Chapter 3
Fundamental Concepts in Video

3.1 Types of Video Signals

3.2 Analog Video

3.3 Digital Video

3.1 TYPES OF VIDEO SIGNALS

Types of Video Signals

Video standards for managing analog output:

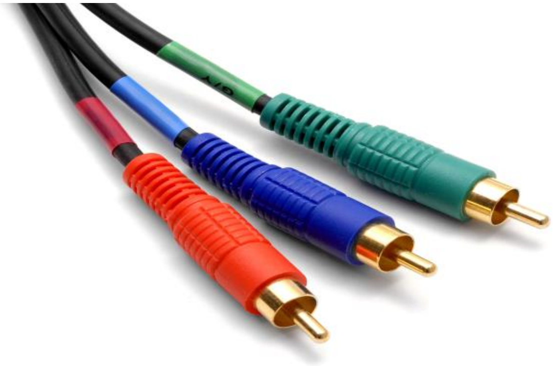
A. Component Video

B. Composite video

C. S-Video

A. Component video - 3 Signals

- Higher-end video systems make use of three separate video signals for the red, green, and blue image planes. Each color channel is sent as a separate video signal.
- Most computer systems use Component Video, with separate signals for R, G, and B signals.

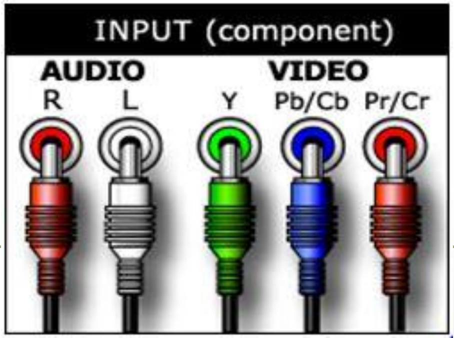


A. Component video - 3 Signals

- For any color separation scheme, Component Video gives the best color reproduction since there is no "crosstalk" between the three channels. This is not the case for S-Video or Composite Video, discussed next.

- Component video, however, requires more bandwidth and good synchronization of the three components.

- component-video cables do not carry audio and are often paired with audio cables.



B. Composite Video - 1 Signal

- **Composite video**: color ("chrominance") and intensity ("luminance") signals are mixed into a *single* carrier wave.
- In video, luminance (***luma*** or Y for short) represents the brightness in an image (the "black-and-white" of the image).
- While chrominance (***chroma*** or C for short) is the signal used in video systems to convey the color information of the picture, separately from the accompanying luma signal

B. Composite Video - 1 Signal

- Since color and intensity are wrapped into the same signal, some interference between the luminance and chrominance signals is inevitable.

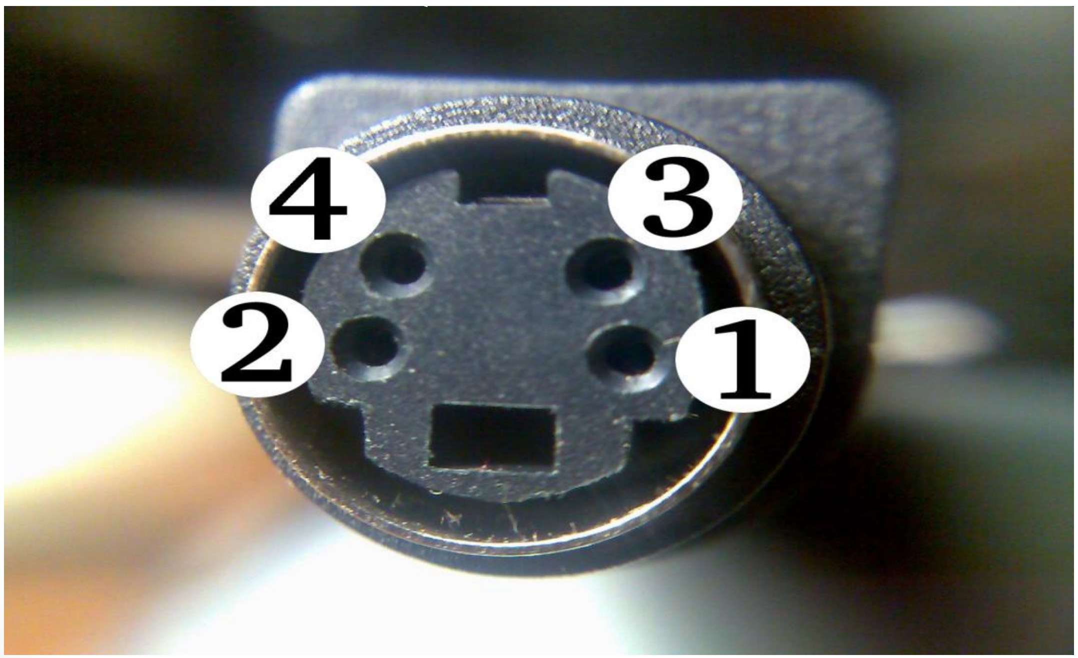
- All the signals are mixed together and carried on a single cable as a composite of the three color channels and the sync signal → Lowest quality for a video signal & less-precise color definition.

C. S-Video - 2 Signals

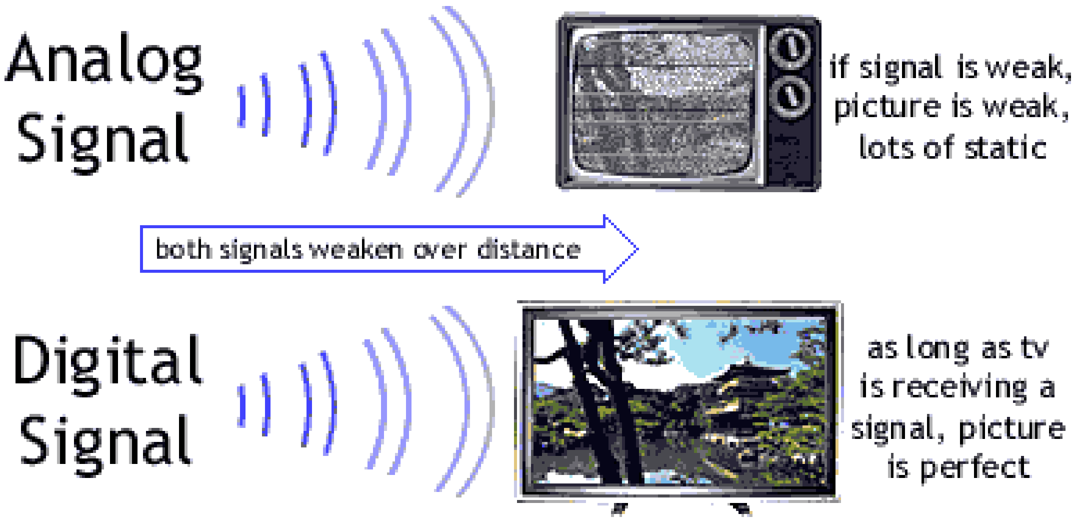
S-Video: as a compromise, (separated video, or Super-video) uses two wires, one for luminance and another for a composite chrominance signal.

