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Under the Hood

Moving to a High-Def Workflow

What do you need to consider when moving from Standard Definition production to High Definition?

More and more businesses are moving video production over to High Definition. If you produce video professionally and have not moved to High Definition yet then you should be planning on doing so as soon as possible, but what sort of hurdles will you need to overcome as part of that move? The first thing to consider with putting any new workflow in place is what your output format will be so I'll cover that first, then I'll move backwards through the workflow and cover monitoring, storage, and finally acquisition & recording technologies.

Output Formats

There is no point in working in HD if nobody is ever going to see your work, so you need to think about how they are going to see it, what does your customer need? The most common market for HD is broadcast television but it is also growing in independent film production and the corporate / event-based market.

In HD broadcast there are:

- Two frame sizes, those being a resolution of 1920 x 1080 (known as 1080) and a resolution of 1280 x 720 (720)
- Two frame/field patterns, progressive where each line in a frame is drawn one after the other and interlaced where one frame consists two fields, one being made up of just the odd numbered lines and the next just the even numbered lines. 25 interlaced frames a second results in 50 fields a second.
- Four different frame rates, 25 & 29.97 frames per second (commonly referred to as 30 fps) for interlaced & progressive video and 50fps & 59.94fps (commonly referred to as 60 fps) for progressive

Virtually any combination of the above is in use somewhere in the world, with some countries (even some broadcasters in the same country) supporting more than one combination.

> "If you retain copyright on the content that you create is there a possibility that you can re-purpose it in the future?"

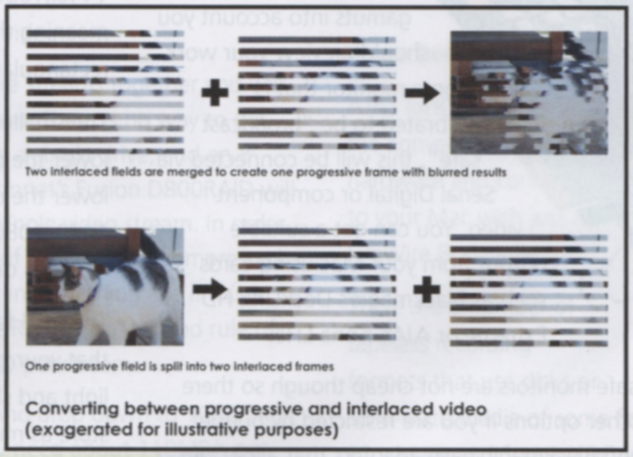
29.97/59.94fps is used primarily in the Americas, South Korea and Japan whereas 25/50fps tends to be used in the rest of the world.

The simplest thing to do is to ask your customer what format they want and then use that as a basis for your workflow. One consideration to also bear in mind, though, is what will happen to the content that you create in the future. If you retain copyright on the content that you create is there a possibility that you can re-purpose it in the future, if so will there be benefit to you in creating the content at a higher resolution or targeting potential overseas sales now? Even if you don't retain copyright will your customer benefit in the long run from you working at the highest resolution possible? In order to keep your options open for future re-use what is the best format to work in?

Things look better when scaled down than when they are scaled up. Recording and editing video in 1080 and then outputting it at 720 will generally give you better

quality output than simply working at 720 because when things are scaled down any artefacts or errors are also scaled down. The converse is also true; if you record and edit at 720 and then scale up to 1080 any problems will be magnified.

In order to create interlaced video from a progressive source you essentially take the odd lines from the frame to make the first field and use the even lines for the second field. However, to create progressive video from an interlaced source you have to find the missing lines from the somewhere, if you take the odd lines from the first field and add them to the even lines from second field you will have something approximating progressive video. That's fine if whatever you are filming is static or moving very slowly, but once you start working with any form of action you will find that the images in the two fields are slightly different, so when you merge the two interlaced fields into one frame things don't quite line up and you end up with a fuzzy result. The faster the objects are moving the fuzzier things will be.



Converting between progressive and interlaced video (exagerated for illustrative purposes)

Going from an edit that is done at one frame rate to output at another can be done in several ways and the methods used were first developed for converting film, which works at 24fps, to television.

If the frame rates are close enough it may be acceptable to simply speed up or slow down the video and apply an appropriate pitch-shift to the audio. This was common practice when going from film (24fps) to Standard Definition UK television (25fps) with the result that films would have a 4% shorter running time when shown on TV, a 1hr film taking 57.6 minutes.

