

# DV Formats

*DV Formats Overviewed and  
Raster Sampling Methods Explained*

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## DV Formats Introduction |

Today, a range of DV and other videotape format standards are in widespread use. In some cases, there are considerable differences in the range of these standards. In other cases, variations are subtler. As a result, a certain amount of confusion around DV format standards exists, as well as concerns around interoperability. To address these issues, this white paper discusses the major digital videotape compression standards currently in use and delineates the differences between them.

Generally, a videotape format refers to both the size and shape of the tape and its holder, as well as the structure of the signal recorded on the tape. Although there are small differences between the tape requirements for some of these formats, the focus here is not on the physical media. It is on the DV signal that is recorded on the tape and passed between equipment that works with the signals.

Format	Providers
Consumer DV	Many
DVCAM	Sony
DVCPPro	Panasonic
DVCPPro50	Panasonic
D-9	JVC
DVCPPro HD100	Panasonic
HDCAM	Sony

## 25-Mbit/s Formats |

These formats are best examined by describing the common elements first, then noting differences between the formats.

### Elements Common to All DV25 Formats

DV25 formats include: Consumer DV, DVCPro, and DVCAM, plus DVCPro50 and DVCPro-P.

#### Video

- Compression: 25-Mbit/s Discrete Cosine Transform (DCT)-based intra frame encoding, i.e., each frame is separately encoded without reference to adjacent frames, using the mathematics of Discrete Cosine Transform –
- NTSC Sampling: 720 x 480 pixels
- PAL Sampling: 720 x 576 pixels

#### Audio

- 2 channels at 48 kHz sampling rate, 16 bits per sample
- or
- 4 channels at 32 kHz and 12 bits per sample
- or
- 44.1 kHz sampling rate, 16-bit samples

*Note that although the format supports all these audio options, there is often no provision for creating different rates within individual pieces of equipment.*

## DV25 Format Variations |

### Consumer DV

Consumer DV was actually the original DV standard. Professional variants have been created from Consumer DV.

#### Video

- NTSC 4:1:1 (See page 9 for an explanation of 4:1:1 and other raster sampling schemes.)
- PAL 4:2:0

#### Audio

The only noteworthy variation here is that the audio is unlocked. This means that there is no firm relationship between the audio sampling clock and the digital sampling clock. Typically, this happens when transferring the audio to a professional VTR. There are, however, some cameras that record locked audio. (See text box on page 3 for more information on locking audio.)

### DVCPro

#### Video

- NTSC 4:1:1 (See page 9 for an explanation of 4:1:1 and other raster sampling schemes.)
- PAL 4:1:1 Note that the major difference with this format is 4:1:1 sampling in PAL and NTSC.

#### Audio

The audio is locked to the video, with a provision for a low-quality analog cue track.

## DVCAM

### *Video*

- DVC follows the DV consumer format and samples
- NTSC 4:1:1 (See page 9 for explanation of 4:1:1 and other raster sampling schemes.)
- PAL 4:2:0

### *Audio*

The audio is locked to the video. Note that on some decks the audio can be unlocked if the recording is made through an IEEE 1394 (FireWire) connection.

### **Locking Audio**

To perform an audio insert edit on a VTR, the number of samples on the tape must match the number of samples to be edited in. To achieve this, professional VTRs ensure that the same number of audio samples exist in every frame. This is known as locked audio. (In the interest of cost savings, consumer machines do not follow this discipline.)

A flag in the audio stream tells the receiving equipment that the audio is unlocked. When this flag is set, many professional recorders handle the signal correctly, although there may be difficulty in editing. In some cases, the unlocked audio causes random clicks when the audio is replayed. In principle, there should be no need to lock audio without a VTR present. If the audio is unlocked, it can create difficulties when the material is to be recorded on tape.

## DVCPro50

This is a high-quality format for professional use. A variation on this format can record progressive (versus interlaced) frames. The implementation of the signal format by JVC is standardized as the D9 format. (Note that the tape and cassette housing used in D9 is from the VHS family, not from the DV family.)

### *Video*

- Sampling 50 Mbit/s.: Each frame is coded independently of the one before and after, i.e., there is no coding of the motion (intra frame coding)
- 4:2:2 for both NTSC and PAL (See page 9 for an explanation of 4:2:2 and other raster sampling schemes.)

Resolution: The full standard definition number of pixels is recorded (as in the case of the 25-Mbit variants) –

- NTSC Sampling: 720 x 480 pixels
- PAL Sampling: 720 x 576 pixels

### *Audio*

DVCPro50 supports four digital audio tracks and one analog cue channel.