- As a result, there is less crosstalk between the color information and the crucial gray-scale information
- Compared to a Composite video connection S-Video simply carries more information to the TV thus producing a slightly better picture than composite.
- Because an S-video cable only carries the video signal you still need the old stand (red/white) audio cables in order to hear sound.

C. S-Video - 2 Signals



Ground Y

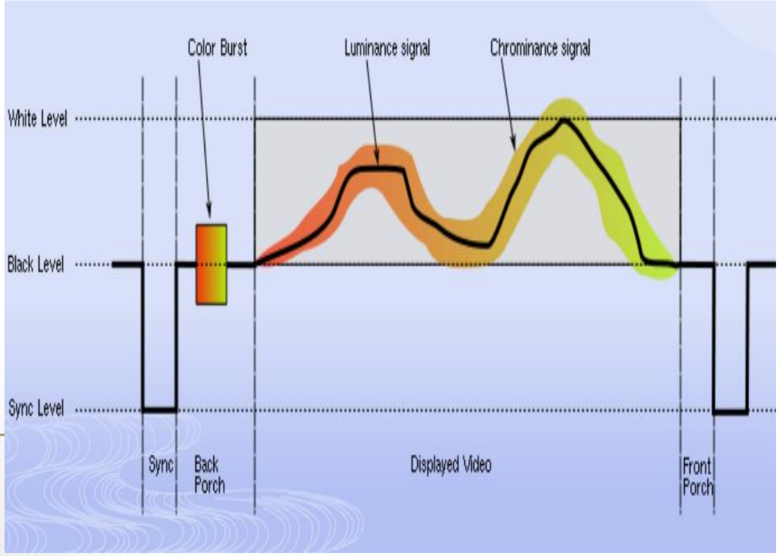


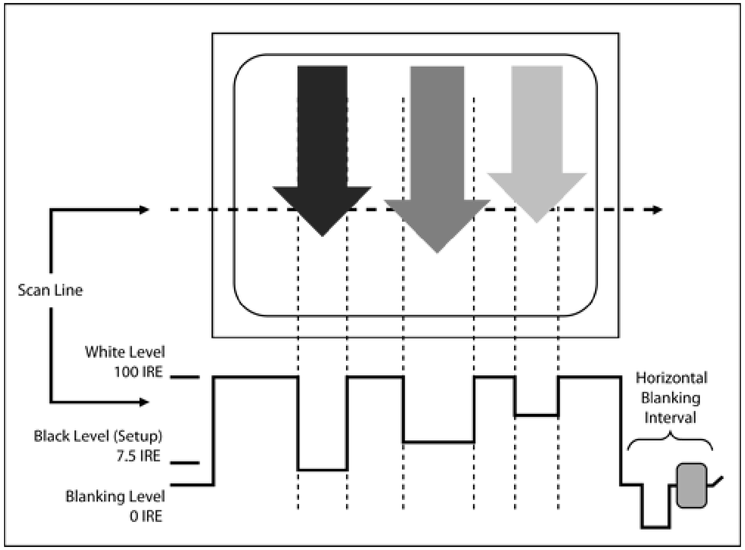
3.2 ANALOG VIDEO

Analog Video

Analog Video

- **Analog video** is represented as a continuous (time varying) signal. (Resolution measured in the number of horizontal scan lines (due to the nature of early cathode-tube cameras)
- Each line in the video image represents continuous measurements of the color and brightness along the horizontal axis.

