APPENDIX A

ADJUSTING A VIDEO MONITOR

The Importance of a Good Video Monitor

We all watch TV and use computers without much thought about how the screens are adjusted for brightness and color. When shooting or editing video, however, having a properly adjusted picture monitor is critical to evaluating and controlling the picture.

While shooting, a monitor displays a likeness of what the camera is capturing, which is not necessarily identical to what the camera is *actually* capturing to tape or disk. The color, shadow detail, contrast, or overall brightness shown by the monitor may or may not match what the camera is actually capturing due to the type and quality of the monitor and the way it is adjusted. The problem here is "seeing is believing"—a concept that's hard-wired into our brains. Whether the monitor is correct or not, we tend to believe what it shows. We'll be tempted to make exposure decisions based on what we see on the monitor, and often make the mistake of giving credence to LCD viewfinders or flip-out screens, only to later discover on a proper CRT picture monitor that the image looks markedly different.

While editing on an NLE, we tend to accept what we see on the computer's monitor, although computer monitors can't accurately reproduce video color space or contrast (see p. 200). Given that NLEs permit sophisticated color correction, this sets the stage for disaster unless color decisions are based on a properly adjusted picture monitor, usually a CRT (though LCDs and plasmas are improving). If you use an NLE's computer screen to color-correct video, you may be in for a nasty shock when the results are played back on a TV.

When your movie is finished and it's time to screen it, video projector adjustment is equally important. A lot of energy goes into producing your project, and you want it to look as good as possible. You want the results on the screen to match all the painstaking color correction you labored over.

In other words, there's no substitute for a good-quality, properly adjusted video picture monitor in production or post. It's a necessity. Video monitors and projectors should always be *set up* (adjusted) using a video signal that contains standard color bars. Today there are many display technologies in use (see Video Monitors and Projectors, p. 197), and the unfortunate fact of the matter is that your movie may look somewhat different on different devices even if they're set up properly. Procedures for adjusting the display, and even terms used for different controls vary between systems.

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While theatrical projection is usually done in a very dark room, video monitors are by design brighter than projection and usually look better with a *little* light in the room. Make sure light sources don't fall directly *on* the screen (which washes out the blacks, lowering contrast, and can affect color reproduction). For production work outdoors, a hood or shade can be fitted over the monitor to protect contrast.

An excellent resource for setting up monitors is Joe Kane's *Digital Video Essentials*, which is available on DVD and other formats and includes test patterns and instructions for calibrating video and multichannel audio playback. For instructions on adjusting computer monitors, see the help section in your operating system, video card, or monitor calibration software. Many systems have a simple step-by-step process you can follow to calibrate the display. Bear in mind, again, that computer monitors, however perfectly set up, can not accurately display video color or tonality.

The color bars setup described below applies to video monitors and TVs only. If any terms are unfamiliar, see Chapters 1 and 5.

Color Bars

Once you have your monitor, it needs to be adjusted correctly for color, shadow detail, and contrast using *color bars*—the only method that truly guarantees that what you see is *really* what you get. Most cameras and NLEs generate color bars. You can send a signal directly into the production monitor or NLE video monitor, or you can record the bars for adjustment from playback. If you're shooting a series of tapes, you need only about 30 seconds of color bars at the head of the first tape for later reference.

In NTSC countries, SMPTE ECR-1 bars are used for standard definition video (see Fig. A). This pattern is 4:3 aspect ratio, with the color bars occupying the upper part of the pattern. From left to right these bars are 75 percent white (a light gray), yellow, cyan, green, magenta, red, and blue. Directly below the bars is a thin horizontal band of color rectangles, one rectangle per color bar. The bottom of the

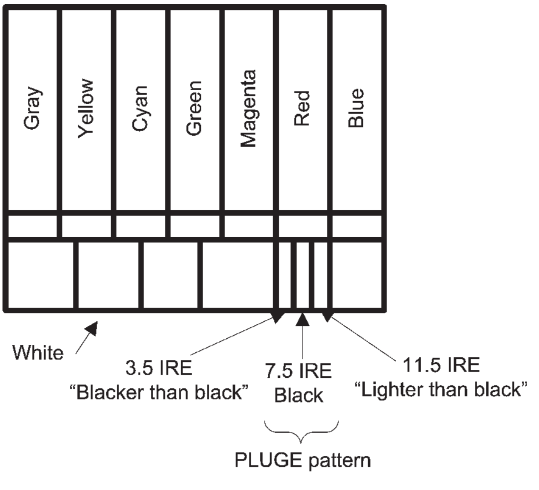

Fig. A. Conventional SMPTE ECR-1 color bars (see also Fig. 3-11).

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pattern is mostly occupied by squares of black and white and dark colors. Each of these bars and pattern elements plays a role—as described below—in fast and accurate monitor setup.

Another common color bar pattern, also 4:3, consists of eight vertical color bars alone (the ones described above plus a black bar on the far right). These non-SMPTE "full-field" color bars are often found in consumer cameras and are of limited use for setting up NTSC monitors. Don't bother with them. In PAL countries, however, they are known as European Broadcasting Union (EBU) bars. Note that the left-most bar in NTSC is always 75 percent white (light gray), while the left-most bar in the EBU pattern is always 100 percent white. SMPTE bars have a clever design that allows repeatable monitor setup visually (without using a waveform monitor), which is not possible with EBU bars because of PAL's different signal architecture.

Since 2002 there's a new color bar pattern called SMPTE RP 219-2002, with a 16:9 aspect ratio and a redesigned pattern intended for high definition (see Fig. B). Also called ARIB bars, it looks like the original SMPTE ECR-1 bars, only with an additional 40 percent gray bar on each end. Along the bottom is a new configuration of sample areas, including a smooth gray scale "ramp." The techniques described below for setting up standard definition monitors using the conventional SMPTE color bars apply equally to the widescreen SMPTE RP 219-2002 color bars if you simply ignore the added 40 percent gray bars on the sides.

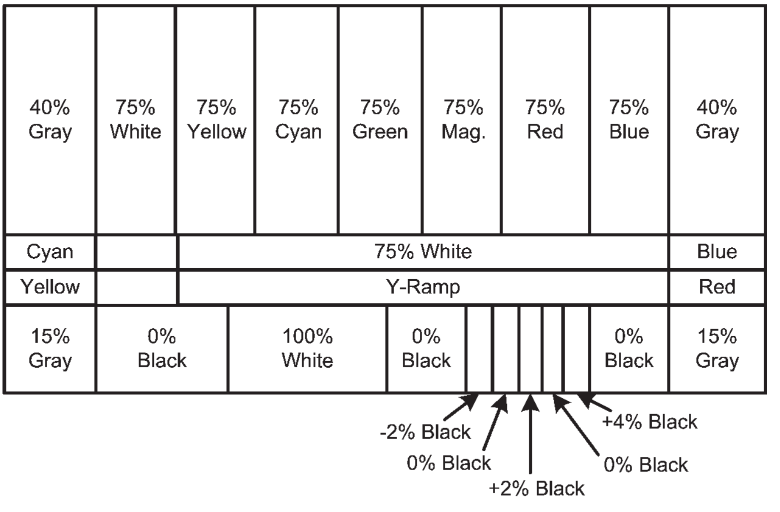

Fig. B. Widescreen SMPTE RP 219-2002 color bars for HD.

Basic Monitor Controls

Two of the main controls on a professional video monitor are *brightness* (sometimes labeled *black level*, or indicated by an icon of the sun) and *contrast* (white level, also called *picture*, and may have an icon of a half-moon). These features are badly named, as the brightness control mainly raises and lowers the blacks, which your eye perceives largely as a change in contrast.

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NTSC color monitors also have adjustments for *hue* (also called *tint*, *phase*, or *chroma phase*) and *color* (saturation, also called *chroma* or *chroma gain*).

Depending on the video system and type of connection, not all of these controls may be used. For example, most PAL TVs and monitors don't have hue (tint) or color (saturation) controls because PAL color stays consistent. Also, when a monitor is connected digitally by DVI or HDMI to the video source, sometimes not all of these adjustments are operative.

Many consumer TV sets have automatic or "smart" settings for color and brightness; turn these off if you are adjusting a TV to color bars.

HOW TO SET UP AN NTSC MONITOR USING SMPTE COLOR BARS

1. **Allow Monitor to Warm Up**

   Run it 15 minutes to stabilize it.

2. **Check Color Temperature**

   Most monitors have a menu setting for color temperature (*white point*), which must be set to a world standard of 6500°K (also called D65) for both NTSC and PAL/SECAM video. If in doubt, check the monitor's menu to confirm the setting. This is not an adjustment you will have to make often.

3. **Set Black Level**

   The control labeled "brightness" on many monitors actually controls the black level, which is the value of the darkest black parts of the image. When brightness is set too low, you lose detail in the blacks (crushed blacks). When brightness is set too high, the blacks look milky or gray.

   In the bottom right-hand corner of the SMPTE bars are three thin vertical gray stripes called PLUGE bars (Picture Line-Up Generating Equipment). Adjusting picture black levels using PLUGE bars takes advantage of the fact that NTSC puts its black level at 7.5 IRE units (instead of at zero as is done with PAL), so it's possible to have an NTSC signal that's "blacker than black." The PLUGE bar on the left represents a 3.5 IRE level ("superblack" or "blacker than black"), the middle one is 7.5 IRE (black), and the right bar is 11.5 IRE (gray or "lighter than black"). Because no NTSC picture detail can truly be blacker than black, all you have to do is to adjust the brightness control until the left and middle bars are indistinguishable. Lower the brightness until the two darker bars merge together, raise it again until you can see three stripes, then decrease it until the darker bars *just* merge again. The gray bar on the right should be just barely visible. That's all there is to it.

   The new widescreen SMPTE RP 219-2002 color bars have a slightly different PLUGE arrangement, with five thin bars that represent -2 percent black, 0 percent black, +2 percent black, 0 percent black, +4 percent black, but the idea is the same. The HD monitor should be adjusted so that the -2 percent black and 0 percent black levels are indistinguishable.

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When adjusting a PAL monitor, since PAL uses the full 1 to 100 IRE unit range for picture detail, there is no blacker-than-black signal. You can still accurately set black level on a PAL monitor by displaying the full-field EBU bars described above, putting the monitor in underscan, then visually matching the black color bar on the right to the black level outside of the active picture area.

4. Set Peak White Level

The "contrast" or "picture" control adjusts the level of midtones and bright whites. It sets the distance or separation between the black level and the brightest whites. In the both the classic and new widescreen SMPTE color bars, there's a square in the bottom row that is 100 percent white. (Note that in NTSC, none of the full-sized bars in the upper area is 100 percent white.) Bring the contrast up until the 100 percent square is comfortably bright, but don't set it so high that the white seems to bloom (get fuzzy and larger in size) or other geometrical distortions occur. The 100 percent white square shouldn't spread into neighboring black bars. If you can see scan lines, adjust the contrast for a bright white, then back off slightly until the bleeding together of scan lines diminishes and separate scan lines are clearly visible.

Often, setting the contrast may change your black level, so you may have to go back and forth between the contrast and brightness settings a few times.

5. Set Chroma and Hue

When adjusting NTSC video, hue and saturation (chroma) should be set together. They will affect each other, so you may have to do each more than once.

This is where SMPTE color bars are so handy. If you have a professional monitor, enable the "blue gun" or "blue only" function (sometimes it's a switch or button on the outside, sometimes it is a menu selection). This will turn off the red and green so that the screen turns deep blue (or sometimes black-and-white). If your monitor doesn't have a blue-gun function, you can view the color bars through a Lee 363 blue gel, although this is much less satisfactory.

In blue only mode, adjust chroma (or color) until the two outer SMPTE ECR-1 bars, now both blue, achieve the same intensity or brightness as the small color rectangles directly below them. When this is done, the two outer bars should also match each other (see Fig. C).

Now adjust the hue (or phase) in a similar way, so the near left and right blue bars and the small color rectangles below them are the same. Counting from the left, these would be bars 3 and 5 (see Fig. D).

All four bars should now match each other and

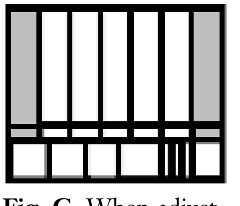

Fig. C. When adjusting color (chroma) on a monitor that displays blue only, these two bars and the patches under them should have the same intensity.

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the small rectangles under them. If this isn't the case, re-tweak chroma/color and hue/phase until you achieve this. The two adjustments are interactive, but it isn't very hard to obtain a good result.

Now leave blue only mode and *voilà!*—perfect color and saturation.

If you have only full-field bars (instead of true SMPTE bars with color rectangles and PLUGE), match the first and seventh bars from the left in blue only mode by adjusting chroma, and match the third and fifth bars from the left by adjusting hue (phase). All four should then match each other. Be sure that you are using NTSC full-field bars with white at 75 percent instead of PAL bars with white at 100 percent.

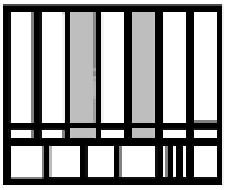

Fig. D. When adjusting hue (tint) on a monitor that displays blue only, these two bars and the patches under them should have the same intensity.

If you don't have a way to display blue only, look especially at the yellow and magenta bars (second and fifth from the left). There's only one hue setting in which both will be correct. The yellow should be a pure lemon yellow, without any hint of green or orange. The magenta bar shouldn't be red or purple. Color level should be rich but not oversaturated.

Getting accurate color without bars is very difficult, since there is no way to know what colors should look like. The best you can do is to go for the most pleasing skin tones. Make the hue and saturation (color intensity) of the skin as natural as possible.

Another method is to look at a shot of a gray test panel and try to adjust hue until there's no color cast in the gray.

OTHER MONITOR SETUP CONSIDERATIONS

Sharpness

Most video monitors and TVs have a sharpness control (also called aperture or detail) that adds a light line around the edges of things in the scene (see Fig. 3-14). In actuality, this *reduces* fine detail, even though shapes look bolder. Turn this all the way down, then raise it until you just reach the point where added lines appear. Get used to watching pictures without added "sharpness." One exception is that professional camcorders often have a detail adjustment in the viewfinder called "peaking" that can help you focus while shooting. The picture in the finder doesn't look "natural," but you can clearly see what's in and out of focus.

Gamma

Computer monitors and some broadcast video monitors have adjustments for gamma. The standard display gamma in Windows and sRGB (web graphics) is 2.2. This is also a standard for NTSC CRT monitors. The Mac (Apple) standard is 1.8, but some people prefer to set Mac systems higher, closer to 2.2. PAL gamma is up

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to 2.8. The gamma of a playback system is determined not just by the monitor's gamma but by the entire chain of image-processing software and hardware in the system.

Lower display gamma makes the image appear to have less contrast. The fact that different playback systems have different gamma can result in contrast looking different, depending on which system you're viewing on. You should try to view your video the way you think most viewers will see it.

Downloadable programs such as QuickGamma can be used for computer monitor calibration. For extremely precise monitor calibration, you can get tools (such as ColorVision OptiCAL and PhotoCAL) with a photometric "spyder" that sits on the monitor surface and measures light output.

Termination

Some monitors have multiple BNC connectors so you can both input and output an analog video signal (composite or component). These can be used to send the analog signal via coaxial cable into the monitor and then out again to connect to another piece of equipment (the signal is then "looped through" or "bridged"). This way, you can connect several monitors together on one line (such as a waveform, vectorscope, and several video monitors). The last monitor on the chain of coaxial cable (or the only monitor if there's only one) needs to be "terminated." Some analog monitors offer automatic termination as a feature. Some instead have a termination switch labeled "75 Ohm Terminator" or just "75 Ω." Switch to the 75 Ω position to terminate. You can also get a special 75 Ω terminator plug to attach to the video-out BNC jack of the last monitor in the chain. Don't use *both* a plug and the switch. An analog monitor not properly terminated will show a noisy, contrasty image with distorted highlights and subtle ghosting. The 75 ohm termination is a requirement of coaxial cable in particular, and therefore affects delivery of SDI and HD-SDI signals too, but monitors that accept these signals are always auto-terminated. Termination is not an issue for short runs of S-Video, DVI, or HDMI.

