

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

Storage note: GB = 1,000,000,000 bytes (decimal); if media capacity in bytes is binary, media will hold less

Actual storage will vary with size and formatting of media

Video	Nominal Data Rate (Mbps)	Nominal Compression Ratio ²	Frame Rate	Chroma Sampling	Bits ³	Estimated STORAGE per minute ⁴	Estimated STORAGE per Hour ⁴	Notes
STANDARD DEFINITION¹								
DVD	3.8 ⁵	31:1	30, 25, 24	4:2:0	8	37 MB	2.3 GB	MPEG-2, variable bit rate (VBR)
DV	25	5:1	30, 25, 24 ⁶	4:1:1 NTSC 4:2:0 PAL	8	217 MB	13 GB	
DVCAM	25	5:1	30, 25, 24	4:1:1 NTSC 4:2:0 PAL	8	217 MB	13 GB	
DVCPRO (D-7)	25	5:1	30, 25, 24	4:1:1 ⁸	8	217 MB	13 GB	
DVCPRO 50	50	3:3:1	30, 25, 24	4:2:2	8	423 MB	25 GB	Panasonic DV format
IMX (D-10)	30	6:1	30, 25, 24	4:2:2	8	227 MB	14 GB	Sony MPEG-2 format used in XDCAM
IMX (D-10)	40	4:1	30, 25, 24	4:2:2	8	298 MB	18 GB	
IMX (D-10)	50	3.3:1	30, 25, 24	4:2:2	8	370 MB	22 GB	
ProRes 720 x 486	42	6:1	30	4:2:2	0	320 MB	19.2 GB	Variable Bit Rate (VBR)
ProRes HQ 720 x 486	63	4.31	30	4:2:2	0	470 MB	28.2 GB	
Digital Betacam	90	2.3:1	30, 25, 24	4:2:2	10	675 MB	41 GB	Sony compression
ITU-R 601 (D-1, D-5)	216 ⁹	uncomp.	30, 25 ⁶	4:2:2	8	1.6 GB	98 GB	
ITU-R 601 (D-1, D-5)	270 ⁹	uncomp.	30, 25 ⁶	4:2:2	10	2 GB	122 GB	

*Table by David Leitner.

	Video Data Rate (Mbps)	Nominal Com- pression Ratio ²	Frame Rate	Chroma Sampling	Bits ³	Estimated STORAGE per minute ⁴	Estimated STORAGE per Hour ⁴	Notes
HIGH DEFINITION—COMPRESSED								
Where multiple frame rates exist, data rates and storage indicated for highest frame rate.								
DVD— 1280 x 720	6 ⁵	various	24	4:2:0	8	45 MB	2.7 GB	MPEG-4 AVC (H.264), VC-1
DVD— 1920 x 1080	8 ⁵	various	24	4:2:0	8	60 MB	3.6 GB	
Blu-ray	36 ¹⁰	various	30, 25, 24	4:2:0	8	270 MB	16.2 GB	MPEG-2, MPEG-4 AVC (H.264), VC-1
HDV 1— 1280 x 720p	19.7	17:1	60, 50, 30, 25, 24	4:2:0	8	142 MB	10 GB	MPEG-2, constant bit rate (CBR)
HDV 2— 1440 x 1080i	25	22:1	30, 25, 24	4:2:0	8	190 MB	13 GB	
AVCHD— 720p	14	16:1	60, 50, 24	4:2:0	8	180 MB	11 GB	MPEG-4 AVC (H.264), variable bit rate (VBR)
AVCHD—1920 x 1080i/p	18	16:1	30, 25, 24	4:2:0	8	180 MB	11 GB	
H.264/MPEG- 4 AVC various DSLRs	45	various	30, 25, 24	4:2:0	8	320 MB	20 GB	Variable bit rate. Example here from Canon EOS 7D
XDCAM HD— 1280 x 720	19	n.a.	60, 50, 30, 25, 24	4:2:0	8	140 MB	9 GB	MPEG-2, CBR, subsampling horizontally. Offered by JVC, equivalent to HDV 720p.
XDCAM HD— 1280 x 720	25	n.a.	60, 50, 30, 25, 24	4:2:0	8	190 MB	12 GB	MPEG-2, CBR, subsampling horizontally, equivalent to HDV 1080i.
XDCAM HD— 1280 x 720	35	n.a.	60, 50, 30, 25, 24	4:2:0	8	262 MB	16 GB	MPEG-2, VBR, subsampling horizontally.
XDCAM HD— 1440 x 1080i/p	18	42:1	30, 25, 24	4:2:0	8	140 MB	9 GB	MPEG-2, VBR, subsampling horizontally. HQ Mode.
XDCAM HD— 1440 x 1080i/p	25	30:1	30, 25, 24	4:2:0	8	190 MB	12 GB	MPEG-2, VBR, equivalent to HDV 1080i. SP Mode.
XDCAM HD— 1440 x 1080i/p	35	21:1	30, 25, 24	4:2:0	8	262 MB	16 GB	MPEG-2, VBR. LP Mode.
XDCAM HD 422—1280 x 720p	50	20:1	60, 50, 30, 25, 24	4:2:2	8	375 MB	23 GB	
XDCAM HD 422—1920 x 1080i/p	50	20:1	30, 25, 24	4:2:2	8	375 MB	23 GB	MPEG-2, constant bit rate.

