Apple ProRes 422

White Paper
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Introduction

The true measure of image quality is how much of the artist's original vision is reproduced on the screen. The new Apple ProRes 422 video format is designed to do exactly that. ProRes 422 can be used for a wide range of applications, and will fit flawlessly into demanding editing and effects workflows. With ProRes 422 inside Final Cut Studio 2, there is now a better choice for ensuring that all creative work maintains its original, pristine color and detail—from capture all the way to final viewing.

For years now, Final Cut Pro editors have relied on HD formats such as DVCPRO-HD and HDV for native, real-time multistream editing. The efficiency and image quality of these workflows are excellent for content that originates with and can be finished natively in these formats. But such formats were designed under significant camcorder engineering constraints, so they limit the full quality that can be carried in an HD signal.

As technology advances, higher-quality HD signals are becoming more common. Examples include scanned film for Digital Intermediate workflows, live events recorded directly to disk, more advanced HD-SDI editing decks with little or no compression, and a new generation of emerging camcorder formats. Users need a new, compact HD format designed specifically for post-production.

At the highest end of the HD quality spectrum, Final Cut Pro supports uncompressed HD as a real-time editing format. But the high-bandwidth, RAID-storage requirements of uncompressed HD are daunting for most users' budgets and put it out of reach of all but the largest post-production facilities and high-budget productions.

Enter Apple ProRes 422, a new format designed for pristine HD quality, economical hardware configurations, yet high-performance, multistream Final Cut Pro real-time editing—for both high-definition (HD) and standard-definition (SD) formats. Apple ProRes 422 features:

- The quality of uncompressed HD at data and storage rates lower than uncompressed SD.
- Performance comparable to or better than the existing HD codecs in Final Cut Pro.
- The ability to work with HD on slower drives, and with more users on shared storage.

Key Features

Apple ProRes 422 brings powerful new capabilities to Final Cut Pro editors thanks to its outstanding technical characteristics.

Stunning HD Quality

- **Quality indistinguishable from the most pristine sources.** Maintains superb quality even after multiple encoding/decoding generations.
- **Full-width 1920-by-1080 and 1280-by-720 resolution.** Offers the highest visual detail possible in any HD format.
- **4:2:2 chroma sampling.** Provides precise compositing and blending at sharp saturated-color boundaries.
- **10-bit sample depth.** Preserves subtle gradients of 10-bit sources (sunsets, graphics, and the like) with no visible banding artifacts.
- **I frame–only encoding.** Ensures consistent quality in every frame and no artifacts from complex motion.

Remarkably Low Data Rates

- **Variable bit-rate (VBR) encoding.** "Smart" encoding analyzes the image and allocates more bits to complex frames. Efficiency is increased because excess bits are not wasted on simple frames.
- **Two target HD bit rates.** Normal quality is targeted at 145 Mbps, and high quality (HQ) is targeted at 220 Mbps. Except in the case of unusually complex material, actual bit rates are typically 5 to 10 percent lower than these targets.
- **Low bit rates increase equipment affordability.** You can edit more streams with more real-time effects on slower drives, or have more users accessing the same media over Xsan. And performance increases as you increase the speed of your storage infrastructure.
  - ProRes 422 produces video indistinguishable from uncompressed HD that needs less storage space than uncompressed SD video. If you have been waiting to jump into high-quality HD editing because of the costs of storage and archiving, this is an opportunity for new business without the added cost of new equipment.
  - Even MacBook Pro laptops can use ProRes 422 to play back full-quality HD in real time. Attach a 23-inch or 30-inch Apple Cinema HD Display—or even a high-resolution projector—and play back high-quality HD in the field during the shoot or at a client's screening room.

Designed for Speed

- **Excellent full-size and blazing 1/2-by-1/2-size decoding speed.** For more effects and more streams in everyday editing, ProRes 422 is perfectly suited for the Dynamic RT capability in Final Cut Pro.
- **Impressive encoding speed.** Capture ProRes 422 in real time from any HD-SDI source.

Benefits for Final Cut Pro Editing and Video I/O

Apple ProRes 422 brings tremendous benefits to many Final Cut Pro workflows, especially those utilizing the highest-quality HD video sources.

