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Video Preservation
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8-bit vs 1- bit Bit depth

ABSTRACT

This test was to determine if there was a difference in capturing 10-bit uncompressed or 8-bit uncompressed digital files from analog video sources. The sources used were VHS, BetacamSP, and ¾" Umatic. The test focused on the color depth of the resulting files.

INTRODUCTION

Bit depth, also known as color depth, is the number of bits used to represent the color of a single pixel in a rendered image. Bit depth expresses how many levels of color can be expressed per pixel, and the higher the bit depth the greater the range of distinct colors is. Computers are based off of a binary language only two numbers: 1 and 0. Each of the primary colors (Red, Blue and Green) has a number of bits that describes the number of shades of color can be displayed on screen. A sample with a bit depth of only 1 bit (2^1) can have a value of 0 or 1, which would result in a black or white pixel. 2-bit color (2^2) would result in four possible values: 00, 01,10, or 11. This results in four shades of grey four color choices. For video signals the bit depth is per channel. The 8 bit-uncompressed format is using 8 bits per color component in the signal. This results in 2^8 gradations or 256 possibilities per channel. In a YCbCr format then the Y channel gets 256 possibilities, the Cb channel gets 256 possibilities, and the Cr channel gets 256 possibilities. This adds up to 16,777,216 potential shades across all channels.[1]

Something with 10 bits per channel provides 2^{10} or 1024 color possibilities. This creates 1,073,741,824 potential shades across all channels. Clearly 10-bit bit depth is more desirable than 8-bit bit depth in terms of color. It should be pointed out that within broadcast standards the entire range is not used. With a 8-bit signal the luma range is from 16-235 (black to white) with the rest used for headroom. 10-bit uses the 64-940 range with 4-63 and 941-1019 reserved.[2] This is because analog video signal amplitude is expressed in IRE units and values between 7.5 IRE and 100 IRE are broadcast safe as they do not cause artifacts in the image. Digital black is equal to 0 IRE and could electrically overload the transmitter as the analog transmission system is set up to put out peak power at lower video levels.[3]

The other factor affecting color in a digital color space is chroma subsampling. This is a method to compress the signal in order to reduce the strain in both broadcast and storage. The human visual system is more sensitive to the luminance of color than the position and motion so chroma subsampling is optimized to store more luminance detail than color. The signal is divided into luma (Y') and two color difference components (chroma). It is usually shown as a three part ratio (4:4:4, 4:2:2, etc) with the first number giving the horizontal sampling

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[1] From the video format section of the Final Cut Pro User guide: http://documentation.apple.com/en/finalcutpro/usermanual/index.html#chapter=C%26section=11%26tasks=true and http://en.wikipedia.org/wiki/Color_depth

[2] From the User Preferences Tab of the Color User Manual: http://documentation.apple.com/en/color/usermanual/index.html#chapter=5%26section=6%26tasks=true

[3] Marcus Weise, Diana Weynand. *How Video Works*. 2nd Edition. New York: Focal Press. 2007. p. 152

reference or width. The second number is the number of chrominance samples in the first row of pixels and the third is the number of samples in the second row:

