

PPU - HDMI

HDMI format restrictions:

- Only 24-bit (8 bits per color) and higher color modes supported by ADV7513 chip [2, pg. 26].
- Minimum supported video is 480p@60Hz, requiring a pixel clock of 25 MHz [1, pg. 60].

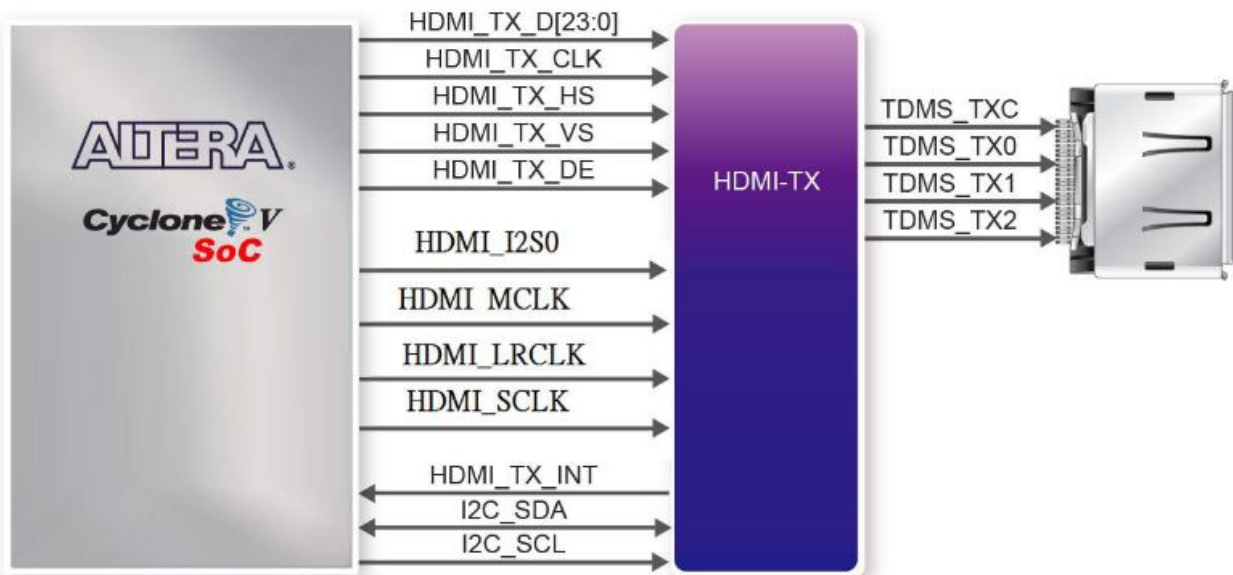
Notes:

- If we want to convert 16-bit (5-6-5) (High Color) to 24-bit (8-8-8) (True Color), we can opt to left-shift the 16-bit values to occupy the MSBs. This results in a slightly non-linear mapping of colors. For true linear mapping, see answers from Stack Overflow [3].
- Use a 1/2 clock divider to obtain the 25MHz pixel clock signal from our 50MHz clock. NEED TO VERIFY WITH ACTUAL HARDWARE.
- The HDMI demo from [1, pg. 60] accomplishes multiple resolutions by using a reconfigurable PLL to support multiple pixel clock frequencies.

Implementation examples:

- Video and sound demo referenced in DE10-Nano User Manual [1, pg. 60].

HDMI Interface with FPGA:



Above: FPGA and HDMI TX Controller interconnects (Figure 3-24 found on [1, pg. 34])

