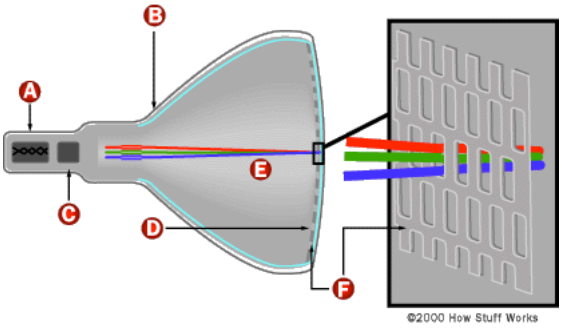
6: Video Basics

Mark Handley

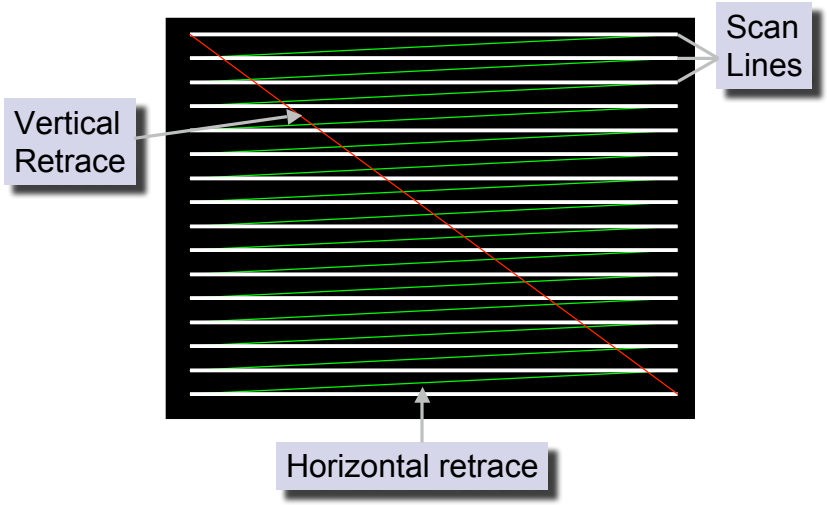
Analog TV: Inside a CRT



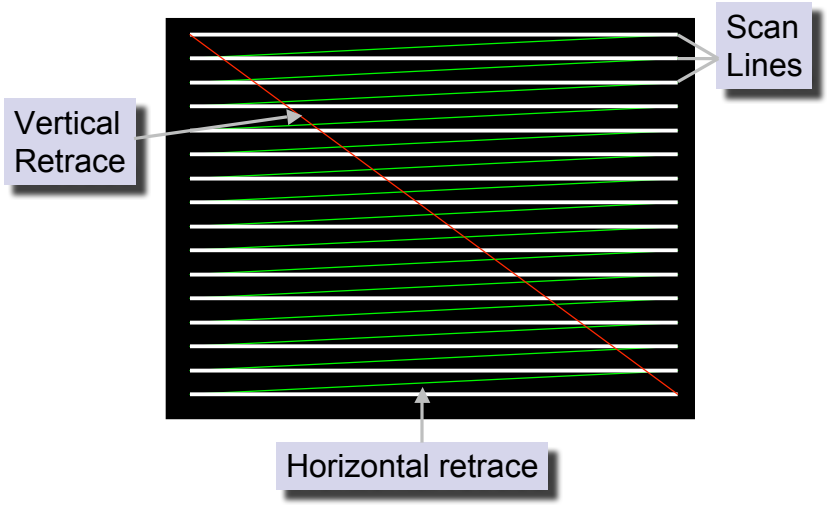
A: Cathode
B: Conductive Coating
C: Anode
D: Phosphor Coated Screen
E: Electron Beams
F: Shadow Mask