Capture

Using Apple ProRes 422 on a Mac Pro equipped with an HD-SDI video card, users can capture the highest-quality, full-width, 10-bit, 4:2:2 HD video from any HD-SDI source, including HD tape decks, broadcast feeds, direct recording from a camera's HD-SDI output, telecine devices, and so on. The ProRes 422 software encoder compresses the incoming video frames and writes them to a QuickTime file on a standard hard drive.

Users may select either the ProRes 422 or ProRes 422 HQ quality setting. Both settings feature HD quality that is indistinguishable from the original, even after many generations of reencoding. Normal ProRes 422 provides excellent preservation of either 8-bit or 10-bit source quality at an economical bit rate. ProRes 422 HQ offers even greater headroom to preserve the quality of even the most demanding, complex material with no visible artifacts.

HD-SDI video sources captured to normal-quality ProRes 422, or even to ProRes 422 HQ, will occupy less disk space than uncompressed standard-definition video. Yet, for virtually all practical purposes, the quality of HD ProRes 422 will be visually equivalent to that of uncompressed HD.

Apple ProRes 422 is also ideal for capturing and preserving not only 8-bit, but also 10-bit SD sources. It captures either bit depth at data rates similar to DVCPRO-50 and IMX-50, which support 8-bit depth only.

Transcoding

Some of the new-generation camcorders use sophisticated new codecs for recording to flash memory, a hard drive, or other internal storage media. One example is the RED ONE Digital Cinema camera, which employs wavelet compression to reduce the data rate of 4:4:4 4K/24p RAW image sequences to rates around 200 Mbps. Another is Panasonic's P2 AVC-Intra format, which uses H.264 intraframe compression to reduce full-width, 10-bit, 4:2:2 1080i60 or 720p60 HD sequences to just 100 Mbps.

New codec formats such as these can be ideal for compressing and preserving such high-quality source imagery at data rates low enough for internal camcorder storage. However, some of these new codecs are too complex to achieve the software decoding speeds needed to support the level of multistream real-time editing performance that Final Cut Pro users have come to expect.

Apple ProRes 422 provides an excellent means of handling these new formats by fully preserving every aspect of their native quality in a format engineered for superb multistream Final Cut Pro real-time performance. In fact, ProRes 422 provides an excellent solution for any video format that does not have native Final Cut Pro support.

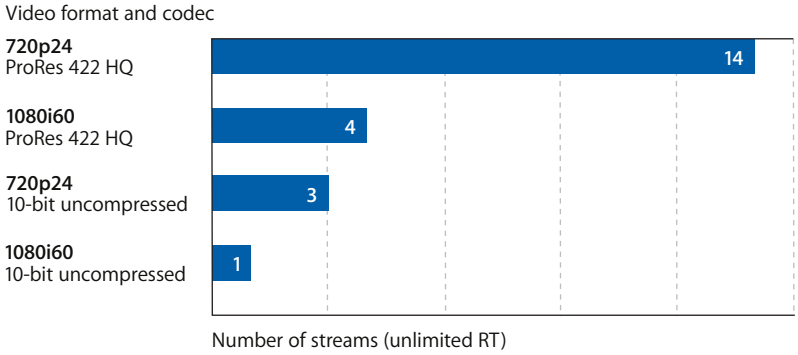
Real-time Playback

Once material has been encoded from an HD-SDI source or transcoded from another format to Apple ProRes 422, users can take advantage of the codec's exceptional real-time playback performance. As Final Cut Pro users know, a project's timeline can be set for real-time playback at different levels of video quality.

At high-quality real-time playback, Final Cut Pro displays video and effects at full resolution. Medium-quality playback shows video at half its full dimensions, to reserve CPU power for more video streams and effects. Apple ProRes 422 has been engineered for excellent decoding speed at full-resolution playback, but provides exceptionally fast speed at 1/2-by-1/2 size. This latter mode provides tremendous value to users for practical editing productivity.

Key ProRes 422 performance benefits include:

- **Real-time performance of Apple ProRes 422 HQ at 220 Mbps.** This is a real-time editing experience equivalent to multistream uncompressed HD playback, but with ordinary hard drives, not costly RAID arrays. The number of real-time streams possible depends on the HD format, as shown in this chart.



