



ECE 516E – ANTENNA & RADIOWAVE PROPSAGATION

INTRODUCTION TO MONOCHROME TELEVISION - STUDY GUIDE/REVISION

1. LEARNING OBJECTIVES

1. Explain the core principles of image scanning and reconstruction (Raster).
2. Understand the generation of a composite video signal, including synchronization.
3. Analyse the amplitude and frequency modulation used for video and audio transmission.
4. Describe the function of key blocks in both the TV transmitter and receiver.
5. Calculate essential parameters like bandwidth, line frequency, and frame rate.

2. INTRODUCTION

The fundamental problem TV solves is turning a 2D spatial image (scene) into a 1D time-varying electrical signal.

2.1. Sequential Scanning (Raster Scanning)

2.1.1 The Scanning Process

- **Horizontal Scan:**

The beam moves left to right across one line, its intensity varying with the brightness of the scene.

- **Horizontal Retrace**

At the end of the line, the beam quickly flies back to the left to start the next line. This period must be blanked.

- **Vertical Scan**

After scanning all lines from top to bottom, the beam is at the bottom of the frame.

- **Vertical Retrace**

The beam quickly flies back to the top-left corner to start the next frame. This period must also be blanked.

2.1.2 Interlaced Scanning:

Interlacing is used to reduce flicker and signal bandwidth without changing the frame rate as follows.

1. One full frame is divided into two fields.
2. Field 1 (Odd Field): Scans all the odd-numbered lines (1, 3, 5,...).
3. Field 2 (Even Field): Scans all the even-numbered lines (2, 4, 6,...).

The main **advantage of interlacing** is that the field rate (e.g., 60 Hz) is double the frame rate (e.g., 30 Hz), reducing perceptible flicker, while the amount of information sent per second remains the same as a 30 Hz progressive scan.

3. THE COMPOSITE VIDEO SIGNAL

This is the most critical concept. The signal sent from the camera to the transmitter (and ultimately to the receiver) contains more than just picture information.

3.1 Components of the Composite Video Signal

1. Picture Information:

- Varying voltage level representing the instantaneous brightness (**luminance**) of the point being scanned.
- **Black Level:** A fixed reference voltage for "black."
- **White Level:** The maximum voltage swing towards "white." The signal between black and white is the "video" itself.

2. Synchronization Pulses:

- **Horizontal Sync Pulses:** Short, high-amplitude pulses placed during the horizontal blanking period. They tell the receiver's beam to start retracing horizontally.
- **Vertical Sync Pulses:** Much wider, high-amplitude pulses placed during the vertical blanking period. They tell the receiver's beam to start retracing vertically.
- **Key Idea:** Sync pulses are "blacker than black." Their amplitude is placed below the black level reference to ensure they are invisible on the screen but easily separable by the receiver's circuitry.

3. Blanking Pulses:

- These force the electron beam to be completely OFF during both horizontal and vertical retrace periods to prevent retrace lines on the picture.

(A simple diagram like this is crucial for understanding the timing relationships.)

4. TRANSMISSION: MODULATION AND THE TV CHANNEL

The composite video and audio signals are modulated onto an RF carrier for broadcast.

A. Video Signal Modulation:

- **Type: Amplitude Modulation (AM)**
- **Polarity: Negative Modulation.** This is a key specification.
 - Increasing light intensity (brighter) causes a *decrease* in the transmitted carrier amplitude.
 - Sync pulses correspond to *maximum* carrier amplitude.
 - **Advantages:**

- Receiver noise (which adds amplitude) appears as dark spots, which is less annoying than white snow.
- Sync pulses are less affected by noise, ensuring stable picture lock.
- Transmitter power is highest during sync pulses and blanking, not during bright scenes, leading to greater average power efficiency.

B. Audio Signal Modulation:

- **Type: Frequency Modulation (FM)**
- The audio carrier frequency is placed *above* the video carrier within the same channel.
- **Advantage:** FM provides high fidelity and excellent immunity to amplitude noise and interference from the video signal.

