18-545 Lab 3 writeup
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Our project goals are focused on processor architecture experimentation; sound would be a non-essential nicety. Therefore, for our Lab 3, we focused on getting basic VGA display output working on our Virtex 7-based VC707 board. This was a more challenging problem than it sounds prima facie since the VC707 board lacks a VGA output connector and has an extremely limited number of easily-accessible GPIO ports we could use for output. Our goals, then were as follows: first, develop a simple VGA output FSM-D in Verilog; second, figure out what GPIO ports on the VC707 were usable for our purposes; third, set up the necessary interface between the digital GPIO and analog VGA.

The first step, developing a VGA FSM-D, was fairly straightforward. We reused some code from past 18-240 instances, and while we encountered a few issues related to hsync/vsync timing at the outset, these were easily overcome with some minor parameter tweaks.

The second and third steps were where we had most of our trouble. There is a lot of GPIO available on the VC707, but it is concentrated in the mezzanine connectors along the top of the board, and we lack the appropriate interface plugs to access these pins. Our only alternative was to remove the onboard LCD module and hijack those pins for our GPIO. However, only a very few pins are available on this header, greatly limiting the number of color bits we can output. We were ultimately forced to use only 3-bit color, one bit each for red, green, and blue, plus another pin for ground and two pins for hsync and vsync.

The next issue came when actually hooking these pins up to a VGA connector. We needed to find a way to convert the 3.3-5V GPIO output voltages down to the proper 0.7V-max required by the VGA spec. We thought that a typical voltage divider would work for this purpose, but found that apparently a connected monitor draws so much current from the color pins that the output voltage sags far below 0.7V. We tried to fix the issue by buffering the VC707 outputs through externally powered transistors, but this generated so much noise on the VGA input pins that the monitor no longer saw a valid input signal. Eventually, we determined that the GPIO voltage sag was actually sufficient to drive VGA color pins at below the 0.7V maximum without a separate voltage divider, and were able to produce a simple test pattern (see picture, below).

The biggest lesson we learned from this lab was that VGA is really hard to do if you don’t have a dedicated VGA port on your board or an easily accessible DAC. In the future, we believe it will be simpler to use the HDMI chip and port on our board to do video output (particularly given the sample HDMI core resources provided by the chip manufacturer).

Photo of working setup: