Revision	Date	Author	Comments
C	2022-07-18	Tim S. timothystotts08@gmail.com	First publishable release of the refresh of the colors palette tester.

https://github.com/timothystotts/fpga-colors-tester-3

Colors Palette Tester Experiment

Note that this project is kept as a beginner-level design that students, hobbyists, and FPGA enthusiasts may find interesting.

Colors Palette Tester Experiment: Folder Structure

The colors palette tester is only implemented in Xilinx MicroBlaze and Zynq-7000 subsystem design. No straight HDL coding exists.

Project Folder	**Project Description**
Color-Tester-Design-MB-A7 (Vivado 2022.2 and Vitis 2022.2)	A utility designed for custom color mixing of four RGB LEDs with comparison to the same palette mix on an OLED RGB display. The LED palette is a simplistic PWM control. The design is completely in MicroBlaze AXI subsystem with standard Xilinx IP Integrator components, Digilent Inc. User IP, and Standalone C language program executing on the MicroBlaze soft processor. This design targets the Digilent Inc. Arty A7-100 development board.
Color-Tester-Design-MB-S7 (Vivado 2022.2 and Vitis 2022.2)	A utility designed for custom color mixing of two RGB LEDs with comparison to the same palette mix on an OLED RGB display. The LED palette is a simplistic PWM control. The design is mostly equivalent to the Color-Tester-Design-MB-A7. This design targets the Digilent Inc. Arty S7-25 development board.
Color-Tester-Design-Zynq (Vivado 2022.2 and Vitis 2022.2)	A utility designed for custom color mixing of two RGB LEDs with comparison to the same palette mix on an OLED RGB display. The LED palette is a simplistic PWM control. The design is mostly equivalent to the Color-Tester-Design-MB-A7. This design targets the Digilent Inc. Zybo Z7-20 development board.

To successfully open the MB-A7 project, for Arty A7-100, it is necessary to create an empty Xilinx Vivado project, select the Part from Boards and click Refresh, then download the Arty A7-100 board definition. To successfully open the MB-S7 project, for Arty S7-25, do the same as mentioned, but download the Arty S7-25 definition instead. To successfully open the Zynq project, it is necessary to do the same, instead selecting the Zybo Z7-20 board. It is no longer necessary to install board_files in the data/boards/board_files folder of the Vivado install.

Additionally, before running a project's init script and block design script, it is necessary to update the GIT submodule in the <project>/IP/vivado-library path. That location is defined as a GIT submodule to clone a custom branch of a custom fork of the Digilent Inc. Vivado User IP repository.

Colors Palette Tester Experiment: Methods of Operation

The purpose of the design is to boot one of the three mentioned development boards with PMOD KYPD and PMOD OLEDrgb peripheral boards, which are a 4 by 4 alphanumeric keypad, and a 96x64 pixel 16-bit color OLED display panel, respectively. The PMOD KYPD connects to the FPGA with its own GPIO signals; and PMOD OLEDrgb connects to the FPGA with its own dedicated SPI bus.

For the Arty A7-100, the PMOD KYPD connects to board PMOD port JA; a slower PMOD port. The PMOD OLEDrgb connects to board PMOD port JB; a faster PMOD port. The use of an extension cable for each makes the PMOD KYPD able to orient upright with the display, and the PMOD OLEDrgb not block other ports. See Figure 1: Arty A7-100 Assembled with Pmod KYPD, Pmod OLEDrgb.

