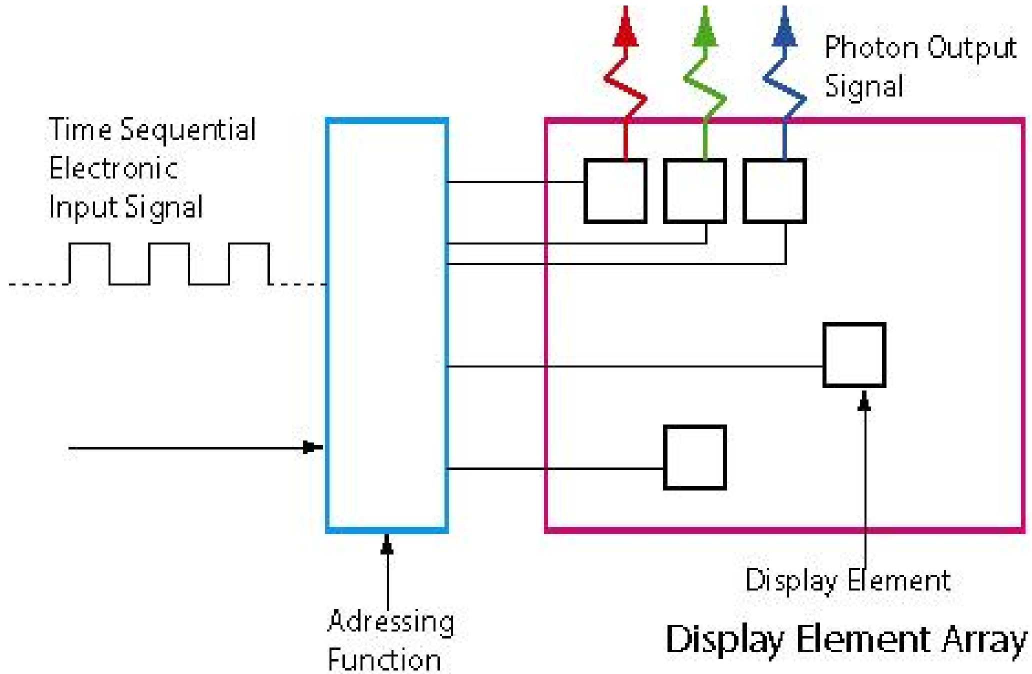
L14 - Video

Slides 2-10 courtesy of Tayo Akinwande
Take the graduate course, 6.973 – consult Prof. Akinwande
Some modifications of these slides by D. E. Troxel

How Do Displays Work?



- **Electronic display is a "**Language Translator**" that converts "**Time Sequential Electrical Signals**" into spatially and temporally configured light signal (**images**) useful to the viewer.**
- **Translation Function carried out by two intertwined sub-functions**
  - **Display element address wherein electrical signals are appropriately routed to the various display elements (**similar to memory addressing**)**
  - **Display element (pixel) converts the routed electrical signal at its input into light of certain wavelength and intensity (**inverse of image capture**)**

Emissive Displays

Emissive Displays **generate photons from electrical excitation of the picture element (pixels).**

- **Can generate energy by**
  - **UV absorbed by a phosphor**
  - **injection by a PN junction**
  - **Electron Beam hitting a phosphor**
- **This energy causes excitation followed by excitation relaxation.**
  - **Hole & Electron recombination**
  - **Exiton formation and annihilation**
  - **Relaxation of excited ions or radicals in a plasma**
- **Sometimes the energy first goes to a dopant and then to photons, especially when changing the wavelength of the emitted light.**
- **Examples of Emissive Flat Panel Displays**
  - **Electroluminescence (Light Emitting Diode),**
  - **Cathodoluminescence (Cathode Ray Tube)**
  - **Photoluminescence (PLasma Displays)**

Light Valve Displays

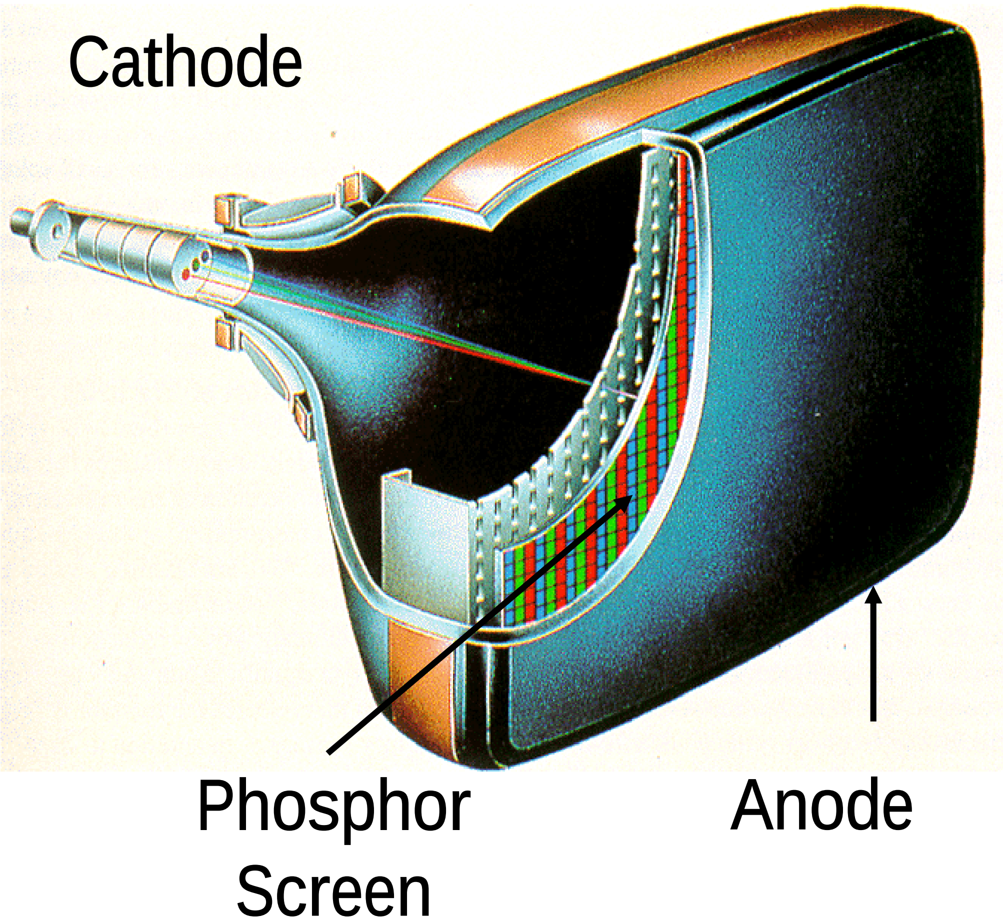
Light Valve Displays **spatially and temporally modulate the intensity pattern of the picture elements (pixels)**

- **Displays that "spatially and temporally" modulate ambient lighting or a broad source of lighting and redirect it to the eye.**
  - **The display element changes the intensity of the light using**
    - **Refraction**
    - **Reflection**
    - **Polarization change**

- **Examples of Light Valve Displays**
  - L**iquid** C**rystal** D**isplays (active & passive matrix)**
  - D**eformable** M**irror** D**isplays**
  - M**embrane** M**irror** D**isplays**
  - E**lectrophoretic** D**isplays (E-Ink)**

Cathode Ray Tube

CRT Display



Courtesy of PixTech

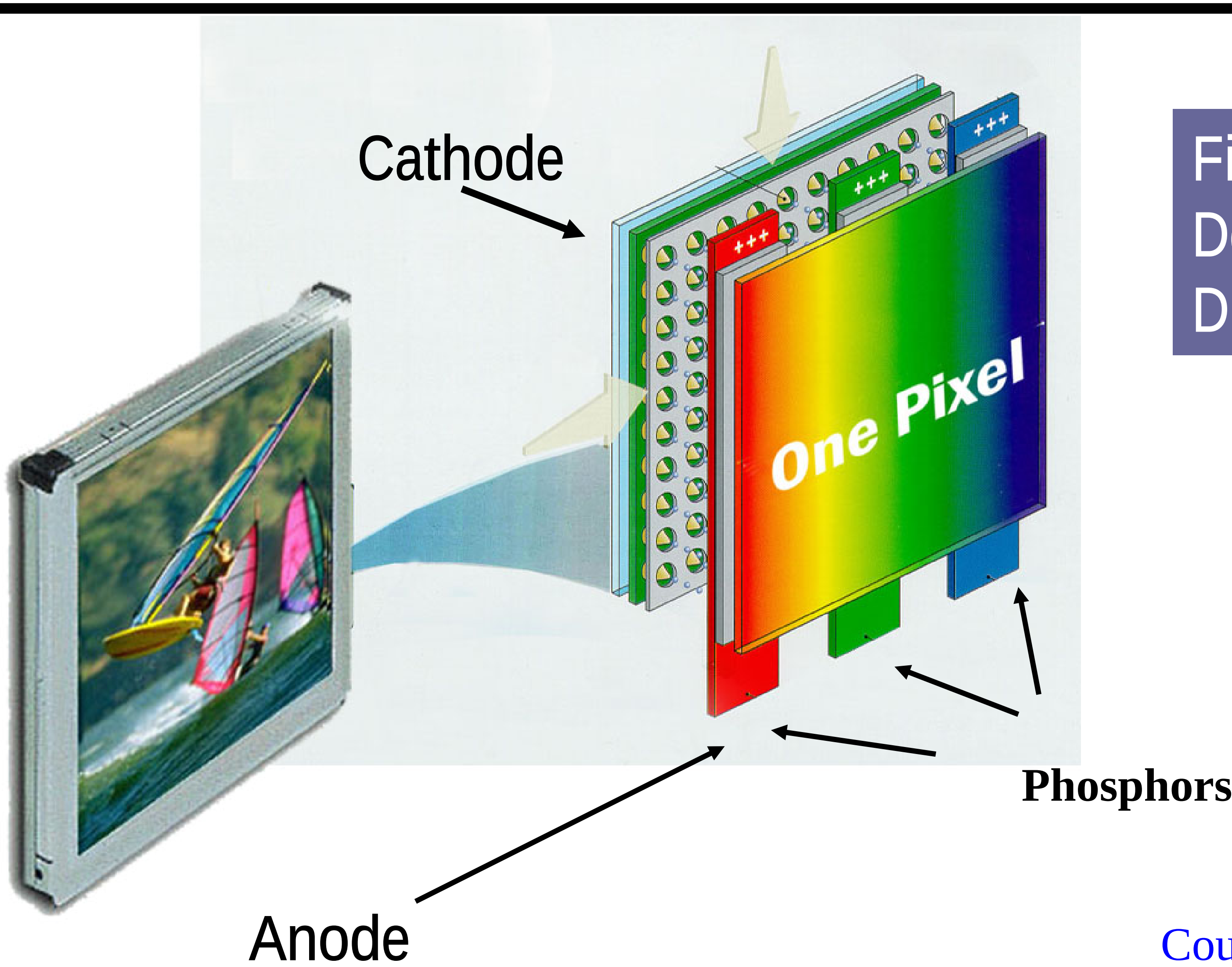
CRT displays are used in TV receivers. Plasma and LCD displays are growing.