From: howstuffworks.com

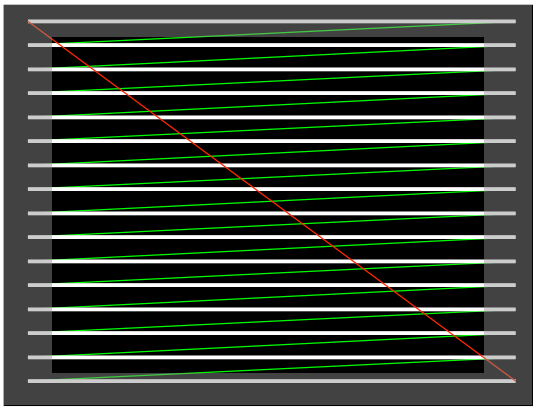
Basic Analog TV



Basic Analog TV



Basic Analog TV: Masking

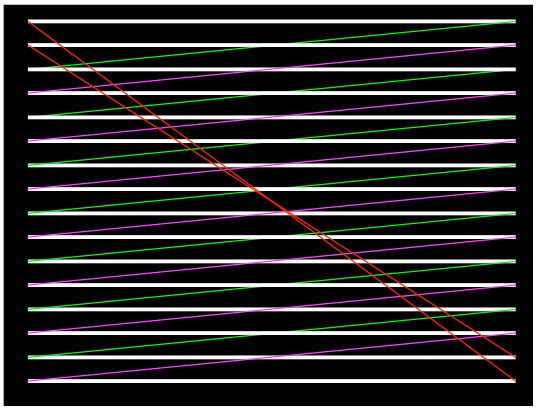


Not all monitors are ideal: can take a little while to retrace.
Not all lines, and not all of every line is used.

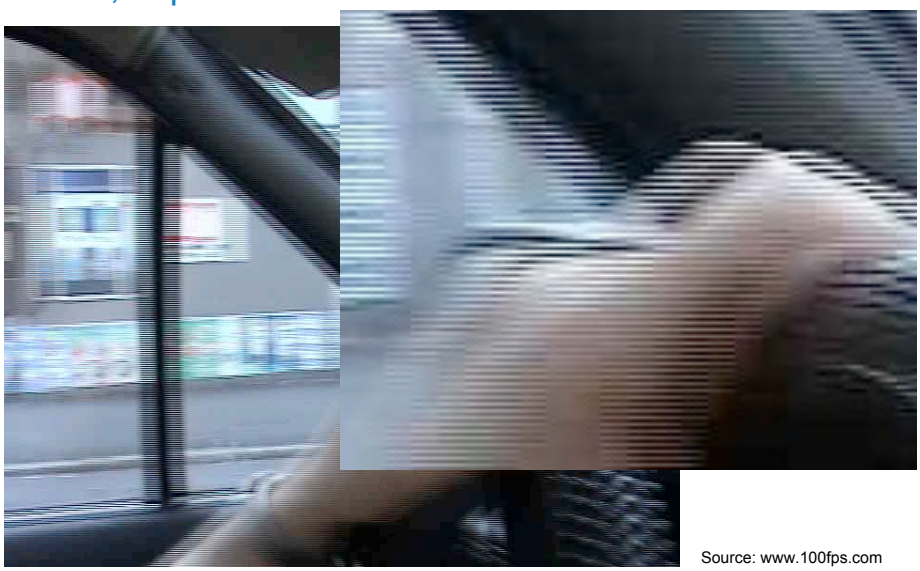
How fast to refresh?

- Movies: 24 frames per second.
  - Really is 24 photographs per second.
  - Not scanned from top to bottom.
  - Flicker, but no motion of the flicker.
  - Cinemas are dark: eye not so sensitive to flicker when it's dark.
- TV:
  - Scanned.
  - Fairly bright environment.
  - How to reduce flicker without requiring excessive bandwidth (for analog TV)?

Basic Analog TV: Interlacing



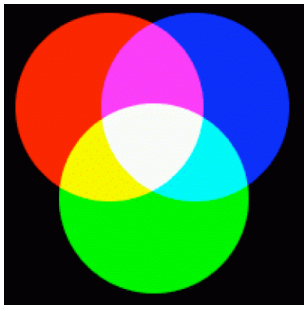
Each interlaced frame has two fields, captured at different times.



