

DV Technology Overview And Video Camera Tests

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1 Introduction

Interesting information on DV technologies can be found on different places all over the web - some important places are mentioned at the end of the report. The most important abbreviations in the video pertaining to this report can be found in the chapter 8 at the end of the report.

2 Overview of standards

2.1 Broadcasting and TV formats

There are two important encoding schemes of color spaces used in video processing of interest for us (R, G, B shall mean gamma corrected values for red, green and blue in range 0 to 255):

YUV: This is the basic color space used by PAL, NTSC and SECAM. It transmits luminance (or luma - denoted as Y) information stream and two color information streams (denoted B and V). This is connected to transition from B/W TV receivers to color ones. It allows B/W receiver to decode B/W information only (Y stream) and color receiver to decode complete color information.

$$Y = 0.299R + 0.587G + 0.114B$$

$$U = 0.147R + 0.289G + 0.436B = 0.492(B - Y)$$

$$V = 0.615R + 0.515G + 0.100B = 0.877(R - Y)$$

YCrCb: This is the format used in DV processing. It's modified (scaled and offset) version of YUV format. DV sampling schemes (e.g. 4:2:2, 4:1:1, 4:2:0) are defined with respect to this format.

$$Y = (77/256)R + (150/256)G + (29/256)B$$

$$Cb = -(44/256)R + (87/256)G + (131/256)B + 128$$

$$Cr = (131/256)R + (110/256)G - (21/256)B + 128$$

Following down-sampling modes are commonly used in DV:

- 4:2:2 means 2:1 horizontal down-sampling, no vertical down-sampling.
(Think 4 Y samples for every 2 Cb and 2 Cr samples in a scan-line.)
- 4:1:1 ought to mean 4:1 horizontal down-sampling, no vertical.
(Think 4 Y samples for every 1 Cb and 1 Cr samples in a scan-line.)
It is often misused to mean the same as 4:2:0
- 4:2:0 means 2:1 horizontal and 2:1 vertical down-sampling.
(Think 4 Y samples for every Cb and Cr samples in a scan-line.)

For consumer and prosumer DV-based standards only 4:2:0 (for PAL) and 4:1:1 (for NTSC) are used. 4:2:2 sampling is used in higher quality technologies (like Betacam SX).

Here is a sort list of TV broadcasting standards with some notes:

- SECAM:**
- SEquential Couleur Avec Memoire
625 scan lines, 50 Fields, 15.625kHz line, Sub-Carrier 4.250MHz & 4.406MHz
 - chrominance and sound signals are frequency modulated, color sub carrier @ 4.434 MHz
 - difficult to edit (video created in PAL and then transcoded to SECAM)
 - obsolete (former communist countries, some countries in Africa and Middle East and France)
- NTSC:**
- National Television Standards Committee
525 scan lines, 60 Fields, 15.734kHz line, Sub-Carrier 3.580MHz
 - resolution 720x486 @ 29.97 fps
 - suffers from color fidelity problems¹.
 - USA standard
- PAL:**
- Phase Alternate Line
 - resolution 720x576 @ 25 fps
 - series of different standards
- PAL:**
- 625 scan lines, 50 fields, 15.625kHz line, Sub-Carrier 4.434MHz
 - European standard

¹That's why the NTSC acronym is sometime explained as "Never Twice the Same Color".

- there are sub-standards for this standard (Czech Republic: PAL D/K, Germany: PAL B/G); further notes on those sub-standards can be found in [TVstandards]
- PAL-N:** - 525 scan lines, 60 Fields, 15.734kHz line, Sub-Carrier 3.576MHz
 - Brazil
- PAL-M:** - 625 scan lines, 50 Fields, 15.625kHz line, Sub-Carrier 3.582MHz
 - some South American countries

NTSC	
640 x 480	Square pixels
720 x 480	Non-square pixels
720 x 540	Square pixels CCIR-601 standard
PAL	
768 x 576	Square pixels CCIR-601 standard
720 x 576	Non-square pixels CCIR-601 standard

Table 1: Different rasterization used in PAL/NTSC to digital conversion

Some notes:

- Conversion of broadcasting format to digital resolution is defined in ITU-R BT.601 (former CCIR-601) specification [CCIR-601].

