to re-encode it to ProRes. For certain video codec formats known to be highly complex and therefore relatively slow to decode, such as JPEG-2000 and the REDCODE RAW (R3D) native codec format, the overall transcoding time will be dominated by the decoding time. Still, fast ProRes encoding helps make the total transcoding time faster.

Fast encoding and decoding also benefits rendering and exporting. Rendering effects, as part of a creative process or the final step before output, is basically a decode of the source media and a re-encode to the chosen final output format. During the rendering process, all of the decoding, blending, and compositing steps must be precomputed before encoding to the compressed format defined in your Final Cut Pro X project. Although you can choose any Apple ProRes codec as a rendering format—from Apple ProRes 422 LT to Apple ProRes 4444 XQ—and change it at any time during post-production, Final Cut Pro X defaults to rendering in Apple ProRes 422.

When rendering to ProRes, the total rendering time is determined by the speed of both the decoding and encoding steps, which can be significantly quicker compared to other, more complex and slower codecs. The speed advantage of ProRes is also beneficial when exporting a file at the end of a project. If you need to deliver to the web, DVD, or Blu-ray disc, you can speed up the export process by choosing to edit the project in ProRes instead of other professional formats, including uncompressed.

Alpha Channel Support in Apple ProRes 4444 Codecs

In addition to supporting $Y'C_BC_R$ or RGB 4:4:4 pixel data, the Apple ProRes 4444 XQ and Apple ProRes 4444 codec types support an optional alpha channel. The sampling nomenclature for such $Y'C_BC_RA$ or RGBA images is 4:4:4:4, to indicate that for each pixel location, there is an alpha—or A—value in addition to the three $Y'C_BC_R$ or RGB values. An alpha value specifies the proportion of its associated RGB or $Y'C_BC_R$ pixel that should be blended with the pixel at the corresponding location of a background image, creating the effect of varying transparency for use in compositing workflows. Unlike $Y'C_BC_R$ or RGB pixel values, alpha values do not represent samples of a real-world image, or even samples of a computer-generated image, both of which are intended for human viewing.

Alpha values are essentially numeric data that specify how to blend, or composite, a foreground image into a background image. For this reason, Apple ProRes 4444 XQ and Apple ProRes 4444 encode alpha values exactly rather than approximately. This kind of exact encoding is called “lossless” (or sometimes “mathematically lossless”) compression. It uses different encoding techniques from those used by the ProRes codec family for RGB or $Y'C_BC_R$ pixel values, where approximate encoding is acceptable as long as differences from the original are not visible to the viewer and do not affect processing. The Apple ProRes 4444 XQ and Apple ProRes 4444 codecs losslessly encode alpha channel values of any bit depth up to and including 16 bits.

In summary, the Apple ProRes 4444 XQ and Apple ProRes 4444 codecs can be considered “visually lossless” for encoding the $Y'C_BC_R$ or RGB pixel values intended for viewing, but “mathematically lossless” for encoding the alpha values that specify compositing. As a result, the degree of quality or fidelity is never a question for Apple ProRes 4444 alpha channels because the decoded data always matches the original perfectly.

With any kind of lossless compression, the data rate varies according to the amount of image detail being encoded. This is true of Apple ProRes 4444 lossless alpha channel compression as well. However, in practice alpha channels typically contain just the information related to object outlines, so the optional alpha channel typically adds just a few percent to the overall Apple ProRes 4444 data rate. For this reason, the presence of an alpha channel in an Apple ProRes 4444 stream typically reduces decoding and encoding performance by only about 10 percent or less.