Source: www.100fps.com

Colour

- Human Eye has receptors for brightness (in low light), and separate receptors for red, green, and blue.
- Can make any colour we can see by mixing red, green and blue light in different intensities.



Colour TV

- Original TV standards were black and white.
  - AM: Amplitude of signal determines brightness.
- How to add colour without changing TV transmitters, and in such a way that it's compatible with existing B&W TVs?
- Add a high frequency subcarrier in band within B&W TV signal.
  - Not noticable on B&W TV - would show as high frequency pattern, but human eye can't really see this well.
- Modulate the phase of the sub carrier to indicate the colour.
  - Problem: how to calibrate the absolute phase.
  - Get this wrong, and the colours display incorrectly.

Colour	Phase degrees
Burst	0
Yellow	15
Red	75
Magenta	135
Blue	195
Cyan	255
Green	315

NTSC

National Television Standard Committee

- Introduced in 1953 (in US)
- Used in US, Canada, Japan
- 30 frames per second (Actually 29.97)
  - Interlaced (even/odd field lines), so 60 fields per second.
  - Same as 60Hz AC power in these countries
- 525 lines
  - Picture only on 480 of these => 640x480 monitors
  - Rest are the vertical rescan.
- Aspect ratio is 4:3
- Needs colour calibration
  - Uses a colour burst signal at start of each line, but needs TV to be adjusted relative to this. “NTSC = Never Twice Same Colour”

PAL

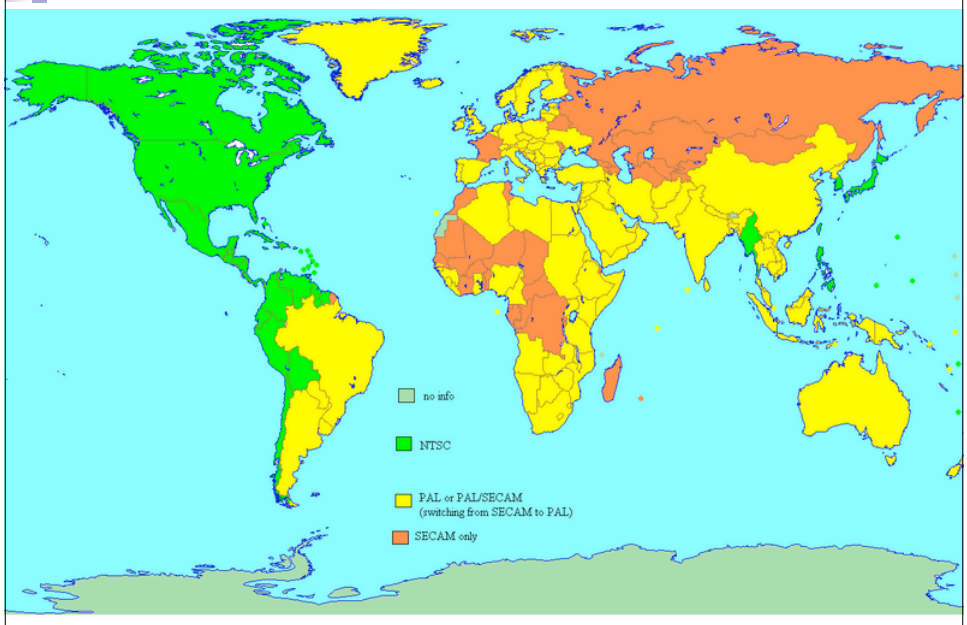
Phase Alternating Line

- Introduced in 1967 (by Walter Bruch in Germany)
- PAL-I(UK), PAL-B/G (much of Europe), PAL-M (Brasil) …
  - Differ mainly in audio subcarrier frequency.
- 25 frames per second
  - Interlaced (even/odd field lines), so 50 fields per second.
  - Same as 50Hz AC power in these countries
- 625 lines
  - Only 576 lines used for picture.
  - Rest are vertical retrace, but often carry teletext information.
- Colour phase is reversed on every alternate line.
  - Originally human eye would average to derive correct colour.
  - Now TV sets autocalibrate to derive correct colour.