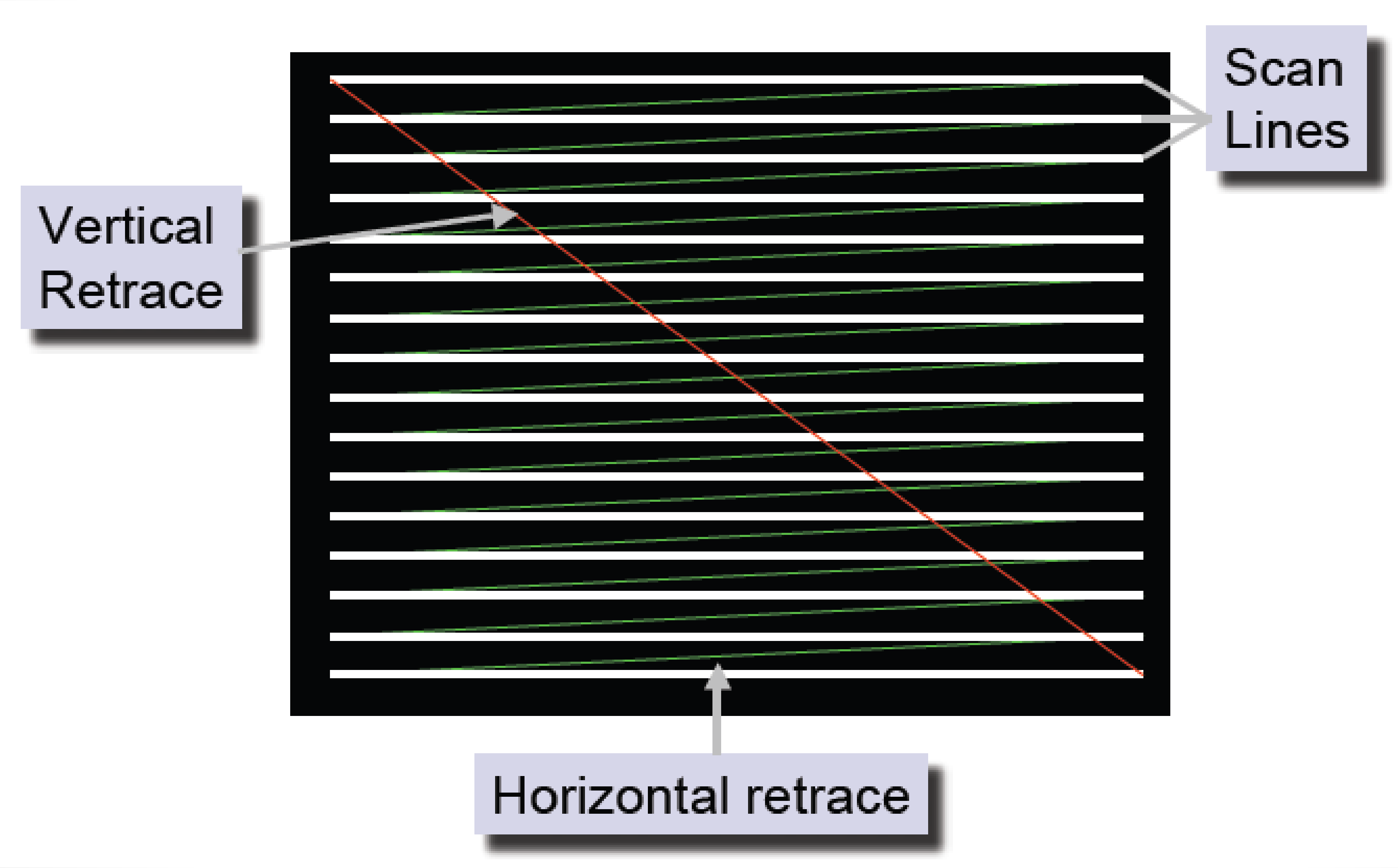




Analog Video

- At the end of each line, there is a portion of the waveform (**horizontal blanking interval**) that tells the scanning circuit in the display to retrace to the left edge of the display and then start scanning the next line.
- Starting at the top, all of the lines on the display are scanned in this way. One complete set of lines makes a picture. This is called a **frame**.
- Once the first complete picture is scanned, there is another portion of the waveform (**vertical blanking interval**) that tells the scanning circuit to retrace to the top of the display and start scanning the next frame, or picture.
- This sequence is repeated at a fast enough rate so that the displayed images are perceived to have continuous motion.

Analog Video



Analog Video Scanning Systems

- These are two different types of scanning systems. They differ in the technique used to "paint" the picture on the screen.

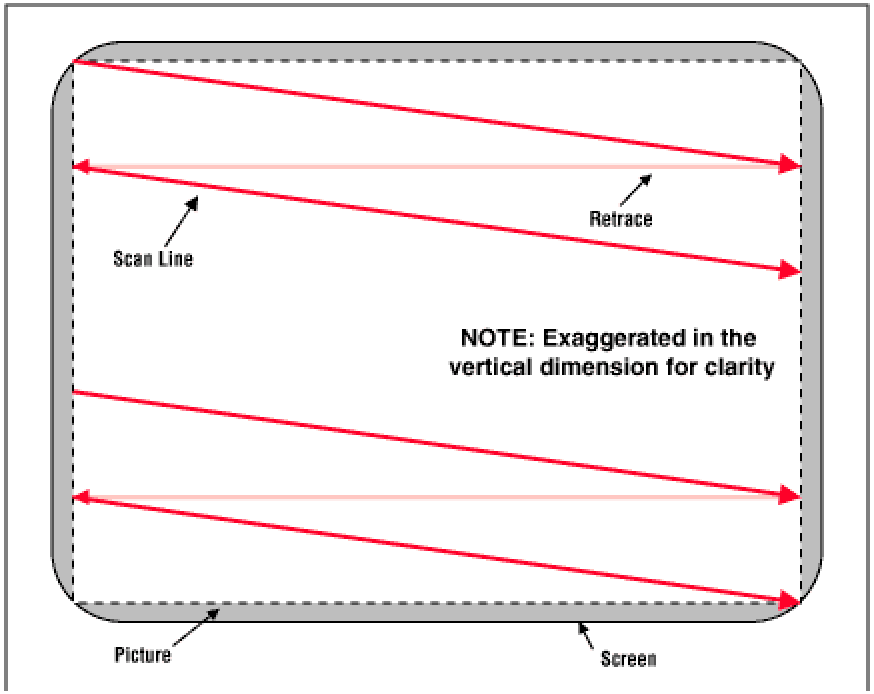
- *Television* signals and compatible displays are typically **interlaced**, and *computer* signals and compatible displays are typically **progressive** (**non-interlaced**).

- These two formats are incompatible with each other; one would need to be converted to the other before any common processing could be done.

You have probably heard of the resolution standards 480i, 480p, 720p, 1080i and 1080p. The "i" and "p" after the number actually stands for "interlaced" and "progressive" respectively,

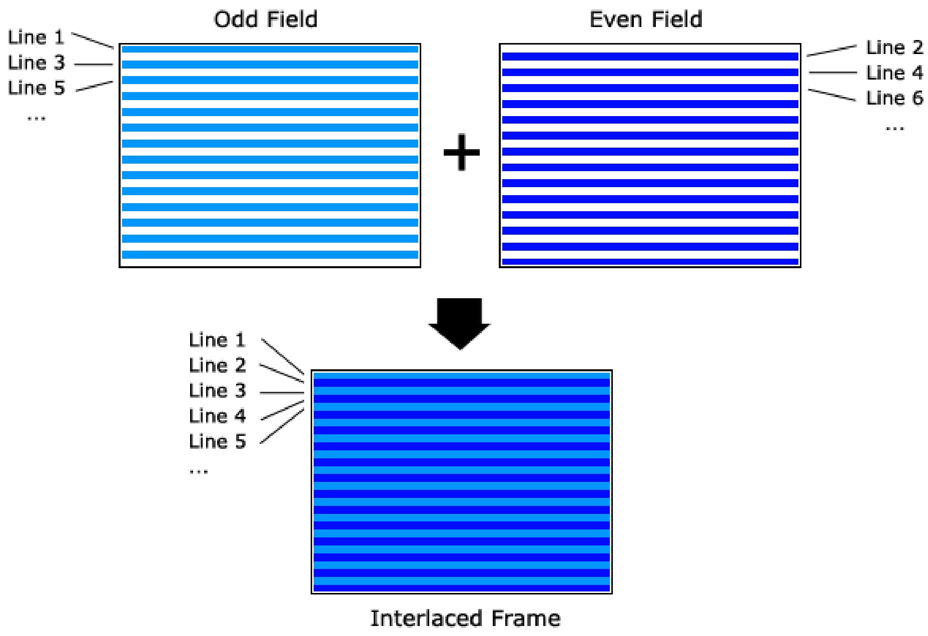
A. Progressive Scanning

- A **progressive**, or non-interlaced, picture is painted on the screen by scanning all of the horizontal lines of the picture in one pass from the top to the bottom.



B. Interlaced Scanning

- In TV, and in some monitors and multimedia standards as well, another system, called "interlaced" scanning is used.
- **Interlaced scanning** is where each picture, referred to as a **frame**, is divided into two separate sub-pictures, referred to as **fields**. Two fields make up a frame.



B. Interlaced Scanning

- An interlaced picture is painted on the screen in two passes, by:
  - First scanning the horizontal lines of the first field and then
  - Retracing to the top of the screen and then
  - Scanning the horizontal lines for the second field in-between the first set.

- In fact, the odd lines (starting from 1) end up at the middle of a line at the end of the odd field, and the even scan starts at a half-way point.