Testing conducted by Apple in April 2007 using preproduction 3.0GHz 8-core Mac Pro units, configured with the operating system on a 250GB internal hard drive, and the media stored on three internal 750GB drives configured as a RAID 0 (striped) volume. The tests used a prerelease version of Final Cut Pro 6.0. The source files were 10 minutes in length and discrete. Performance tests were conducted using specific Mac Pro configurations and reflect the approximate performance of Mac Pro systems.

- **Optional half-resolution playback for even better real-time performance.** When real-time playback in Final Cut Pro is set to medium quality, ProRes 422 is decoded to half of the horizontal resolution and half of the vertical resolution. This produces more real-time performance for effects, transitions, and multistream playback.

- **Real-time performance of Apple ProRes 422 at 145 Mbps.** Normal-quality ProRes 422 provides pristine quality for the vast majority of material. With this mode, the data rate is lower and decoding speed is faster, resulting in even better real-time performance.

- **Real-time playback of HD ProRes 422 on a laptop.** Even on a MacBook Pro, Final Cut Pro provides real-time playback of HD ProRes 422. For ProRes 422 HQ streams in 1080i60 format, most laptops can achieve real-time playback at the medium-quality setting (1/2-by-1/2 size) in Final Cut Pro. But for 24p HD formats, even ProRes 422 HQ streams will play back at full resolution on most MacBook Pro laptops. And with normal-quality ProRes 422, multistream HD laptop playback is a reality.

Rendering

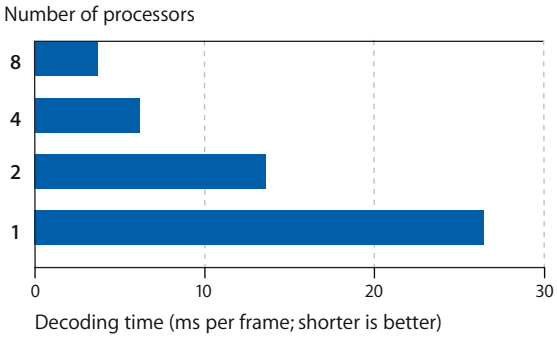
Although native editing of HDV and XDCAM HD formats with Final Cut Pro is popular and has many advantages, ProRes 422 can still bring significant benefits to the rendering process. Because long GOP formats are complex and highly compressed, rendering tends to be slow and may reduce the quality headroom present in the stream. Through a new user preference in Final Cut Pro 6.0, the editor can choose to render effects in HDV and XDCAM HD using ProRes 422. This will result in faster rendering time and a higher-quality 4:2:2 composite. For projects that are mastering to HD-SDI, ProRes 422 is the perfect rendering choice.

Video Output

ProRes 422 can take advantage of third-party video I/O devices to output a true 10-bit signal over HD-SDI. Choose the video card as the output choice, and ProRes 422 plays back in real time from the Final Cut Pro timeline to any HD-SDI tape deck. Because the decoding speed of ProRes 422 is superior to that of many other formats, encoding to distribution formats such as H.264 for the web or MPEG-2 for DVD can be faster even than uncompressed HD. This decoding advantage also means that ProRes 422 has the potential to be used on servers to play out multiple simultaneous HD-SDI streams.

Technical Details

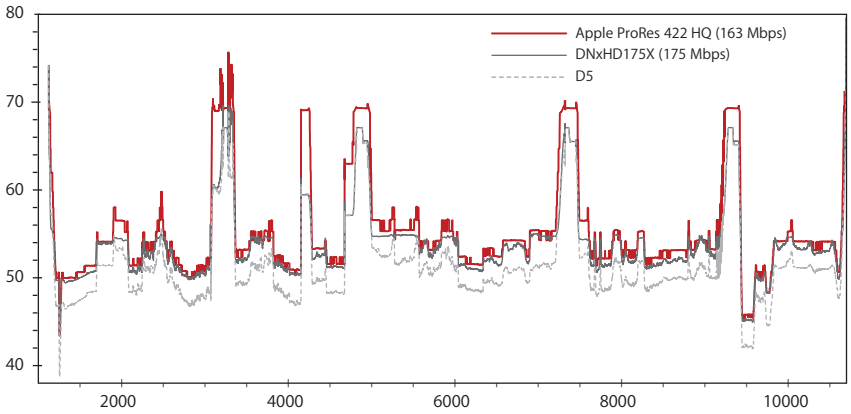
Apple ProRes 422 was designed from the bottom up for great software flexibility and performance. No extra hardware is required for encoding or decoding. In particular, ProRes 422 has been designed to take advantage of multicore processors. The performance of ProRes 422 will scale up—which means that the decoding time per frame will go down—as the number of processors increases. When the system spends less time decoding each frame, it has time for more real-time effects processing.