An electron beam "boiled off a metal" by heat (**thermionic emission**) is sequentially scanned across a phosphor screen by magnetic deflection. The electrons are accelerated to the screen acquiring energy and generate light on reaching the screen (**cathodoluminescence**)

Flat Panel Displays

- **Time sequential electrical signals describing an image need to be routed to the appropriate picture element (pixel).**
- **Typical flat panel displays are two-dimensional arrays of picture elements (pixels) that are individually addressed from the perimeter or the back. Methods of scanning include**
  - **Sequential addressing (CRT)**
  - **Row scan addressing (Thin-CRT, Plasma, Mirror, LCD)**
- **Row scanning of a matrix of pixels requires picture elements with non-linear** Luminance – Voltage **(L-V) characteristics.**
  - **If the L-V characteristics is linear (or is not non-linear enough), a non linear switch element is required in series with the pixel.**

Thin-CRT

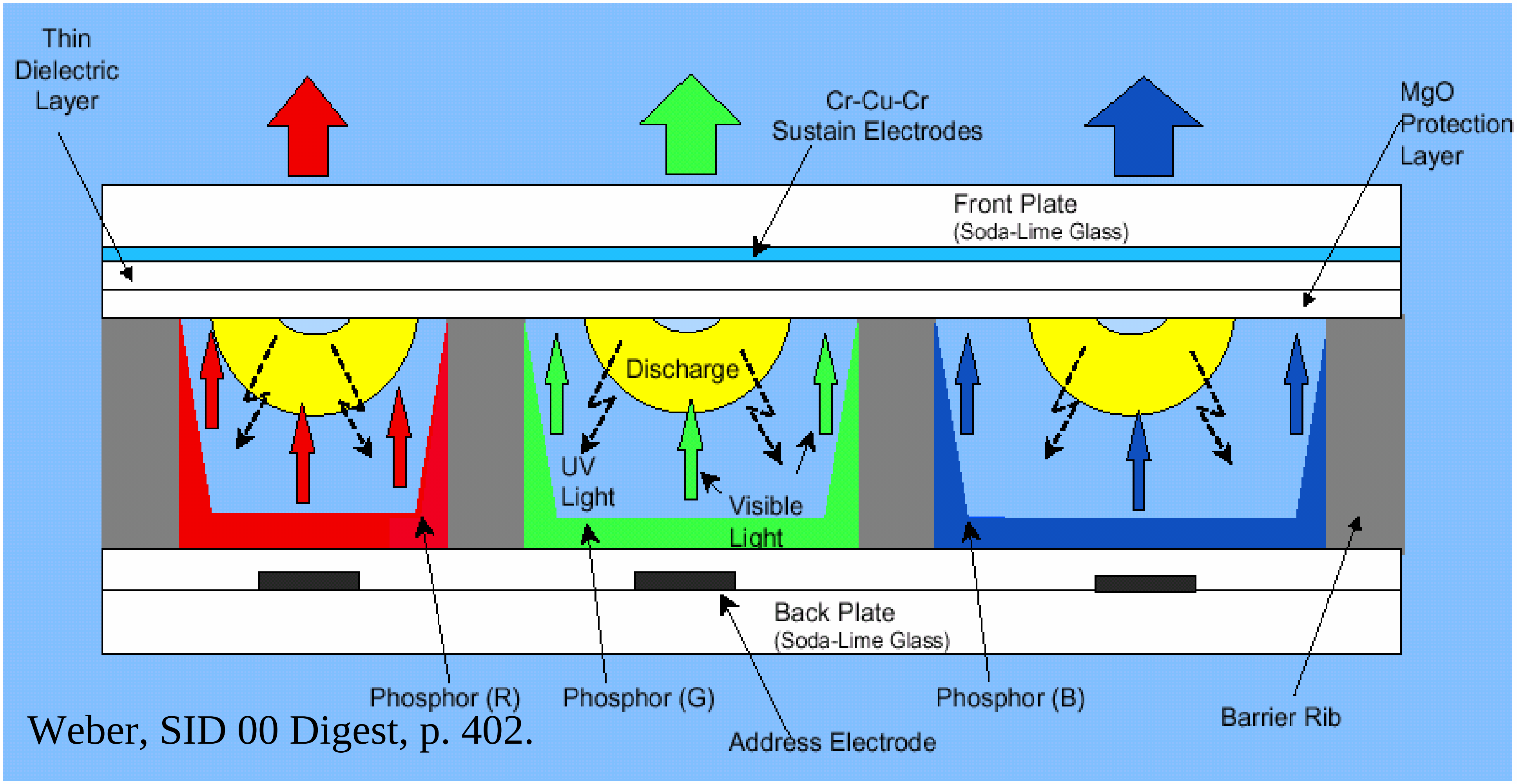


Field Emission Device (FED) Display

Courtesy of PixTech

In principle similar to the CRT except that it uses a **two-dimensional array of electron sources (field emission arrays)** which are matrix addressed allowing the vacuum package to be thin

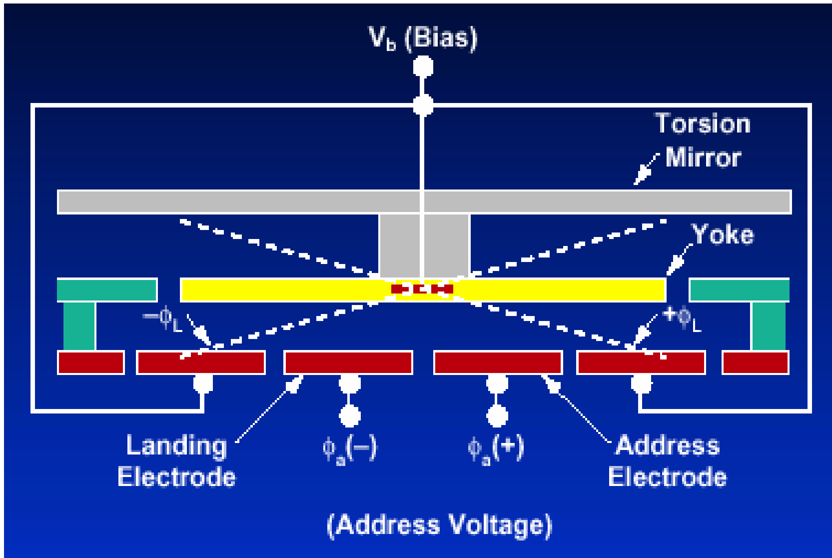
Plasma Displays



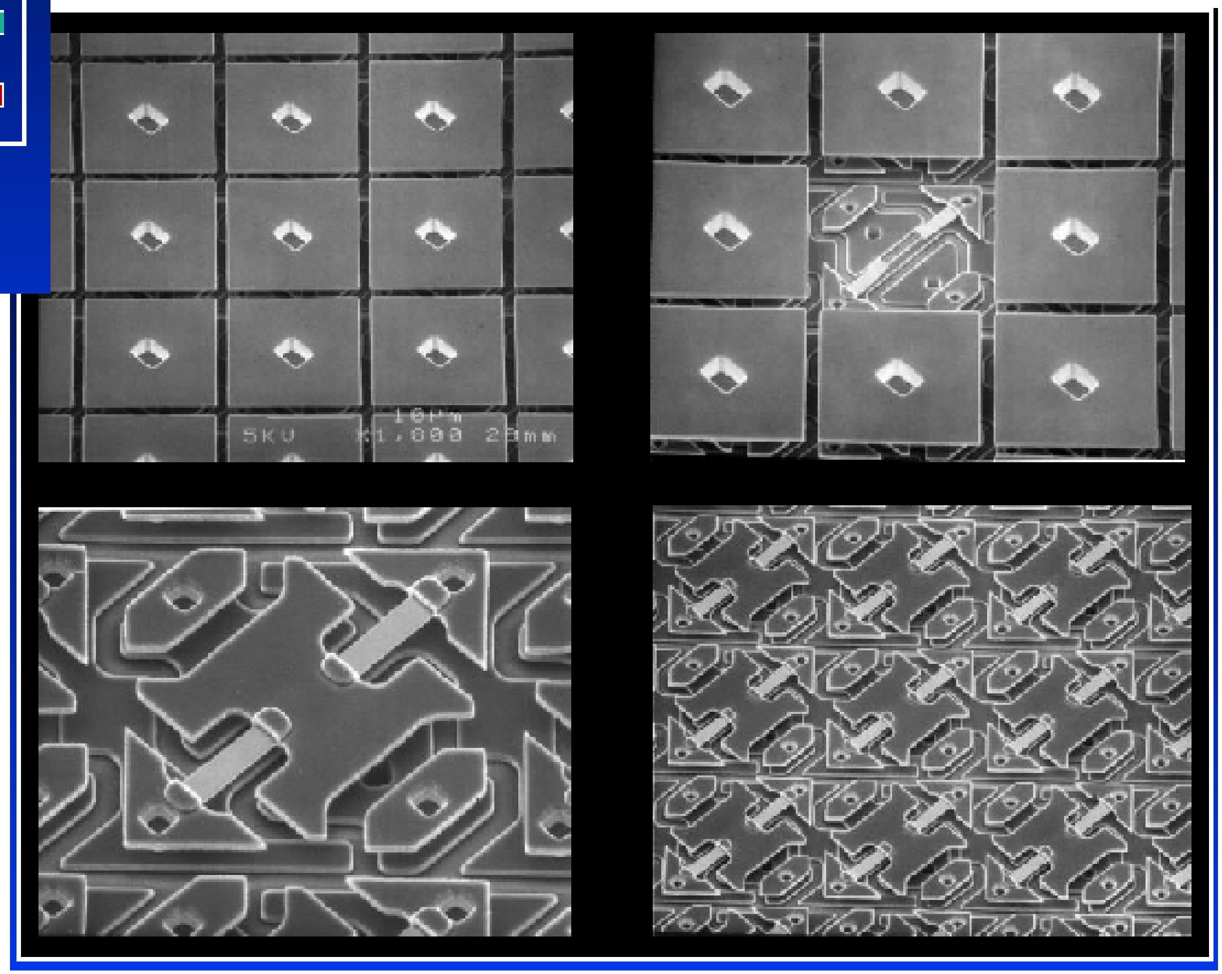
Weber, SID 00 Digest, p. 402.

