# Project Daltonismo

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October 4, 2016

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ECE 310L, 3 rd Year CE Project

**Abstract**

Sufferers of color vision deficiency (CVD) report that videogames rarely take CVD into account during design. Sufferers of CVD are left at a distinct disadvantage during gameplay, especially when color is an integral part of gameplay. Project Daltonismo aims to create a device that transforms the set of colors used in a video signal, such that users who suffer from CVD can more easily discern colors from one another. The aforementioned device will be constructed on an FPGA. The device will have access to the video signal by being connected between the video source and display via a High Definition Multimedia Interface (HDMI) input and an HDMI output. Color Transformations will be done by first converting the original image from the RGB (for Red, Green and Blue) color space into a second color space, transformed to move colors out users' ambiguous hue range, converted back into the RGB color space, and then transformed once again, to minimize image distortion. Daltonization is a popular technique of colorblindness transformation that will be investigated and, based on feedback from users, may be used. Transformation of the video signal will be done in real time at a minimum of 60Hz, with much less than a frame of latency, taking advantage of the speed of the FPGA.

# 1 Introduction

For this project we are looking to create a device that transforms the color space for the people with CVD. The end goal is a device that will alter the color space when plugged in between an HDMI source and HDMI sink requiring no modification to either device to operate. It will have switches to switch between different color filters for different types of CVD. We will consider our device a success if video is outputted when inputted and color filters are applied when switches are flipped. Previous work of getting HDMI passthrough on an FPGA was done by Mike Field using VHDL on the Nexys Video FPGA [1]. Similar work of making colors easier to differentiate was done by mapping words or slashes to the colors [2].

# 2 Methods, Techniques, and Design

Our device will take HDMI as an input and output HDMI, while the signal is internal to the FPGA, we will perform some color manipulation to make the colors more differentiable (Figure 1).

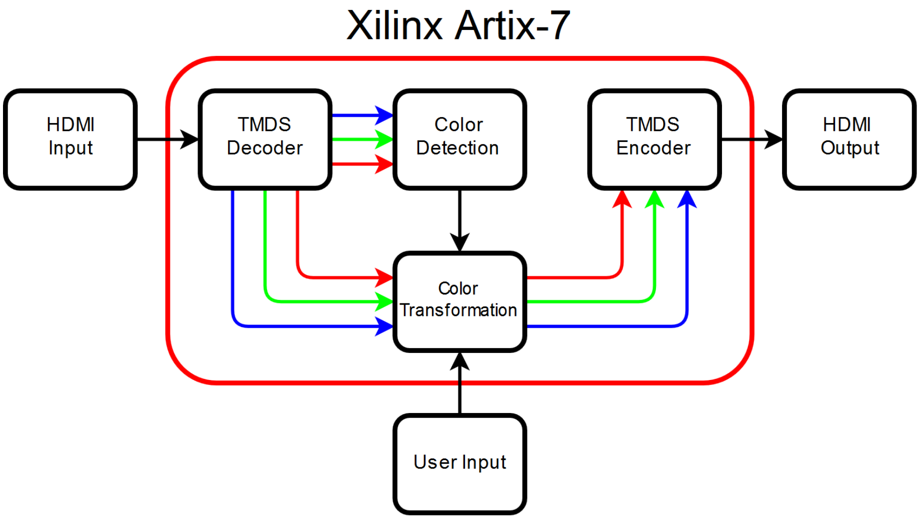


Figure 1: Block Diagram

### 2.1 Color Conversion

Color transformation begins by converting colors to a new color space from RGB, the color space they are provided in by the HDMI signal. The colors are then transformed within the new color space. After the new transformation, colors are then converted back into RGB and are given one last operation from within RGB in order to fine tune the output image (Figure 2).

The RGB color space is ubiquitous in cameras, computers, video sources and video displays. For what RGB provides in ubiquity, it introduces new challenges in difficulty of color transformation. Each color space provides its own benefits and drawbacks, depending on the use case. In the case of Project Daltonismo, transformations outside of RGB will be done within the LMS color space or within the HSV color space, depending on what algorithm is used.