Appendix

Target Data Rates

Dimensions	Frame Rate	ProRes 422 Proxy		ProRes 422 LT		ProRes 422		ProRes 422 HQ		ProRes 4444 (no alpha)		ProRes 4444 XQ (no alpha)	
		Mb/s	GB/hr	Mb/s	GB/hr	Mb/s	GB/hr	Mb/s	GB/hr	Mb/s	GB/hr	Mb/s	GB/hr
720 x 486	24p	10	4	23	10	34	15	50	23	75	34	113	51
	60i, 30p	12	5	29	13	42	19	63	28	94	42	141	64
720 x 576	50i, 25p	12	6	28	13	41	18	61	28	92	41	138	62
960 x 720	24p	15	7	35	16	50	23	75	34	113	51	170	76
	25p	16	7	36	16	52	24	79	35	118	53	177	80
	30p	19	9	44	20	63	28	94	42	141	64	212	95
	50p	32	14	73	33	105	47	157	71	236	106	354	159
	60p	38	17	87	39	126	57	189	85	283	127	424	191
1280 x 720	24p	18	8	41	18	59	26	88	40	132	59	198	89
	25p	19	9	42	19	61	28	92	41	138	62	206	93
	30p	23	10	51	23	73	33	110	49	165	74	247	111
	50p	38	17	84	38	122	55	184	83	275	124	413	186
	60p	45	20	101	46	147	66	220	99	330	148	495	223
1280 x 1080	24p	31	14	70	31	101	45	151	68	226	102	339	153
	60i, 30p	38	17	87	39	126	57	189	85	283	127	424	191
1440 x 1080	24p	31	14	70	31	101	45	151	68	226	102	339	153
	50i, 25p	32	14	73	33	105	47	157	71	236	106	354	159
	60i, 30p	38	17	87	39	126	57	189	85	283	127	424	191

Target Data Rates (continued)

Dimensions	Frame Rate	ProRes 422 Proxy		ProRes 422 LT		ProRes 422		ProRes 422 HQ		ProRes 4444 (no alpha)		ProRes 4444 XQ (no alpha)	
		Mb/s	**GB/hr**	**Mb/s**	**GB/hr**	**Mb/s**	**GB/hr**	**Mb/s**	**GB/hr**	**Mb/s**	**GB/hr**	**Mb/s**	**GB/hr**
1920 x 1080	24p	36	16	82	37	117	53	176	79	264	119	396	178
	50i, 25p	38	17	85	38	122	55	184	83	275	124	413	186
	60i, 30p	45	20	102	46	147	66	220	99	330	148	495	223
	50p	76	34	170	77	245	110	367	165	551	248	826	372
	60p	91	41	204	92	293	132	440	198	660	297	990	445
2K 2048 x 1080	24p	41	19	93	42	134	60	201	91	302	136	453	204
	25p	43	19	97	44	140	63	210	94	315	142	472	212
	30p	52	23	116	52	168	75	251	113	377	170	566	255
	50p	86	39	194	87	280	126	419	189	629	283	944	425
	60p	103	46	232	104	335	151	503	226	754	339	1131	509
2K 2048 x 1556	24p	56	25	126	57	181	81	272	122	407	183	611	275
	25p	58	26	131	59	189	85	283	127	425	191	637	287
	30p	70	31	157	71	226	102	340	153	509	229	764	344
	50p	117	52	262	118	377	170	567	255	850	382	1275	574
	60p	140	63	314	141	452	203	679	306	1019	458	1528	688
QFHD 3840 x 2160	24p	145	65	328	148	471	212	707	318	1061	477	1591	716
	25p	151	68	342	154	492	221	737	332	1106	498	1659	746
	30p	182	82	410	185	589	265	884	398	1326	597	1989	895
	50p	303	136	684	308	983	442	1475	664	2212	995	3318	1493
	60p	363	163	821	369	1178	530	1768	795	2652	1193	3977	1790
4K 4096 x 2160	24p	155	70	350	157	503	226	754	339	1131	509	1697	764
	25p	162	73	365	164	524	236	786	354	1180	531	1769	796
	30p	194	87	437	197	629	283	943	424	1414	636	2121	955
	50p	323	145	730	328	1049	472	1573	708	2359	1062	3539	1593
	60p	388	174	875	394	1257	566	1886	848	2828	1273	4242	1909