- **Electrons are accelerated by voltage and collide with gasses resulting in ionization and energy transfer.**
- **Excited ions or radicals relax to give UV photons.**
- **UV photons cause hole-electron generation in phosphor and visible light emission.**

Digital Mirror Device



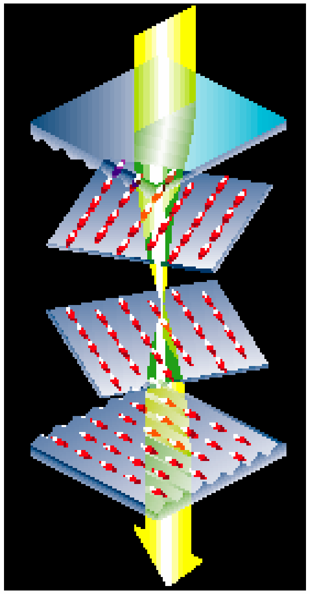
Courtesy of Texas Instruments

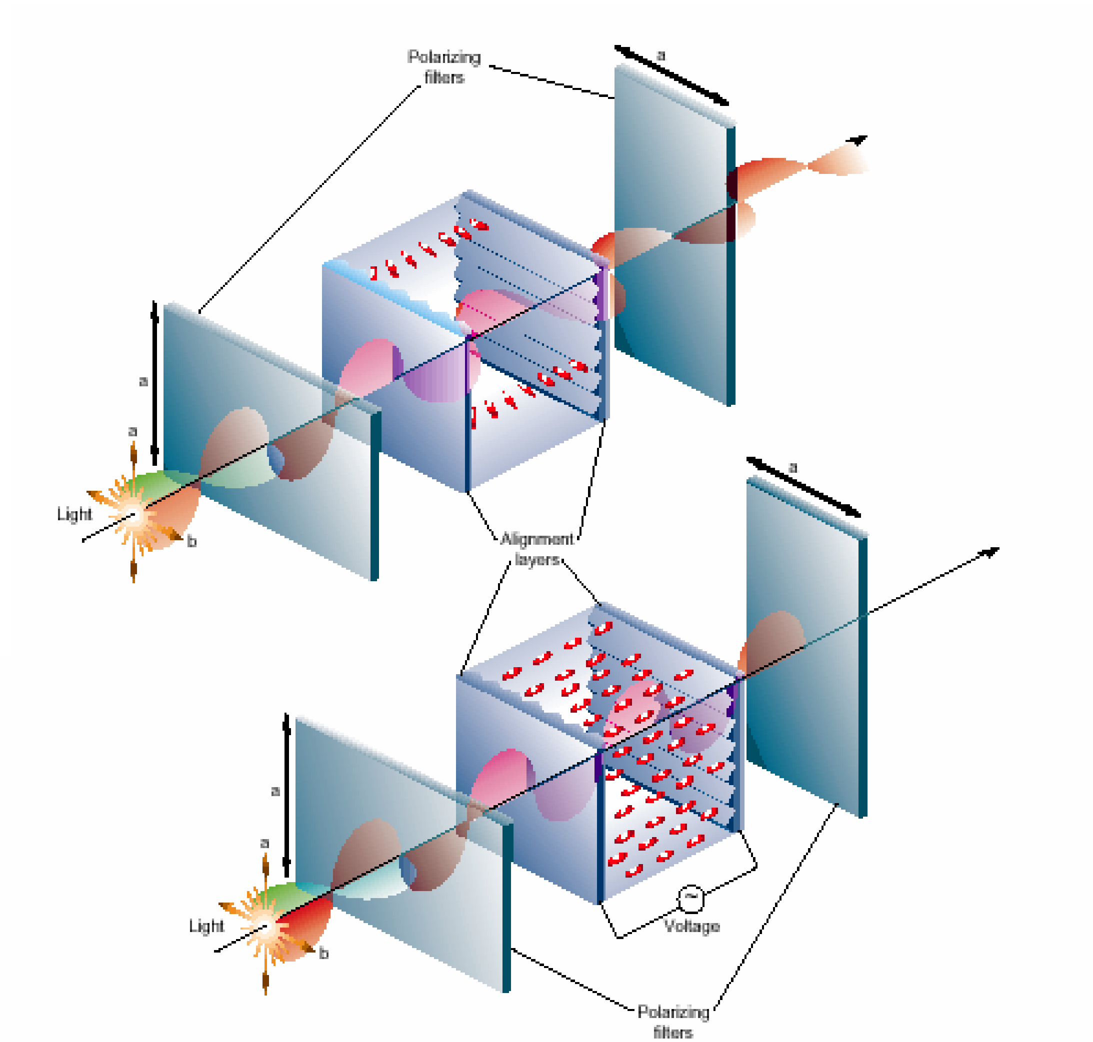


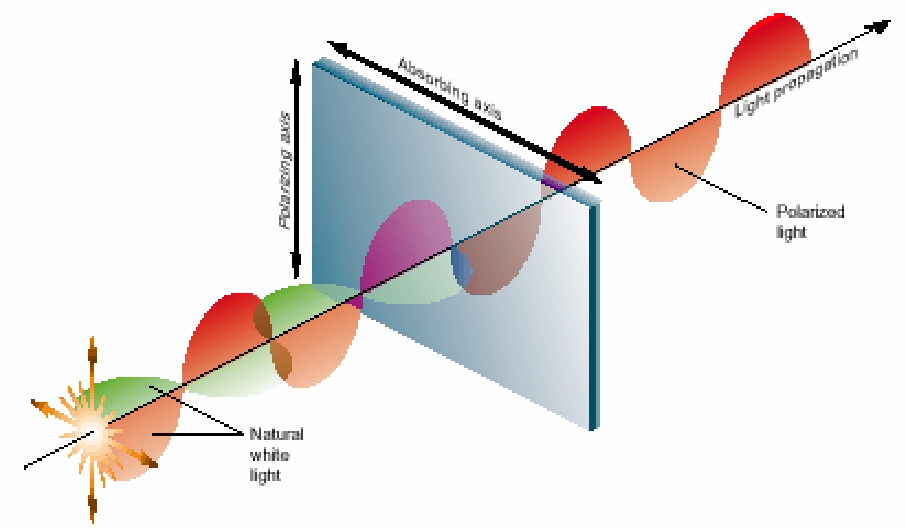
Applied voltage deflects
Mirror and hence direct light

Liquid Crystal Displays

Liquid Crystals rotate the plane of polarization of light when a voltage is applied across the cell



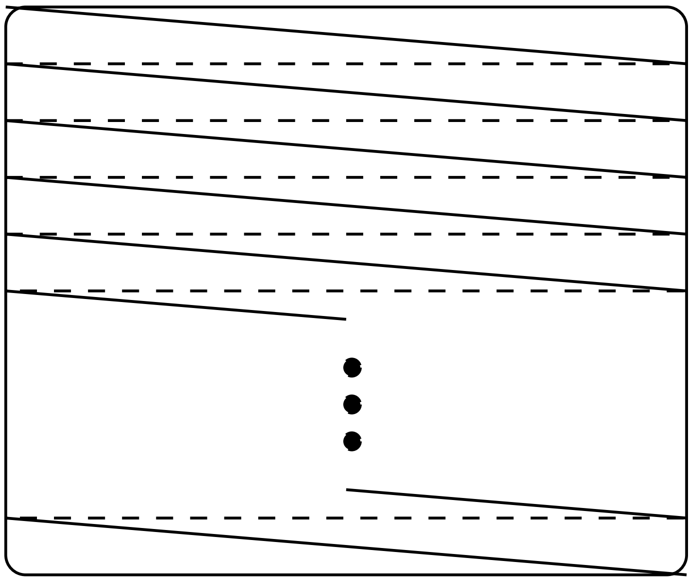


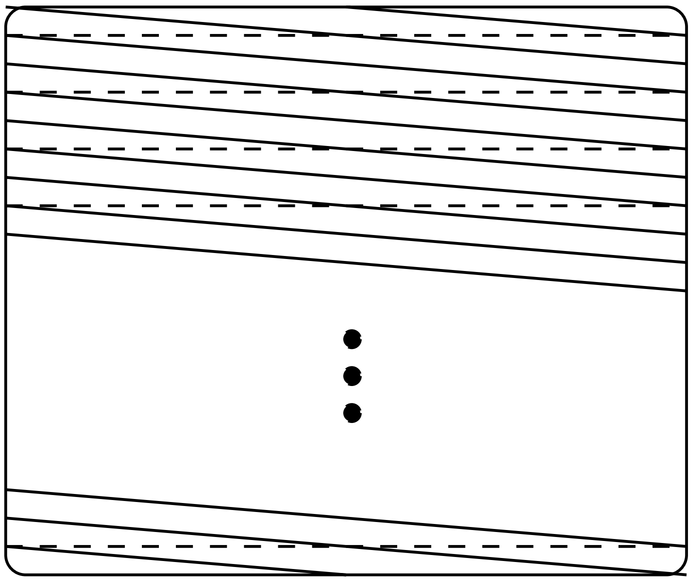


Courtesy of Silicon Graphics

Raster Scan

- **Television and most computer displays use raster scan.**





Non−Interlaced: Frame rate may be 60, 72, etc. frames/sec.