B. Interlaced Scanning

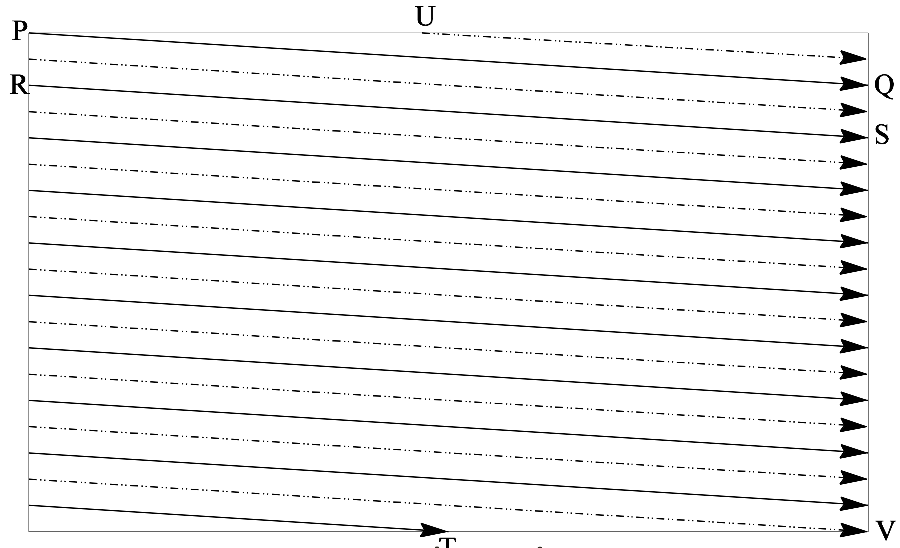
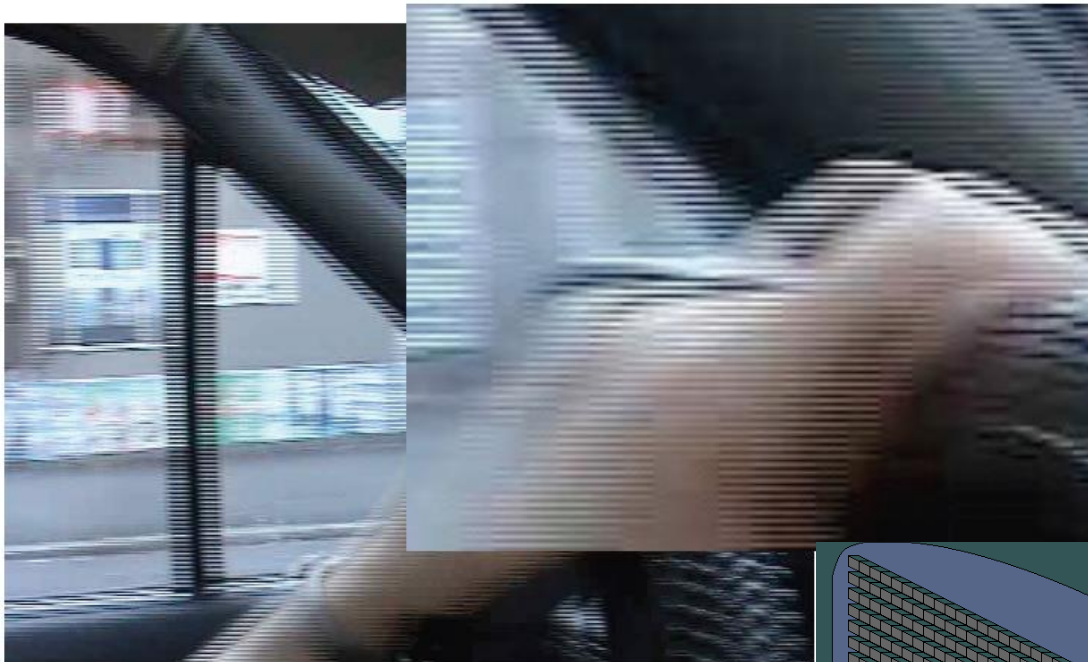
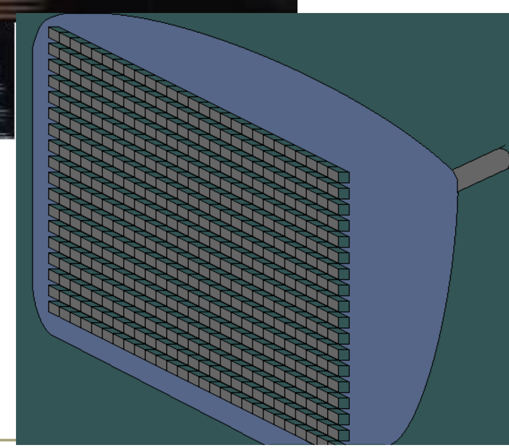


Fig. 3.1: Interlaced raster scan

- Figure 3.1 shows the scheme used. First the solid (odd) lines are traced, P to Q, then R to S, etc., ending at T; then the even field starts at U and ends at V.
- The jump from Q to R, etc. in Figure 3.1 is called the **horizontal** retrace, during which the electronic beam in the CRT is blanked. The jump from T to U or V to P is called the **vertical retrace**.

B. Interlaced Scanning





Interlaced & Progressive examples

The animated picture shows the difference between interlaced and progressive

[Difference between Interlaced Scan and Progressive Scan?]

Advantages of Interlaced Scanning

Popularity

- Interlaced scan was the most popular format in which broadcasters output their TV signals. This is due to the reduced bandwidth that interlaced scanning requires.

Lower prices

- The internal workings of televisions or other display units using the interlaced scan method of image rendering are far less complex than progressive scan devices, meaning that prices for interlaced units are generally much lower than progressive scan units

Disadvantages of Interlaced Scanning

Image artefacts

- During high-motion videos, images rendered by interlaced devices are prone to distracting image artefacts. This is because each frame of interlaced video is composed of two segments that are captured at different moments in time. If the recorded object – for example, a fast moving sports sequence, is moving fast enough to be in different positions when each individual segment is captured, a "motion artefact" will result.

1. Blurring

- To counter the problem of image artefacts, images produced on interlaced scan systems are sometimes intentionally blurred, thus producing an image of lesser quality.

