Victor Steinberg

Video Standards

Signals, Formats and Interfaces

Part 8

Scanning, Sampling & Packing

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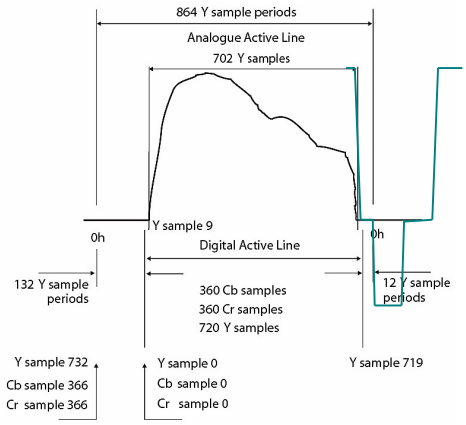
1st Unified Global Digital Component Standard



Example of the Y line timeline for the component **625i25** format.

The 0h (digital line datum) moment marks the analog sync pulse leading edge mid point. Note that Y sample 0 (Digital Active Line Start) comes 132 samples later.

The **BT.601** (CCIR Rec.601) standard established **for the first time** a unified global **digital component format**, which **shared** the **sampling frequency** with **both** widely used scanning standards of the world **– 625i25** & **525i29.97**.

Coded digital signals:

• Luminance signal: **Y** *(without sync pulses),* sampling rate **13.5 MHz**

• Color-difference signals: **Cb** and **Cr**, sampling rate **6.75 MHz**

Cb and Cr samples co-sited with odd (1st, 3rd, 5th, etc) Y samples in each line (UYVY 4:2:2).

Note: The sampling frequency should be derived from the line frequency of the relevant scanning standard.

Number of samples per **Digital Active Line**: **720** for Y, **360** for Cb, Cr (U, V)

Digital Active Lines Number depends on the scanning standard:

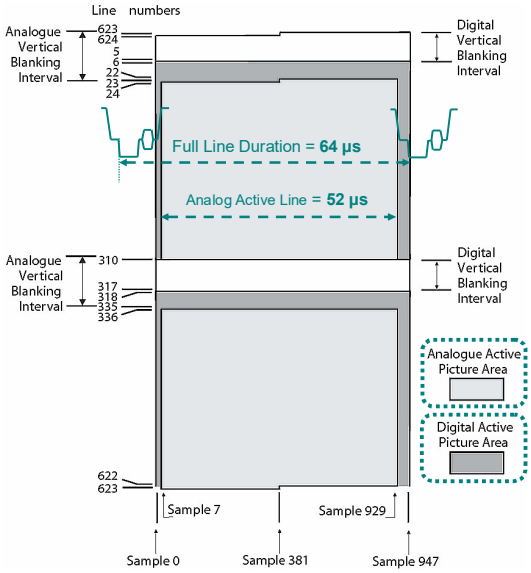
• **507** lines for **525i29.97**, each line contains **858** Y sample, **429** Cb, Cr samples

• **576** lines for **625i25**, each line contains **864** Y sample, **432** Cb, Cr samples

in accordance with the BT.601 standard the sampling rate **13.5 MHz** and the digital active line **720 / 360** pixel counts are **common** for **50 Hz** and **60Hz** countries. This **commonality** made possible the fast global spreading of digital component equipment and analog-to-digital transition.

All following video standards (SDI, HD, UHD, MPEG, etc.) are based on this concept; they are only the smart siblings of the Great Mother born in 1982: **Rec.601**!

Active Frame, Active Lines, Active Part of the Line



This diagram illustrates, on the example of **digital composite PAL**, a variety of the analog and digital, component and composite, **formats** related to one **scanning standard**; in this example – related to **625i25** standard.

Full line duration in this standard = 1 s / (625 x 25) = **64 µs**, of which **Analog Active Line** = **52 µs** and **Analog Line Blanking Interval** = **12 µs**.

Sample numbers in this example are derived from the **analog video time positions** multiplied by **digital composite PAL sampling rate** = **17.73447 MHz**

(17.73447 = 4 x Fsc, much higher than the BT.601 sampling rate 13.5 MHz).

With this sampling rate the **total number of samples per full line duration** is:
64 µs x 17.73447 MHz = **1135**,
and the **number of samples per analog active line** is:
52 µs x 17.73447 MHz = **922** (samples from 7 to 929)

Note that Digital Active Picture Area is much greater than its analog counterpart, thus providing for flexibility in the post-processing of the digitized images.

After digital composite decoding, de-interlacing, cropping and scaling the image comes out in a **digital component format**. The captured file may be labeled 720x576p25 or 720x576p50, depending on the de-interlacing mode.

Frame Rates & Frame Rates Families

Currently used frame rates: **23.976**, **24**, **25**, **29.97**, **30**, **50**, **59.94** & **60** fps.

Compatibility with the interlaced video materials and existing infrastructure requires **25** and **29.97** fps operation.