———— Scan line

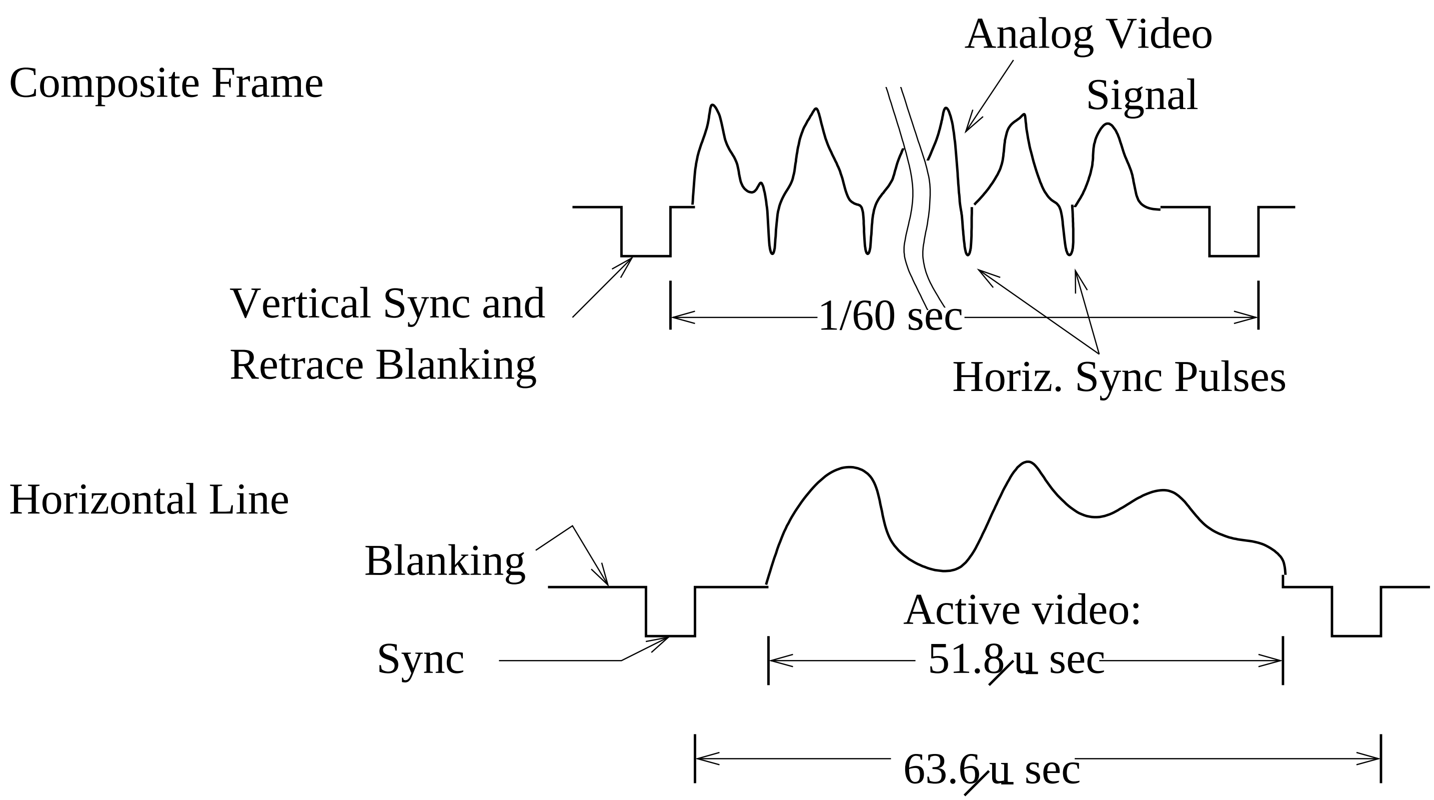
- - - - - - Retrace line

Interlaced: Frames alternate. This is like television: 60 half frames/sec.

Electron beam "scans" tube. Beam location is shown here. Beam current determines brightness of display.

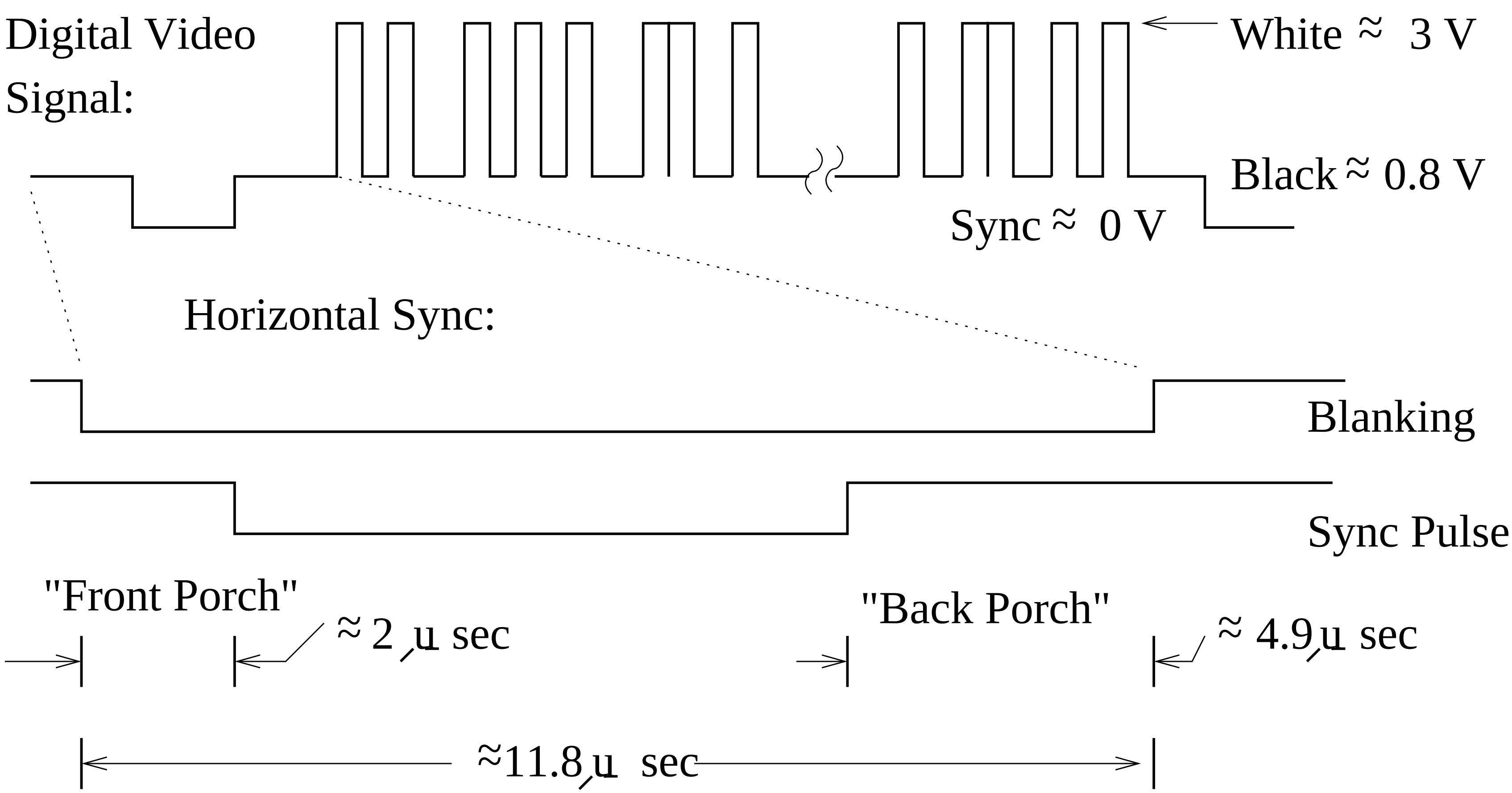
Composite Frames

- The 'frame' is a single picture (snapshot).
  - It is made up of many lines.
  - Each frame has a synchronizing pulse (vertical sync).
  - Each line has a synchronizing pulse (horizontal sync).
  - Brightness is represented by a positive voltage.
  - Horizontal and Vertical intervals both have blanking so that retraces are not seen (invisible).