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APPENDIX B

DATA RATES AND STORAGE NEEDS FOR VARIOUS DIGITAL FORMATS*

Frame rate note: "24" = 24 or 23.98; "30" = 29.97; "60" = 59.97

	Video Data Rate (Mbps)	Nominal Compression Ratio[1]	Frame Rate	Chroma Sampling	Bits	STORAGE per minute[2]	STORAGE per hour[2]	Notes
STANDARD DEFINITION[3]								
DVD	3.8[4]	31:1	30, 25, 24	4:2:0	8	37 MB	2.3 GB	MPEG-2 variable bit rate
M-JPEG (offline editing)[5]	8	25:1	30, 25, 24	various[5]	8	60 MB	260 MB	
DV	25	5:1	30, 25[6]	4:1:1 NTSC 4:2:0 PAL	8	217 MB	12.7 GB	
Digital8	25	5:1	30, 25	4:1:1 NTSC 4:2:0 PAL	8	217 MB	12.7 GB	
DVCAM	25	5:1	30, 25	4:1:1 NTSC 4:2:0 PAL	8	217 MB	12.7 GB	
DVCPRO (D-7)[7]	25	5:1	30, 25	4:1:1[8]	8	217 MB	12.7 GB	
Betacam SX	18	10:1	30, 25	4:2:2	8	188 MB	11.3 GB	Sony MPEG-2 tape format
DVCPRO 50	50	3.3:1	30, 25	4:2:2	8	423 MB	24.8 GB	Panasonic DV format
Digital S (D-9)	50	3.3:1	30, 25	4:2:2	8	423 MB	24.8 GB	JVC DV format; ½-inch tape
IMX (D-10)	30	6:1	30, 25	4:2:2	8	227 MB	13.25 GB	Sony MPEG-2 format
IMX (D-10)	40	4:1	30, 25	4:2:2	8	298 MB	17.4 GB	
IMX (D-10)	50	3.3:1	30, 25	4:2:2	8	370 MB	21.7 GB	
ProRes 720 x 486	42	6:1	30	4:2:2	10	320 MB	19.2 GB	Apple editing and finishing codec
ProRes HQ 720 x 486	63	4:3:1	30	4:2:2	10	470 MB	28.2 GB	
XDCAM[9]	—	—	—	—	—	—	—	
Digital Betacam	90	2.3:1	30, 25	4:2:2	10	675 MB	40.5 GB	Sony compression
ITU-R 601 (D-1, D-5)	216[10]	uncomp.	30, 25[6]	4:2:2	8	1.2 GB	71 GB	
ITU-R 601 (D-1, D-5)	270[10]	uncomp.	30, 25[6]	4:2:2	10	1.6 GB	94 GB	

*Table by David Leitner.