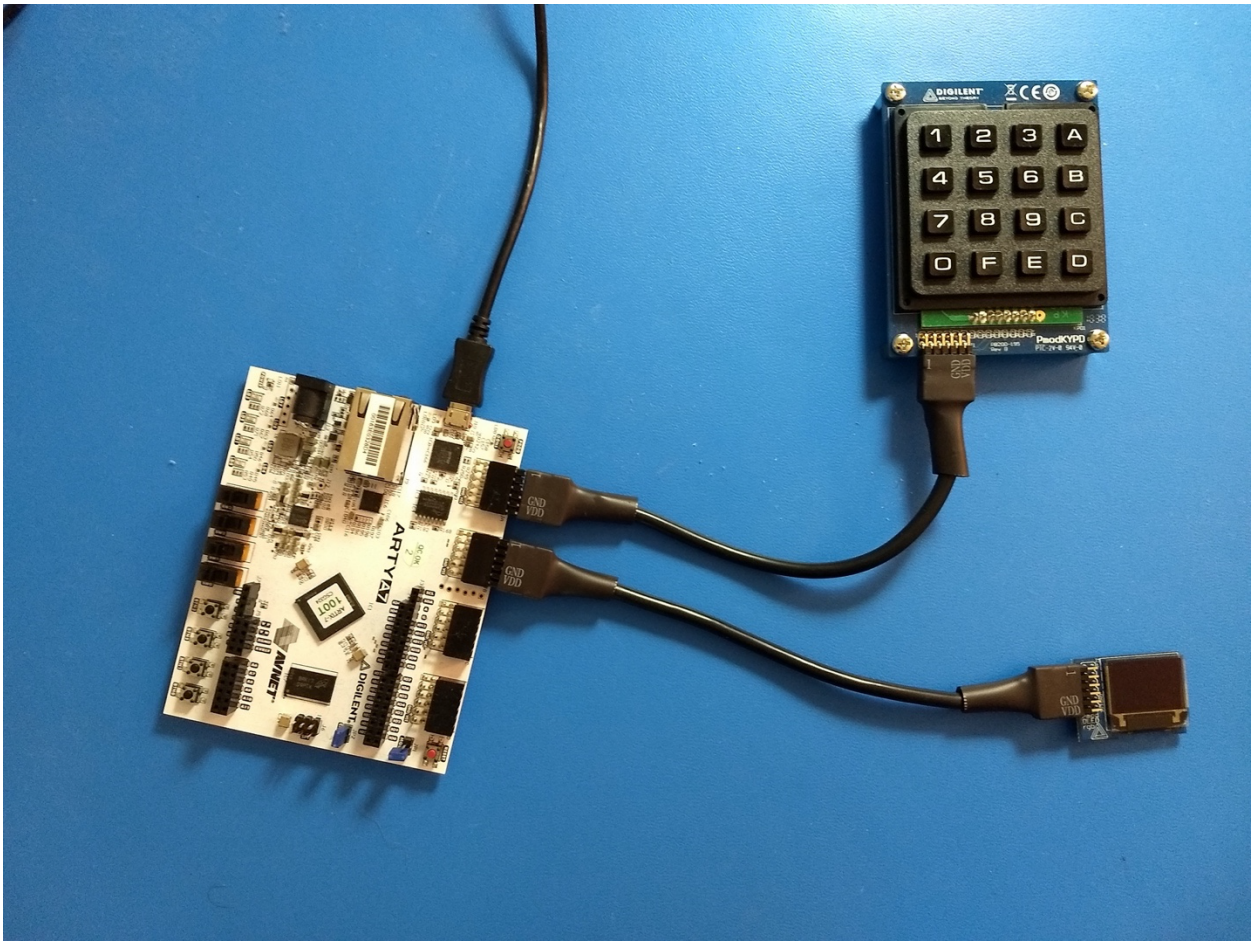

Figure 1: Arty A7-100 Assembled with Pmod KYPD, Pmod OLEDrgb

For the Arty S7-25, the PMOD KYPD connects to board PMOD port JC; a slower PMOD port. The PMOD OLEDrgb connects to board PMOD port JA; a faster PMOD port. The use of an extension cable for each makes the PMOD KYPD able to orient upright with the display, and the PMOD OLEDrgb not block other ports. See Figure 2: Arty S7-25 Assembled with Pmod KYPD, Pmod OLEDrgb.