Disadvantages of Interlaced Scanning

2. Flickering

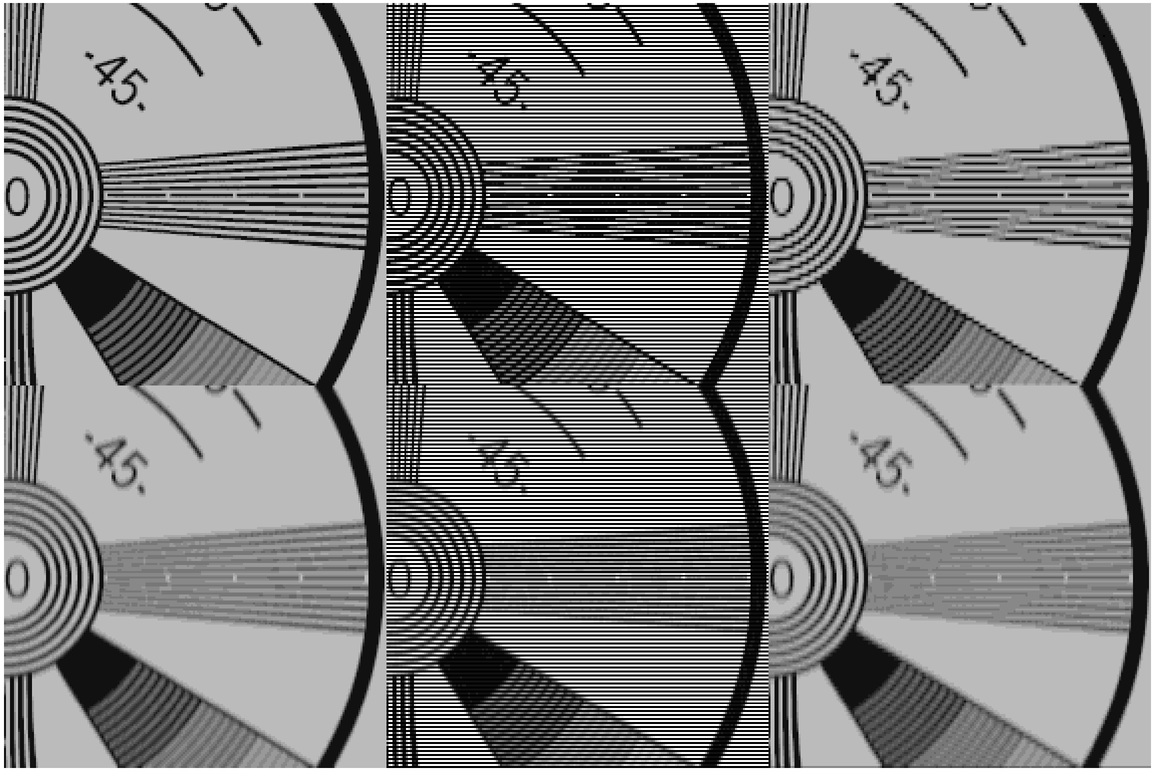
- On larger screens particularly, an irritating flickering effect can sometimes become apparent. This flickering is also called "**interline twitter**" and is caused by the image on the screen containing vertical detail that approaches the horizontal resolution of the video format. Whenever you have seen a TV presenter's striped shirt or suit flickering on a screen, this is interline twitter in action!

Interlacing problems (Blurring)

Figure 1: TECHSPEC® Man's High-Speed Movement Using a Progressive Scanning Sensor

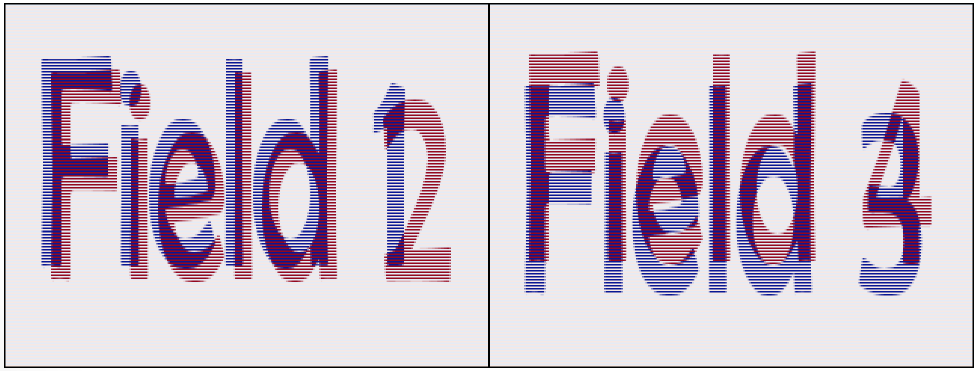
Figure 2: Ghosting and Blurring of TECHSPEC® Man's High-Speed Movement Using an Interlaced Scanning Sensor

Interlacing problems (Flickrring)



De-interlacing

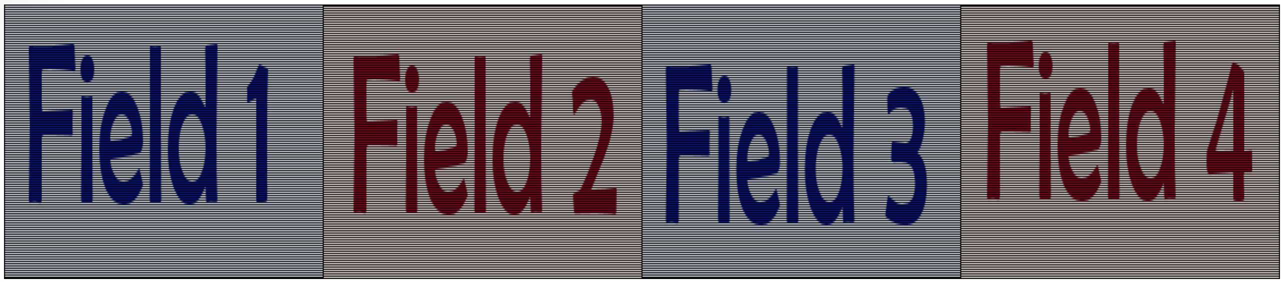
- Deinterlacing is the process of converting interlaced video, such as common analog television signals or 1080i format HDTV signals, into a non-interlaced form.
- The simplest de-interlacing method consists of discarding one field and duplicating the scan lines of the other field. The information in one field is lost completely using this simple technique.



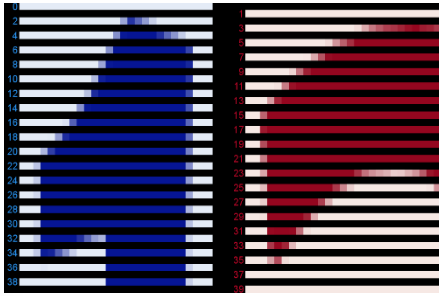
Take the picture as an example, with four different fields numbered 1 to 4:

How to Deinterlace Footage

De-interlacing



The fields have been separated.



Demonstrating how the top field (fields 1 and 3) is on even numbered lines, while the bottom field (fields 2,4) is on odd numbered lines.

You'll notice that the height has been cut in half and Dante looks too short (or too wide).

Advantages of Progressive Scanning

No image artefacts

- None of the image artefacts associated with interlaced images are apparent in systems using progressive scan technology, because the lines on the screen are displayed sequentially, not at two different times.