- 48 kHz sampling rate
- 16 bits per sample

Note that cue channels support up to about 6 kHz only and are therefore not suitable for production use.

## DVCPro-P

This format from Panasonic is also a 50-Mbit/s format and is designed for recording 480 progressive pictures. The differences between DVCPro-P format and DVCPro50 are all in the video features, plus the DVCPro-P format is only for 525-line (NTSC) use.

### *Video*

- Full-field (known as progressive scanning): 60 frames per second recorded with every frame encoded in the same way as DV25. (Since there are effectively twice as many frames, the data rate is 50 Mb/s.)
- Sampling: 4:2:0

## High Definition |

High definition is a general term covering a range of different picture sizes that contain more information than standard NTSC or PAL pictures. DVCPro HD and HDCAM are not compatible, with each other aside from the baseband video level. Mixing of media types is not easily achieved. (See text box below for additional details on high-definition formats.)

### DVCPro HD

This is a 100-Mbit/s format that records 1080i or 720p HD pictures.

#### Video

- Data rate 100 Mbit/s: Each frame is coded independently of the one before and after (i.e., there is no coding of the motion (intra frame coding)).
- The recorder acquires frames of 1920 by 1080 pixels. The recorded signal reduces the horizontal resolution (but not the vertical resolution) in a similar but incompatible method to HDCAM.

#### Audio

DVCPro HD supports eight digital audio tracks and one analog cue channel.

- 48 kHz sampling rate
- 16 bits per sample

Cue channel support is to about 12 kHz only and is therefore not suitable for production use.

## High Definition

*Within high-definition production, a number of ways to scan are possible. The two main variables are:*

- The number of pixels (scanning points) per images – This is normally expressed as the number of points across the image and the number of points down the image, thus PAL is 720 by 576.
- Interlaced or progressive – Interlaced is the way that conventional television works, where every other line is scanned or assigned to one field, and the alternate lines are assigned to the second scan of the field. With progressive scanning, there is only one field; that is, all lines are included in a single scan.

Standards bodies have settled on two common standards for the transfer of images:

- 1920 by 1080 interlaced
- 1280 by 720 progressive

There are other high-definition formats, but these are the most common.

## HDCAM

### *Video*

- Data rate 143 Mbit/s. Each frame is coded independently of the one before and after, i.e., there is no coding of the motion (intra frame coding).
- HDCAM supports many frame rates: 24p, 25p, 30p, 50i, 60i.

*Note that the Sony recorder acquires frames of 1920 by 1080 pixels, then downsamples the frame on the horizontal axis by reducing the horizontal resolution for Luminance to 1440 pixels and 480:480 pixels for the two-color signals. It does not change the vertical resolution.*

### *Audio*

HDCAM supports four digital audio tracks and one analog cue channel.

- 48 kHz sampling rate
- 16 bits per sample

**HD CAM is not part of the DV family and will not play DV videotapes.**

## **DV Formats Conclusion |**

A range of DV standards are based on the original consumer format. These standards have built on the success of the consumer format, but as they continue to diverge, some subtle and some obvious incompatibilities are emerging.

As a result, it is necessary to pay close attention to the differences in the DV standards in order to avoid interfacing difficulties and system integration woes.

