Video Theory I

Technology For Performers

On today's menu:

- Frame Rate
- Resolution

Frame Rate

- Much like digital audio, video is **not** a continuous stream of uninterrupted content

- It is a series of still-frames, played in rapid succession (like an animation flip-book)

- This process creates the illusion of motion, referred to as the **Phi Phenomenon**.

Defining Frame Rate

- We describe the speed at which we change these still frames as the **frame rate**
    - Frame rate is expressed as **fps**, or **frames per second**
        - It is also sometimes expressed in **hertz** (**Hz)**, since this unit of measurement represents ‘cycles per second’
- Humans can process up to 10-12 images per second (10-12 FPS) and perceive them individually
    - Above this rate, we perceive motion

A Little History…

- Early films were silent, and cameras/projectors were often hand-cranked. This meant frame rate was not perfectly consistent.
    - Cinematographers/Projectionists would take advantage of this ‘human element’; manually varying the frame rate to suit the mood of a scene by ‘undercranking' or ‘overcranking’ the camera/projector.
- Target frame rates ranged from 16-24 fps
    - This kept things above the motion-threshold, but would be slow and jerky by modern film standards

Sound Arrives

- Movies with sound appeared in the mid 1920's and variation in film speed was no longer acceptable as it would manifest itself as noticeable pitch-fluctuation
    - Film projectors became motor driven to maintain consistency
- In **1929**, frame rate became internationally standardized at **24 fps**
    - Why 24? Depends on who you ask…
        - A reasonable average of established frame rates
        - Provided good audio fidelity
        - Was an easily divisible number for quick math (12 frames = half second, 6 frames = 1/4 second, etc.)

*Notice the audio track on the left side of the film

Flicker Fusion Threshold

- Even though motion may seem continuous at frame rates above 12 fps, we may still perceive a ‘flickering’ of brightness as the frames are changed

- The point at which we no longer notice the flicker of light is called the **flicker fusion threshold**, and is also described in **Hz/fps**

- Thomas Edison argued that any frame rate less than 46 fps would “strain the eye”, but using that many *discreet* frames would be very costly…