SÉCAM

Séquentiel Couleur Avec Mémoire

- Introduced in 1967 (in France)
  - "*System Essentially Contrary to American Method*"
- Used in France, Russia, Eastern Europe…
- 625 lines, 25 fps interlaced, like PAL
- Uses FM modulation of subcarrier.
  - Red-Luminance difference on one line
  - Blue-Luminance difference on next line
  - Uses a video linestore to recombine the two signals
  - Vertical colour resolution is halved relative to NTSC and PAL.
  - Human eye is not sensitive to lack of spatial colour information.



[Source: wikipedia]

Connectors and Formats

Coaxial or RF

All audio/video components of all channels modulated onto the one wire (PAL, NTSC, etc) using a different VHF/UHF carrier for each channel.

Composite

Video-only components of one channel on one wire (PAL, NTSC, etc)

S-Video

Two wires: one for luminance, and one for colour (Y/C video)

Component Video

3 Separate wires: luminance + 2 colour difference signals (Y, P_b, P_r)

$P_b = B - Y$, $P_r = R - Y$

RGB, RGBS, RGBHV

3, 4, 5 wires carrying Red, Green, Blue and horizontal + vertical sync signals.

SCART

May carry Composite, S-Video, or RGB video, with two channel audio + control signals (eg 4x3, 16x9 aspect ratio)

Colourspace Representations

- RGB (Red, Green, Blue)
  - Basic analog components (from camera/to TV tube)
- YP_bP_r (Y, B-Y, R-Y)
  - Colour space derived from RGB used in component video. Y=Luminance, B = Blue, R = Red
- YUV
  - Similar to YP_bP_r but scaled to be carried on a composite carrier.
- YCbCr Digital representation of YP_bP_r colourspace (8 bit, twos complement)

RGB to YUV conversion

Y = 0.299R + 0.587G + 0.114B

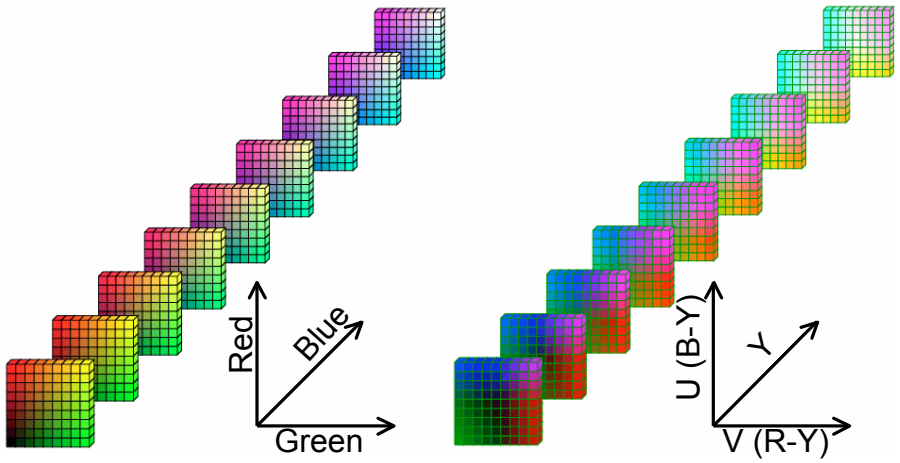
U= (B-Y)*0.565

V= (R-Y)*0.713

Output is clamped to the ranges:

- Y=[16..235]
- U,V=[16..239]

RGB vs YUV



Gamma Correction

- A power law relationship that approximates the relationship between the encoded luminance and the actual brightness.
- The light intensity L is related to the encoded value (eg source voltage) V_s by the formula:

$$L \propto (V_s)^{\gamma}$$

[γ is the Greek letter gamma]

- Different monitors have different native gamma, and so a gamma correction may be needed to display correctly.