## Raster Sampling Methods Explained |

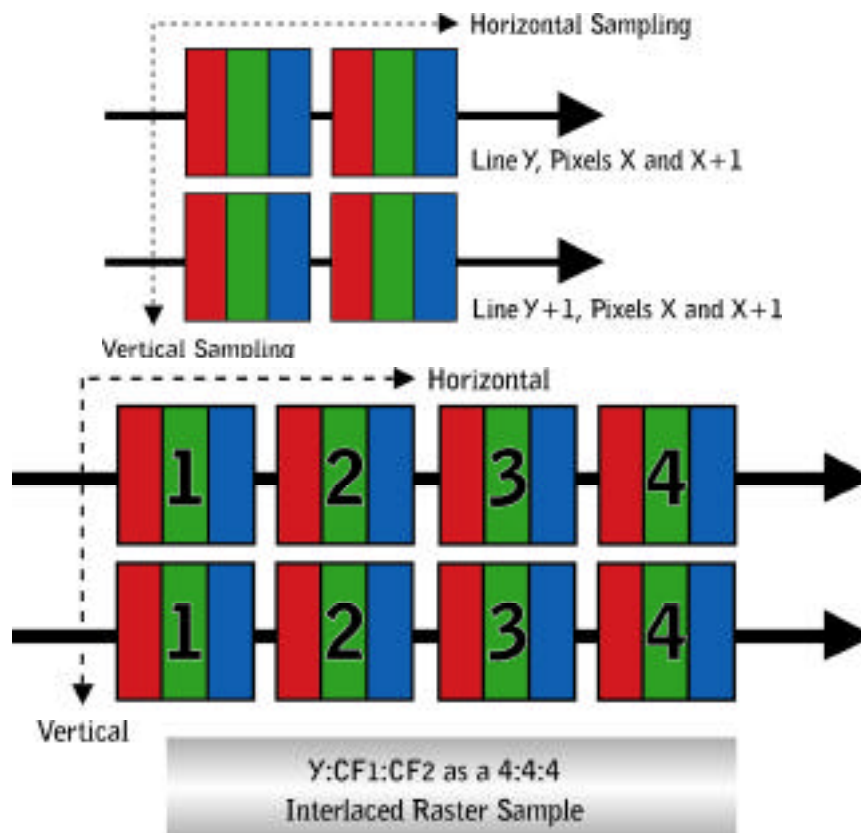
Every video frame exists within a two-dimensional plane, known as a raster. The raster prescribes the image's frame, which is defined by numbers of sampling points (pixels) in rows (horizontal lines) stacked in columns (vertical).

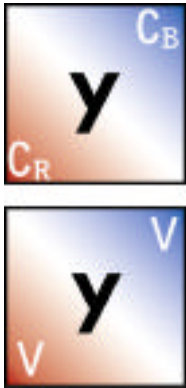
The frame may be scanned (or sampled) row by row, from top to bottom in a single progressive sweep. The frame may also be scanned (or sampled) by every other row, from top to bottom in two interlaced sweeps known as fields. Field one contains all the odd numbered lines. Field two contains the even lines.

With both interlace and progressive scanning methods in mind, the sampling rate convention expresses how the sampled pixels in two-dimensional space are defined.

### 4:4:4 Sampling and R,G,B Color Channels

All video cameras discriminate color through a standard tristimulus technique, detecting three standard primary colors – Red, Green and Blue – at each sample point, or pixel. Each of the R,G,B color channels begins as a full bandwidth signal in both the horizontal and vertical dimensions, and the sampling rate is the same for all colors at 4:4:4. Generally speaking, computer graphics systems process colors and prescribe color space as three separate R,G,B channels.





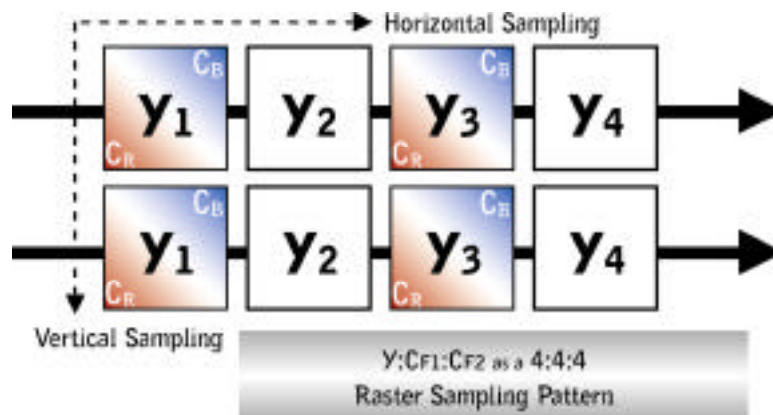
### Luminance and Chrominance Matrixing for Video

The video camera initially detects R,G,B 4:4:4 color samples. It then combines these three primary color channels through a matrix to derive a Luminance signal, Y, that defines pixel brightness as a mix of 30R, 59G, 11B for standard video. For high-definition video, the Luminance matrix mix is slightly modified to 21R, 72G, 07B. The matrix of R, G, B into Luminance approximates the human eye's acuity to light at these colors respectively. The matrix also converts R, G, B into a pair of color difference signals that accompany Luminance (Y) to define the entire color gamut. The color difference signals are comprised of Red minus the Luminance, R-Y, and Blue minus the Luminance, B-Y. These color difference signals vary in matrixing and designations. These are commonly expressed as Y,R<sub>Y</sub>,B<sub>Y</sub> or Y,C<sub>R</sub>,C<sub>B</sub> in North America, or Y,U,V in Europe where the color difference signal levels are a bit different. Thus, for any pixel, there exist three primary color samples of R, G, B, which are matrixed into the three video values of Y, C<sub>R</sub>, C<sub>B</sub>.