If the frame rates are further apart simply speeding up or slowing down will not work since any movement will seem unnaturally fast or slow, e.g. a 1hr film would be over in just 48 minutes if you were converting from 24fps to 30fps or would take 75 minutes if going the other way. What we need is a way of changing the number of frames per second without changing the speed of the video, and this is done by either repeating or removing some of the video fields, this is known as pull down. To go from film to Standard Definition US television (30fps) we take the first frame of the film and make three video fields from it, we then take the second frame and make two fields of video, the third frame we make into three fields and so on. Given 24 frames of film we end up with 60 fields of video, which makes 30 frames.

This conversion is known as Three Two Pull Down, from the pattern of three fields followed by two. Things now get a little messy as Standard Definition US television is actually 29.97fps, this is close enough for the difference in speed not to be noticed.

That's all well and good if you start with film, which runs at 24fps but things are further complicated by the fact that 24p video doesn't actually run at 24fps, in reality it is 23.976fps. The reason for this is that if you take 23.976fps video and apply a Three Two Pull Down you end up at 29.97fps.

In order to have the maximum flexibility of output you would probably want to be working in 1080 at 24fps with progressive fields, this is known as 1080/24p and from here you can get to just about any frame size, pattern or rate without loss of quality. Video converted from 1080/24p has what is known as a "filmic" look, which may not be suitable for sport due to the slow frame rate. As a result a lot of sport will be shot, edited and delivered in 50/60fps progressive.

Video Monitoring

If you are producing anything professionally you need to ensure that what you see whilst editing is the same as what the end-user sees. When a picture is viewed on a TV it is actually cropped slightly, that is the edges of the picture spill over the edges of the screen. Fortunately Final Cut Pro can give you an overlay in the canvas window that shows you the "safe area" but you still need to be aware that not everything you see on your Mac's screen will end up in the finished product. This is known as overscan. The next thing to bear in mind is that

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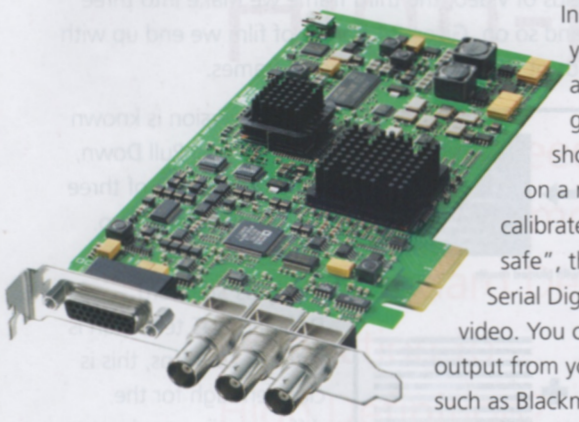
computer displays and televisions display colours differently, known as their colour gamuts, so you will may see colour shifts or colours being indistinguishable from each other when you go from your edit on your Mac to watching the same video on a DVD or TV.



In order to ensure that you take both overscan and the different colour gamuts into account you should preview your work on a monitor that is calibrated to be "broadcast safe", this will be connected via Serial Digital or component video. You can get a suitable output from your Mac using cards such as Blackmagic's DeckLink HD Extreme or AJA's Kona LHe.

Broadcast safe monitors are not cheap though so there are a few other options if you are restricted by budget. Both AJA and Blackmagic have adapters that allow you to connect an Apple 23" Cinema Display to the SDI or HD-SDI output and will handle proper scaling of the image for the display.

Stepping further down you can use a regular HD TV for monitoring so long as it has an HDMI input by installing Blackmagic's Intensity or Intensity Pro card, at present the Intensity is only supported in Mac Pros although Blackmagic are looking at support for PCIe based G5s.

Storage for High-Def

We've already looked at what sort of output formats we should be working in, these focus on things like frame size, frame pattern and field rate, but there is another format question to ask and that is what video codec you will be using when recording, editing and outputting. The choice of codec will influence the quality of your output and, in turn, will also determine the sort of storage that you need.

In general the more compressed a codec you use the slower your hard drives can be, the more powerful your computer has to be, and the lower the quality of the output as more data needs to be thrown away to achieve the compression. Once thrown away data can never be fully recovered.

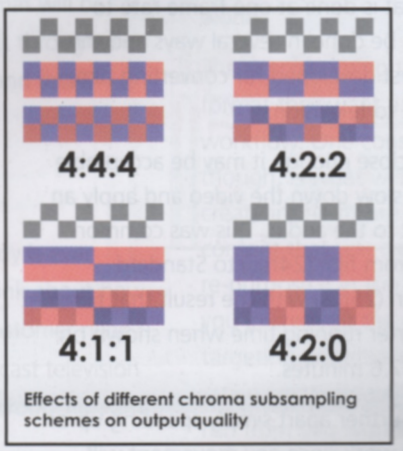
Different codecs also use different pixel ratios, even if you are intending to work in 1920x1080 by choosing the wrong codec you may actually end up working with a 1440x1080 image that has been stretched horizontally, meaning that each pixel that makes up the image is rectangular rather than square.