Frame Rate/Flicker Rate

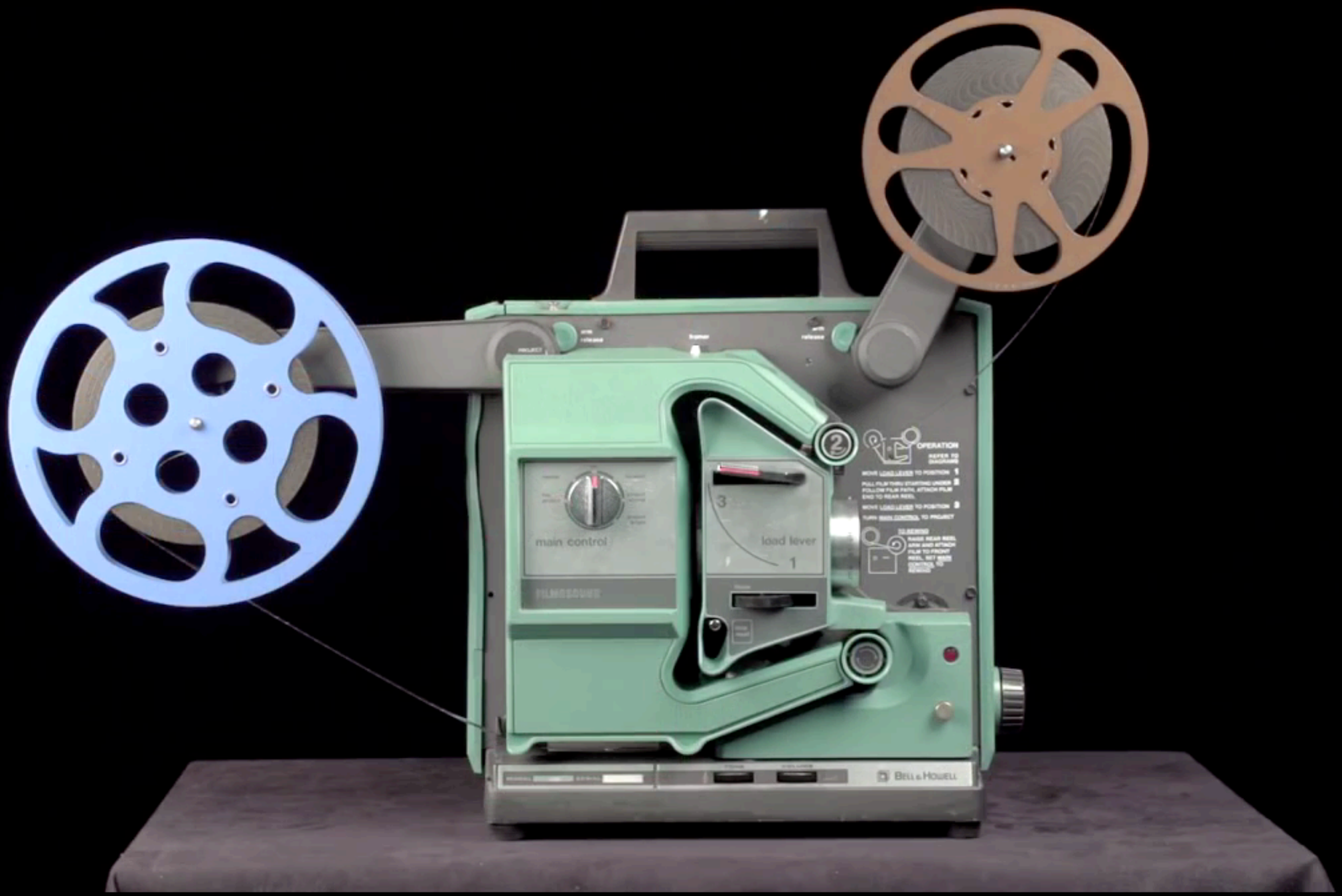
- So we use another illusion:
    - By playing film back at 24 fps and flashing each frame twice, we create the *illusion* of 48 fps, which satisfies Edison's theoretical flicker fusion threshold
        - By flashing each frame three times at 24 fps, we create the *illusion* of 72 fps, which is well above that threshold
- Keep in mind that for all of these examples the **frame rate** remains at **24 fps**
- It is the **flicker rate** that is increased to 48 Hz and 72 Hz

Film Mechanics

- In an analog film camera/projector:
  - **Frame Rate** is controlled by the **Shuttle**
  - **Flicker Rate** is controlled by the **Shutter**
    - The more **blades** on a shutter, the higher the flicker rate

Let’s see how it works…

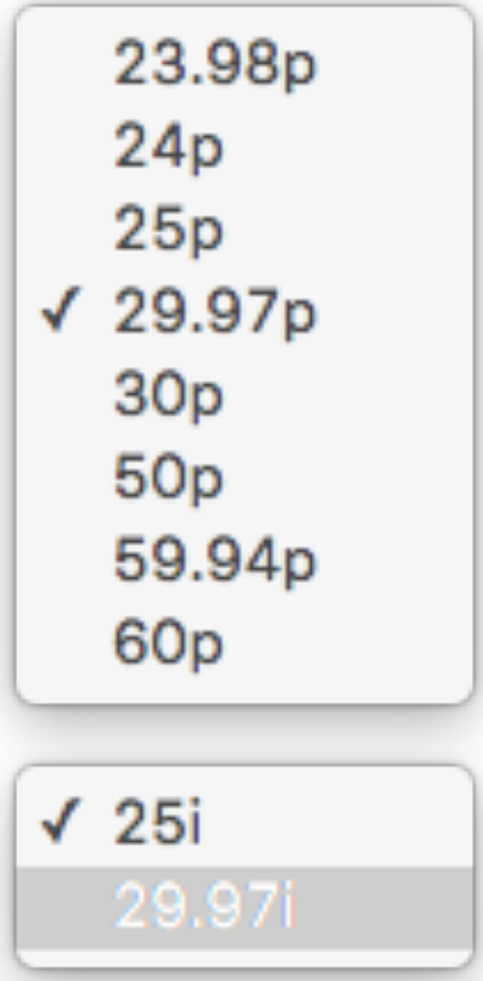
- https://www.youtube.com/watch?v=En__V0oEJsU


main control
load lever
OPERATION
BELL & HOWELL

Beyond Film

- Though 24 fps is the original **film** standard (and is still the standard in Hollywood), we have many other options when working with **video**

- With the development of television and digital devices we have adapted frame rates to suit each delivery format



Progressive vs Interlaced

- You'll notice that frame rates are often listed with either a letter '**p**' or a letter '**i**' after them
  - Example: 24p, 25i, etc.