Apple ProRes 422 was also designed for the highest possible HD quality. For video codecs, the goal is fidelity. The encoded image should be as nearly identical to the original image as possible. In engineering, a widely used measure of codec fidelity is the peak signal to noise ratio (PSNR). The higher the PSNR value, the more closely an encoded image frame matches the original.

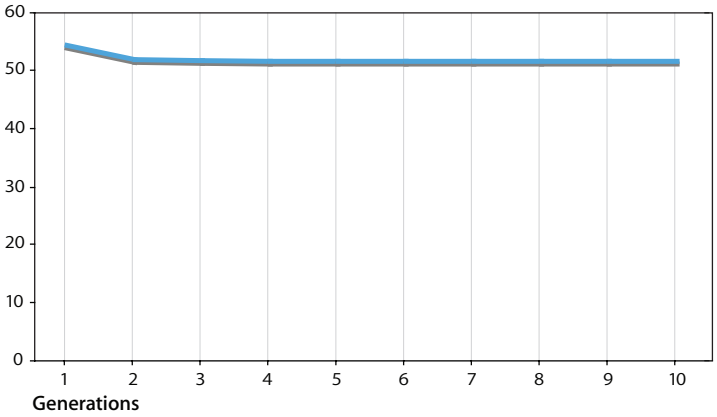
The chart below plots the PSNR value for each image frame in the Digital Cinema Initiatives StEM (Standard Evaluation Material) sequence. The HD version of this sequence was converted to a 10-bit, Rec. 709–compliant sequence. This was used as the source for computing PSNR values for each of three 10-bit capable HD codecs: Apple ProRes 422 HQ, Avid DNxHD, and Panasonic D5. The average PSNR values were 56.4 dB for ProRes 422 HQ, 54.4 dB for DNxHD, and 52.2 dB for D5. These averages and the plots on the chart show that the image fidelity of ProRes 422 HQ is consistently superior to the other codecs—even at its lower bit rate.

Luma PSNR (dB)



Not only does ProRes 422 preserve image quality in a superior way after one generation of encoding, it can withstand many generations of successive decoding and reencoding with almost no further degradation in quality. The StEM sequence from the previous chart was decoded and then reencoded with ProRes 422 HQ, and this cycle was repeated multiple times. The average PSNR after each generation is plotted on the chart below.

Luma PSNR (dB) – Apple ProRes 422 HQ



ProRes 422 is designed to target the data rates and storage requirements shown in the accompanying chart.

Comparative Data Rates

Frame Dimensions	Frame Rate (fps)	Target HQ Data Rate (Mbps)	Storage Requirements (GB/min)	Target Data Rate (Mbps)	Storage Requirements (GB/min)
720x486	29.97	63	0.47	42	0.32
720x576	25	61	0.46	41	0.31
1280x720	23.976	88	0.66	59	0.44
1280x720	25	92	0.69	61	0.46
1280x720	29.97	110	0.82	73	0.55
1280x720	50	184	1.38	122	0.92
1280x720	59.94	220	1.65	147	1.10
1920x1080	23.976	176	1.32	117	0.88
1920x1080	25	184	1.38	122	0.92
1920x1080	29.97	220	1.65	147	1.10

Conclusion

Apple ProRes 422 is changing the rules of post-production. The combination of industry-leading image quality, low data rates, and the real-time performance of Final Cut Studio 2 makes ProRes 422 the ideal format to meet the challenges of today's demanding HD production workflows.