C. The Complete TV Channel:

A standard monochrome TV channel has a bandwidth of **6 MHz** (in the US NTSC system). The allocation is as follows:

- **Video Carrier:** Lower edge of the channel + 1.25 MHz.
- **Vestigial Sideband Filtering:** The lower sideband of the AM video signal is partially suppressed to save bandwidth. This is called Vestigial Sideband Modulation (VSB).
- **Audio Carrier:** Video Carrier + 4.5 MHz. It is frequency modulated.
- **Color Carrier (for later color TV):** Video Carrier + 3.579545 MHz (but this is not used in pure monochrome).

5. THE MONOCHROME TELEVISION RECEIVER (THE TV SET)

The receiver is a complex superheterodyne receiver. Key blocks include:

1. **Tuner (RF Stage):** Selects the desired channel, amplifies the weak RF signal, and converts it to a fixed **Intermediate Frequency (IF)** using a local oscillator.
2. **IF Amplifiers:** Provide the majority of the receiver's gain and selectivity. They are sharply tuned to the specific IF (e.g., 45.75 MHz for video, 41.25 MHz for audio in NTSC).
3. **Detection / Demodulation:**
 - **Video Detector:** Demodulates the AM video IF signal to recover the original composite video signal.
 - **Sound IF Take-off:** A trap circuit picks off the 4.5 MHz intercarrier sound signal (which is created by mixing the video and audio carriers in the detector). This 4.5 MHz signal is then FM demodulated to get the audio.
4. **Sync Separation:** A clipper/amplifier circuit strips away the picture information, leaving only the strong sync pulses. A simple low-pass/high-pass filter network then separates the wide vertical sync pulses from the short horizontal sync pulses.
5. **Deflection Circuits:**
 - **Horizontal Deflection:** Uses a Voltage-Controlled Oscillator (VCO) locked to the horizontal sync pulses (a **Phase-Locked Loop** concept). This drives the horizontal

output stage which sends a sawtooth current through the horizontal deflection coils on the CRT neck.

- **Vertical Deflection:** A triggered oscillator, synchronized by the vertical sync pulses, generates a 60 Hz (field rate) sawtooth wave to drive the vertical output stage and vertical deflection coils.

6. **CRT (Cathode Ray Tube):** The final display device.

- The recovered video signal is amplified and applied to the **** cathode**** (or control grid) to modulate the intensity of the electron beam.
- The synchronized deflection coils create magnetic fields that bend the beam to scan the raster on the phosphor-coated screen.

6. SUMMARY & KEY FORMULAS

Parameter	Typical Value (NTSC Mono)	Description & Formula
Total Lines/Frame	525	Total number of scanning lines per complete frame.
Active Lines/Frame	~483	Lines actually containing picture information (total - vertical blanking).
Aspect Ratio	4:3	Ratio of picture width to height.
Frame Rate	30 Hz	Number of complete pictures displayed per second.
Field Rate	60 Hz	Number of fields displayed per second (2 fields/frame).
Horizontal Line Frequency	15.75 kHz	$f_h = \text{Frame Rate} * \text{Total Lines} = 30 * 525 = 15,750 \text{ Hz}$
Video Signal Bandwidth	~4.2 MHz	Determines the horizontal resolution. Based on the Kell factor and active line time.
Channel Bandwidth	6 MHz	Total RF bandwidth allocated for one TV channel.

7. Study Questions & Problems

1. **Conceptual:** Why is interlaced scanning used? Explain the trade-off between progressive and interlaced scanning in terms of flicker and bandwidth.
2. **Conceptual:** Draw a labelled waveform of the composite video signal for two scan lines, showing the video, front porch, horizontal sync pulse, back porch, and the next line's video.
3. **Analysis:** Explain why negative modulation for the video signal is preferable to positive modulation.
4. **Calculation:**

A 625-line system (used in PAL/SECAM) uses 50 Hz field rate and 2:1 interlace, calculate the following:

- (i) frame rate
- (ii) horizontal line frequency.