	Video Data Rate (Mbps)	Nominal Compression Ratio ²	Frame Rate	Chroma Sampling	Bits ³	Estimated STORAGE per minute ⁴	Estimated STORAGE per Hour ⁴	Notes
HIGH DEFINITION—COMPRESSED (continued)								
XDCAM EX— 1280 x 720p	35	21:1	60, 50, 30, 25, 24	4:2:0	8	263 MB	16 GB	MPEG-2, VBR. HQ mode recorded to SxS cards. Includes Sony EX1, EX3, F3.
XDCAM EX— 1920 x 1080i/p	35	21:1	30, 25, 24	4:2:0	8	263 MB	16 GB	
MPEG-2 Long GOP—1440 x 1080i/p	25	n.a.	30, 25, 24	4:2:0	8	188 MB	12 GB	
MPEG-2 Long GOP—1280 x 720p	35	n.a.	60, 50, 30, 25, 24	4:2:0	8	263 MB	16 GB	
MPEG-2 Long GOP—1920 x 1080i/p	35	n.a.	30, 25, 24	4:2:0	8	263 MB	16 GB	Constant bit rate. Used in Canon C300.
MPEG-2 Long GOP—1280 x 720p	50	n.a.	60, 50, 30, 25, 24	4:2:2	8	375 MB	24 GB	
MPEG-2 Long GOP—1920 x 1080i/p	50	n.a.	30, 25, 24	4:2:2	8	375 MB	24 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	
DVCPRO HD (D-12)— 1280 x 1080i/p	100	6.7:1	30, 24	4:2:2	8	835 MB	49 GB	Subsampled horizontally.
DVCPRO HD (D-12)— 1440 x 1080i/p	100	6.7:1	25	4:2:2	8	835 MB	49 GB	
AVC Intra 50—1440 x 1080i/p	50	n.a.	30, 25, 24	4:2:0	10	375 MB	23 GB	Panasonic P2 alternative to DVCPRO HD
AVC Intra 100—1920 x 1080i/p	100	n.a.	30, 25, 24	4:2:2	10	750 MB	45 GB	
AVC—LongG— 1920 x 1080i/p	25	n.a.	30, 25, 24	4:2:2	10	188 MB	12 GB	Panasonic AVC Ultra based on H.264. Long GOP.
AVC Ultra 200—1920 x 1080i/p	226	n.a.	24	4:2:2	10	1.7 GB	102 GB	Panasonic AVC Intra codec based on H.264.
AVC Ultra 444—720p, 1080p, 4K	440	n.a.	24	4:2:2	10/12	3.3 GB	200 GB	