No blurring

- As a result of the lack of image artefacts, no intentional blurring is necessary in progressive scan systems.

Disadvantages of Progressive Scanning

Higher quality images

- Images are smoother are more detailed in progressive scan as they are refreshed at a faster frequency.

Higher bandwidth means lack of use

- As an image using a progressive scan requires a higher bandwidth than an interlaced image of the same size, broadcasters using analogue signals hardly ever use progressive scan images.

Analog Video Broadcast Standards

- Broadcast standards, are ways of **encoding video information** for broadcast to television receivers. These standards are also used to **describe the display capabilities of video monitors** and are thus also called video output formats (VOFs).

- They are **encoding or formatting standards** for the transmission and reception of television signals.

- There are three main **analog television systems** in use around the world:
  - NTSC: in USA but replaced with ATSC Digital Television Standard
  - PAL, and SECAM: In Europe

A. NTSC

NTSC: National Television Standards Committee:

- United States, Canada, Mexico, Japan
- Defined a method for encoding information into the electronic signal that ultimately created a television picture.
- A single frame of video → 525 horizontal scan lines
  - NTSC follows the interlaced scanning system, and each frame is divided into two fields, with 262.5 lines/field.
- Higher Frame Rate - Use of 30 frames per second (really 29.97) reduces visible flicker.
  - Thus the horizontal sweep frequency is 525×29.97 ≈ 15, 734 lines/sec, so that each line is swept out in (1/15734) × 10 ^{6} sec ≈ 60 μsec.

A. NTSC

- Fig. 3.4 shows the effect of “vertical retrace & sync” and “horizontal retrace & sync” on the NTSC video raster.

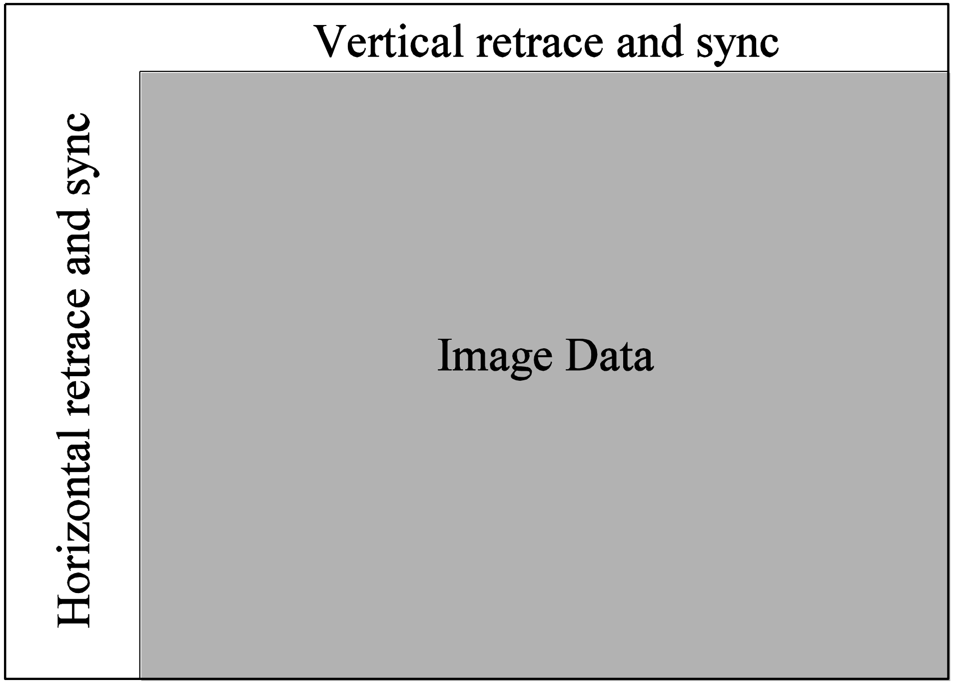


Fig. 3.4: Video raster, including retrace and sync data

A. NTSC

- Vertical retrace takes place during 20 lines reserved for control information at the beginning of each field. Hence, the number of active *video lines* per frame is only 485.
- Similarly, almost 1/6 of the raster at the left side is blanked for horizontal retrace and sync. The non-blanking pixels are called *active pixels*.
  - Since the horizontal retrace takes 10.9 μsec, this leaves 52.7 μsec for the active line signal during which image data is displayed.
  - NTSC TV is only capable of showing about 70% of the specified active lines.

B. PAL

PAL: Phase Alternate Line

- United Kingdom, Western Europe, Australia, South Africa, China, and South America.
- Screen resolution: 625 horizontal lines → more picture detail.
- Interlaced, each frame is divided into 2 fields, 312.5 lines/field
- Scan rate to 25 fps → More Flicker - Due to the lower frame rate
- Field: 1/50 of a second to draw (50 Hz).