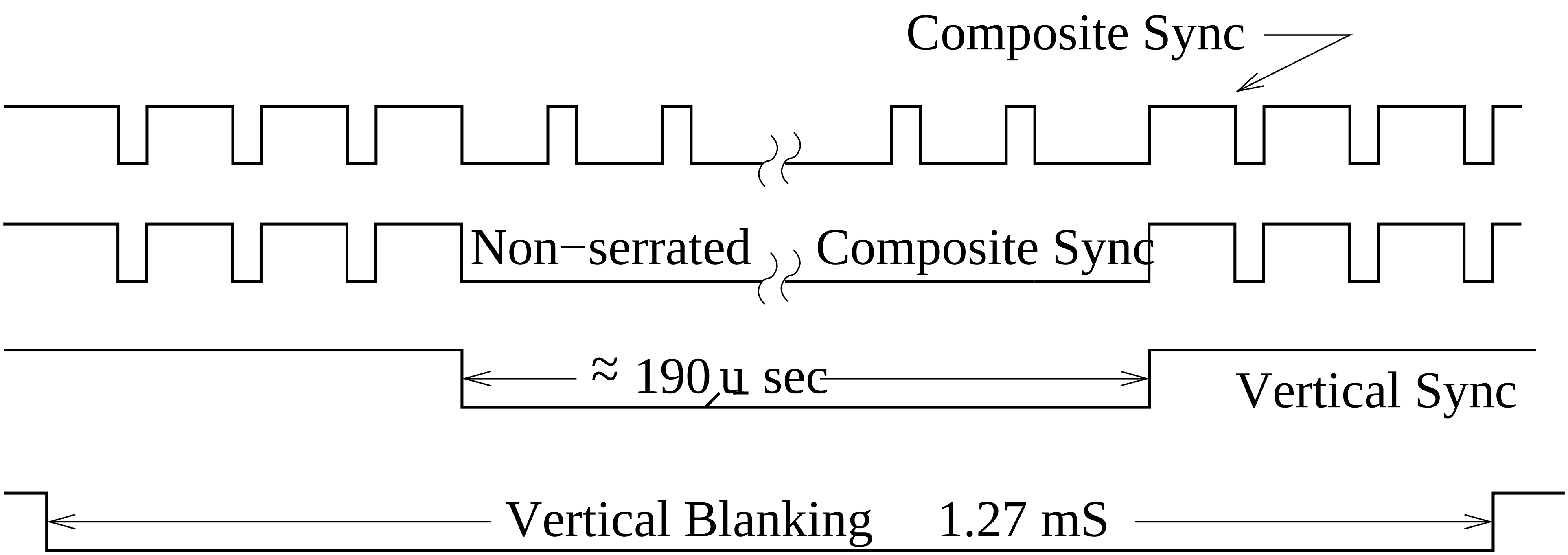
Horizontal Synchronization

- The picture consists of white dots on a black screen.
  - White is the highest voltage.
  - Black is a low voltage.
  - Sync is below the black voltage.
- Sync pulses are surrounded by the blanking interval so one doesn't see the retrace.



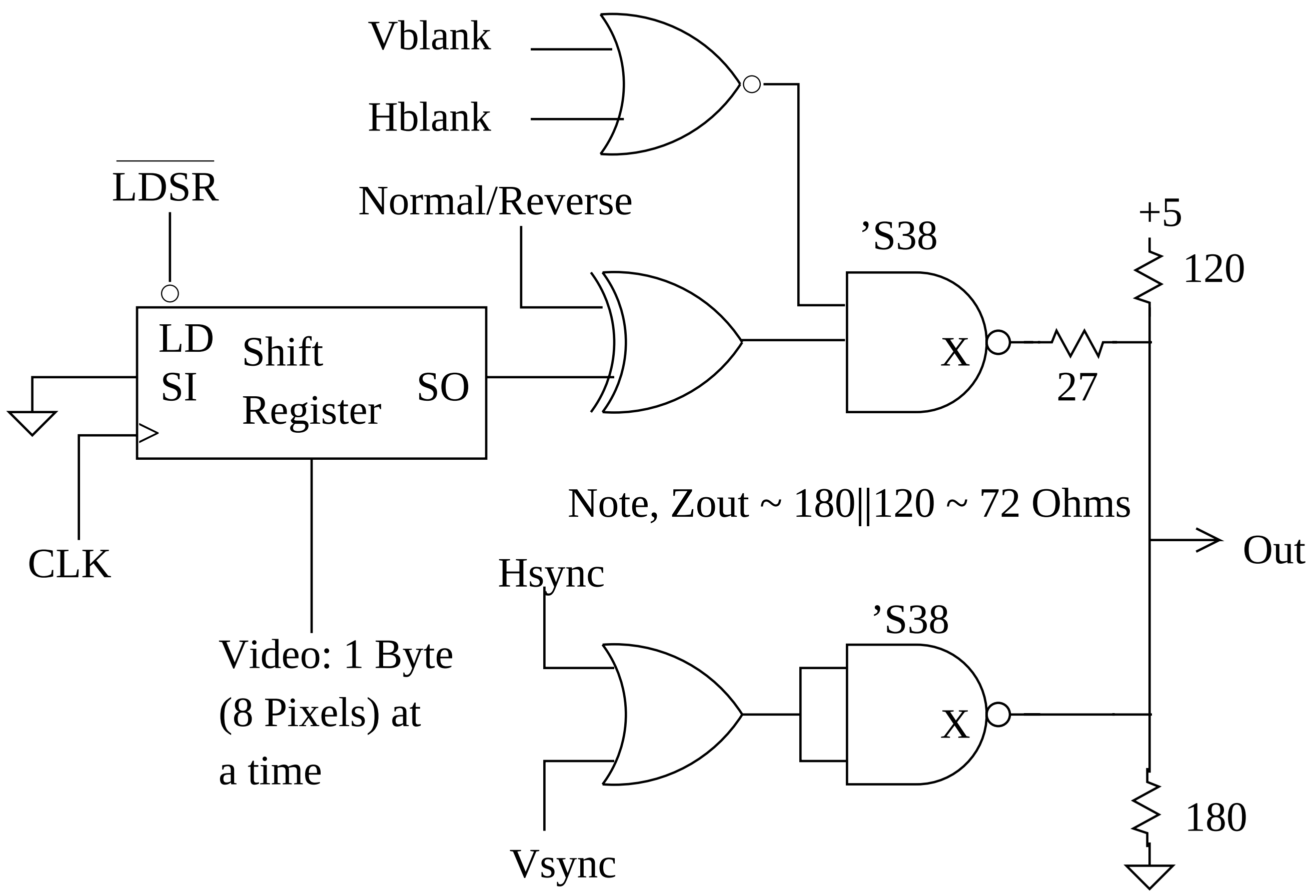
Composite Synchronization

- Horizontal sync coordinates lines.
- Vertical sync coordinates frames.
- They are similar except for the time scales and they are superimposed on each other. The numbers are for TV-like displays.
  - What purpose is there for serrated sync?

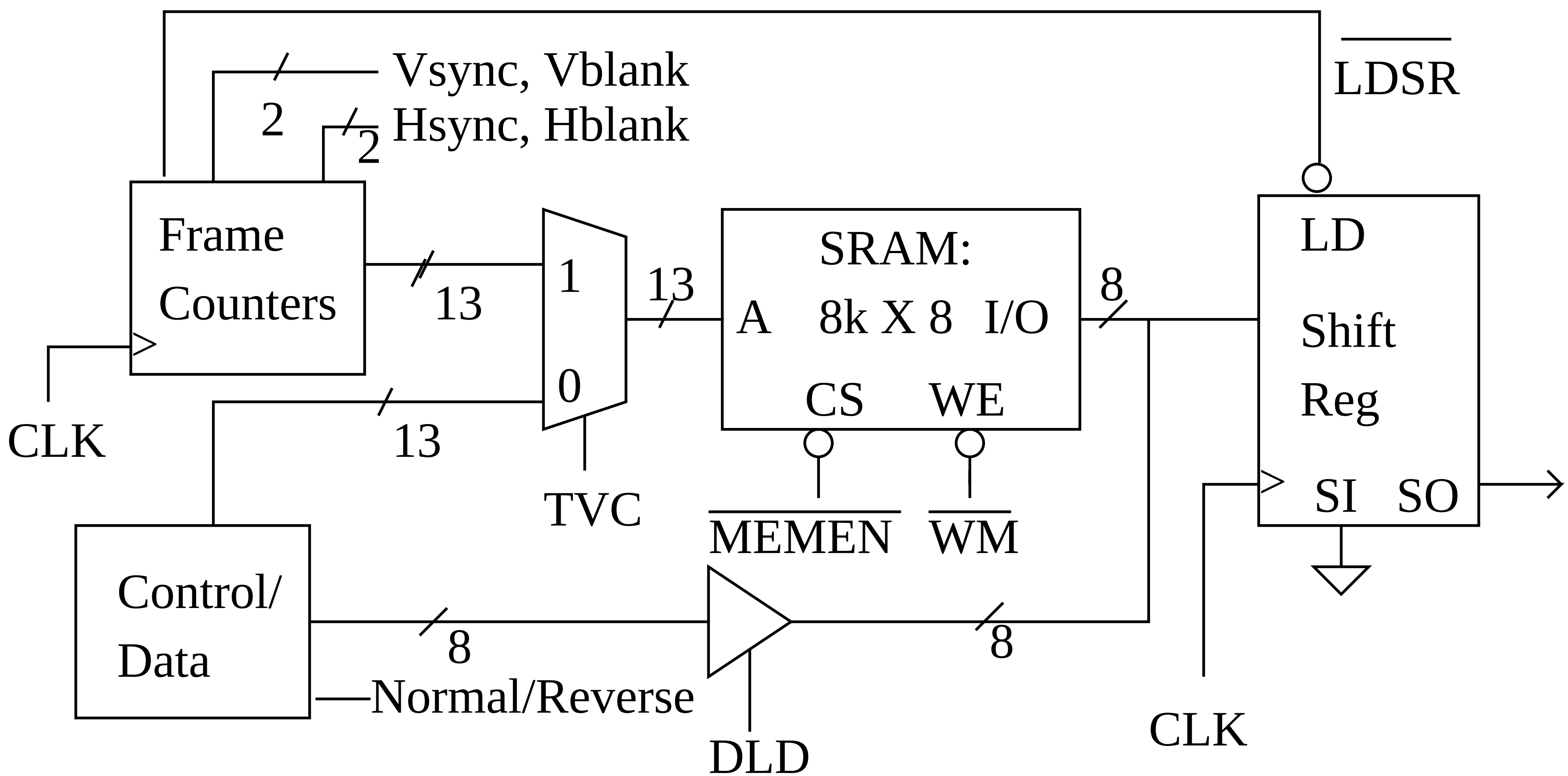


Generation of TV Signal

- Assume one bit per pixel and provide for reverse video.
- This is a simple 'D/A' to generate monochrome composite video.
  - The 'S38 is an open collector part so the voltages are determined by the resistor network. The output resistance is ~ 75 ohms.
  - What signals should be glitch free?
  - Vblank, Hblank, Vsync, Hsync, /LDSR, Normal/Reverse

