VGA Port

The Spartan-3 Starter Kit board includes a VGA display port and DB15 connector, indicated as (5) in Figure 1-2. Connect this port directly to most PC monitors or flat-panel LCD displays using a standard monitor cable.

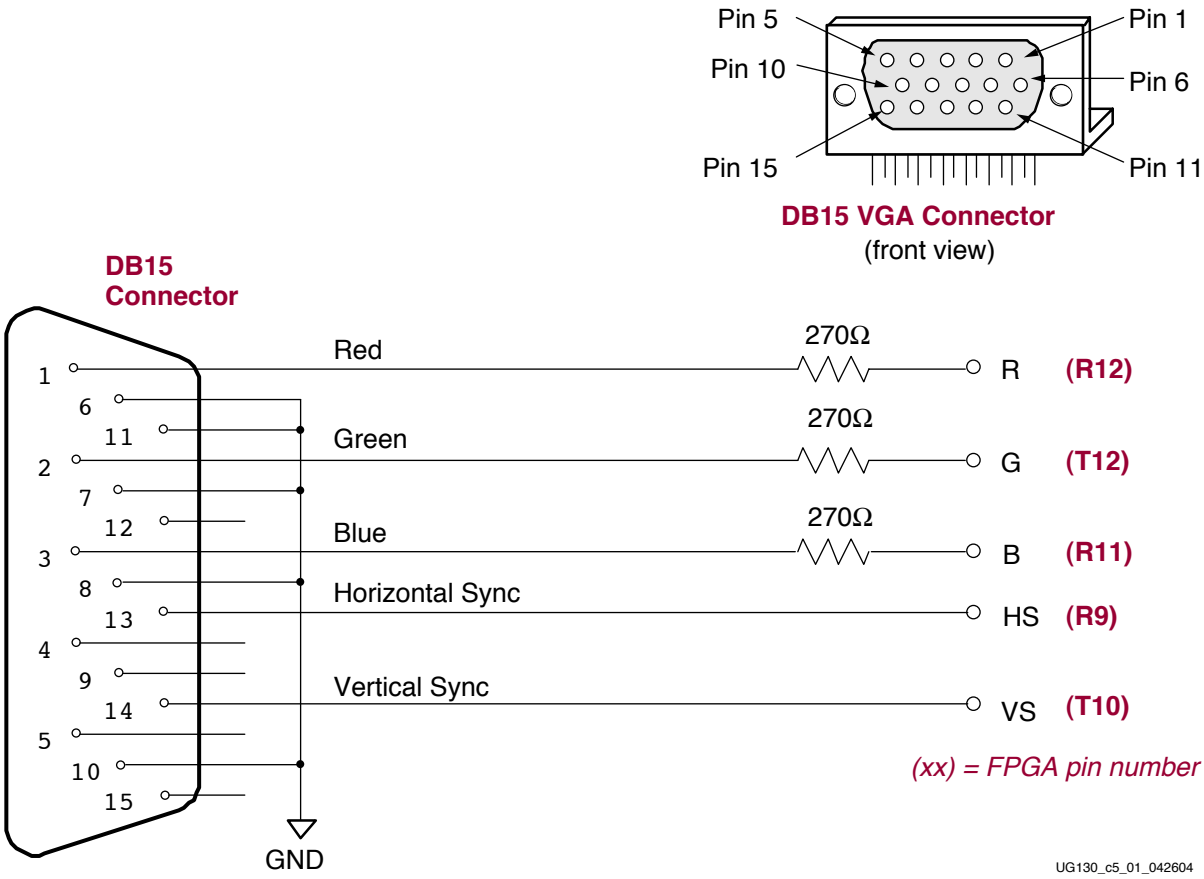

Figure 5-1: **VGA Connections from Spartan-3 Starter Kit Board**

As shown in Figure 5-1, the Spartan-3 FPGA controls five VGA signals: Red (R), Green (G), Blue (B), Horizontal Sync (HS), and Vertical Sync (VS), all available on the VGA connector. The FPGA pins that drive the VGA port appear in Table 5-1. A detailed schematic is in Figure A-7.

Table 5-1: **VGA Port Connections to the Spartan-3 FPGA**

Signal	FPGA Pin
Red (R)	R12
Green (G)	T12
Blue (B)	R11
Horizontal Sync (HS)	R9
Vertical Sync (VS)	T10

Each color line has a series resistor to provide 3-bit color, with one bit each for Red, Green, and Blue. The series resistor uses the 75Ω VGA cable termination to ensure that the color signals remain in the VGA-specified 0V to 0.7V range. The HS and VS signals are TTL level. Drive the R, G, and B signals High or Low to generate the eight possible colors shown in Table 5-2.