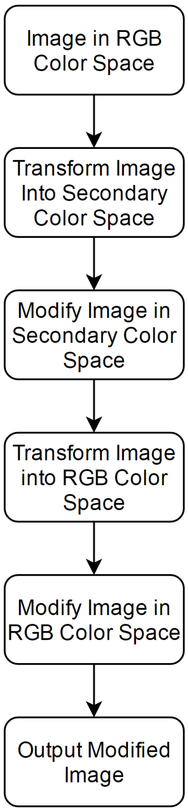


Figure 2: Flowchart of Image transformation sequence.

#### 2.1.1 Daltonization

Daltonization is an algorithm proposed to utilize the way the LMS color space inherently supports a matrix of color responses, or a Chromatic Adaptation Transform (CAT) matrix. Daltonization is preformed in four basic steps:

1. Convert RGB into LMS
2. Simulate colorblindness with a CAT matrix
3. Shift the colors that are mapped closely on the CAT matrix away from each other
4. Convert LMS back into RGB

Since one can easily change how the different levels of colors are perceived in the LMS color space, daltonization naturally lends itself to using the LMS color space.

#### 2.1.2 Red-Stripes Method

The Red-Stripes Method of color transformation, starts by converting into the LMS color space, like daltonization, in order to detect which colors are closely mapped. The difference comes when the colors are converted into the HSL color space. The HSL color space allows for easily brightening colors without altering their saturation. The Red-Stripes uses this to brighten stripes in some of the colors that would be hard to tell apart so that those which are brightened and those which aren't an be differentiated.

## 2.2 HDMI

High Definition Multimedia Interface(HDMI) is an interface capable of transporting video and audio simultaneously. It uses four differential signaling wire pairs, three for pixel data and one for the pixel clock. There are 10 bits sent across each of the pixel data pairs for one transition of the clock pair [3].

HDMI was chosen as the transmission medium for this project because it is very commonly used for video output on consoles and computers. To give good compatibility with other devices, our project is aiming for a maximum resolution of 1920x1080 at 60Hz, the clock rate at this resolution will be 165Mhz and the bit rate on the three data pairs will be 1.65GHz.

### 2.2.1 TMDS Encoding

HDMI and DVI use a signal encoding technique called Transition Minimized Differential Signaling (TMDS) to reduce the EMI that the cable experiences. This encoding scheme performs either the XOR or the XNOR operation on the inputted bit with the previously derived bit and adds a ninth bit to represent whether XOR or XNOR was used (Figure 3). Next, a tenth bit is added to represent whether the entire bit is inverted. This is done to maintain an overall DC balance of the Differential signaling lines.

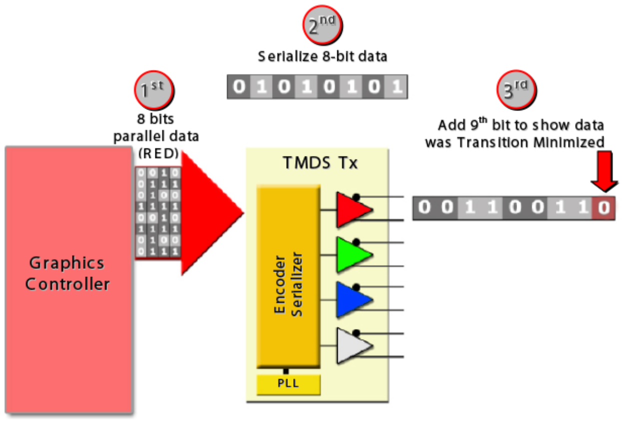


Figure 3: TMDS Encoding [4]

# 3 Schedule

First Milestone (Week 7):

- VGA Output of an image.

- Basic Color Filtering working.

Second Milestone (Week 12):

- HDMI Input of a video signal.

- Daltonization of inputted video signal.