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Given Information

Total Lines per Frame: 625 lines

Field Rate: 50 Hz (50 fields per second)

Interlacing: 2:1 (One frame is made of two fields)

- (i) In a 2:1 interlaced system, two fields make one complete frame. The field rate is 50 fields per second. Therefore, the frame rate is half of the field rate, or

$$\begin{aligned} \text{Frame Rate} &= \text{Field Rate} / 2 \\ &= 50 \text{ Hz} / 2 = 25 \text{ Hz (or 25 frames per second)} \end{aligned}$$

- (ii) The horizontal line frequency (f_h) is the number of horizontal lines scanned per second. This includes all lines, both the visible ones and those in the vertical blanking interval. This question can be answered using two methods as follows:

Method 1: Using Frame Rate and Lines per Frame

Each frame consists of 625 lines and the system displays 25 frames every second.

$$\begin{aligned} f_h &= \text{Lines per Frame} \times \text{Frame Rate} \\ &= 625 \text{ lines/frame} \times 25 \text{ frames/second} \\ &= 15,625 \text{ Hz} \end{aligned}$$

Method 2: Using Field Rate and Lines per Frame

System has 2:1 interlace. Therefore, each field has half the lines of a frame. So, one field has $625 / 2 = 312.5$ lines. The system displays 50 fields every second. Therefore,

$$\begin{aligned} f_h &= \text{Lines per Field} \times \text{Field Rate} \\ &= 312.5 \text{ lines/field} \times 50 \text{ fields/second} \\ &= 15,625 \text{ Hz} \end{aligned}$$

5. **Systems:** Trace the signal path through a TV receiver, from the RF input at the antenna to the electron beam in the CRT, for both picture and sound.
6. **Design:** How does the sync separator circuit work? Design a simple circuit using a transistor to act as a sync separator (clipper).

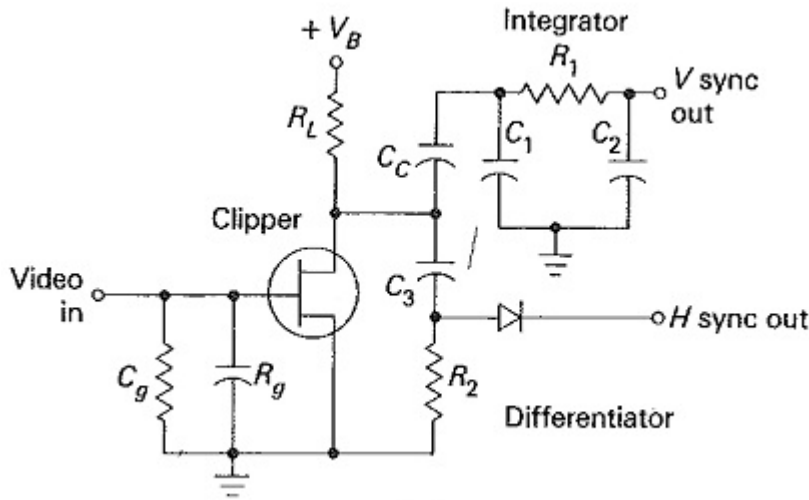
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The sync separator circuit typically works in two distinct stages: Amplitude Separation and Frequency Separation.

Stage 1: Amplitude Separation (Slicing the Tops Off) uses the fact that sync pulses are the most negative part of the signal. It's a simple but clever circuit, often just a single transistor or a diode, biased to act as a clipper.

Stage 2: Frequency Separation (Telling Horizontal from Vertical) uses the fact that horizontal and vertical sync pulses have very different durations (pulse widths), which corresponds to different frequencies. Frequency separation uses two simple filter circuits, i.e.

- (i) Differentiator (for Horizontal Sync) which is simple High-Pass Filter (typically a small capacitor and a resistor). The differentiator produces a sharp "spike" at the beginning of each horizontal pulse, which is perfect for triggering the fast horizontal oscillator.
- (ii) Integrator (for Vertical Sync) which is a simple Low-Pass Filter (typically a resistor and a larger capacitor). An integrator "adds up" or averages the signal over time. The short horizontal pulses are too brief to charge the capacitor to a high voltage. However, the long, wide vertical sync pulse has enough time to charge the capacitor up to a significant voltage, creating a distinct, rounded pulse.



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