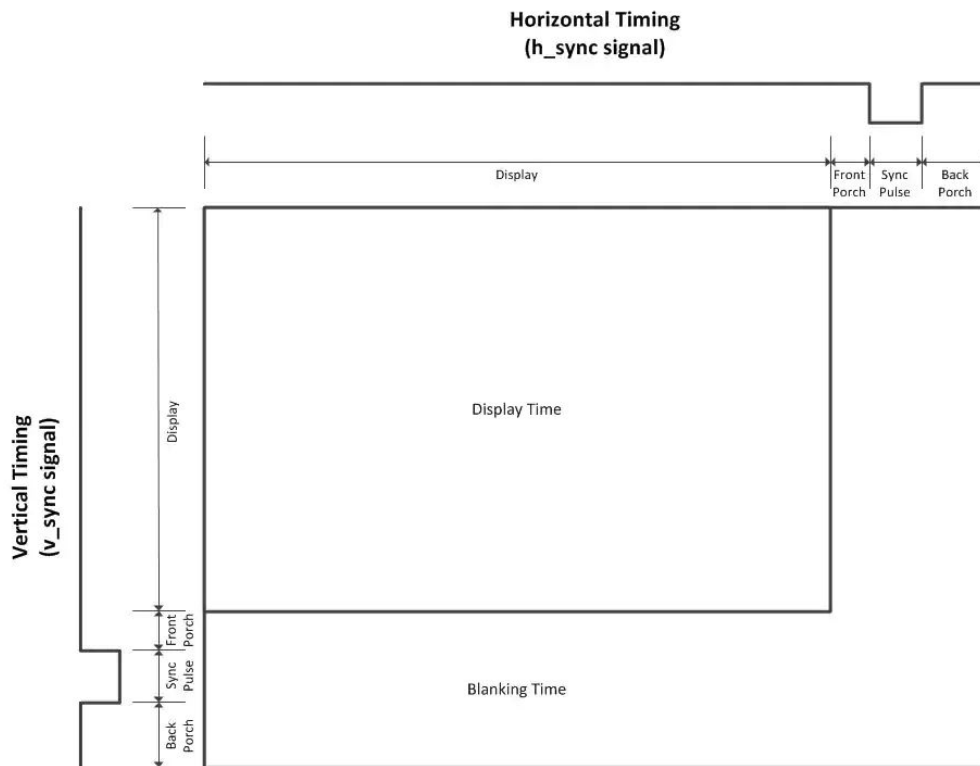
- Notably, the FPGA sets up the expected video parameters with the HDMI TX Controller via I2C.
- Then, the FPGA uses a VGA-like interface (Horizontal Sync, Vertical Sync, and Data Enable).

HDMI Protocol (TMDS):

- HDMI implements the TMDS (Transition-minimized differential signaling) protocol. This is the same TMDS used by DVI [4].
- This isn't very relevant to our work since the ADV7513 chip takes care of the specifics. We will actually output a VGA-like signal to the ADV7513 system, which will do the translation.

HDMI-TX Controller Interface Protocol:

- These notes describe the protocol the FPGA sends to the HDMI TX Controller (the ADV7513).
- HDMI Mode: 25MHz Pixel clock for 640x480@60Hz. Timings are identical to the VGA standard for 640x480@60Hz. See table at the bottom of the webpage in [5] or the tables in [6].



Above: HS and VS signal timing diagram [5, Figure 3]

The example code from the demo project has timing which corresponds exactly to VGA (with some additional built-in delays for clocking logic).

- See `vga_generator.v` for the generation of HS, VS, color (24-bit RGB), and DE signals.

Resources

[0] Terasic DE10-Nano - Official Website

<https://www.terasic.com.tw/cgi-bin/page/archive.pl?Language=English&CategoryNo=205&No=1046&PartNo=1>

[1] DE10-Nano User Manual (rev. B2/C Hardware)

https://www.terasic.com.tw/cgi-bin/page/archive_download.pl?Language=English&No=1046&FD=1c19d1d50e0ee9b21678e881004f6d81

[2] ADV7513 (HDMI Transmitter Chip) Programming Guide

https://www.analog.com/media/en/technical-documentation/user-guides/ADV7513_Programming_Guide.pdf

[3] Stack Overflow Guide on 16-bit 5-6-5 to 24-bit 8-8-8 Color Conversion

<https://stackoverflow.com/questions/2442576/how-does-one-convert-16-bit-rgb565-to-24-bit-rgb888?noredirect=1&fq=1>

[4] Short Wikipedia overview of TMDS

https://en.wikipedia.org/wiki/Transition-minimized_differential_signaling

[5] An overview of VGA. It even has a table full of timing specifications for each variation of VGA

<https://www.digikey.com/eewiki/pages/viewpage.action?pageId=15925278>

[6] A collection of specific timings for 640 x 480 @ 60Hz VGA that we care about

<http://tinyvga.com/vga-timing/640x480@60Hz>

Other Resources:

The CD for DE10-Nano CD-ROM (rev. C Hardware) can be found here:

- <https://www.terasic.com.tw/cgi-bin/page/archive.pl?Language=English&CategoryNo=205&No=1046&PartNo=4>
- Contains tons of datasheets for every major system component.
- Contains demo projects
- Contains some of the manuals mentioned above + quick-start guides.
- Contains board schematics.
- Contains a project generator tool which generates quartus project files (.qpf).