- '**p**' stands for **progressive**. In progressive formats, an entire frame is displayed at once, just like film

- '**i**' stands for **interlaced**. Interlaced formats are designed for TV and work a little differently…

Interlacing

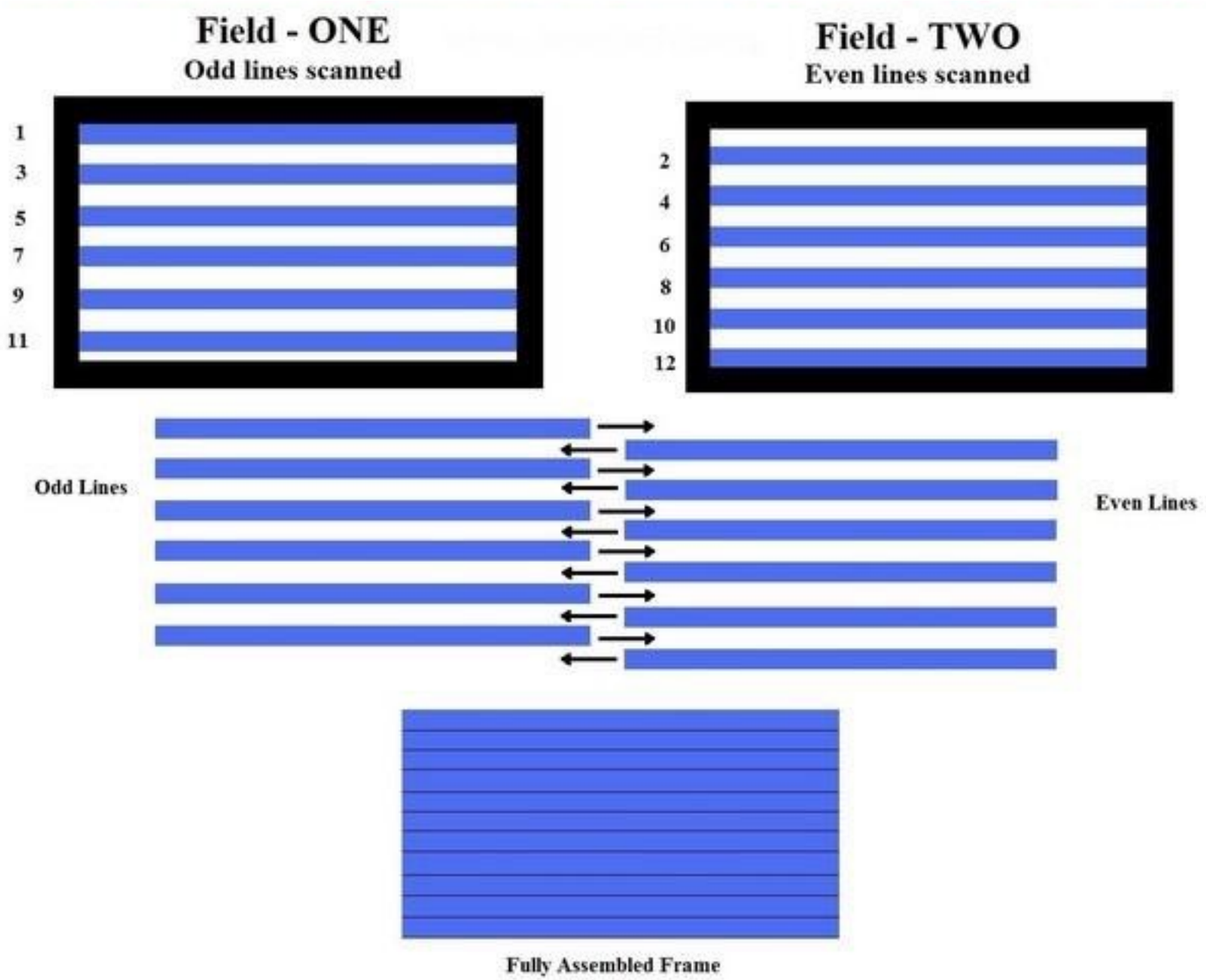
- The television industry needed a way to deal with the same flicker problem as the film industry, however the repeated frames trick wasn't a viable option due to bandwidth limitations