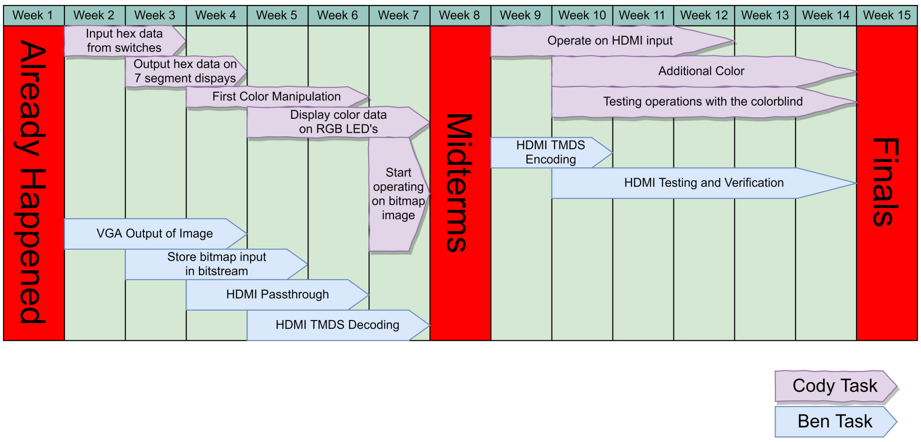


Figure 4: Project Schedule

# 4 Parts

Digilent Nexys Video Part#:410-316 - $490 or $290 (With Educational Discount)
2-HDMI male to male cables - $12

# 5 Appendix

## 5.1 Color Space Definitions

**RGB** The RGB color space stands for red, green, and blue. RGB is a color space wherein colors are represented by values of red ($\sim$665nm), green ($\sim$550nm), and blue ($\sim$470nm) light. This color space is what is used for most photographs, videos, cameras and electronic displays.

**HSV** The HSV color space stands for hue, saturation, and value. HSV is a color space wherein colors are represented by their hue (the base color, e.g. red, orange, yellow, green, etc.), their saturation (how close the color is to the pure color and far from a gray color) , and value (how bright the color is). Hues are represented on a 360° spectrum, with red ($\sim$665nm) at both 0° and 360°, orange ($\sim$630nm) at 30°, yellow ($\sim$600nm) at 60°, green ($\sim$550nm) at 120°, blue ($\sim$470nm) at 240°, indigo ($\sim$425nm) at 270°, and violet ($\sim$400nm) at 300°.

**XYZ** The XYZ color space is very similar to the RGB color space. It is also a color space wherein colors are represented by values of red, green, and blue. The difference in the XYZ color space is that the primary colors it uses are based off which primary colors human eyes are actually sensitive to. XYZ's red is a range of hues $\sim$564–580nm instead of RGB's $\sim$665nm, XYZ's green is $\sim$534–545nm instead of RGB's $\sim$550nm, and XYZ's blue is $\sim$420–440nm instead of $\sim$470nm.

**LMS** The LMS color space is very similar to the XYZ color space since it has the goal of modeling human vision. This combined with the fact that the XYZ color space uses the wavelength bands which human eyes can primarily sense, as the three primary colors, allows for easy transformation between the XYZ and LMS color spaces. Theses three colors with differently weighed color responses are based on the three primary bands of color from the XYZ color space, which are directly based on the three bands of color that human eyes can perceive. The inherent way that LMS simulates human color vision stems from the process of conversion into LMS. The only step necessary is to use a Chromatic Adaptation Transform (CAT) matrix which would map the primaries from XYZ color space into the amount that they stimulate in the LMS color space. The problem is that there is no definitive transformation matrix, though various Color Appearance Models (CAMs) offer their of CAT matrices.

# References


[1] Mike Field. Artix 7 1080p passthrough, 2015.

[2] David R. Flatla, Alan R. Andrade, Ross D. Teviotdale, Dylan L. Knowles, and Craig Stewart. Colourid: Improving colour identification for people with impaired colour vision. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, CHI '15, pages 3543–3552, New York, NY, USA, 2015. ACM.

[3] DDWG. *DVI Spec Rev 1.0.* 1999.

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