Table 5-2: **3-Bit Display Color Codes**

Red (R)	Green (G)	Blue (B)	Resulting Color
0	0	0	**Black**
0	0	1	**Blue**
0	1	0	**Green**
0	1	1	**Cyan**
1	0	0	**Red**
1	0	1	**Magenta**
1	1	0	**Yellow**
1	1	1	**White**

VGA signal timing is specified, published, copyrighted, and sold by the Video Electronics Standards Association (VESA). The following VGA system and timing information is provided as an example of how the FPGA might drive VGA monitor in 640 by 480 mode. For more precise information or for information on higher VGA frequencies, refer to documents available on the VESA website or other electronics websites:

Video Electronics Standards Association
http://www.vesa.org

VGA Timing Information
http://www.epanorama.net/documents/pc/vga_timing.html

Signal Timing for a 60Hz, 640x480 VGA Display

CRT-based VGA displays use amplitude-modulated, moving electron beams (or cathode rays) to display information on a phosphor-coated screen. LCD displays use an array of switches that can impose a voltage across a small amount of liquid crystal, thereby changing light permitivity through the crystal on a pixel-by-pixel basis. Although the following description is limited to CRT displays, LCD displays have evolved to use the

same signal timings as CRT displays. Consequently, the following discussion pertains to both CRTs and LCD displays.

Within a CRT display, current waveforms pass through the coils to produce magnetic fields that deflect electron beams to transverse the display surface in a "raster" pattern, horizontally from left to right and vertically from top to bottom. As shown in Figure 5-2, information is only displayed when the beam is moving in the "forward" direction—left to right and top to bottom—and not during the time the beam returns back to the left or top edge of the display. Much of the potential display time is therefore lost in "blanking" periods when the beam is reset and stabilized to begin a new horizontal or vertical display pass.