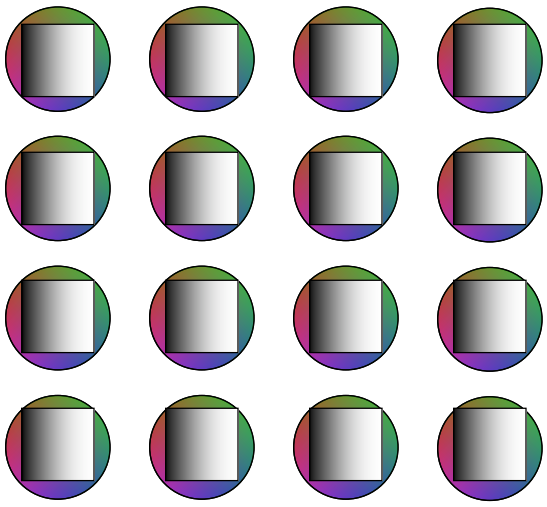
Digitisation (sampling)

- As TV signals are natively in luminance (from B&W days) and chrominance-difference form, when you capture video its native form is YUV.
- Question:
  - How may bits of chrominance for each bit of luminance?
  - Human eye is less spatially sensitive to chrominance.
  - Original TV signal had less chrominance information than luminance.

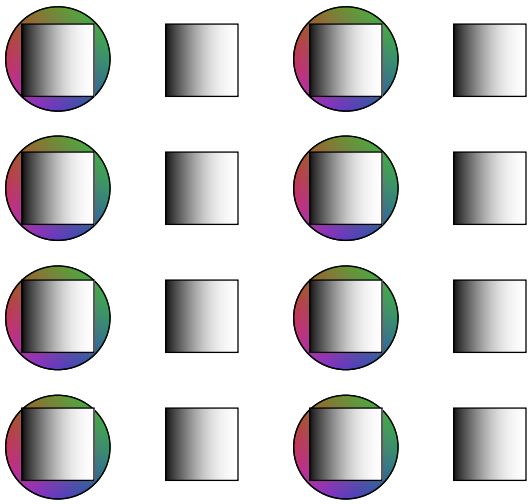
YUV Formats

- YUV 4:4:4
  - 8 bits per Y,U,V channel (no chroma downsampling)
- YUV 4:2:2
  - 4 Y pixels sample for every 2 U and 2V
  - 2:1 horizontal downsampling, no vertical downsampling
- YUV 4:2:0
  - 2:1 horizontal downsampling
  - 2:1 vertical downsampling
- YUV 4:1:1
  - 4 Y pixels sample for every 1 U and 1V
  - 4:1 horizontal downsampling, no vertical downsampling