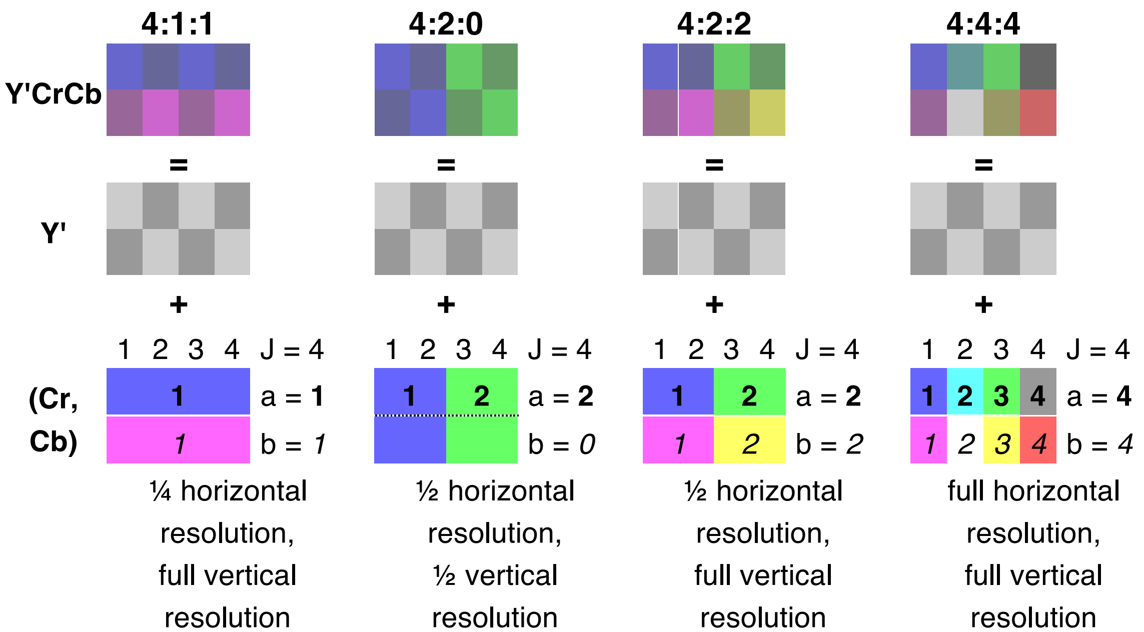


Chart Source: http://en.wikipedia.org/wiki/Chroma_subsampling

Chroma subsampling impacts the test as usually 10-bit codecs use a 4:2:2 sample, where chroma is sampled at half the rate of luma, which reduces the overall bandwidth by 1/3. 8-bit codecs usually use a 4:2:0 sample which samples vertically and horizontally (as compared to 4:2:2 which only samples horizontally) because the chroma channels are only sampled on each alternate line.[4] However this is not always the case. For example YUV422 allows 8-bit interleafed 4:2:2 subsampling, which is what Apple uses in its 8-bit Uncompressed codec.

METHODOLOGY

Two different sources from each analog video format were chosen. VHS samples were from a Sonic Youth concert and the opening trailer reel from a Warner Brothers film. Both were chosen for the variety of color present and because

[4] http://en.wikipedia.org/wiki/Chroma_subsampling

there was not a color bar sample available for the VHS during the test. The ¾" Umatic sources were SMPTE color bars and a section from a Sonic Youth video that was made up of many different layered colors. The BetacamSP samples were SMPTE color bars and a segment from a music video that was chosen for its fast movement and color gradation.

Depending on the source thirty seconds to one minute was captured in both 8 bit uncompressed NTSC 48 kHz and 10 bit uncompressed NTSC 48 kHz formats. The following are the signal paths used for capture:

BetacamSP

Sony UVW1800 -> component out -> Blackmagic Decklink Studio 2

¾" Umatic

Sony BVU950 -> composite out -> TBC DPS295 -> composite-> Blackmagic Decklink Studio 2

VHS

Samsung SV5000W VHS -> composite out ->Blackmagic Decklink Studio 2

The clips were then brought into Final Cut Pro for comparison. Each clip was viewed with the Final Cut Pro video scopes tool turned on. The 10 bit and 8 bit clips were then brought into the sequence editor and cropped using Motion's crop tool and matched by frame so that the 10 bit sample was on the left and the 8 bit sample was on the right. This was then exported using QuickTime as a 10 bit Uncompressed NTSC 48 kHz file. This was done to provide a source for a subjective qualitative analysis of the difference between 10 and 8 bit capture. All of the files were put onto an external hard drive and outside of the lab they were run through Color and viewed with the waveform monitor's overlay display, which lays the red green, and blue channels over each other and areas where they overlap appear white. They were also viewed through RGB histogram, which compares the relative distribution of each color channel across the tonal range of the frame.

