Display Technology

- Images stolen from various locations on the web...

Cathode Ray Tube

Electron Gun

Beam Steering Coils
Color

Shadow Mask and Aperture Grille

Liquid Crystal Displays

Liquid Crystal Displays

DLP Projector

LCoS

- Liquid Crystal on Silicon
  - Put a liquid crystal between a reflective layer on a silicon chip
Grating Light Valve (GLS)

- Lots (8000 currently) of micro ribbons that can bend slightly
- Make them reflective
- The bends make a diffraction grating that controls how much light where
- Scan it with a laser for high light output
- 4000 pixel wide frame every 60Hz

Digistar 3 Dome Projector

VGA

- Stands for Video Graphics Array
- A standard defined by IBM back in 1987
  - 640 x 480 pixels
  - Now superseded by much higher resolution standards...
- Also means a specific analog connector
  - 15-pin D-subminiature VGA connector

VGA Connector

Raster Scanning
This all sounds pretty strict and exact... It's not really... The only things a VGA monitor really cares about are:

- **Hsync**
- **Vsync**

Actually, all it cares about is the falling edge of those pulses!

The beam will retrace whenever you tell it to. It's up to you to make sure that the video signal is 0V when you are not painting (i.e. retraceing).
VGA Voltage Levels

- Voltages on R, G, and B determine the color
  - Analog range from 0v (off) to +0.7v (on)
  - But, our pads produce 0-5v outputs!

More colors

- More colors means more bits stored per pixel
- Also means D/A conversion to 0 to 0.7v range

What to Display?

- You need data to display on the screen...
  - Brute force: put it all in a giant ram that has the same resolution as your screen and just walk through the RAM as you paint the screen
  - More clever: Fill a row buffer with data for a scan line
  - Multi-level: Fill a (smaller) row buffer with pointers to glyphs that are stored in another RAM/ROM
- Just keep track of where the beam is and where your data is...

CharROM
CharROM

The Character ROM contains the 64 member ASCII open-face character set. The characters are addressed with a 6-
bit binary address A[5:0] and a third unary decoded address, R[2:0] or E[2:0]. The Character ROM outputs a single row
of the selected character at a time on the output [2:0].

A[2:0] = row of character
R[2:0] = column of CharRom
E[2:0] = row of CharRom

The decoder Dec2 selects one of the eight rows. For instance, if the character “A” is selected with A[2:0] = 0 and E[2:0]
free AD12 will produce the following binary output on T[8:0].

<table>
<thead>
<tr>
<th>A[2:0]</th>
<th>B</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>10</td>
<td>0111</td>
</tr>
<tr>
<td>001</td>
<td>10</td>
<td>0111</td>
</tr>
<tr>
<td>010</td>
<td>10</td>
<td>0111</td>
</tr>
<tr>
<td>011</td>
<td>10</td>
<td>0111</td>
</tr>
<tr>
<td>100</td>
<td>10</td>
<td>0111</td>
</tr>
<tr>
<td>101</td>
<td>10</td>
<td>0111</td>
</tr>
<tr>
<td>110</td>
<td>10</td>
<td>0111</td>
</tr>
<tr>
<td>111</td>
<td>10</td>
<td>0111</td>
</tr>
</tbody>
</table>

Two Lines of Text

- 16 characters/line x 8
- 6 bits to address a character
  - A[4:3] = row of CharRom
  - R[2:0] = column of CharRom
  - A[2:0] = row of character

RAM/ROM Generator

- Designed by Allen Tanner 4 years ago as his class project...
- makemem
- Simple SRAM and ROM arrays

ROM vs. Verilog

- ROM vs. Verilog
- ROM vs. Verilog

- ROM vs. Verilog
- ROM vs. Verilog
ROM vs. Verilog

- Number of rows is limited to 64 by address decoder design
- Columns are not restricted
- For ROM you can add a tristate bus at the output which is another level of decoding
  - width must be an even number
- SRAM has single, dual, and triple port options

makemem Limits

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makemem

- Enter the following:
- where choice specifies the creation of either ROM or SRAM:
  - for ROM enter -r rname: rname.rom is the file name.
  - for SRAM version 1 enter -s r c: Version 1 SRAM single port.
  - for SRAM version 2 enter -s1 r c: Version 2 SRAM single port.
  - for SRAM version 2 enter -s2 r c: Version 2 SRAM dual port.
  - for SRAM version 2 enter -s3 r c: Version 2 SRAM triple port.
- r is the number of rows (decimal).
- c is the number of columns (decimal).
- -h -H help (no processing occurs when help is requested).
- -f fname output file name. Used with .cif, .v, & .il files.
- -r rname rname: name for array top cell name.
- -t n use tristate buffers on the outputs of ROM.
- -q output hello.txt file to find the working file directory.