- What they came up with instead was **interlacing**

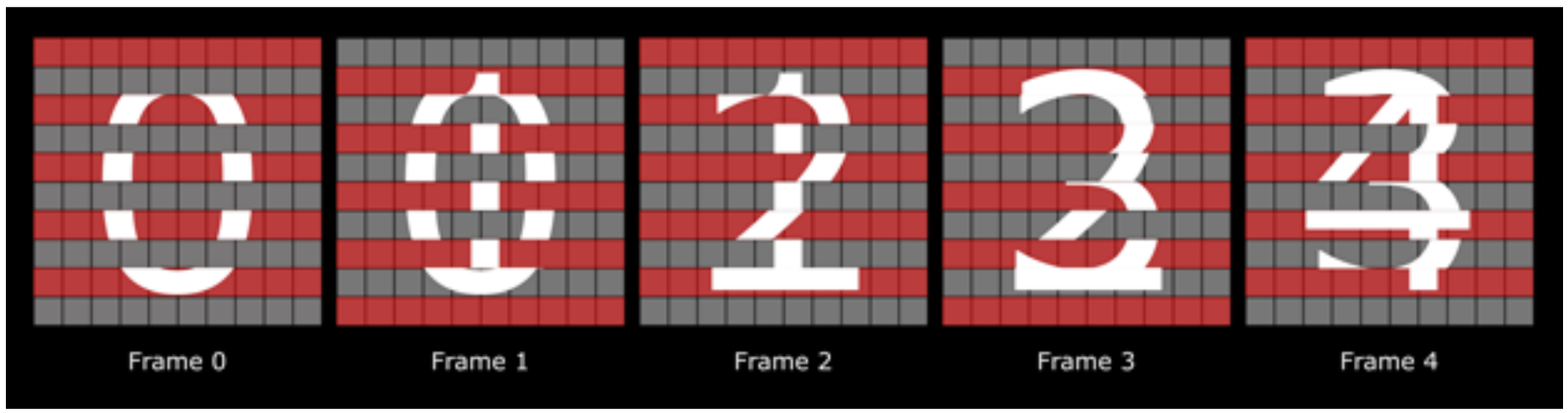
  - Developed in the early 1930's, interlacing splits the display area of a TV into **2 alternating fields**, which essentially display *slices* of a frame

  - These fields refresh fast enough to satisfy the flicker fusion threshold

Interlacing



Interlacing



- Each field updates independently, resulting in a simultaneous display of two different half-frames

- This looks harsh with the ‘one-number-per-frame’ example above, but in reality, changes from frame to frame tend to be more subtle

Interlacing

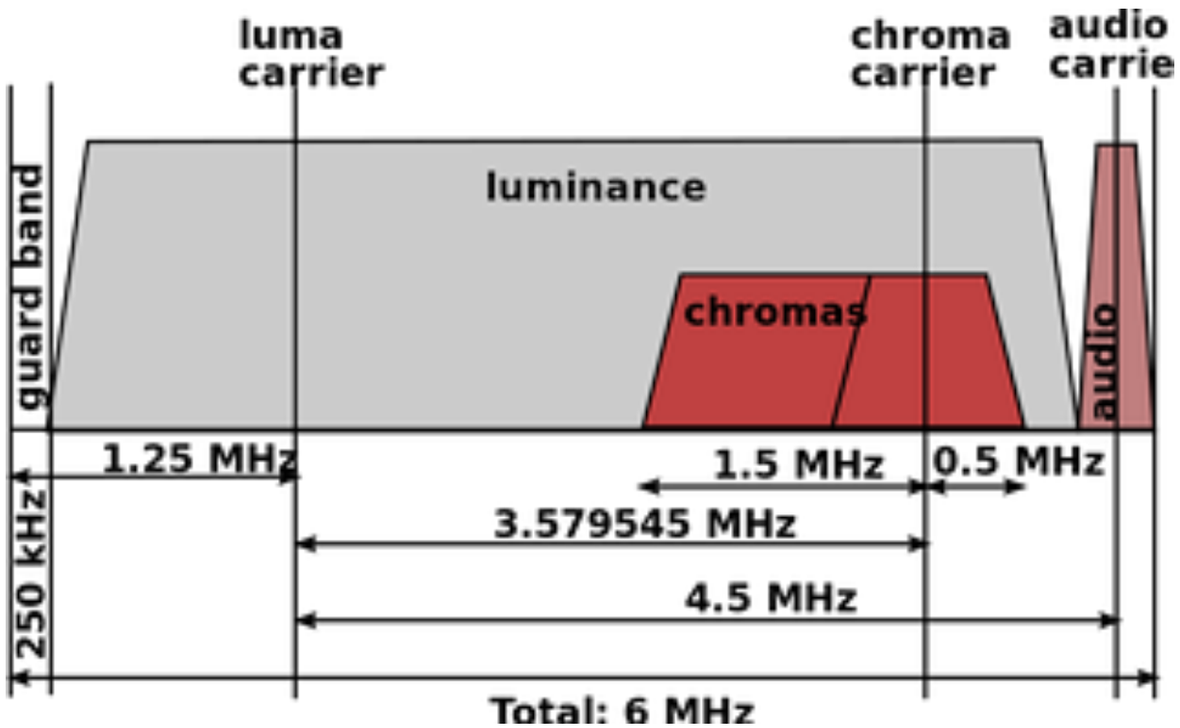
In this image we can see the alternating fields displaying two different frames at once