FINDINGS

Initially I expected that the 8-bit captures would show banding in areas were color gradients were present. This is an issue where there aren't enough bits to represent the full range of colors and the colors appear to be stepped and the gradient is no longer smooth. This is especially noticeable in things like sunsets where there are a lot of colors present in the analog signal. However I quickly discovered that no banding took place in any of the sample clips I ingested. Even with the ¾" Umatic sample where the color bar included a gradient there was no noticeable banding. In fact, in an informal survey conducted with the split screen samples, I couldn't find anyone who could discern the difference between the 10-bit and 8-bit samples. This follows from a previous test run at the Barbara Goldsmith Preservation and Conservation Department at Bobst over the summer.

The test used 30 clips at 10 seconds each that were digitized from various analog sources. Each clip was rendered in 5 codecs: 10-bit uncompressed, 8-bit uncompressed, DV25, DV50 and IMX MPEG. Each clip was assigned a number 1 to 30 and each codec was assigned a number as follows:

1. 10 bit uncompressed
2. 8 bit uncompressed
3. DV25

4. DV50
5. IMX MPEG

The test used random.org's integer and sequence generators in order to eliminate as much bias as possible in the choices of clip order and type of codec played during the test. The sequences were set to values of 1 to 30 in 1 column. This was copy and pasted to column 2 of the spreadsheet and defined the clip # that was to be played by the test giver. The integers were set to give us an output of 60 random integers with a value between 1 to 5 in 2 columns of 30. These were copied and pasted into two columns (3 and 4) of the spreadsheet. These columns defined the codecs that were to be played by the test giver.

The test subjects were tested one at a time and given the instructions verbally by the test taker. They were given a sheet and a pencil and sat in front of the monitor. The test giver played the sequences within Final Cut Pro telling the test taker which cycle number they were on to avoid confusion. Between each test a screen of 20% gray was displayed. Each test took between 15 and 20 minutes. In total 5 test subjects were tested. Each subjects test was randomized separately for both clip order and codec choice. The test subjects were asked to subjectively compare the clips in terms of visual quality on a scale of 1 to 5 based on the following criteria:

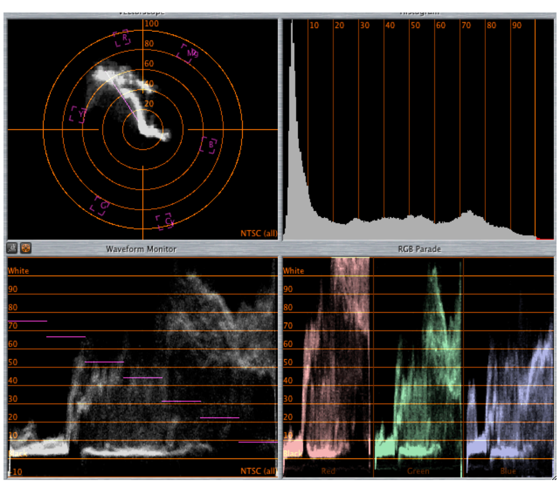
1. Clip A is much better than Clip B
2. Clip A is slightly better than Clip B
3. Clip A is equal to Clip B
4. Clip A is slightly worse than Clip B
5. Clip A is much worse than Clip B

The sample size used as proof of concept for the test was too small to conclusively determine but a Mean Comparison was done and the results were as follows:

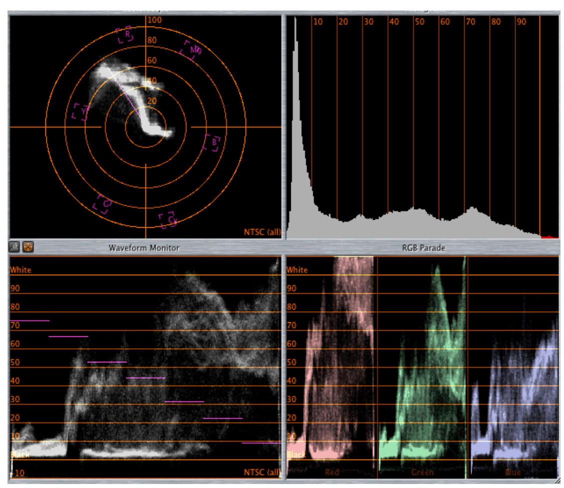
	1	2	3	4	5
1	2.83	3.00	3.00	2.00	3.75
2	1.83	4.00	3.40	2.83	3.00
3	2.00	3.00	2.70	2.80	3.00
4	3.00	2.80	3.50	3.50	2.33
5	2.67	2.50	3.25	2.83	2.67

The findings show that the mean choice across the sample test subjects was close to 3, or that they were unable to determine a qualitative difference between 10-bit and DV25, let alone 10-bit and 8-bit uncompressed formats.