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	Video Data Rate (Mbps)	Nominal Com-pression Ratio[1]	Frame Rate	Chroma Sampling	Bits	STORAGE per minute[2]	STORAGE per hour[2]	Notes
HIGH DEFINITION—COMPRESSED								
Where multiple frame rates exist, data rates and storage indicated for highest frame rate.								
DVD— 1280 x 720	6[4]	various	24	4:2:0	8	45 MB	2.7 GB	MPEG-4 AVC (H.264)VC-1
DVD— 1920 x 1080	8[4]	various	24	4:2:0	8	60 MB	3.6 GB	
HD-DVD	36[11]	various	30, 25, 24	4:2:0	8	270 MB	16.2 GB	MPEG-2, VC-1, MPEG-4 AVC (H.264)
Blu-ray	36[11]	various	30, 25, 24	4:2:0	8	270 MB	16.2 GB	
HDV1— 1280 x 720p	19.7	17:1	60, 50 30, 25	4:2:0	8	142 MB	8.3 GB	MPEG-2 constant bit rate
HDV2— 1440 x 1080i	25	22:1	30, 25	4:2:0	8	190 MB	11.3 GB	
HDV— 1280 x 720p @ 24fps	19.7	13.5:1	24	4:2:0	8	142 MB	8.3 GB	JVC only, not HDV standard
AVCHD— 720p	14	16:1	60, 50, 24	4:2:0	8	180 MB	10.8 GB	MPEG-4 AVC (H.264) variable bit rate
AVCHD 1920 x 1080i/p	18	16:1	30, 25, 24	4:2:0	8	180 MB	10.8 GB	
XDCAM HD 1440 x 1080i/p	18	n.a.	30, 25, 24	4:2:0	8	140 MB	8.2 GB	MPEG-2, variable bit rate subsampled horizontally
XDCAM HD 1440 x 1080i/p	25	22:1	30, 25, 24	4:2:0	8	190 MB	11.1 GB	MPEG-2, constant bit rate, subsampled horizontally.Equivalent to HDV 1080i
XDCAM HD 1440 x 1080i/p	35	n.a.	30, 25, 24	4:2:0	8	262 MB	15.3 GB	MPEG-2, variable bit rate, subsampled horizontally
JPEG 2000 1920 x 1080	50	n.a.	30, 25, 24	4:2:2	10	375 MB	22.5 GB	Intraframe wavelet compression. Used in Grass Valley Infinity camcorder.
JPEG 2000	75	n.a.	30, 25, 24	4:2:2	10	563 MB	33.8 GB	
JPEG 2000	100	n.a.	30, 25, 24	4:2:2	10	750 MB	45 GB	
D9 HD— 960 x 720p	100	6.7:1	60, 50, 30 25, 24	4:2:2	8	835 MB	49 GB	
D9 HD— 1280 x 1080i/p	100	6.7:1	30, 25, 24	4:2:2	8	835 MB	49 GB	
DVCPRO HD (D-12) 960 x 720p	100	6.7:1	60, 50, 30 25, 24	4:2:2	8	835 MB	49 GB	subsampled horizontally
DVCPRO HD (D-12) 1280 x 1080i/p	100	6.7:1	30, 24	4:2:2	8	835 MB	49 GB	
DVCPRO HD (D-12) 1440 x 1080i/p	100	6.7:1	25	4:2:2	8	835 MB	49 GB	
AVC-Intra 1440 x 1080i/p	50	n.a.	30, 25, 24	4:2:0	10	375 MB	22.5 GB	Panasonic P2 alternative to DVCPRO HD
AVC-Intra 1920 x 1080i/p	100	n.a.	30, 25, 24	4:2:2	10	750 MB	45 GB	
DNxHD 145 1280 x 720p	145	7:1	60, 50, 24	4:2:2	8	1 GB	56 GB	AVID intraframe compression. Future SMPTE VC-3 standard.