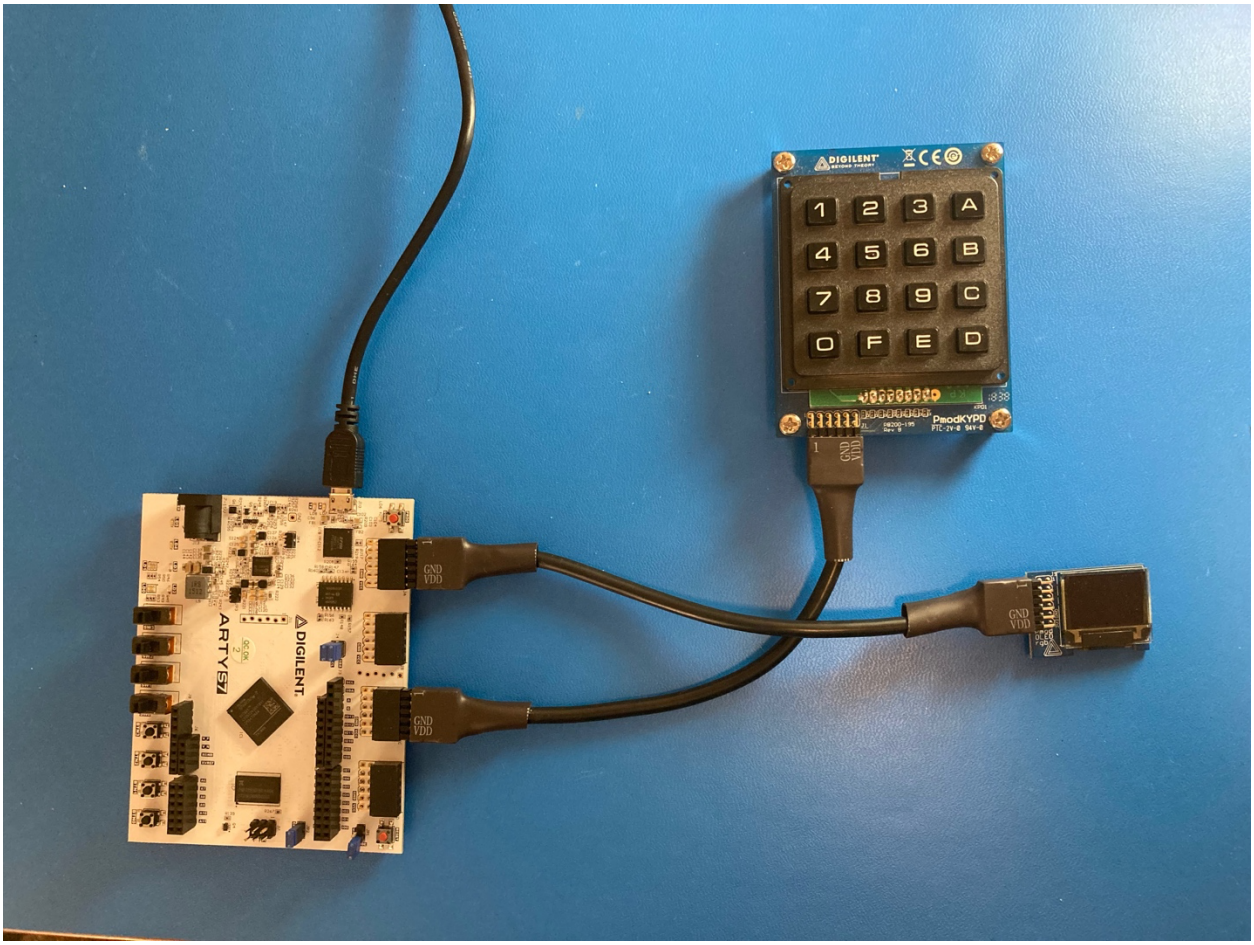

Figure 2: Arty S7-25 Assembled with Pmod KYPD, Pmod OLEDrgb

For the Zybo Z7-20, the PMOD KYPD connects to board PMOD port JE; a slower PMOD port. The PMOD OLEDrgb connects to board PMOD port JB; a faster PMOD port. The use of an extension cable for each makes the PMOD KYPD able to orient upright with the display, and the PMOD OLEDrgb not block other ports.