The video scopes show a similar lack of discernable difference in the signals:

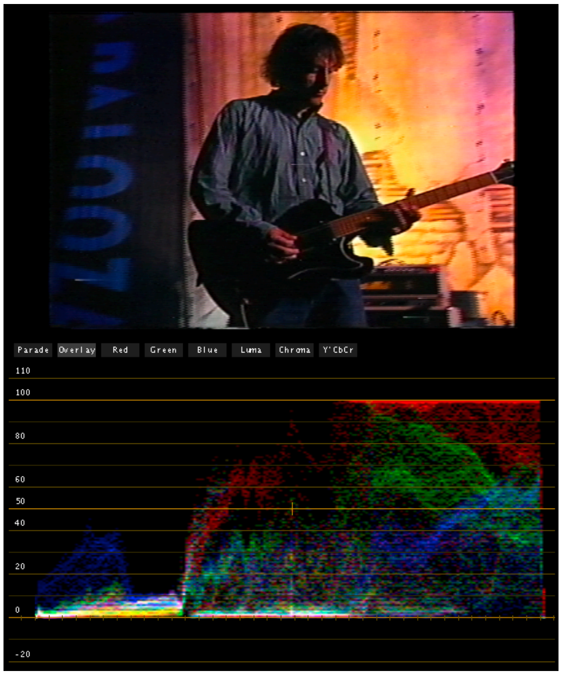


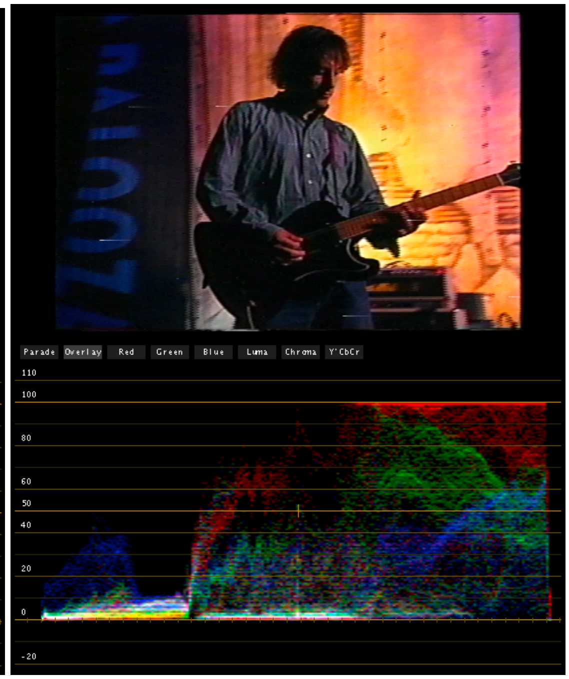
10 bit VHS sample from Sonic Youth



8 bit VHS sample from Sonic Youth

Even when brought into color, which has a larger array of tools for color analysis, the difference just can't be seen:

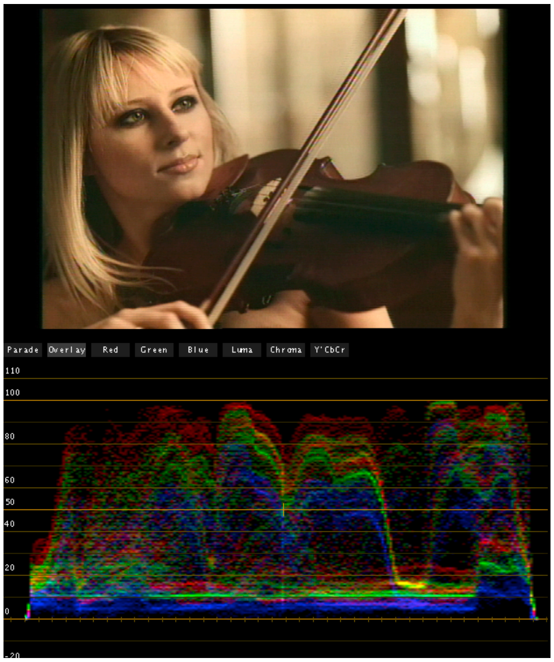


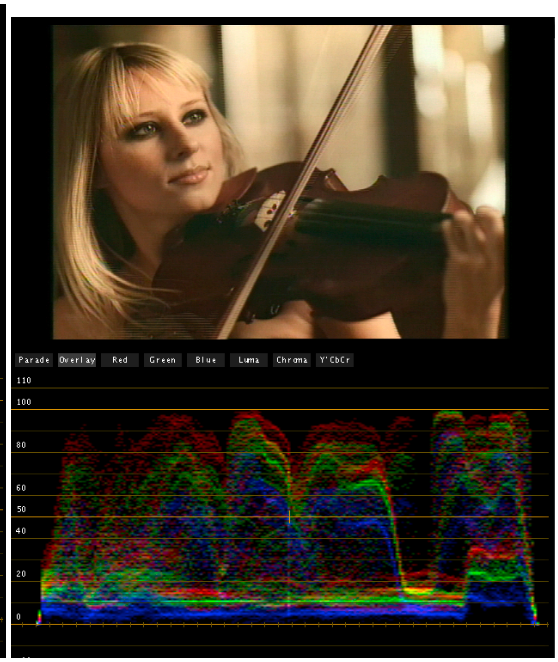


10bit VHS sample from Sonic Youth

8bit VHS sample from Sonic Youth

Even on the BetacamSP music video sample, which had a much cleaner higher resolution image than the dropout and noise prone VHS and Umatic tapes, the difference was negligible:





10-bit BetacamSP sample 8-bit BetacamSP sample

Perhaps these results are not surprising as both the 8-bit and 10-bit codecs in Final Cut Pro use a 4:2:2 chroma subsampling rate in the YUV (YCbCr) color range. The scopes are analyzing the lines of the image from left to right and the results are plotted on the waveform relative to the scale used (-20 to 110 IRE here). Despite the increased color possibility of 10-bit the 8-bit codec managed to reproduce the analog signal for playback on computer monitors well. Even using the MIAP lab's CRT monitor the difference could not be seen.

CONCLUSION

In archiving we are trained to always capture the most information from the source during digitization. Following this maxim 10-bit capture is preferable as it captures the most color information from the source. The storage for both is large, 8-bit is about 1.25 Gb/min and 10-bit is about 1.7 Gb/min, and must be factored into the decision when deciding what codec an institution will choose. The other thing that must be brought into this decision is the quality of the original source. If it was a home movie shot on a low grade consumer VHS recorder and the image quality is severely compromised would capturing at 10-bit really make a difference over say DV50? Bit depth is important in the production process and if something needs a lot of color correction in post then it is better to capture at 10-bit to allow manipulation of the color easier.

This could also be a factor of viewing things on 8-bit monitors or a quirk of human visual biology. Using tests like PSNR (peak signal to noise ratio) could objectively determine video quality, and results such as Pierre Larbier's test "Using 10-bit AVC/H.264 Encoding with 4:2:2 for Broadcast Contribution" show that you can expect to see better results in compression schemes using higher bit depth as things like motion compensation, intra prediction and in-loop filtering.[5] A longer and more structured test that would not be possible in the time frame allotted in class would be required for a more objective analysis of the video. To the human eye there is no discernable difference, but with storage becoming cheaper 10-bit will not be significantly more expensive to store than 8-bit. Most small institutions cannot afford uncompressed format storage, and codecs are better at compressing video and color while maintaining the quality at a lower bandwidth. So even though best practice dictates that we capture at 10-bit, in reality a much smaller lossy codec may be necessary. More qualitative and objective testing must be done covering a wider range of codecs in order to serve the needs of smaller institutions as well as large.

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[5] Larbier is from ATEME and his report can be found here: http://x264.nl/x264/10bit_01-ateme_pierre_larbier_422_10-bit.pdf