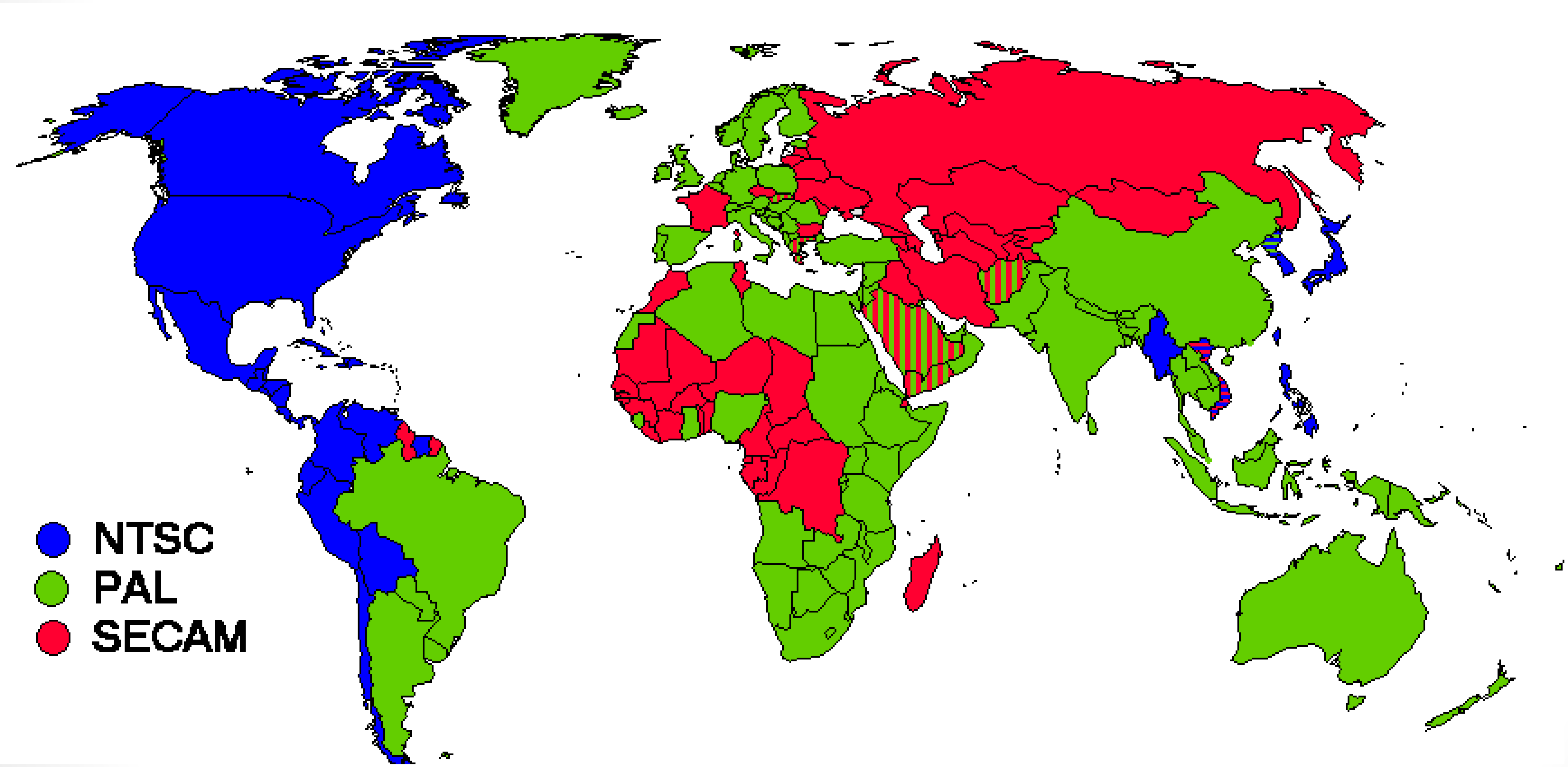
C. SECAM

SECAM: Sequential Color and Memory

- France, Eastern Europe, the former USSR.
- Similar to PAL:
  - SECAM is a 625-line, 50 Hz system.
  - SECAM shares with PAL/625, the higher number of scan lines than NTSC/525.
  - Scan rate to 25 fps → More Flicker - Due to the lower frame rate

- They differ slightly in their color coding scheme

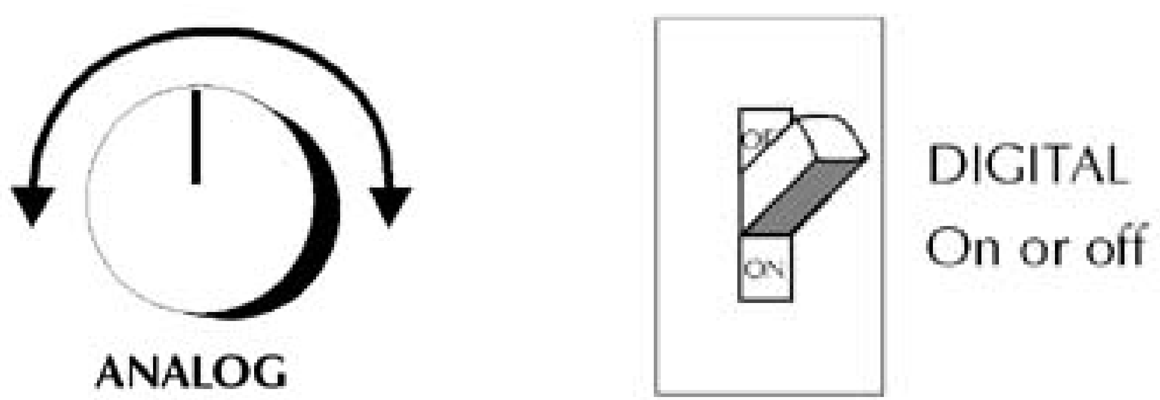
Color TV Systems of the world

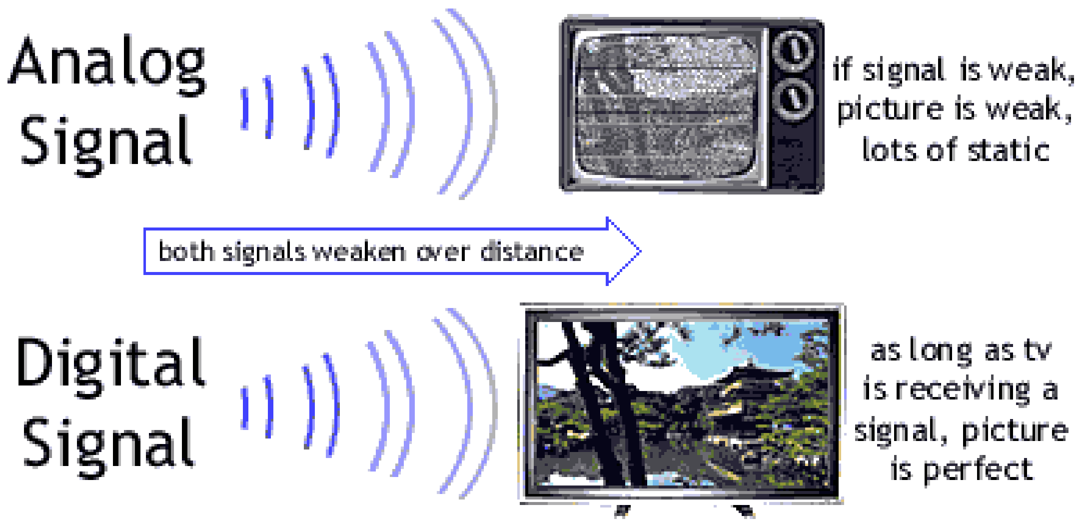


- Table 3.2 gives a comparison of the three major analog broadcast TV systems.

  - Table 3.2: Comparison of Analog Broadcast TV Systems

TV System	Frame Rate (fps)	# of Scan Lines	Total Channel Width (MHz)	Bandwidth Allocation (MHz)		
				Y	I or U	Q or V
NTSC	29.97	525	6.0	4.2	1.6	0.6
PAL	25	625	8.0	5.5	1.8	1.8
SECAM	25	625	8.0	6.0	2.0	2.0





3.3 DIGITAL VIDEO

Digital Video

Digital video is a type of digital recording system that works by using a digital rather than an analog video signal.