Compatibility with the film world which tends to shoot at 24 frames per second requires **23.976** and **24** fps.

There are **two** main families of HD and SubHD scanning standards: "**1080**" and "**720**"

720 Line Family Frame Rates

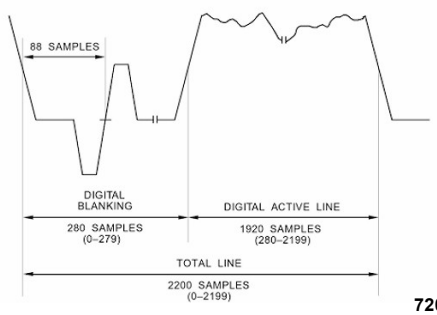
Progressive (p)
60 / 59.94
50
30 / 29.97
25
24 / 23.976

1080 Line Family Frame Rates

Interlaced (i)	Segmented (psf)	Progressive (p)
		60 / 59.94 *
		50 *
30 / 29.97	30 / 29.97	30 / 29.97
25	25	25
	24 / 23.976	24 / 23.976

* *These 2 formats require higher 148.5 MHz sampling rate; currently they are not in widespread use*

Frame Rates & Sampling Rates



Example of the Y line timeline for the **1125 lines** (1920x1080), **30 / 29.97** fps formats.

The sampling rate:
74.25 for 30 fps,
74.176 for 29.97 fps

The 50 Hz countries use only **24**, **25** and **50** Hz frame rates.
In 60 Hz countries frame rates come **in two flavors**. An integer number of frames per second or one part per thousand less than this:
60 Hz x 1000/1001 ≈ **59.94** Hz (*more accurately 59.94005994005994…)*
30 Hz x 1000/1001 ≈ **29.97** Hz
24 Hz x 1000/1001 ≈ **23.976** Hz
This is implemented by reducing the clock speed by 1 part in a thousand,
e.g. sampling rate **74.25** MHz x 1000/1001 ≈ **74.176** MHz
.

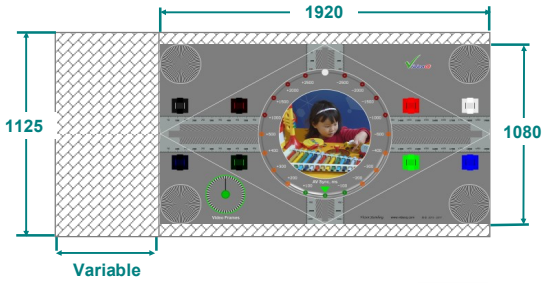
720p50 / 720p60 (SubHD) and **1080p24 / 1080p25 / 1080p30** (low frame rates HD) formats share **the same** sampling rate **74.25 MHz** despite the big difference in the number of samples per Active Frame. This is possible only because both formats use **Common Image Format** sampling structure.

1920x1080	
Frame Rate	**Sampling Rate**
23.976 Hz	74.176 MHz
24.000 Hz	74.250 MHz
25.000 Hz	74.250 MHz
29.970 Hz	74.176 MHz
30.000 Hz	74.250 MHz
50.000 Hz	148.50 MHz
59.940 Hz	148.35 MHz
60.000 Hz	148.50 MHz

BT.2077 standard describes various variants of **UHD** sampling rates and multi-link connections based on the multi-stream transfer of (somehow split) UHD image data. So, the UHD case is more complicated.

Frame Rates Families & Common Image Format

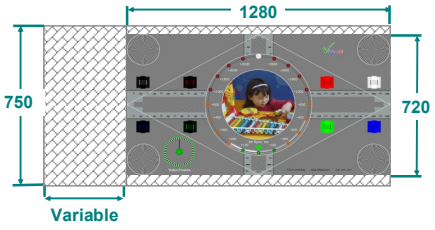
1125 (1080) Line Family Common Image Format



Total lines per frame **1125**
Active lines per frame **1080**
Active pixels per line **1920**

Total pixels per line ***varies*** with frame rate,
e.g. **2200** for **29.97i**, but **2640** for **25i**

750 (720) Line Family Common Image Format



Total lines per frame **750**
Active lines per frame **720**
Active pixels per line **1280**

Total pixels per line **varies** with frame rate,
e.g. **1650** for **60p**, but **4125** for **24p**