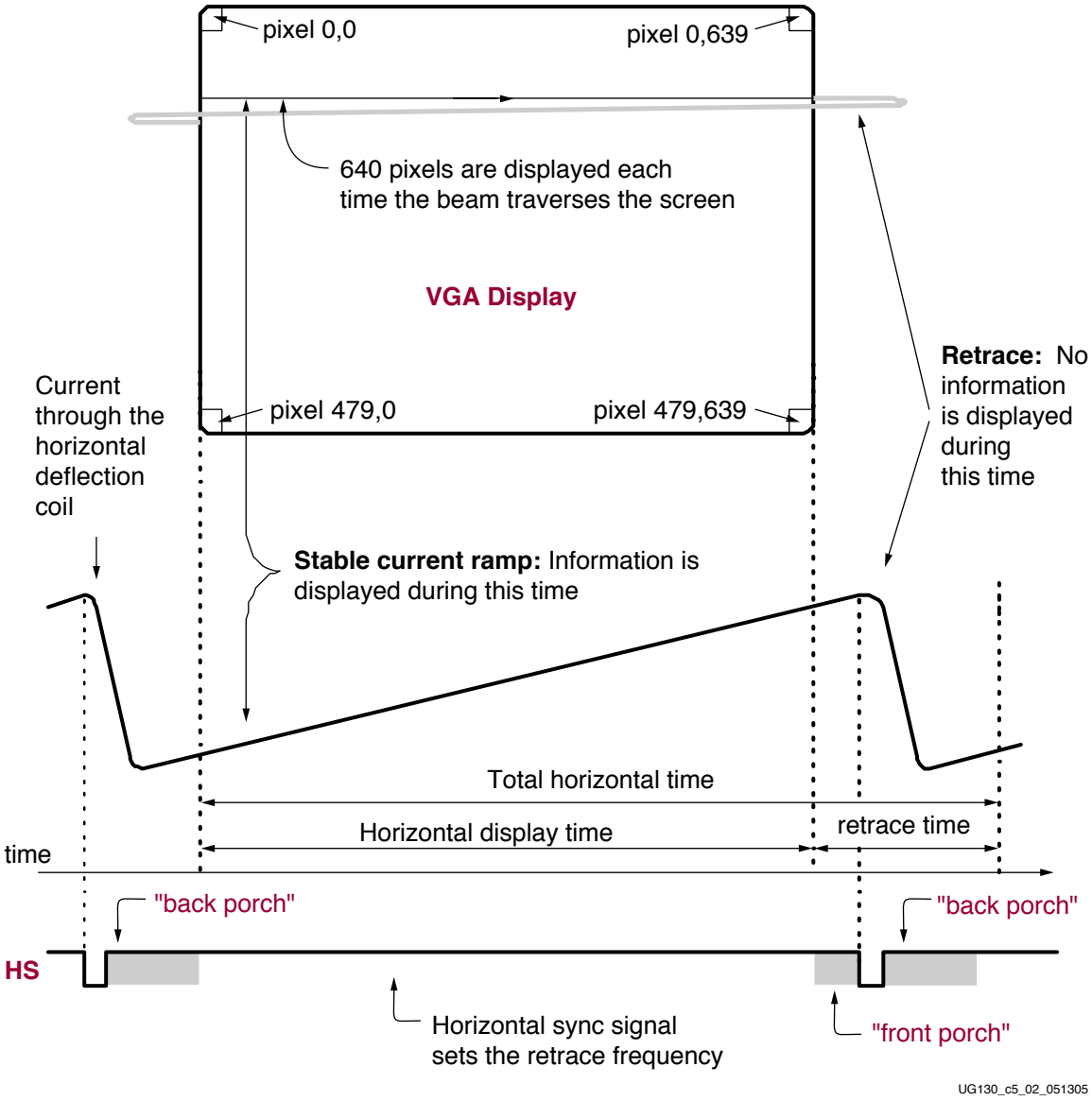

Figure 5-2: **CRT Display Timing Example**

The size of the beams, the frequency at which the beam traces across the display, and the frequency at which the electron beam is modulated determine the display resolution.

Modern VGA displays support multiple display resolutions, and the VGA controller dictates the resolution by producing timing signals to control the raster patterns. The controller produces TTL-level synchronizing pulses that set the frequency at which current flows through the deflection coils, and it ensures that pixel or video data is applied to the electron guns at the correct time.

Video data typically comes from a video refresh memory with one or more bytes assigned to each pixel location. The Spartan-3 Starter Kit board uses three bits per pixel, producing one of the eight possible colors shown in Table 5-2. The controller indexes into the video data buffer as the beams move across the display. The controller then retrieves and applies video data to the display at precisely the time the electron beam is moving across a given pixel.

As shown in Figure 5-2, the VGA controller generates the HS (horizontal sync) and VS (vertical sync) timings signals and coordinates the delivery of video data on each pixel clock. The pixel clock defines the time available to display one pixel of information. The VS signal defines the "refresh" frequency of the display, or the frequency at which all information on the display is redrawn. The minimum refresh frequency is a function of the display's phosphor and electron beam intensity, with practical refresh frequencies in the 60 Hz to 120 Hz range. The number of horizontal lines displayed at a given refresh frequency defines the horizontal "retrace" frequency.

VGA Signal Timing

The signal timings in Table 5-3 are derived for a 640-pixel by 480-row display using a 25 MHz pixel clock and 60 Hz ±1 refresh. Figure 5-3 shows the relation between each of the timing symbols. The timing for the sync pulse width (T_{PW}) and front and back porch intervals (T_{FP} and T_{BP}) are based on observations from various VGA displays. The front and back porch intervals are the pre- and post-sync pulse times. Information cannot be displayed during these times.

Table 5-3: **640x480 Mode VGA Timing**

Symbol	Parameter	Vertical Sync			Horizontal Sync	
		Time	Clocks	Lines	Time	Clocks
T_S	Sync pulse time	16.7 ms	416,800	521	32 s	800
T_{DISP}	Display time	15.36 ms	384,000	480	25.6 s	640
T_{PW}	Pulse width	64 s	1,600	2	3.84 s	96
T_{FP}	Front porch	320 s	8,000	10	640 ns	16
T_{BP}	Back porch	928 s	23,200	29	1.92 s	48

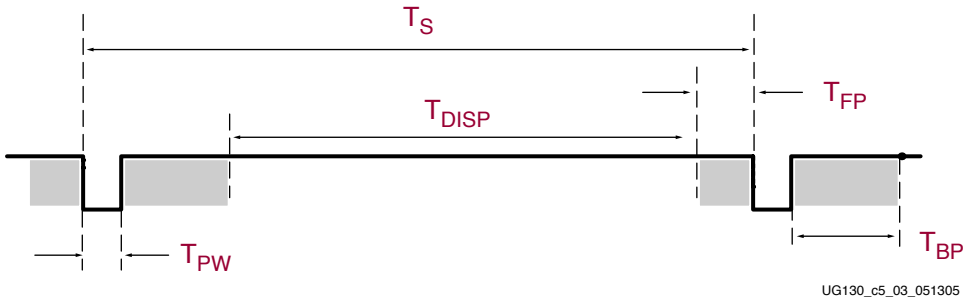

Figure 5-3: **VGA Control Timing**

Generally, a counter clocked by the pixel clock controls the horizontal timing. Decoded counter values generate the HS signal. This counter tracks the current pixel display location on a given row.

A separate counter tracks the vertical timing. The vertical-sync counter increments with each HS pulse and decoded values generate the VS signal. This counter tracks the current display row. These two continuously running counters form the address into a video display buffer. For example, the on-board fast SRAM is an ideal display buffer.

No time relationship is specified between the onset of the HS pulse and the onset of the VS pulse. Consequently the counters can be arranged to easily form video RAM addresses, or to minimize decoding logic for sync pulse generation.