2.2 DV formats

2.2.1 Consumer DV technology

Some facts about consumer **DV** technology

- 1/4" ME tapes, 10 microns track width and pitch
- sampling:
 - 720 pixels per line (the same as D-1, D-5 or Digital Betacam)
 - 4:1:1 in 525 lines for NTSC or 4:2:0 in 625 lines for PAL (half of D-1)
- compression:
 - DCT with higher local optimization in the picture then JPEG => higher quality than M-JPEG
 - nominal ratio 5:1

- intra-frame compression (the basic one)
- inter-field compression - if two fields (half frames) in the frame differ only slightly they are compressed together => slightly better representation of static object with respect to moving ones (slight tendency to pixelization near the moving objects)
- sound recording
 - 2 channels @ 48 kHz, 16 bits
 - 4 channels @ 32 kHz, 12 bits
 - 2 channels @ 44.1 kHz, 16 bits via Firewire (IEEE-1394) I/O; unlocked (but can record locked audio via 1394)²

DV uses two types of tapes: DV (also called full size DV) and Mini DV ones. In portable cameras only Mini DV tapes are used commonly. Full size DV tapes are used rather rarely. DV can be used in two recording modes - SP (standard one) and LP (lower quality but longer time recorded - decreases track width and pitch to 6.7 microns).

Except for DV SONY uses a new **Digital8** standard in its product portfolio. Digital8 uses Hi8 tapes for video storing and the Digital8 cameras allow user to digitalize Hi8 records. Hi8 tapes behave being approximately one third when storing digital data. Other things (sampling, compression etc.) are same as DV format.

DV suffers from so called artifacts which are often mentioned in DV literature. It is *feathering*, *quilting* and *motion blocking* - further discussion can be found in [DVartefacts].

2.2.2 DV based prosumer technologies

There are three main DV-based prosumer formats currently in use:

DVCPRO: is Panasonic proprietary standard though it is licensed by Philips, Ikegami and Hitachi too. Uses MP tapes with 18 microns track width, additional control audio track for better behavior in linear editing machines and 4:1:1 compression for PAL (Panasonic says it provides better quality - which is on contrary to DV consortium). DVCPRO can be played in DVCPRO and DVCAM VTRs. Price range is 300.000 Kč through 2.000.000 Kč.

²“Locked” means that audio sampling frequency is exactly the same as video sampling frequency. That allows audio signal to be precisely so called locked to video signal. Devices for precise audio clocking are very expensive so DV as consumer format allows unlocked audio too. Maximum allowed slippage is +/- 1/3 of frame. Consumer DV cameras and VTRs produce unlocked audio while professional DVCPRO and DVCAM equipment produces locked audio.

DVCAM: is SONY proprietary standard. Uses ME tapes with 15 microns track width. Price range 150.000 Kč through 1.500.000 Kč. DVCAM can be played in DVCAM, DV (with quality loss) and some DVCPRO VTRs.

DVCPRO-50: newer Panasonic proprietary format deviating more from DV format. Uses 3.3:1 compression with 4:2:2 sampling, doubles data rate to 50 Mbps. This format is intended for video archiving where 4:2:2 is considered to be a must.

Intended market for all of those standards are ENG (e.g. in regional broadcasting studios) and industrial applications. Technical note on prosumer (professional consumer) formats can be found on the web [DVformats].

Professional formats differ only slightly from consumer DV format (except for DVCPRO-50). Basically DV format is of such quality, that increasing track width for improved recording reliability (it decreases number of dropouts to zero) makes professional format from consumer one. Major difference is in quality of equipment - cameras and lenses. Furthermore even with professional formats there is tendency to maintain reasonable data rate for data to be easily transmitted via satellite links and edited in field on non-studio editing machines (this holds true even for different Betacam standards discussed below).