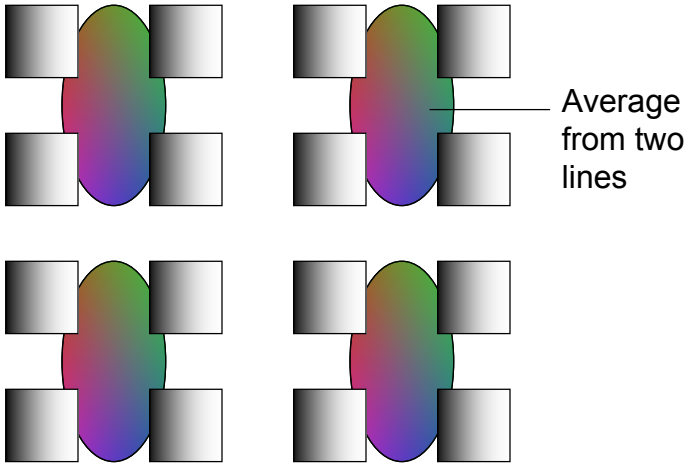
YUV 4:4:4 Sample Positions



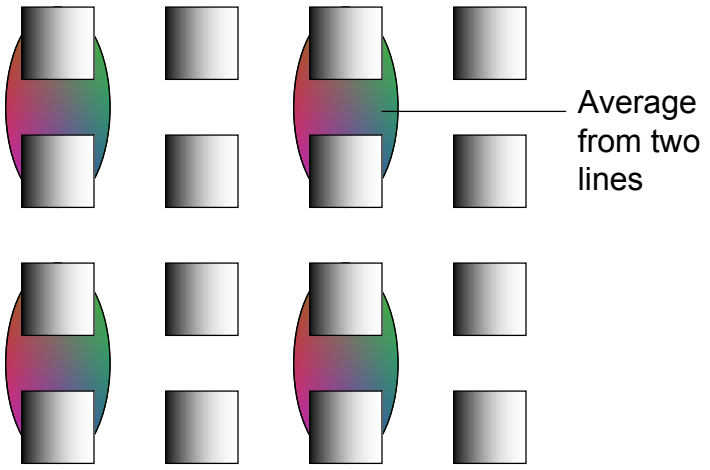
YUV 4:2:2 Sample Positions



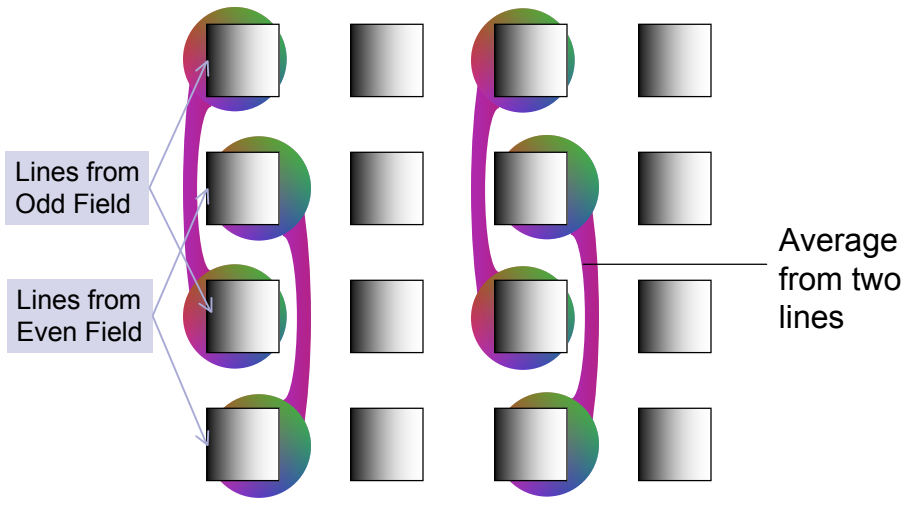
YUV 4:2:0 (MPEG1/H.261/H.263)



YUV 4:2:0 (MPEG 2, Progressive Source)



YUV 4:2:0 (MPEG 2, Interlaced Source)



Video Resolutions (non-HDTV)