	Video Data Rate (Mbps)	Nominal Compression Ratio ²	Frame Rate	Chroma Sampling	Bits ³	Estimated STORAGE per minute ⁴	Estimated STORAGE per Hour ⁴	Notes
HIGH DEFINITION—COMPRESSED (continued)								
DNxHD 36— 1920 x 1080i/p	36	24:1	24, 25	4:2:2	8	270 MB	16.2 GB	
DNxHD 145— 1280 x 720p	145	7:1	60, 50, 24	4:2:2	8	1 GB	66 GB	
DNxHD 220— 1280 x 720p	220	4:1	60, 50, 24	4:2:2	8	1.6 GB	100 GB	
DNxHD 220— 1280 x 720p	220	6:1	60, 50, 24	4:2:2	10	1.6 GB	100 GB	AVID intraframe compression, part of SMPTE 2019-2006 (VC-3) standard.
DNxHD 145— 1920 x 1080i/p	145	7:1	30, 25, 24	4:2:2	8	1 GB	66 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	
ProRes 422 (Proxy)— 1920 x 1080i/p	45	20:1	30, 25, 24	4:2:2	10	338 GB	21 GB	
ProRes 422 (LT)—1920 x 1080i/p	102	9:1	30, 25, 24	4:2:2	10	765 GB	46 GB	Variable bit rate. Accepts most image file types, from SD to 4K
ProRes 422— 1920 x 1080i/p	147	6:1	30, 25, 24	4:2:2	10	1.1 GB	67 GB	
ProRes 422 (HQ)—1920 x 1080i/p	220	4:1	30, 25, 24	4:2:2	10	1.65 GB	99 GB	
ProRes 4444— 1920 x 1080i/p	330	n.a.	30, 25, 24	4:4:4	12	2.48 GB	150 GB	Includes an alpha channel
CineForm 422—1920 x 1080	115	n.a.	30, 25, 24	4:2:2	10	863 MB	52 GB	Wavelet compression, VBR. Accepts most image file types, from SD to 4K. Compressed file is typically 15% of the original in size.
CineForm 444—1920 x 1080	230	n.a.	30, 25, 24	RGB	12	1.7 GB	104 GB	
D5 HD—1280 x 720p	223	4:1	60	4:2:2	8	2.3 GB	135 GB	
D5 HD—1920 x 1080i	223	4:1	30	4:2:2	8	2.3 GB	135 GB	Advanced M-JPEG, 8 channels audio.
D5 HD—1920 x 1080p	223	4:1	24	4:2:2	8	1.94 GB	116 GB	
D5 HD—1920 x 1080i/p	223	4:1	25	4:2:2	8	2 GB	121 GB	

	Video Data Rate (Mbps)	Nominal Com- pression Ratio ²	Frame Rate	Chroma Sampling	Bits ³	Estimated STORAGE per minute ⁴	Estimated STORAGE per Hour ⁴	Notes
HIGH DEFINITION—COMPRESSED (continued)								
HDCAM (D-11)—1440 x 1080i/p	144	4.4:1 ¹¹	30, 25, 24	3:1:1	8	1.1 GB	65 GB	Sony compression, subsampling 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	
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 (8 bits)	829		25	4:2:2	8	5.8 GB	348 GB	
1920 x 1080i (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)	829		25	4:2:2	8	5.8 GB	348 GB	
1920 x 1080p (8 bits)	994.3		30	4:2:2	8	7.0 GB	417 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 (10 bits)	1.03 Gbps		25	4:2:2	10	7.7 GB	464 GB	
1920 x 1080i (10 bits)	1.24 Gbps		30	4:2:2	10	9.3 GB	559 GB	