2.2.3 Non DV based prosumer technologies

BETACAM: Series of professional formats used e.g. in TV studios and for indoor and high quality outdoor shooting. It has many variations - SP (analog one), SX (digital - uses inter-frame MPEG2 4:2:2P@ML compression), Digital (uses intra-frame compression). Price range 2.000.000 Kč through 5.000.000 Kč.

HDCAM: Professional format that approaches cinematography quality. Sometimes used as a replacement for very costly standard cinematography equipment. Price range is above 4.000.000 Kč.

More information about SONY professional products can be found on <http://bpgprod.sel.sony.com/>.

2.2.4 Comparism table of different technologies

3 Computer camera interconnections

3.1 IEEE-1394 (FireWire)

First possibility is to use FireWire *with software codecs*. FireWire is used to download movie from the camera to the computer. Further processing is done

D-5 (10-bit non-compressed digital)	10.0
D-1 (8-bit non-compressed digital)	9.9
Digital Betacam, Ampex DCT	9.7
D-9 (Digital-S), DVCPRO50	9.6
DV, DVCAM, D-7(DVCPRO), Digital8	9.0
MII, Betacam SP	8.9
1" Type C	8.7
3/4" SP	6.5
3/4", Hi8, S-VHS	5.0
Video8, Betamax	4.0
VHS	3.0
Fischer-Price Pixelvision	1.0

Table 2: Standards comparison - 10 means current top technology, 1 means the worst one

either directly in DV format using software codec or usually after conversion to M-JPEG (which means loss of quality but which is implemented in many video processing hardware). After processing movie can be downloaded back to camera using FireWire once again.

The other possibility is to use FireWire *with hardware codecs*. This is better choice since it allows processing on-the-fly and allows YUV compatibility (e.g. for Betacam SP). The processing is similar to the previous one except for no need for M-JPEG recompression.

3.2 Computer Software

For capturing and further editing in Windows environment we suggest following software:

- Adobe Premiere 6.0 (commercial)
<http://www.adobe.com/products/premiere/main.html>
- VirtualDub 1.4.7 (freeware)
<http://www.virtualdub.org/>
- MovieXone 4.0 (freeware)
http://www.aist.de/products/4_moviexone/MovieXone_content.html

Adobe Premiere is full-featured and powerful software for both capturing and editing with many effects included. VirtualDub is very powerful and free software which lack capability of editing DV using interface provided by Microsoft in Windows 2000. MovieXone is lightweight version of advanced editing solution

provided by German company AIST. It is missing some advanced features but it is still very useful for simple capturing (includes DV capturing capability in Windows 2000) and editing (includes only one transition effect; this is sufficient for simple editing). It lacks deinterlace capability.

4 Testing methodology

4.1 Resolution test

We used Photolife³ testing image for resolution testing. Since almost all consumer cameras don't allow exact reading of focal length used we decided for following:

- distance between camera and image is 1,6 m (as shown in figure 1) measured from the end of lens
- testing image is to be placed in exactel vertical position (parallel to camera lens)
- focal length should be set in that way that image should fit exaxtely in the image (if set using viewfinder or LCD mounted on camera there is usually a slight border around the testing page what is acceptable since some small varition is further gained by refocusing)