The smaller the number of real pixels in your image the lower the performance needs of your storage but the lower the quality of your output. You will be working at 1440x1080 if you are working in HDV, DVCPRO HD, HDCAM or XDCAM HD.

The final factor to consider is the chroma subsampling that your codec uses. The eye is much more sensitive to light and shade than it is colour so you do not need to store as much information about the colour of a pixel as you do for it's brightness.

The type of subsampling scheme used by a codec determines the performance needs of your storage. The more samples per channel you use the better the quality of your image but the higher your storage needs.

There are a number of subsample schemes in use with the most common ones being:



Effects of different chroma subsampling schemes on output quality

- 4:4:4 (HDCAM-SR) where the same number of samples are used for each channel
- 4:2:2 (DVCPRO HD & Apple's ProRes 422) where colour has half the number of horizontal samples as brightness
- 4:2:0 (DV, DVCAM & HDV) where colour has half the number of horizontal and vertical samples as brightness.

There are significant reductions in bandwidth possible by using fewer subsamples, 4:2:2 uses about a third of the bandwidth of 4:4:4 and it is difficult to tell the difference with the naked eye. Once you step down to 4:2:0 the difference is much more noticeable.

In the best of all worlds we would work in 1080/24p to give us the most flexibility and uncompressed 4:4:4 to give us the best quality. However there is a "but", a very big but, with this though. In order to support 1080/24p uncompressed 4:4:4 our storage would need to be capable of supplying data to our Mac at a rate of in excess of 170MB/s for each stream of video.

"No camera or recorder supports ProRes 422 so you will need to record in another format"

If you are editing two or more streams together you will need over 170MB/s per stream. There is no way to get that level of throughput with a single drive, and an 8 drive SATA II RAID such as Sonnet's Fusion D800RAID will only be able to cope with a single video stream. In order to support multiple streams of 1080/24p uncompressed 4:4:4 you will need to invest in something like an Xsan consisting of multiple Xserve RAID units, a good rule of thumb is one full Xserve RAID per stream.

If we lower our sights a bit and drop down to 1080/24p uncompressed 4:2:2 we only need about 110MB/s per stream and if we give up using uncompressed video and switch to ProRes 422 we drop right down to about 19MB/s per stream which is just about achievable with internal drives and the new Mac Pro RAID card. If we sacrifice subsampling and pixel ratio as well as greater compression and work in HDV we can get away with just over 3MB/s, which can be accomplished with a single internal hard drive.

Acquisition & Recording

Depending on what format you are working in and the codec you will be using for editing in you will need to make some choices about how you record the video and then get it into your Mac in the first place.

If you have decided that you want to work in HDV then things are relatively easy since an HDV camera will probably have a FireWire port on it just like a DV camcorder.

DVCPRO HD & HDCAM will need a capture card such as Blackmagic's DeckLink HD Extreme or AJA's Kona LHe since these connect via HD-SDI. A number of DVCPRO HD cameras also support recording to a camera-mounted hard disk drive that you can then connect to your Mac.

No camera or recorder supports ProRes 422 so you will need to record in another format such as HDCAM and then convert to ProRes 422 when bringing the video into your Mac. Both the AJA and Blackmagic cards above support doing this in software but if you want to be able to edit on a MacBook Pro or want the flexibility to move your capture device between a number of Macs then

AJA's IoHD will handle the conversion in hardware and connects to your Mac with just a FireWire 800 cable.

There are a number of tapeless recording formats that use disks or solid-state media of some form; these include Panasonic's P2 system and Sony's XDCAM HD which either use an HD-SDI connection between the deck, if you want to re-encode the video, or connect via FireWire or USB so that the files can be imported into Final Cut Pro using the Log and Transfer Window.

If you want to import video in 4:4:4 you will need to invest in something like a Blackmagic Multibridge Eclipse or an AJA Kona 3, both of which support the Dual Link HD-SDI which is needed to move the data from an HDCAM-SR deck.

In general, working in true 1920x1080 4:2:2 needs quite an expensive camera but there is a way around it if you are prepared to give up the ability to be mobile while you record and restrict yourself to a studio of some form. Blackmagic's Intensity and Intensity Pro cards aren't only useful for monitoring on a budget but they also support recording via HDMI. Whilst HDV cameras only record to tape using 1440x1080 4:2:0 some, such as Sony's HDR-HC3, provide a raw 1920x1080 4:2:2 stream over an HDMI port. The downside is that you cannot record this stream to tape, you will need to capture it directly into your Mac using Blackmagic's On-Air software which is why you are restricted to recording somewhere that you can get your Mac Pro and a storage system that is able to write to disk at over 100MB/s.