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HIGH DEFINITION—COMPRESSED (continued)								
DNxHD 220 1280 x 720p	220	4:1	60, 50, 24	4:2:2	8	1.6 GB	100 GB	AVID intraframe compression. Future SMPTE VC-3 standard.
DNxHD 220 1280 x 720p	220	6:1	60, 50, 24	4:2:2	10	1.6 GB	100 GB	
DNxHD 145 1920 x 1080i/p	145	7:1	30, 25, 24	4:2:2	8	1 GB	56 GB	
DNxHD 220 1920 x 1080i/p	220	4:1	30, 25, 24	4:2:2	8	1.6 GB	100 GB	
DNxHD 220 1920 x 1080i/p	220	6:1	30, 25, 24	4:2:2	10	1.6 GB	100 GB	
DNxHD 36	36	24:1	24, 25	4:2:2	8	270 MB	16.2 GB	offline only
ProRes 1280 x 720 p	147	7:1	24, 25, 30, 60	4:2:2	10	1.1 GB	66 GB	Apple codec. Storage listed is for 60 fps.
ProRes HQ 1280 x 720 p	220	6:1	24, 25, 30, 60	4:2:2	10	1.65 GB	99 GB	
ProRes 1920 x 1080	147	7:1	24, 25, 30	4:2:2	10	1.1 GB	66 GB	Apple codec. Storage listed is for 30 fps.
ProRes HQ 1920 x 1080	220	6.1	24, 25, 30	4:2:2	10	1.65 GB	99 GB	
D5 HD 1280 x 720p	223	4:1	60	4:2:2	8	2.3 GB	135 GB	advanced M-JPEG 4 channels audio
D5 HD 1920 x 1080i	223	4:1	30	4:2:2	8	2.3 GB	135 GB	
D5 HD 1920 x 1080p	223	4:1	24	4:2:2	8	1.94 GB	116 GB	advanced M-JPEG 8 channels audio
D5 HD— 1920 x 1080i/p	223	4:1	25	4:2:2	8	2 GB	121 GB	
HDCAM (D-11) 1440 x 1080i/p	144	4.4:1[12]	30, 25, 24	3:1:1	8	1.1 GB	64.8 GB	Sony compression, subsampled horizontally
HDCAM SR (D-16) 1920 x 1080i/p	440	2.78:1	30, 25, 24	4:2:2	10	3.3 GB	198 GB	MPEG-4 Studio Profile
HDCAM SR (D-16) 1920 x 1080i/p	440	4.2:1	30, 25, 24	4:4:4	10	3.3 GB	198 GB	
HIGH DEFINITION—UNCOMPRESSED								
1280 x 720p (8 bits)	353.6		24	4:2:2	8	2.5 GB	149 GB	
1280 x 720p (8 bits)	368.3		25	4:2:2	8	2.6 GB	155 GB	
1280 x 720p (8 bits)	441.9		30	4:2:2	8	3.1 GB	186 GB	
1280 x 720p (8 bits)	737.3		50	4:2:2	8	5.2 GB	310 GB	
1280 x 720p (8 bits)	883.9		60	4:2:2	8	6.2 GB	371 GB	
1280 x 720p (10 bits)	442.4		24	4:2:2	10	3.4 GB	201 GB	
1280 x 720p (10 bits)	460.9		25	4:2:2	10	3.5 GB	209 GB	
1280 x 720p (10 bits)	552.5		30	4:2:2	10	4.2 GB	251 GB	

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HIGH DEFINITION—UNCOMPRESSED (continued)								
1280 x 720p (10 bits)	921.8		50	4:2:2	10	7.0 GB	418 GB	
1280 x 720p (10 bits)	1.10 Gbps		60	4:2:2	10	8.4 GB	501 GB	
1920 x 1080i/p (8 bits)	829		25	4:2:2	8	5.8 GB	348 GB	
1920 x 1080i/p (8 bits)	994.3		30	4:2:2	8	7.0 GB	417 GB	
1920 x 1080p (8 bits)	795.6		24	4:2:2	8	5.6 GB	334 GB	
1920 x 1080p (8 bits)	1.66 Gbps		50	4:2:2	8	11.6 GB	696 GB	
1920 x 1080p (8 bits)	1.99 Gbps		60	4:2:2	8	13.9 GB	834 GB	
1920 x 1080i/p (10 bits)	1.03 Gbps		25	4:2:2	10	7.7 GB	464 GB	
1920 x 1080i/p (10 bits)	1.24 Gbps		30	4:2:2	10	9.3 GB	559 GB	
1920 x 1080p (10 bits)	993		24	4:2:2	10	7.4 GB	446 GB	
1920 x 1080p (10 bits)	2.07 Gbps		50	4:2:2	10	15.5 GB	928 GB	
1920 x 1080p (10 bits)	2.48 Gbps		60	4:2:2	10	18.6 GB	1.1 TB	
1280 x 720p	1.69 Gbps		60	RGB 4:4:4	10	12.4 GB	742 GB	
1920 x 1080i/p	1.58 Gbps		25	RGB 4:4:4	10	11.6 GB	695 GB	
1920 x 1080i/p	1.90 Gbps		30	RGB 4:4:4	10	14 GB	834 GB	
DIGITAL CINEMATOGRAPHY								
CineForm RAW 1920 x 1080	96	5:1	24	RAW	10	720 MB	43.2 GB	in-camera wavelet
RAW HD 1920 x 1080	498	uncomp.	24	RAW	10	3.7 GB	224 GB	single sensor Bayer filter
RAW 3K 3018 x 2200[13]	1.91 Gbps	uncomp.	24	RAW	12	14.3 GB	860.5 GB	Arri D-20 single sensor
RAW 4K 4046 x 2048	3.18 Gbps	uncomp.	24	RAW	16	23.9 GB	1.43 TB	Dalsa Origin
HDCAM SR (1920 x 1080p)	880	2:1	24	RGB 4:4:4	10	6.6 GB	396 GB	
1920 x 1080p	1.49 Gbps	uncomp.	24	RGB 4:4:4	10	11.1 GB	667 GB	dual-link HD-SDI
2K (2048 x 1556)[13]	2.29 Gbps	uncomp.	24	RGB	10	17.3 GB	1.04 TB	
4K (4096 x 3112)[13]	9.18 Gbps	uncomp.	24	RGB	10	70.3 GB	4.22 TB	
AUDIO FOR DIGITAL VIDEO								
32 kHz—PCM	0.768	uncomp.		2 channels	12	5.8 MB	.35 GB	DV only
48 kHz—PCM	1.536	uncomp.		2 channels	16	11.5 MB	.69 GB	
48 kHz—MPEG1	0.384	Audio Layer II		2 channels	16	2.9 MB	172.8 MB	HDV only
96 kHz—PCM	18.432	uncomp.		8 channels	24	138.2 MB	8.3 GB	