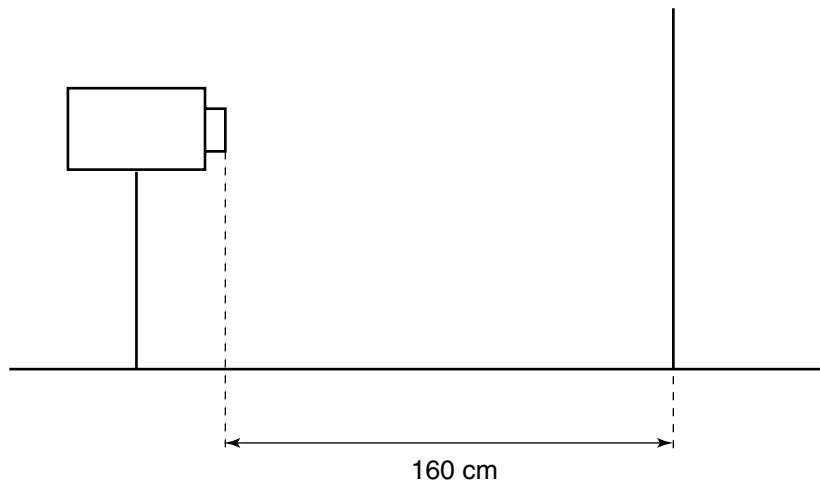


Figure 1: Resolution methodology illustration

³PhotoLife - Czech photography magazine. Resolution testing image has been published in number 20 (year 2000) and color image we used for testing has been published in number 18 (year 2000).

4.2 Color test

We have used exposure compensation table with color grid from Photolife for color testing. Some interesting problems with color display were also found in resolution tests (see below).

4.3 Final editing

Capturing was performed using simple Texas Instrument OHCI based Firewire PCMCIA card by FirewireDirect and Adobe Premiere 6.0 Tryout in Windows 2000 SP2 environment. Final movie was converted from DV to DivX format 3.11 with highest quality possible (6 Mbps and as clear image as possible) in full PAL resolution. Deinterlacing was done using Adobe Premiere internal deinterlacing filter.

5 Our Experiences

5.1 SONY DCR-TRV30E

SONY consumer camera for DV standard. Features Carl Zeiss lens and paper ability of 530 vertical lines resolution. Price is approximately 75.000,- Kč.

- Link to edited DivX movie from the testing (14,0 MB)⁴ What's included:
 - resolution test both interlaced/deinterlaced
 - color test deinterlaced (ambient artificial fluorescent light)

5.2 SONY DCR-PC110

SONY consumer camera for DV standard. Price is approximately 70.000,- Kč.

- Link to edited DivX movie from the testing (16,8 MB)⁵ What's included:
 - resolution test both interlaced/deinterlaced
 - color test deinterlaced (ambient natural light)

⁴<http://miro.cesnet.cz/publish/reports/cameras/video/DCR-TRV30E.avi>

⁵<http://miro.cesnet.cz/publish/reports/cameras/video/DCR-PC110.avi>

5.3 SONY DSR-300P with Canon lens

SONY prosumer camera for DVCAM standard featuring 1/2" CCD chip. Camera body has replacable lens. Price for this set would be about 600.000,- Kč.

We have omitted color test since the camera requires demanding color calibration which was not feasible during the testing.

- Link to edited DivX movie from the testing (65,9 MB)⁶ What's included:
 - resolution test both interlaced/deinterlaced
 - movement test both interlaced/deinterlaced (there were some dropouts during the capturing but it doesn't matter for the purpose of image quality assesments)

5.4 SONY DSR-500P with Canon lens

SONY prosumer camera for DVCAM standard featuring 2/3" CCD chip. Camera body has replacable lens. Price for this set would be about 900.000,- Kč.

We have omitted color test since the camera requires demanding color calibration which was not feasible during the testing.

- Link to edited DivX movie from the testing (12,6 MB)⁷ What's included:
 - resolution test both interlaced/deinterlaced

5.5 Canon MV30i

Canon consumer DV camera. Price about 47.000,- Kč

- Link to edited DivX movie from the testing (14,4 MB)⁸ What's included:
 - resolution test both interlaced/deinterlaced
 - color test deinterlaced (ambient artificial fluorescent light)

⁶<http://miro.cesnet.cz/publish/reports/cameras/video/DSR300P.avi>

⁷<http://miro.cesnet.cz/publish/reports/cameras/video/DSR500P.avi>

⁸<http://miro.cesnet.cz/publish/reports/cameras/video/MV30i.avi>

5.6 Canon XL-1S

Canon prosumer DV camera with replacable lens. Price is about 170.000,- Kč.