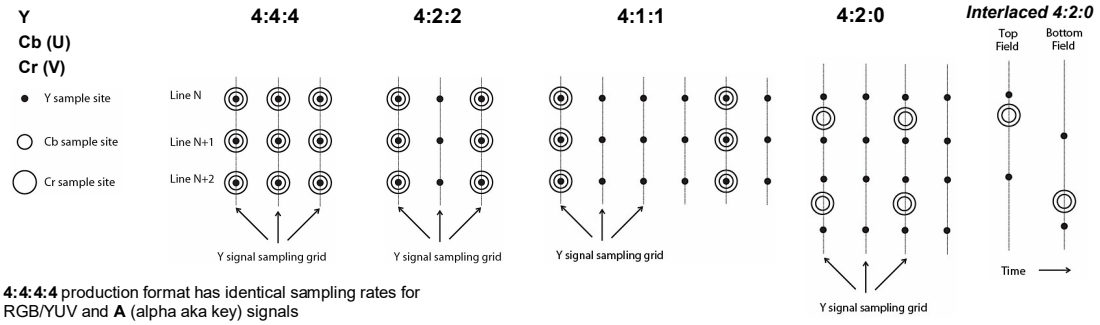
Note that total number of lines in the full frame, sampling rate value and Common Image Format numbers make sense only with application to the **digitization** of **analog HD** signals and/or **real time transfer** of digital data over the **physical interface**, e.g. SDI (BT.1120).
For **file based operations** only **Active Image** data are relevant and sampling rate value has no meaning.

RGB & YUV Spatial Sampling Structures

RGB and **Y** channels spatial sampling grids are always **uniform**, but the horizontal and/or vertical sampling rates of **U** and **V** channels are often **reduced** to save the bandwidth and/or storage capacity.
The reduction of U and V channels spatial resolution is possible because it is less noticeable than the reduction of RGB or Y resolution.

To designate various YUV spatial sampling structures a special naming convention was invented.
Original (full) **horizontal** sampling rate of Y and R, G, B channels was designated as "**4**", half of this rate is called "**2**", and quarter is "**1**".
Later the special name was also invented to designate the 50% reduction of the **vertical** UV sampling rate. Funnily enough this name is "**0**"!

Thus, we have now **4:4:4**, **4:2:2**, **4:1:1** and even **4:2:0** spatial YUV sampling structures. The separator is often omitted, e.g. **422** instead of **4:2:2**.
Most component production equipment uses 4:4:4 or 4:2:2 sampling, but in distribution of compressed streams the most used format is 4:2:0.



4:4:4 production format has identical sampling rates for RGB/YUV and **A** (alpha aka key) signals

RGB & YUV Pixel Formats

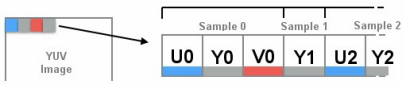
There are two major groups of formats used to arrange **R**, **G**, **B** or **Y**, **U**, **V** samples within a stream/file along the timeline and/or memory index.

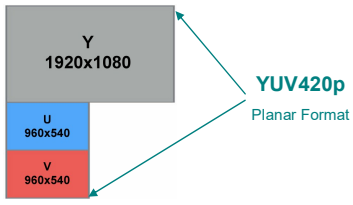
Interleaved (aka packed) formats are based on the pixel sequential multiplex of color component (channel) samples,
e.g. **UYVY** is a **422**, **8 b**it **p**er **c**omponent (bpc), **16 b**it **p**er **p**ixel (bpp) format used for video streaming via SDI and for the corresponding video files.

Planar formats are based on the sequential storage/transmission of 3 color separated frames aka **color planes**,
e.g. **YUV422p10** is a **422**, **p**lanar, **10 bpc**, **32 bpp** format used for mildly compressed video production files.

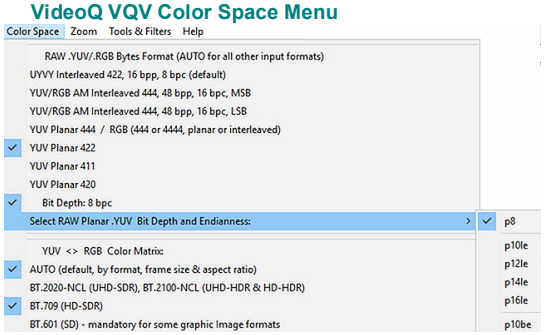
In ffmpeg and similar software programs this parameter is called "**pixel format**". Though, this term is not used in standards, it is wide spread.
Optionally, some interleaved/planar streams/files may include additional **A** channel – alpha channel aka mask, e.g. 4444 RGBA32 format.

UYVY – 422 Interleaved Format





VideoQ VQV Color Space Menu



About This Presentation

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"Video Standards: Signals, Formats and Interfaces" by Victor Steinberg
Published by Snell & Wilcox

For further reading we recommend wikipedia.org

About VideoQ

Company History

- Founded in 2005
- Formed by an Engineering Awards winning team sharing between them decades of global video technology.
- VideoQ is a renowned player in calibration and benchmarking of video processors, transcoders and displays, providing tools and technologies instantly revealing artifacts, problems and deficiencies, thus raising the bar in productivity and video quality experience.
- VideoQ products and services cover all aspects of video processing and quality assurance - from visual picture quality estimation and quality control to fully automated processing, utilizing advanced VideoQ algorithms and robotic video quality analyzers, including latest UHD and HDR developments.

Operations

- Headquarters in Sunnyvale, CA, USA
- Software developers in Silicon Valley and worldwide
- Distributors and partners in several countries
- Sales & support offices in USA, UK