The advantages of digital representation for video are many. For example:

1. Video can be stored on digital devices or in memory, ready to be processed (noise removal, cut and paste, etc.), and integrated to various multimedia applications;
2. Direct random access is possible, which makes nonlinear video editing achievable as a simple, rather than a complex, task;
3. Repeated recording does not degrade image quality;
4. Ease of encryption and better tolerance to channel noise → Almost all digital video uses component video
5. No need for blanking and sync pulse

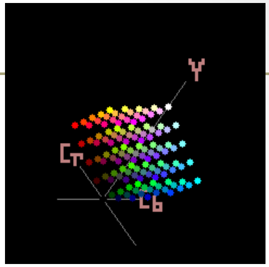
Video color models - Y color spaces

- Y is luminance, Such as : YIQ, YUV, YCbCr…
- Used in television sets and videos, I or U and Q or V is chromaticity

- Black & White television sets display only Y.
- color TV sets convert to RGB, YUV=PAL, YIQ=NTSC.

- Can be used as well before image compression where High bandwidth for Y and Small bandwidth for chromaticity.

YCbCr color space



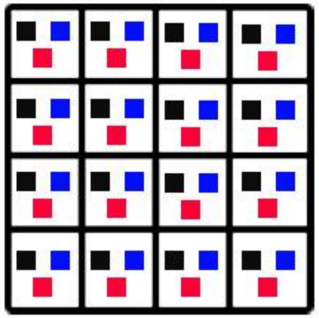
- YCbCr is a color space for digital television systems.
- YCbCr Color Space is used in MPEG video compression standards: Y is luminance, Cb is blue chromaticity, Cr is red chromaticity.
- Chroma Cb corresponds to the U color component, and chroma Cr corresponds to the V component of a general YUV color space.

Chroma Subsampling

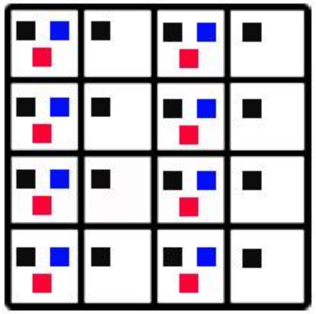
- **it** is the practice of encoding images by implementing less resolution for chroma information than for luma information, taking advantage of the human visual system's lower acuity for color differences than for luminance.
- Since humans see color with much less spatial resolution than they see black and white, it makes sense to “decimate” the chrominance signal.
- Interesting (but not necessarily informative!) names have arisen to label the different schemes used.

Chroma Subsampling

- To begin with, numbers are given stating how many pixel values, per four original pixels, are actually sent:
  - The chroma subsampling scheme "4:4:4" indicates that no chroma subsampling is used: each pixel's Y, Cb and Cr values are transmitted, 4 for each of Y, Cb, Cr.

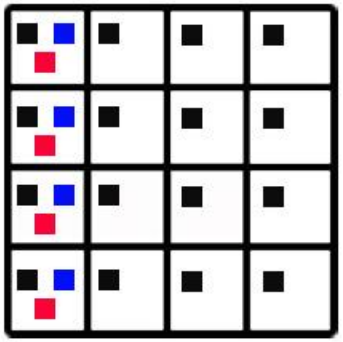


- The scheme "4:2:2" indicates horizontal subsampling of the Cb, Cr signals by a factor of 2. That is, of four pixels horizontally labelled as 0 to 3, all four Ys are sent, and every two Cb's and two Cr's are sent, as (Cb0, Y0)(Cr0, Y1)(Cb2, Y2)(Cr2, Y3)(Cb4, Y4), and so on (or averaging is used).

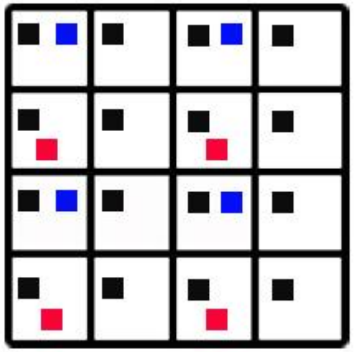


Chroma Subsampling

- The scheme "4:1:1" subsamples *horizontally* by a factor of 4.



- The scheme "4:2:0" subsamples in both the *horizontal* and *vertical* dimensions by a factor of 2. Theoretically, an average chroma pixel is positioned between the rows and columns as shown Fig.3.6.
- Scheme 4:2:0 along with other schemes is commonly used in JPEG and MPEG (see later chapters in Part 2).



Chroma Subsampling

Types of Digital Displays

- **DTV** - Digital television encompasses all of the underlying standards for SDTV, EDTV and HDTV developed by the ATSC.

- A TV described as being DTV-ready, will be able to display the new digital broadcasts and will use one of the three standards listed below:
  - **SDTV (Standard Definition TV)**: the NTSC TV or higher.
  - **EDTV (Enhanced Definition TV)**: 480 active lines or higher.
  - **HDTV (High Definition TV)**: 720 active lines or higher.

[Differences]

Types of Digital Displays

Standard-Definition TV:

- SDTV is the digital broadcast television standard defined under the DTV standards developed by the ATSC.
- An SDTV is defined as being able to receive an ATSC signal and in most cases will have 480 lines of resolution.
- aspect ratio of 4:3.
- An SDTV will be the basic television compatible with the new standards.

Types of Digital Displays

Enhanced-Definition TV:

- EDTV, like SDTV, displays 480 lines.
- However, instead of being interlaced, it is a progressive scan image.
- This results in a smoother image, especially during action sequences, as well as a brighter picture.
- Nearly all ED televisions have an aspect ratio of 16:9.
- Just a note, most EDTV displays are plasma panels. Although, most plasma screens are HDTVs.

Types of Digital Displays

High-Definition TV:

- HDTV comes in three flavors, 720p, 1080i and now 1080p; really there are 18 DTV formats, but most TVs will use one of these three.
- The first resolution displays 720 lines progressively while the second displays 1,080 lines interlaced.
- 1080p should also be fully backward compatible for 720p and 1080i TVs.
- Nearly all HD televisions have an aspect ratio of 16:9.

- The standard supports video scanning formats shown in Table 3.4. In the table, “I” mean interlaced scan and “P” means progressive (non-interlaced) scan.

  - Table 3.4: Advanced Digital TV formats supported by ATSC

# of Active Pixels per line	# of Active Lines	Aspect Ratio	Picture Rate
1,920	1,080	16:9	60I 30P 24P
1,280	720	16:9	60P 30P 24P
704	480	16:9 & 4:3	60I 60P 30P 24P
640	480	4:3	60I 60P 30P 24P

- **The salient difference between conventional TV and HDTV**:
    - HDTV has a much wider aspect ratio of 16:9 instead of 4:3.
    - HDTV moves toward progressive (non-interlaced) scan. The rationale is that interlacing introduces serrated edges to moving objects and flickers along horizontal edges.

Comparison

The differences between standards are summarized below in this handy chart:

	SDTV	EDTV	EDTV	HDTV	HDTV	HDTV
Width/Scan	480i	480p	480p	720p	1080i	1080p
Resolution	640x480	640x480	720x480	1280x720	1920x1080	1920x1080
Ratio	4:3	4:3	16:9	16:9	16:9	16:9