60i

- To work with the 60Hz AC power that TVs run on, the interlaced fields refresh independently every 1/60 of a second (60Hz).
    - This rate of change satisfies Edison's theoretical flicker fusion threshold.
- A half-frame every 1/60 of a second (60Hz) means we see a full frame every 1/30 of a second (30Hz). This translates to an effective 30 full-frames per second.
    - This gives us our first alternative frame rate to film's 24 fps:
        - **60i** ('60' for the *fields per second*, and 'i' for *interlaced*)
        - This frame rate is also sometimes referred to as **30 fps** or (incorrectly) **30p** because it delivers an *effective* 30 full-frames per second but it's important to understand that **60i** is <u>not</u> a progressive frame rate

Enter Colour

- 60i worked well for black and white TV, but broadcasting in colour created issues
- In the early 1950's, a standard was adopted for adding colour information to television broadcast signals that would still allow for black and white televisions to pick up and interpret the signal
- However, the chroma carrier frequency had the potential to interfere with the audio carrier frequency of a broadcast signal



59.94i

- The solution was to slow down the frame rate of the broadcast by a factor of 0.1%, putting the audio and chroma information in a phase relationship that wouldn't cause interference

    - This turns our previous 60 fields per second into **59.94** fields per second, or **29.97** full frames per second

- This is where it really gets confusing - this frame rate is still sometimes referred to as **60i/30 fps** even though it's really **59.94i** or **29.97 fps**!

- None the less, **29.97 fps/59.94i** is the **NTSC** (National Television Standards Committee) standard frame rate for television in North America and any countries which follow NTSC standards

Meanwhile, in Germany…

- 60i worked great in North America, parts of South America and in a handful of other countries where the power runs at 60Hz,

BUT

- most of the world runs on **50Hz** AC power.
  - This means we need another standard…

PAL/50i

- Enter the **PAL** (phase-alternating line) television standard, adopted in **1963**
- In PAL, to work with the 50Hz AC power that TVs run on in the rest of the world, the interlaced fields refresh independently every 1/50 of a second (50Hz).
    - This rate of change still satisfies Edison's theoretical flicker fusion threshold.
- A half-frame every 1/50 of a second (50Hz) means we see a full frame every 1/25 of a second (25Hz). This translates to an effective 25 full-frames per second.
- This means that PAL uses a frame rate of **50i** ('50' for the *fields per second*, and 'i' for *interlaced*)
    - This frame rate is also sometimes referred to as **25 fps** or (incorrectly) **25p** because it delivers an *effective* 25 full-frames per second but it's important to understand that **50i** is <u>not</u> a progressive frame rate

Basic Frame Rate Summary

- To summarize the terrible mess we've made:
  - **24 fps**: the original film frame rate
  - **25 fps (50i)**: PAL broadcast standard
  - **29.97 fps (54.94i)**: NTSC broadcast standard for colour
  - **30 fps (60i)**: original black and white broadcast standard
- There are more frame rates still, but that's enough for now.