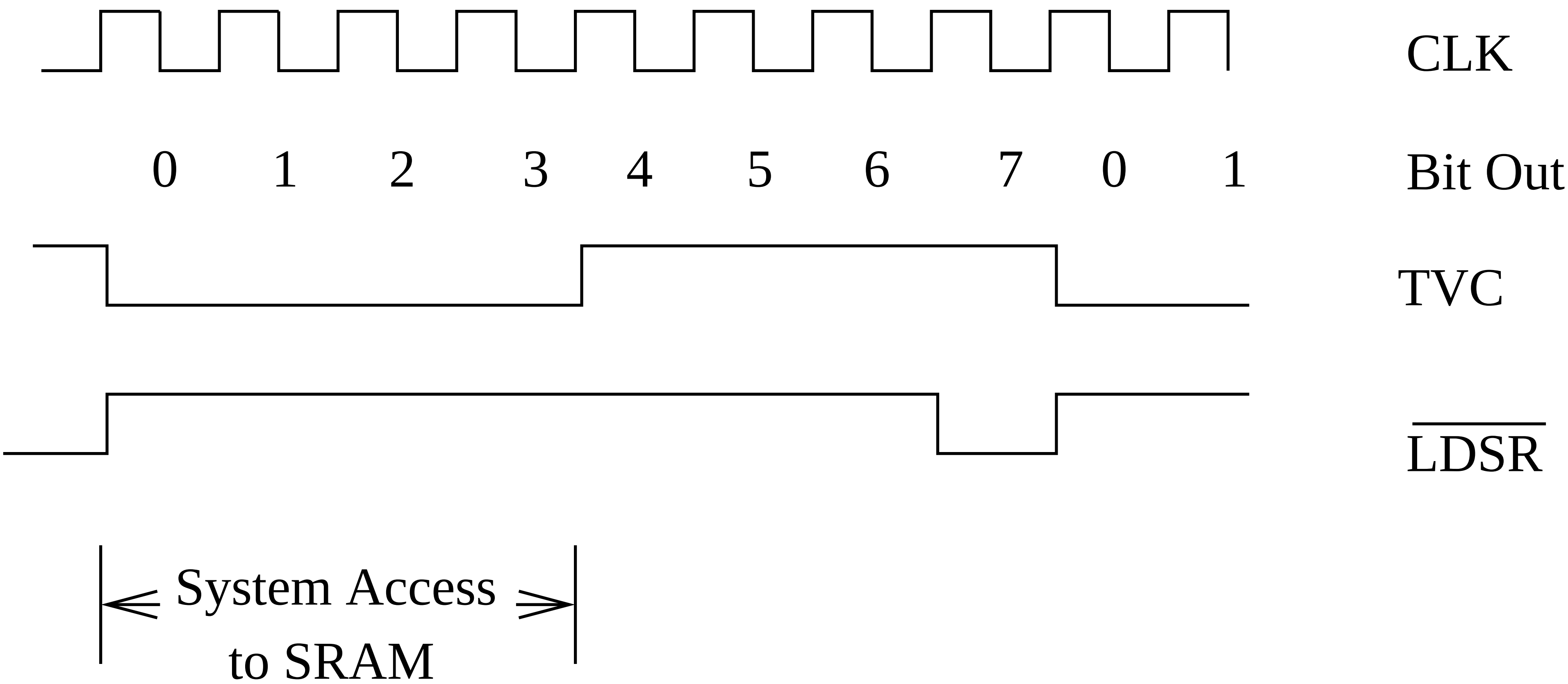


Store bit-mapped video in a RAM with pixels packed into bytes.
Half the time, the video subsystem accesses the data to drive the TV monitor.
Half the time, the project can modify (update) the bits in the RAM.



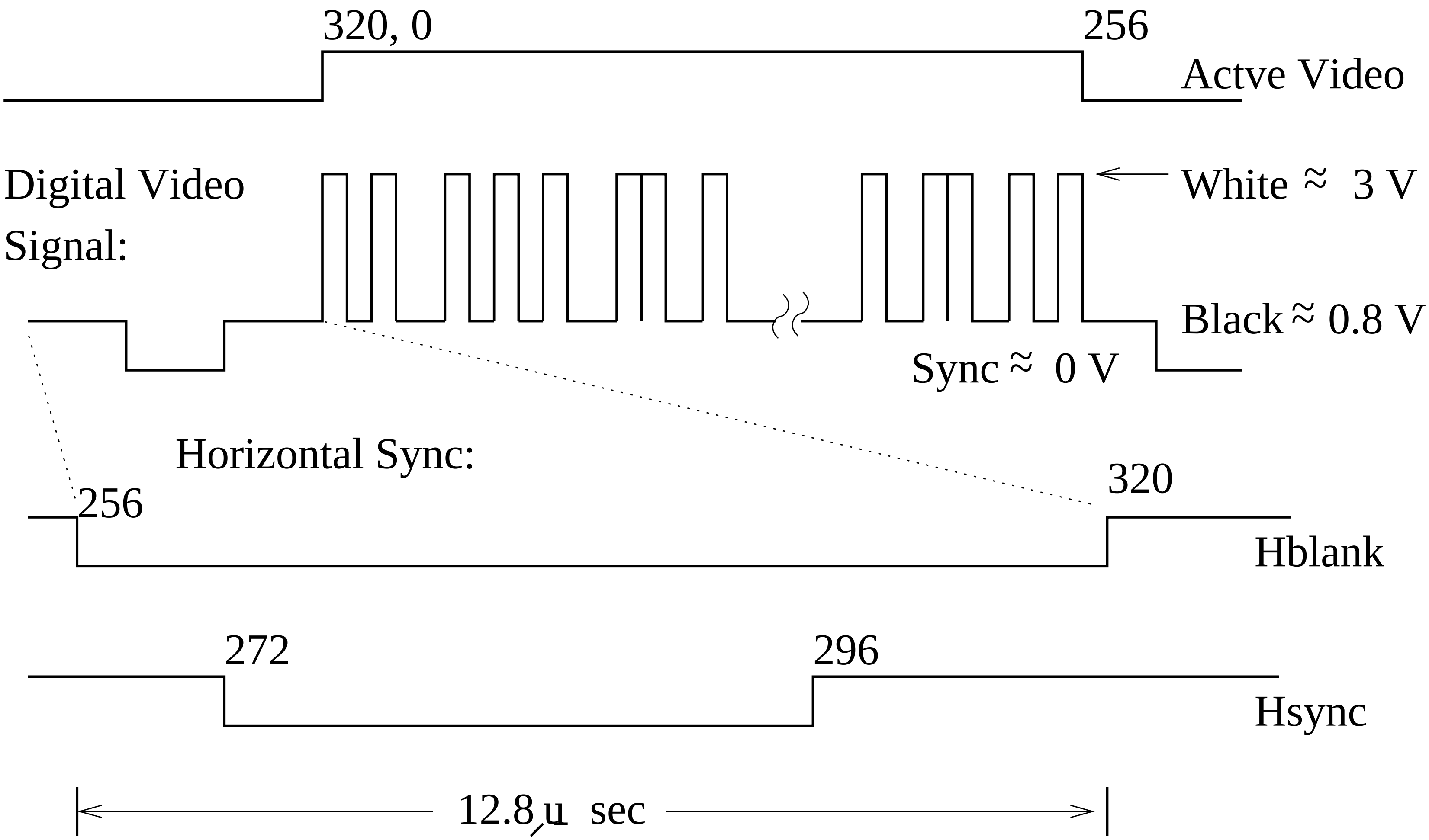
Timing of Control Signals

- **Data is loaded into a shift register and shifted out to generate the video signal.**
  - **CLK is at the pixel rate.**
  - **TVC divides access to the SRAM giving half the time to get data to load into the shift register .**