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Table by David Leitner

1. Digital video compression encompasses competing techniques from DCT to wavelet compression, constant bit rate to variable, intraframe to interframe. Rarely is compression a simple number or constant ratio, even though we refer to it this way. Each set of techniques may yield a different quality even at the same nominal compression ratio. Compression ratios are therefore unreliable indicators of final picture quality.

2. Where possible, includes overheads for video stream (header and container format) as well as two tracks of 16-bit audio, error detection/correction, timecode, and track information. Actual storage also varies, depending upon factors such as the size and formatting of hard drives. Always keep 25 to 30 percent of disk capacity free as headroom to accommodate variations in disk speeds and data management.

3. Component formats only. Composite digital formats such as D-2 and D-3 not listed.

4. Average video data rate for DVDs is 3.8 Mbps. Compression of standard definition video for DVDs ranges from heavy MPEG-2 compression of 2 Mbps to high-quality compression of 6 Mbps. Maximum DVD data rate is about 10 Mbps.

5. Motion-JPEG (M-JPEG) is not a standardized compression but rather a technique of converting video frames into a sequence of compressed JPEG stills for economical offline editing. There are many variants with different chroma sampling and compression ratios.

6. NTSC 525-line, 29.97 fps digital formats and PAL 625-line, 25 fps formats share virtually identical data rates. The former has a higher frame rate with fewer lines, while the latter has a lower frame rate with more lines. Listing a format as "25, 30" fps in this chart does not imply that all such camcorders and VTRs record and play both standards.

7. Formats with "D" names like D-1, D-5, D-9, etc., are SMPTE standards.

8. Where a single chroma sampling ratio is listed, it applies equally to both NTSC-derived and PAL-derived digital formats.

9. Standard definition XDCAM is not a compression but rather a disc-based capture technology for camcorders. It uses both DVCAM (25 Mbps) and IMX (30, 40, 50 Mbps).

10. These are well-known format rates for Rec. 601 including audio and timecode. The 10-bit data rate of 270 Mbps is the basis of the SMPTE 259M standard that defines the common Serial Digital Interface (SDI). Rec. 601's video bit rates per se are slightly smaller.

11. Nominal baseline bit rate. Blu-ray, for one, can achieve a greater 54 Mbps (1.5x) transfer rate. Forthcoming application of a variety of compression technologies will result in a range of lesser but more practical bit rates to extend programming length.

12. HDCAM MPEG-2 compression is 4.1:1. However, prior to MPEG-2 compression, HDCAM horizontally filters and downsamples an original 1920 x 1080 image to 1440 x 1080. This prefiltering combined with the 4.1:1 MPEG-2 compression creates a cumulative compression of 7.1:1, which is how HDCAM is often described.

13. Aspect ratio is 4:3 like full-aperture 35mm, not widescreen like 16:9 or 1.85. CMOS can omit top and bottom of sensor to output 16:9, dropping data rate by 25 percent.

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