- Link to edited DivX movie from the testing (17,0 MB)⁹ What's included:
 - resolution test both interlaced/deinterlaced with both image stabilization and without it
 - color test deinterlaced (ambient natural light)

6 Conclusions

6.1 Resolution tests

- One major difference between consumer and prosumer cameras we found is what we call “resolution stability”. Although consumer cameras seem to have even better resolution than prosumer ones the overall image from prosumer ones seems to be better. This is due to the fact that prosumer cameras offer smooth transition between areas that are above the resolution of camera and areas that are below the resolution. Consumer camera produce images that have much less regular lining especially in the horizontal direction. (That's probably why video professionals get usually very nervous when computer or photo specialist starts to talk about resolution - meant resolution in pixels by pixels.)
- The other important difference is in “color/gray stability” while capturing dense raster below the resolution of the respective camera. Consumer cameras produced “color rainbow” in the areas below the resolution. This is probably also due to lack of 3 CCD sensor capability of consumer cameras.

6.2 Movement tests

One of the major obstacles one encounters while capturing the movement in the picture is subject of interlacing. When moving image is displayed on non-interlaced computer display one notices an awful destruction of image. One solution is use of software deinterlace while storing image but this reduces resolution in vertical direction (i.e. horizontal lines are blended).¹⁰ The other solution is to either use interlaced monitor/TV or to switch computer display

⁹<http://miro.cesnet.cz/publish/reports/cameras/video/XL1S.avi>

¹⁰Comparison of Adobe Premiere 6.0 and VirtualDub deinterlace methods show very similar results obtained.

to interlaced mode. This way retains the resolution and produces quite a nice image but it is very inconvenient for doing general computer tasks (e.g. word editing or playing of movie inside the window). We are currently searching for some convenient hardware solution that would allow display of interlaced video on non-interlaced display (hardware deinterlace).

6.2.1 Color tests

Color test cannot be easily evaluated since camera test were done in different light conditions. Furthermore SONY professional cameras require thorough color calibration that we were not able to pass. Canon professional camera DM-XL1S has just quite simple color calibration resembling the calibration present in consumer cameras, i.e. several predefined conditions, automatic, and manual settings.

7 Contacts

- **Elvia-pro (oddělení profesionální videotechniky)**
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8 Used abbreviations

Following abbreviations are widely used in digital video literature.

DV: Digital Video (somewhat overlaps with DV format definition)

ENG: Electronic News Gathering

ME: Metal Evaporated (tapes)

MP: Metal Particle (tapes)

prosumer: PROfessional conSUMER

VTR: Video Tape Recorder

DCT: Discrete Cosine Transform

References

[DVcentral] <http://www.dvcentral.org/>

[DVformats] http://www.chumpchange.com/parkplace/Video/DVPapers/dv_fmt.htm

[DVartefacts] <http://www.dv.cz/index.php3?id=1047>
<http://www.dvcentral.org/DV-Beta.html>

[grafika.cz] <http://www.grafika.cz/video/>

[TVstandards] http://miro.cesnet.cz/publish/3rd_party/TV_standards/standards.en.html
<http://www.grafika.cz/art/dv/clanek646847424.html>

[VirtualDub] <http://www.virtualdub.org>

[DV.cz] <http://www.dv.cz>

[DVediting] *DV editing @* <http://www.grafika.cz/art/dv/clanek1416919498.html>

[DV-FAQs] *DV FAQs @* <http://www.videouniversity.com/dvformat.htm>
<http://www.adamwilt.com/DV-FAQ-tech.htm>

[CCIR-601] CCIR-601 Specification
<http://www.crs4.it/luigi/MPEG/ccir601.html>