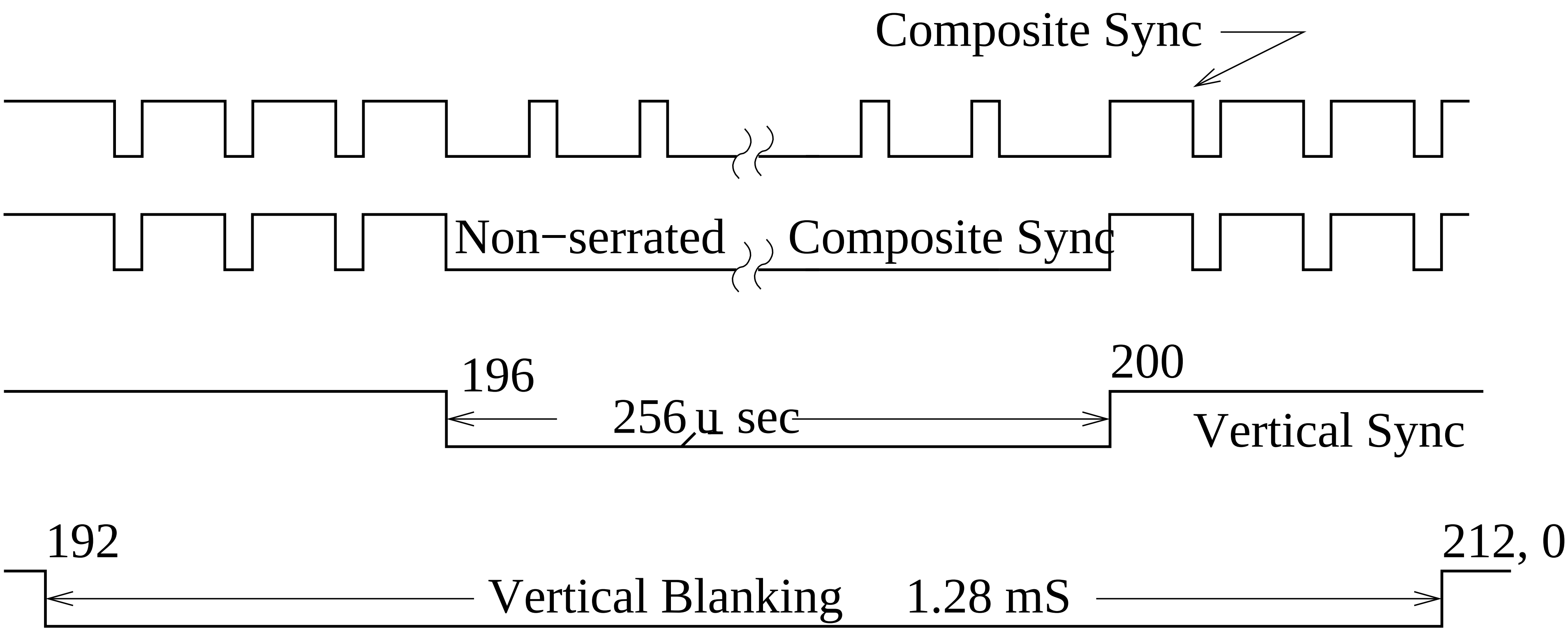
Horizontal Sync Timing

- We choose this display format.
  - 256 pixels X 192 rows
  - 10 MHz clock => 200 nanoseconds per pixel
  - 256 X 192 = 49,152 = 48K pixels = 6 K bytes



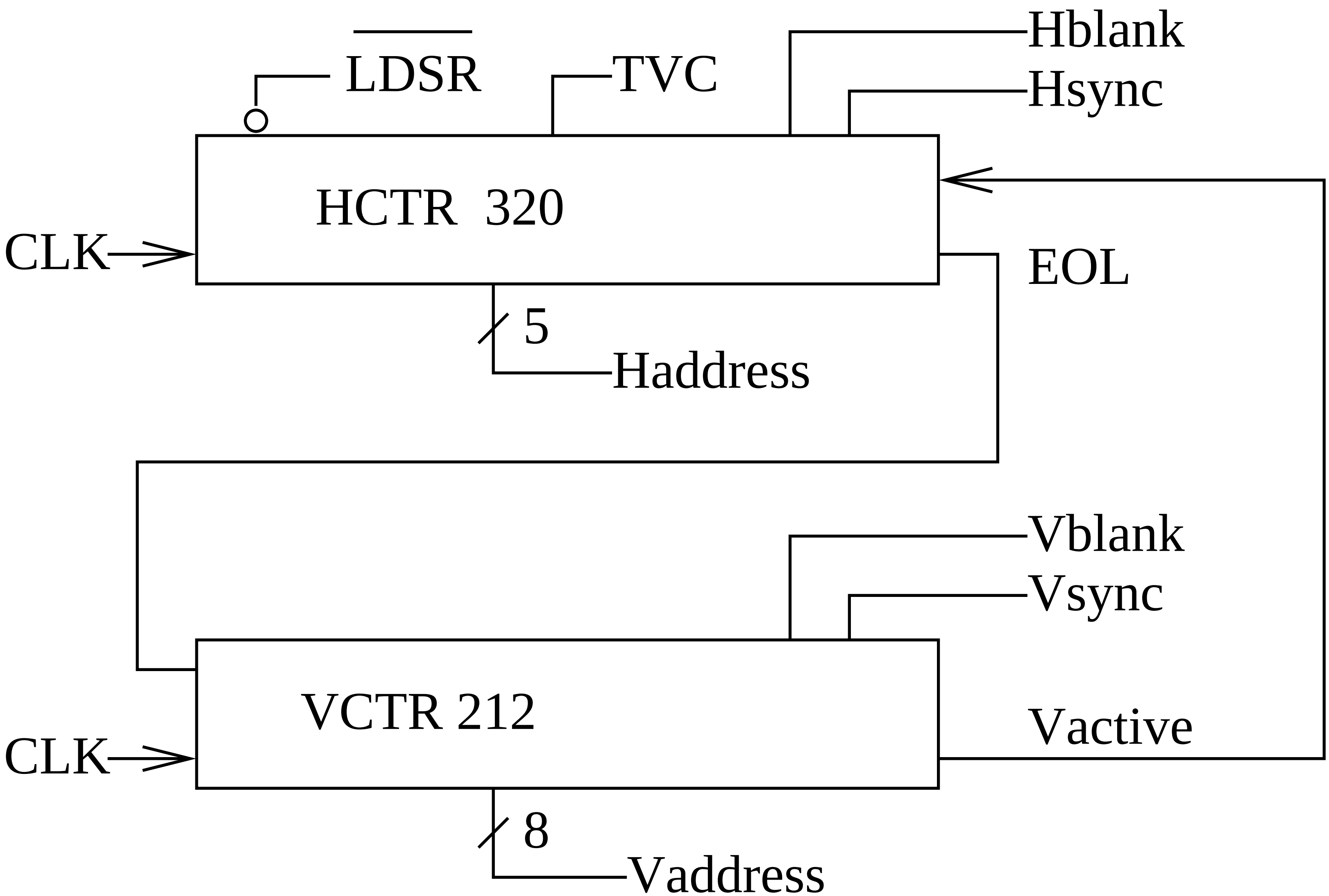
Vertical Sync Timing

- **Our display format.**
  - **256 pixels X 192 rows**
  - **10 MHz clock => 200 nanoseconds per pixel**
  - **256 X 192 = 49,152 = 48K pixels = 6 K bytes**



Block Diagram of Sync Generator

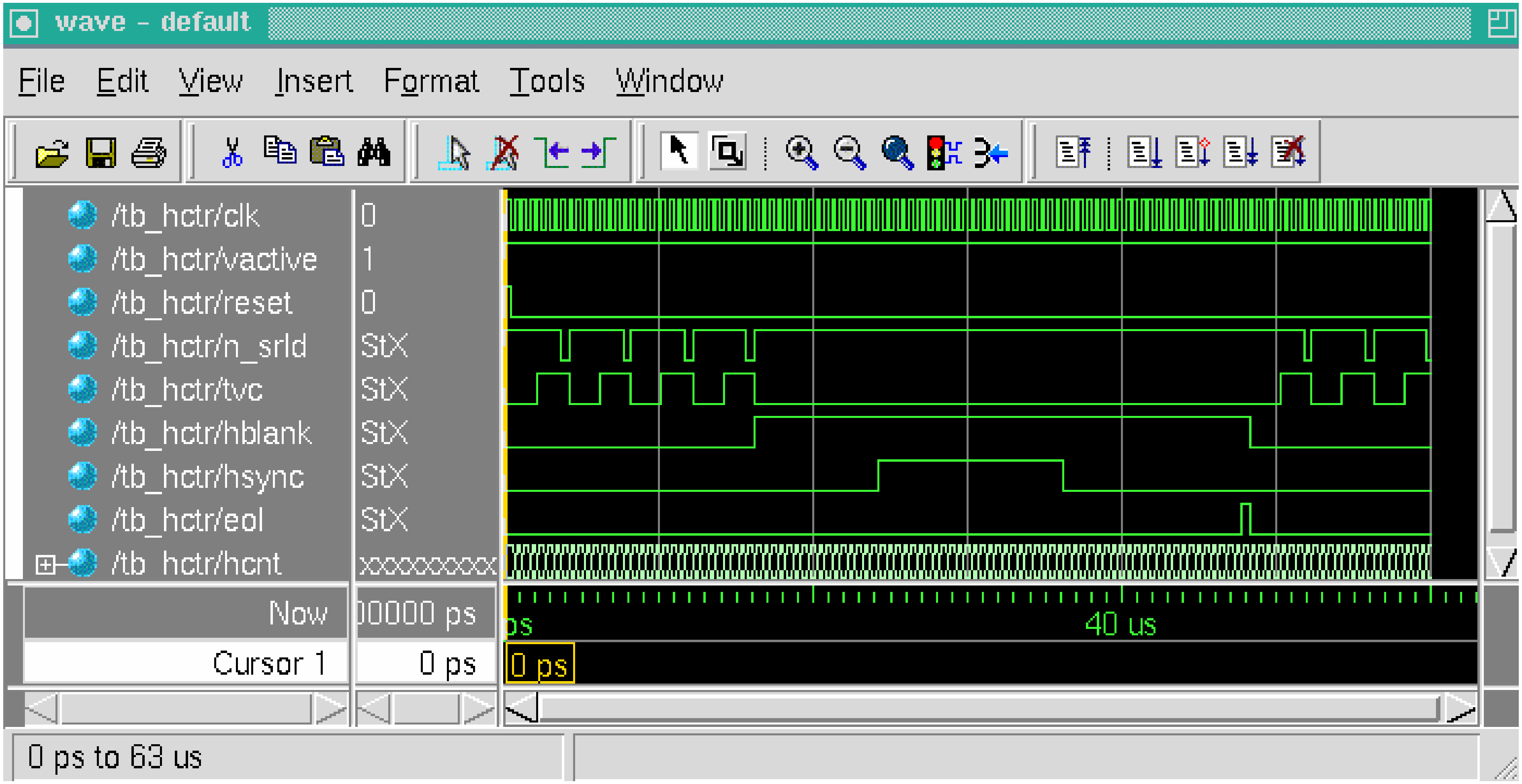
- **What signals need to be glitch free?**