Target Data Rates (continued)

Dimensions	Frame Rate	ProRes 422 Proxy		ProRes 422 LT		ProRes 422		ProRes 422 HQ		ProRes 4444 (no alpha)		ProRes 4444 XQ (no alpha)	
		Mb/s	GB/hr	Mb/s	GB/hr	Mb/s	GB/hr	Mb/s	GB/hr	Mb/s	GB/hr	Mb/s	GB/hr
5K 5120 x 2700	24p	243	109	547	246	786	354	1178	530	1768	795	2652	1193
	25p	253	114	570	257	819	369	1229	553	1843	829	2765	1244
	30p	304	137	684	308	982	442	1473	663	2210	994	3314	1492
	50p	507	228	1140	513	1638	737	2458	1106	3686	1659	5530	2488
	60p	608	273	1367	615	1964	884	2946	1326	4419	1989	6629	2983
6K 6144 x 3240	24p	350	157	788	354	1131	509	1697	764	2545	1145	3818	1718
	25p	365	164	821	370	1180	531	1769	796	2654	1194	3981	1791
	30p	437	197	985	443	1414	636	2121	955	3182	1432	4772	2148
	50p	730	328	1643	739	2359	1062	3539	1593	5308	2389	7962	3583
	60p	875	394	1969	886	2828	1273	4242	1909	6364	2864	9545	4295
8K 8192 x 4320	24p	622	280	1400	630	2011	905	3017	1358	4525	2036	6788	3055
	25p	649	292	1460	657	2097	944	3146	1416	4719	2123	7078	3185
	30p	778	350	1750	788	2514	1131	3771	1697	5657	2545	8485	3818
	50p	1298	584	2920	1314	4194	1887	6291	2831	9437	4247	14,156	6370
	60p	1556	700	3500	1575	5028	2263	7542	3394	11,313	5091	16,970	7636

Glossary

alpha channel An additional channel of information that may optionally be included with RGB and $Y'C_BC_R$ images. If included with an RGB image, for each R, G, and B value that defines a pixel, there is an A value that specifies how the RGB pixel should be blended with a background image. Typically, one extreme value of A indicates 100% transparency and the other extreme value indicates 100% opacity. Values in between the extremes indicate the degree of opacity.

Apple ProRes format A ProRes-encoded bitstream, typically in the form of a .mov file, for which the ProRes codec type and video format are specified. For example, an "Apple ProRes 422 HQ 1920 x 1080i 29.97 format."

codec Abbreviation for *compressor/decompressor*. A general term referring to both encoder and decoder.

decoder An algorithm or processing system that takes a compressed bitstream as input and delivers a sequence of images or video frames as output. For ProRes, this term refers to a QuickTime decompressor component that converts a ProRes-encoded .mov file to a sequence of images, for further processing or display.

encoder An algorithm or processing system that takes uncompressed images as input and delivers a compressed bitstream as output. For ProRes, this term refers to a QuickTime compressor component that generates a ProRes-encoded .mov file.

image sequence An ordered set of image frames that, when displayed at a specified frame rate, is perceived by the viewer as a real-time motion image sequence. If not referred to as "video," an image sequence is often a set of RGB images (with an optional alpha channel), such as the DPX, TIFF, and OpenEXR file formats.

lossless A type of codec for which putting an image frame through encoding followed by decoding results in an image that is mathematically guaranteed to have exactly the same pixel values as the original.

video An image sequence for which the image frames typically use the $Y'C_BC_R$ color space and subsampled chroma channels, usually with one of the following patterns: 4:2:2, 4:2:0, or 4:1:1.

video format A video sequence for which the frame height, frame width, and frame rate are all specified. For example, a "1920 x 1080i 29.97 video format."

visually lossless A type of codec for which putting an image frame through encoding followed by decoding results in an image that is not mathematically lossless, but is visually indistinguishable from the original when viewed alongside the original on identical displays.