Resolution

- Resolution refers to the number of pixels used to represent an image (remember - video is just a series of images)
- Resolution is typically expressed as **width** x **height** (in **pixels**)
    - Example: 1920x1080
    - This is 1920 pixels wide, by 1080 pixels high
- In video-speak, resolutions are sometimes referred to only by height
    - ‘1080’ just means 1080 pixels tall
    - However, the ‘**p**’ in the 1080p you sometimes see is referring to the aforementioned **progressive** format of certain frame rates, <u>not</u> ‘pixels’

Aspect Ratio

- Resolution also defines the **aspect ratio** of an image/video
- Aspect ratio is just **the ratio of width to height**
- Examples:
  - 800x600 (resolution) = 4:3 (aspect ratio)
  - 1280x720 (resolution) = 16:9 (aspect ratio)

Standard Resolutions

- Standard Definition (SD) TV/DVD: 720x480
- High Definition (HD): 1280x720
- Full HD: 1920x1080
- 2K: 2048x1080
- 4K Ultra HD: 3840x2160

Standard Resolutions

Formats & Standards

- Deciding what frame rate and resolution to work at are major decisions which should be made at the **start** of a video project

- The best practice is to consider your final delivery format and choose settings that will allow you to see the project through without changing them

  - There are many standardized formats to follow depending on the situation

  - Not every camera will shoot at every potential resolution/ frame rate, so be aware of your options

General Guidelines

- Frame Rates:
    - For a good ‘all-around’ default that easily conforms to NTSC, consider shooting at 30 fps
    - To emulate the motion capture of film, consider shooting at 24 fps
    - For crisper motion capture, use a higher frame rate such as 60 fps
    - To capture footage you plan on turning into slow-motion later, capture at a much higher frame rate (96 fps or greater)
    - For HD deliverables, or for content you plan to deliver to the web (YouTube, Vimeo, etc.) shoot in a **progressive** format (24p, 30p, etc.)

General Guidelines

- Resolution:
    - Unless your using a camera from the 90's, shoot in HD!
        - If you aren't sure which HD setting to use, try 1920x1080
    - Err on the side of higher quality - you can always export at a lower quality later but you can't go the other way

Zoom Q8

Zoom Q8 Settings

Video: video recording resolution and frame rate

Setting	Resolution	Frames/ second	Explanation	File size
3M HD/30 24Mbps	2304 x 1296	30	Record at a resolution higher than Full HD.	Large
HD 1080/30 24Mbps	1920 x 1080	30	Play on HD TVs.	
HD 1080/30 16Mbps	1920 x 1080	30	Save SD card space and play on HD TVs.	
HD 720/60 15Mbps	1280 x 720	60	Record scenes with fast movement.	
HD 720/30 8Mbps	1280 x 720	30	Playback on HD TVs and computers.	
WVGA/60 8Mbps	800 x 480	60	Save SD card space and record scenes with fast movement.	
WVGA/30 5Mbps	800 x 480	30	Save SD card space.	Small