One point of confusion is that the sample rate expression, 4:x:x and Luma/Chroma representation, Y,c,c began as a common expression of horizontal resolution. Now that definition has expanded to also express vertical resolution. Today, sample rates are expressed across a 2D video frame, and are best understood as follows: The first value is the Luminance sample rate for the entire video frame as Y. The second value states the combined C<sub>R</sub> and C<sub>B</sub> color samples for Field 1. The last value, the C<sub>R</sub> and C<sub>B</sub> samples for Field 2 to yield Y:C<sub>F1</sub>:C<sub>F2</sub>. The C<sub>F1</sub> and C<sub>F2</sub> color sample rate expresses the sampling points for both C<sub>R</sub> and C<sub>B</sub>.

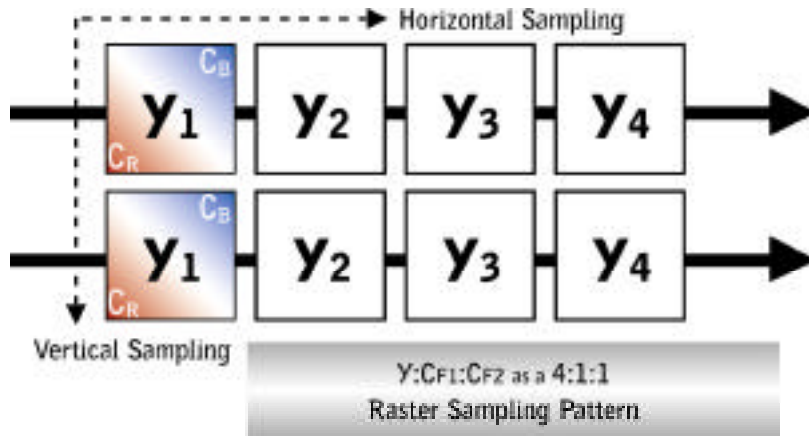
### Downsampling

Because the human eye can sense brightness and detail with considerably greater acuity than color information, the color sample rate can be set lower than the Luminance rate. Thus, half the color resolution is removed by a 4:2:2 downsampling scheme. As a result, a matrixing of R,G,B down to the Y:C<sub>F1</sub>:C<sub>F2</sub> sample rate at 4:2:2 appears as:

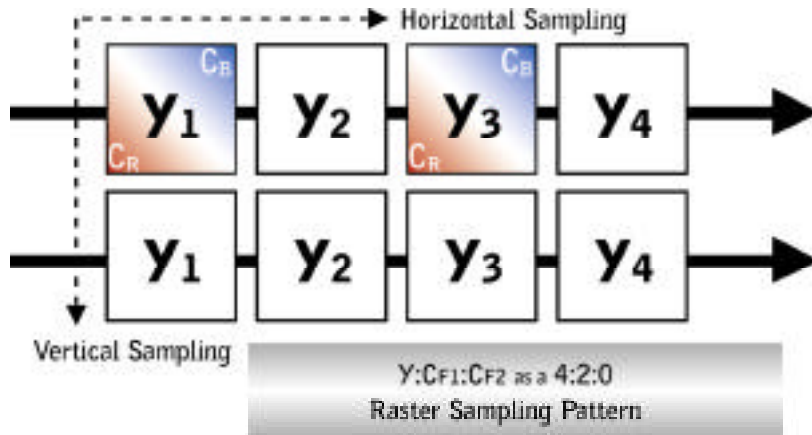


For every 4 samples of Y across a horizontal line in Field 1, there are two samples taken for CR and CB. The same holds true for Field 2. Thus, color detail is reduced by half along the horizontal axis only.

Other Y:CF1:CF2 sample rates have been introduced with the advent of newer, smaller digital videotape formats. In the 4:1:1 sampling scheme, the color is further reduced to 25 percent of the horizontal Y resolution. Vertical color resolution remains unchanged



In the 4:2:0 sampling scheme the color is sampled as in the 4:2:2 scheme, but only on every other line. For every second line, there are no color samples. A 4:2:0 sampling reduces color resolution to half both horizontally and vertically and 25 percent overall.



In an interlaced video scanning system, Field 2 contains no color samples. The color information is retained and repeated from Field 1. In a progressive scanning system, the color samples from the odd numbered lines are retained and repeated for the even numbered lines.

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