## VGA Signal Timing

A single dot of color on a video monitor doesn't impart much information. A horizontal line of pixels carries a bit more information. But a frame composed of multiple lines can present an image on the monitor screen. A frame of VGA video typically has 480 lines and each line usually contains 640 pixels. In order to paint a frame, there are deflection circuits in the monitor that move the electrons emitted from the guns both left-to-right and top-to-bottom across the screen. These deflection circuits require two synchronization signals in order to start and stop the deflection circuits at the right times so that a line of pixels is painted across the monitor and the lines stack up from the top to the bottom to form an image. The timing for the VGA synchronization signals is shown in Figure 2.
Negative pulses on the horizontal sync signal mark the start and end of a line and ensure that the monitor displays the pixels between the left and right edges of the visible screen area. The actual pixels are sent to the monitor within a 25.17 μs window. The horizontal sync signal drops low a minimum of 0.94 μs after the last pixel and stays low for 3.77 μs. A new line of pixels can begin a minimum of 1.89 μs after the horizontal sync pulse ends. So a single line occupies 25.17 μs of a 31.77 μs interval. The other 6.6 μs of each line is the horizontal blanking interval during which the screen is dark.
In an analogous fashion, negative pulses on a vertical sync signal mark the start and end of a frame made up of video lines and ensure that the monitor displays the lines between the top and bottom edges of the visible monitor screen.
The lines are sent to the monitor within a 15.25 ms window. The vertical sync signal drops low a minimum of 0.45 ms after the last line and stays low for 64 μs. The first line of the next frame can begin a minimum of 1.02 ms after the vertical sync pulse ends. So a single frame occupies 15.25 ms of a 16.784 ms interval. The other 1.534 ms of the frame interval is the vertical blanking interval during which the screen is dark.

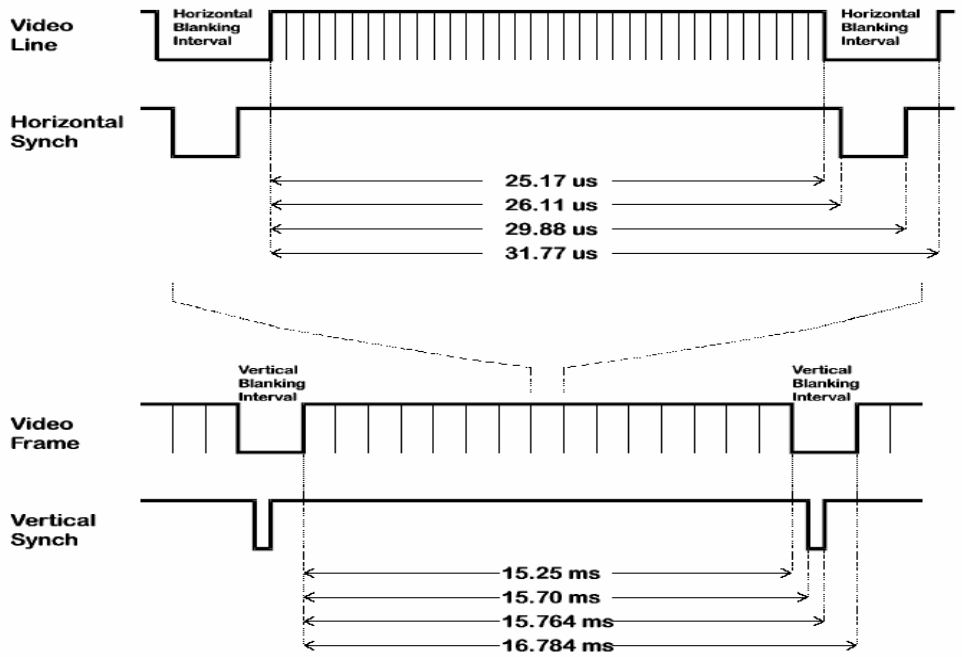


Figure 2: VGA signal timing.

# VGA Signal Generator Algorithm

Now we have to figure out a process that will send pixels to the monitor with the correct timing and framing. We can store a picture in RAM. Then we can retrieve the data from the RAM, format it into lines of pixels, and send the lines to the monitor with the appropriate pulses on the horizontal and vertical sync pulses. The pseudo code for a single frame of this process is shown in Listing 1. The pseudo code has two outer loops: one which displays the L lines of visible pixels, and another which inserts the V blank lines and the vertical sync pulse.
Within the first loop, there are two more loops: one which sends the P pixels of each video line to the monitor, and another which inserts the H blank pixels and the horizontal sync pulse.
Within the pixel display loop, there are statements to get the next byte from the RAM. Each byte contains four two-bit pixels. A small loop iteratively extracts each pixel to be displayed from the lower two bits of the byte. Then the byte is shifted by two bits so the next pixel will be in the right position during the next iteration of the loop. Since it has only two bits, each pixel can store one of four colors. The mapping from the two-bit pixel value to the actual values required by the monitor electronics is done by the
COLOR_MAP () routine.