Good Default Setting →

Audio: recording audio quality

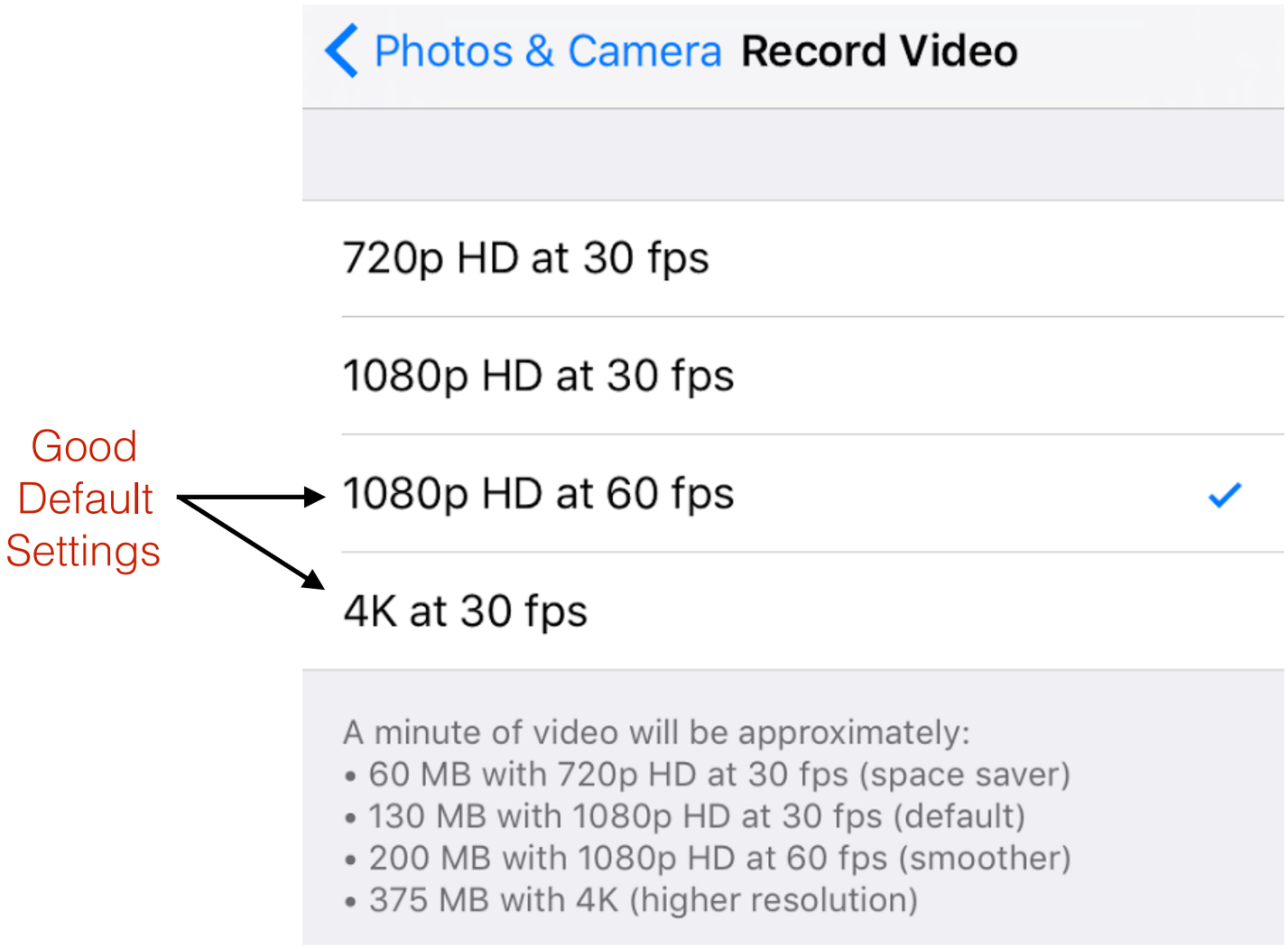
Setting	Explanation	File size
WAV 96kHz/24bit	Record in an uncompressed WAV format when audio quality is important. The higher the sampling frequency (kHz) and bit rate, the better the audio quality.	Large
WAV 96kHz/16bit		
WAV 48kHz/24bit		
WAV 48kHz/16bit		
WAV 44.1kHz/24bit		
WAV 44.1kHz/16bit		
AAC 320kbps	Record in a compressed AAC format when you need to save SD card space. The higher the bit rate (bps), the better the audio quality.	
AAC 256kbps		
AAC 192kbps		
AAC 128kbps		
AAC 64kbps		Small

Good Default Setting →

NOTE

Only 44.1/48kHz, 16/24-bit WAV formats can be selected when the recording mode setting is MOV+ -WAV or MULTI AUDIO.

iPhone 6s Settings



Canon XF-100 Settings

Available bit rate, resolution and frame rate settings

Bit rate*	Resolution	Frame rate			
		60i	60P	30P	24P
50 Mbps (CBR 4:2:2)	1920 x 1080	●	–	●	●
	1280 x 720	–	●	●	●
35 Mbps (VBR 4:2:0)	1920 x 1080	●	–	●	●
	1440 x 1080	●	–	–	–
	1280 x 720	–	●	●	●
25 Mbps (CBR 4:2:0)	1440 x 1080	●	–	●	●

* The first line indicates the bit rate (in Mbps); the second line indicates in parentheses whether the bit rate is constant (CBR) or variable (VBR), and the color sampling.