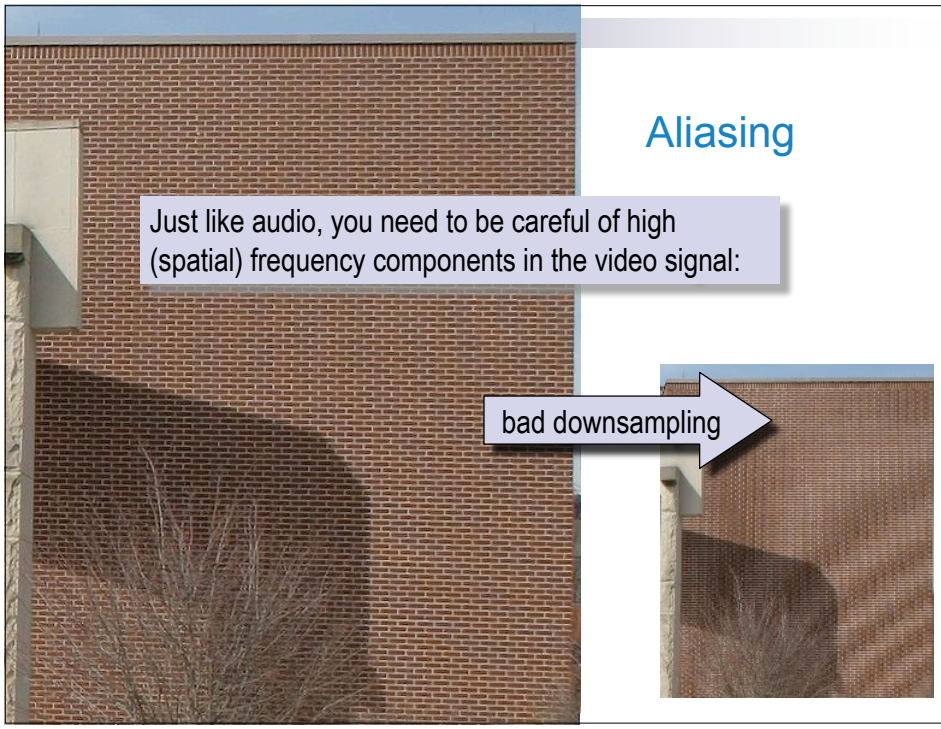
- PAL
  - Full resolution: 833x625 (4:3 aspect ratio)
  - Visible resolution: (Super CIF): 704x576
  - CIF (Common Image Format): 352x288
  - QCIF (Quarter CIF): 176x144
- NTSC
  - Full resolution: 700x525 (4:3 aspect ratio)
  - Visible resolution: 640x480
  - SIF (Standard Image Format): 352x240
  - SIF SP (Standard Image Format, Square Pixel): 320x240
  - QSIF (Quarter SIF): 176x120
  - QSIF SP (Quarter SIF, Square Pixel): 160x120

Video Resolutions (Digital HDTV)

- **720p** - 1280x720 progressive
- **1080i** - 1920x1080 interlaced
- **1080p** - 1920x1080 progressive

Aliasing

Just like audio, you need to be careful of high (spatial) frequency components in the video signal:

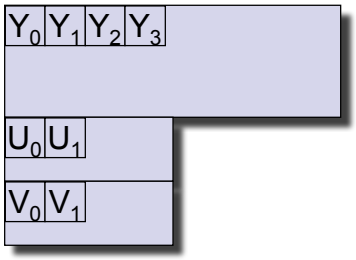


Video Stream Format

- YUV 4:2:2 formats:
  - YUV2: $Y_0U_0Y_1V_0$ $Y_2U_1Y_3V_1$ $Y_4U_2Y_5V_2$
  - UYVY: $U_0Y_0V_0Y_1$ $U_1Y_2V_1Y_3$ $U_2Y_4V_2Y_5$

4 bytes

- YUV 4:2:0 formats (12 bits per pixel packed format)
  - YV12



All the Y samples precede all the U samples, then all the V samples

Colour Mapping

- True Colour
  - RGB values used directly for display.
- Indexed Colour
  - RGB 24 bit: 16.7 million colours.
  - Can maintain a palette of 256 most commonly used colours from the 16.7 million possible colours.
  - For each pixel, store index into palette (8 bits).
  - Store mapping from index to real colour only once.
  - Other colours are approximated, typically using dithering.

Uncompressed Video Data Rate

- Examples (CCIR 601)
  - PAL signal: 864x625, YUV 4:2:2 20 bits/pixel, 25fps. 270Mb/s
  - PAL signal: 864x625, YUV 4:2:2 16 bits/pixel, 25fps. 216Mb/s
  - PAL video: 720x576, YUV 4:2:2 16 bits/pixel, 25fps. 166Mb/s (~1GByte/min)
- Firewire: 400Mb/s (800Mb/s)
- USB 2.0: 480Mb/s