	Video Data Rate (Mbps)	Nominal Compression Ratio ²	Frame Rate	Chroma Sampling	Bits ³	Estimated STORAGE per minute ⁴	Estimated STORAGE per Hour ⁴	Notes
HIGH DEFINITION—UNCOMPRESSED (continued)								
1920 x 1080p (10 bits)	993		24	4:2:2	10	7.4 GB	446 GB	
1920 x 1080p (10 bits)	1.03 Gbps		25	4:2:2	10	7.7 GB	464 GB	
1920 x 1080p (10 bits)	1.24 Gbps		30	4:2:2	10	9.3 GB	559 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	44 GB	In-camera wavelet
REDCODE (RED One)	267	9:1	24	RAW	12	2 GB	120 GB	Example of REDCODE 36 “R3D” files for 4K capture. REDCODE 28 (12:1 compression) and REDCODE 42 (8:1) also available.
REDCODE (Scarlet)	374	6:1	24	RAW	12	2.8 GB	168 GB	REDCODE “R3D” files for 4K capture
REDCODE (Epic)	1.21 Gbps	3:1 or 18:1	24	RAW	12	9.1 GB	546 GB	Example of REDCODE “R3D” files for full-frame 5k capture.
ARRIRAW—2880 x 2160, 2880 x 1620	1.25 Gbps	uncomp.	24	RAW	12	9.4 GB	564 GB	ARRI Alexa, Log recording
RAW 4K—4096 x 2160	19 Gbps	3:1	24	RAW	16	16.7 GB	1 TB	Sony F65, Linear recording. Data rates per Sony.
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) ¹²	2.29 Gbps	uncomp.	24	RGB	10	17.3 GB	1.04 TB	
4K (4096 x 3112) ¹²	9.18 Gbps	uncomp.	24	RGB	10	70.3 GB	4.22 TB	

	Data Rate (Mbps)	Compression	Channels	Bits ³	Estimated	Estimated	Notes
					per minute ⁴	per Hour ⁴	
AUDIO FOR DIGITAL VIDEO							
32 kHz—PCM	0.768	uncomp.	2 channels	12	5.8 MB	0.35 GB	DV only
44.1 kHz—PCM	1.411	uncomp.	2 channels	16	10.5 MB	0.63 GB	
44.1 kHz—PCM	2.117	uncomp.	2 channels	24	15.9 MB	0.95 GB	
48 kHz—PCM	1.536	uncomp.	2 channels	16	11.5 MB	.69 GB	
48 kHz—PCM	2.304	uncomp.	2 channels	24	17.3 MB	1.04 GB	
48 kHz—PCM	3.072	uncomp.	2 channels	32	23 MB	1.38 GB	
48 kHz—MPEG1	0.0384	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	

1. Component formats only. Legacy composite digital formats such as D-2 and D-3 not listed.

2. Digital video compression encompasses a variety of competing techniques, from discrete cosine transform 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.

3. Per color in the case of digital video.

4. Where possible, includes overheads for video stream (header and container format) as well as two to four tracks of 16-bit audio, error detection/correction, timecode, and track information. To avoid fractions, estimates are rounded up to the nearest GB. Actual storage varies depending on size and formatting of hard drives or solid-state media. Always keep 25–30 percent of disk capacity free as headroom to accommodate disk data management and variations in disk speeds.

5. 3.8 Mbps is average video data rate for DVDs. 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.

6. 525-line, 29.97 fps digital formats for NTSC countries and 625-line, 25 fps formats for PAL countries 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. Some can, but most are restricted for use in their respective markets.

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. These are well-known format rates for Rec. 601 that include 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 bitrates per se are slightly smaller.

10. Nominal baseline bitrate. Blu-ray can achieve a 54 Mbps (1.5x) transfer rate. Forthcoming application of compression technologies will result in a range of lesser but more practical bitrates to extend programming length.

11. 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 pre-filtering combined with the 4.1:1 MPEG-2 compression creates a cumulative compression of 7.1:1, which is how HDCAM is often described.

12. 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.