hctr.v

```
/*************************************
* Filename:    hctr.v                    *
* Description: Horizontal counter  *
* Author:      Don Troxel               *
* Date:        3/13/2004                *
* Course:      6.111                    *
**************************************/

module hctr (clk, vactive, reset,
            hcnt, n_srld, tvc, hblank, hsync, eol);

   input clk, vactive, reset;
   output n_srld, tvc, hblank, hsync, eol;
   output [8:0] hcnt;

   wire n_srld, tvc, eol, hactive;
   reg hblank, hsync;
   reg [8:0] hcnt;

//   parameter start = 9'd224;
   parameter start = 9'd000;

   assign n_srld = !(hcnt[0] & hcnt[1] & tvc);
   assign tvc = hcnt[2] & hactive & vactive;
   assign eol = (hcnt == 9'b100111111) ? 1'b1 : 1'b0;
   assign hactive = (hcnt < 9'b100000000) ? 1'b1 : 1'b0;

always @(posedge clk, posedge reset)
     begin
       if(reset == 1)
         begin
           hcnt <= start;
           hblank <= 1'b0;
           hsync <= 1'b0;
         end
       else if (hcnt == 9'd319)  // reset to 0
         begin
           hcnt <= start;
           hblank <= 1'b0;
         end
       else
         hcnt <= hcnt + 1;

       if (hcnt == 9'd255)
         hblank <= 1'b1;
       else if (hcnt == 9'd271)
         hsync <= 1'b1;
       else if (hcnt == 9'd295)
         hsync <= 1'b0;
     end

endmodule
```

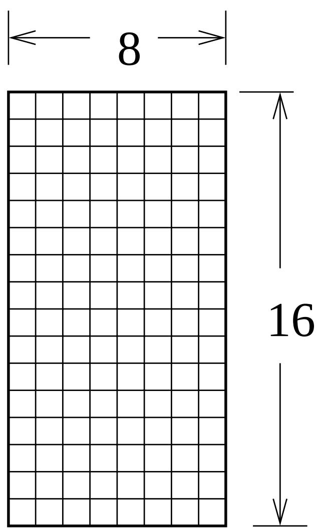
Simulation of hctr.v

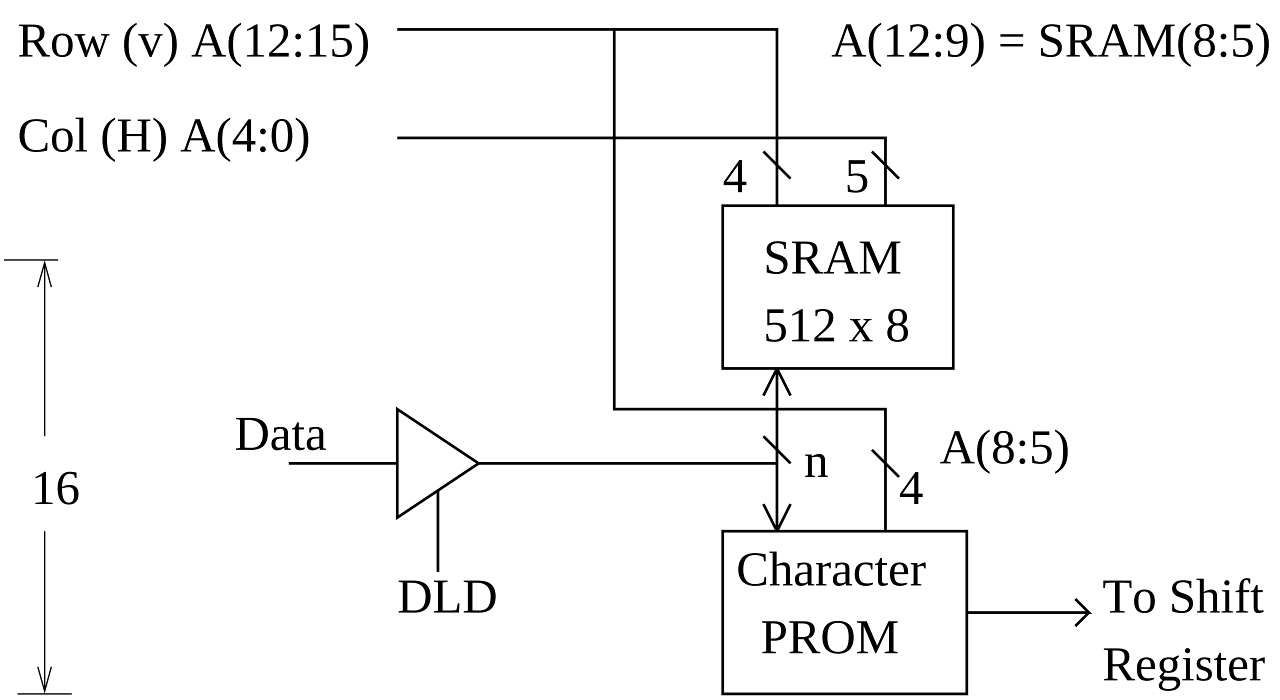


Character Displays (8 x 16 pixels)

- Characters are fixed bit patterns.
  - They always have the same shape but can appear at different places on the screen.
  - Use of characters can save video memory and make the manipulation of video memory contents simpler.

For a screen 256 x 192 one gets 384 characters. The screen address is used to specify the position and part of the address of the character ROM

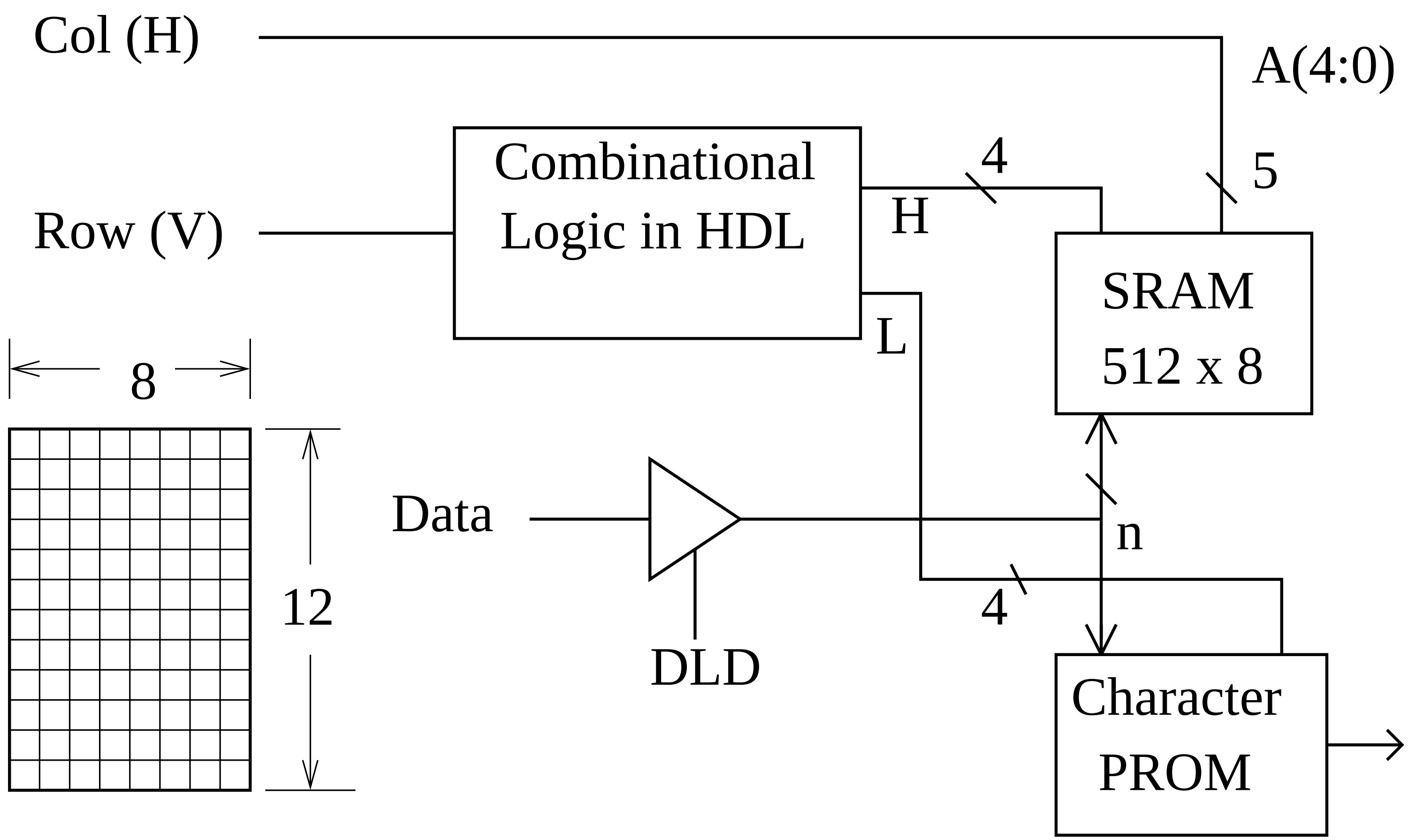




Character Displays (8 x 12 pixels)

- Row formatting is not as simple as before.
  - But remapping is easily done in an HDL.

For a screen 256 x 192 one gets 512 characters. The screen address modified by combinational logic is used to specify the position and part of the address of the character ROM



Pairs of Characters

- Sometimes, pairs of characters can create the same motion effect as bit-mapped graphics.
  - The speed of the motion depends on the update rate.
- These 24 characters (12 x 2) can display an arrow at any vertical position.