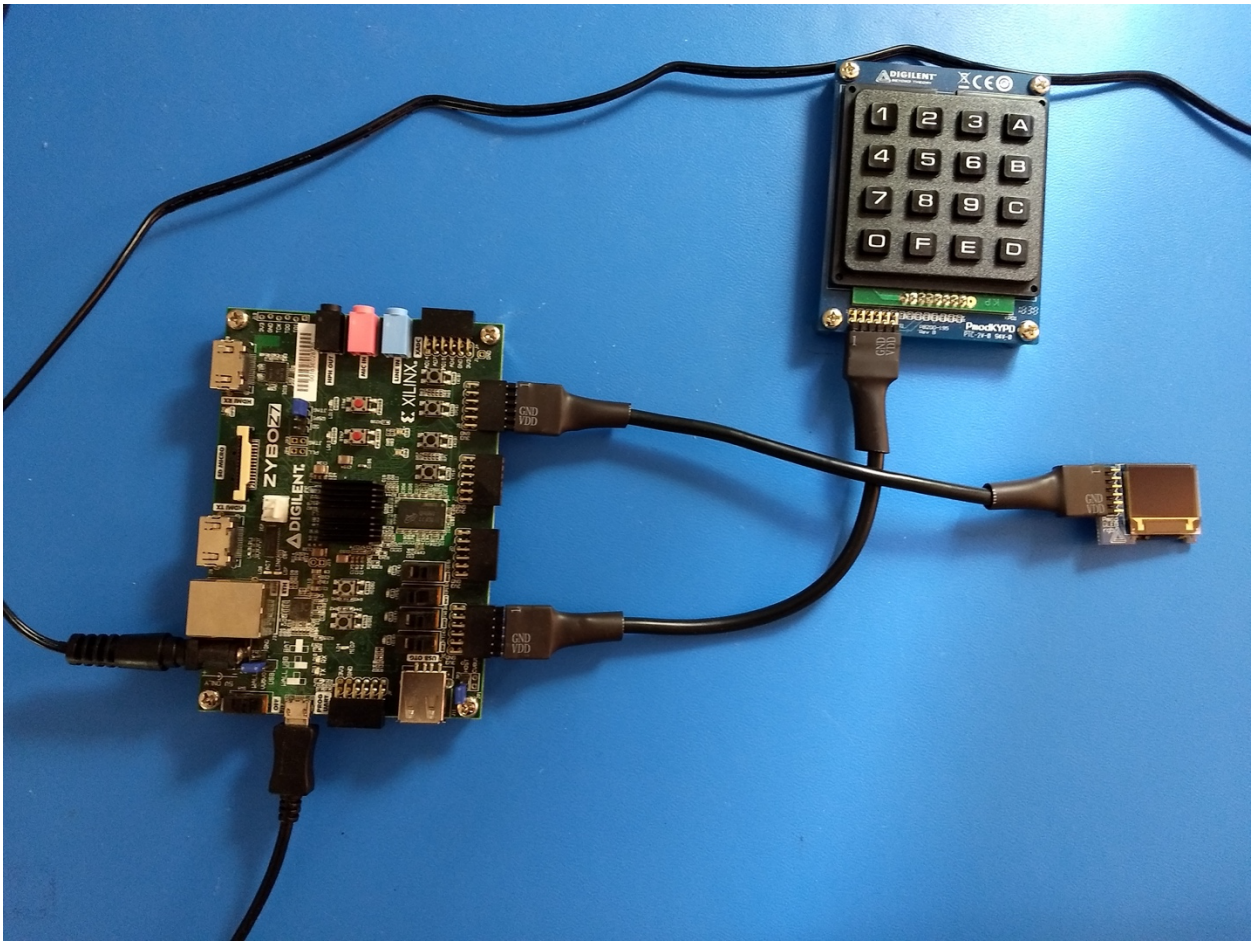

Figure 3: Zybo Z7-20 Assembled with Pmod KYPD, Pmod OLEDrgb

Colors Palette Tester Experiment: Method of Operation: enter LED index and palette value on the keypad, and the discrete RGB LED and display will both update

Colors Palette Tester Experiment: Design Operation

With the MicroBlaze/Zynq implementations, the four switches and buttons are ignored. User entry is through the Pmod KYPD keypad. To start an entry, the letter ‘A’ is typed, followed by a digit, ‘0’, ‘1’, ‘2’, ‘3’, ‘5’, or ‘6’. The number must match the PCBA silk screen of the color RGB LED to light and is dependent upon which of the three development boards is being operated. The digit following ‘A’ indicates the silkscreen index of the RGB LED to update. Following this, three digits are entered with the decimal number range 000 to 255 to indicate the Red palette 8-bit value of 24-bit color. Following this, three digits are entered for the Green palette 8-bit value, and then three more digits for the Blue palette 8-bit value. After the eleventh key press, the indexed LED will display similar to the entered color, and a corresponding line on the display will display text with foreground of the entered color.

Note that in the downloaded Git submodule, drivers obtained from Digilent Inc. for the PMOD KYPD and PMOD OLEDrgb are used in the block design with some minimal modification. The implementations integrate vendor components plus adds additional C code. Note that the program is with the Standalone OS BSP, a bare-metal operating system.

Colors Palette Tester Experiment: Design Changes

Note that in each IPI-BD Design, drivers downloaded from Digilent Inc. for the PMOD KYPD and PMOD OLEDrgb are used in the block design with some minimal modification to target the Arty A7-100 or the Zybo Z7-20. Both drivers target the respective board instead of the Arty. The forked repository of "vivado-library" was also updated to properly build 16-bit RGB values for the OLED on a MicroBlaze or Zynq processor due to a difference in endianness. For each project, the Git repository contains a submodule that pulls from a branch of the author's fork of the Digilent vivado-library repository on GitHub.

Coding style and choices of block design

Software design practices were used to author the C sources. The sources were drafted with a modest top-level module and uses the cohesive driver modules to operate the Pmods.

Serial Flash Sector-Tester Experiment: 3rd-party references:

Digilent Inc. References

Arty – Getting Started with Microblaze Servers
https://reference.digilentinc.com/learn/programmable-logic/tutorials/arty-getting-started-with-microblaze-servers/start

How To Store Your SDK Project in SPI Flash
https://reference.digilentinc.com/learn/programmable-logic/tutorials/htsspisf/start

Vivado Board Files
https://github.com/digilent/vivado-boards

Master XDC files for all Digilent Inc. boards, including Arty A7-100, Arty S7-25, Zybo Z7-20
https://github.com/Digilent/digilent-xdc

Digilent Inc IP library for Xilinx Vivado
https://github.com/Digilent/vivado-library/

Textbook References

Use of IP Integrator to create the Microblaze AXI block diagram and synthesis:

- Tutorials followed from text to understand IPI block design,

L. H. Crockett, R. A Elliot, M. A. Enderwitz, and R. W. Stewart, *The Zynq Book: Embedded Processing with the ARM Cortex-A9 on the Xilinx Zynq-7000 All Programmable SoC*, First Edition, Strathclyde Academic Media, 2014.