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CMPE 123A
Fall 2008

Design Project

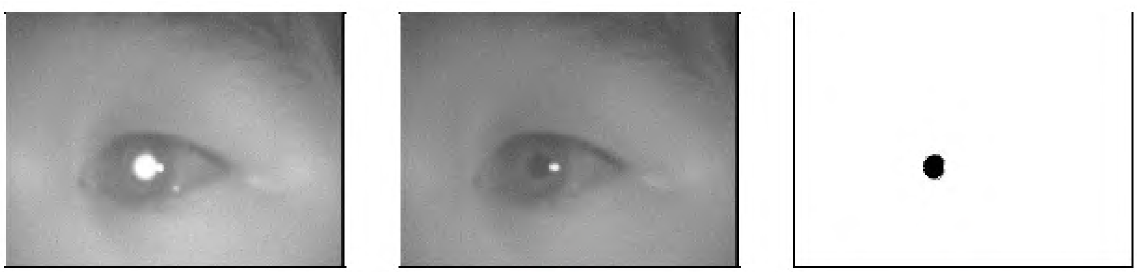
Introduction: John Robertson is a 5th year Computer Engineering student at UCSC with a focus in computer systems and interest in digital hardware design. Nghia Nguyen is a 5th year Electrical Engineering student interested in RF.

Functional Description

The function of this system is to capture images and report the coordinates of any pupils detected to a USB interface. This is accomplished by alternately flashing two sets of infrared light emitting diodes in synchronization with a camera and performing some processing in hardware on a FPGA board.

One set of lights is aligned with the cameras axis, and as a result of the eyes high retro-reflectivity, pupils have a very high intensity in this image (See Figures 1 and 2). An image with off-axis lighting is captured in quick succession with the on-axis image and the two are subtracted (and thresholded).

The result is a binary image with only highly retro-reflective subjects. A basic algorithm checks the properties of the components in this image and those that have the characteristics of a pupil are reported to the USB interface.



a b c

Figure 1. (a) Bright and (b) dark pupil images. (c) Shows the difference of the dark from the bright pupil after thresholding

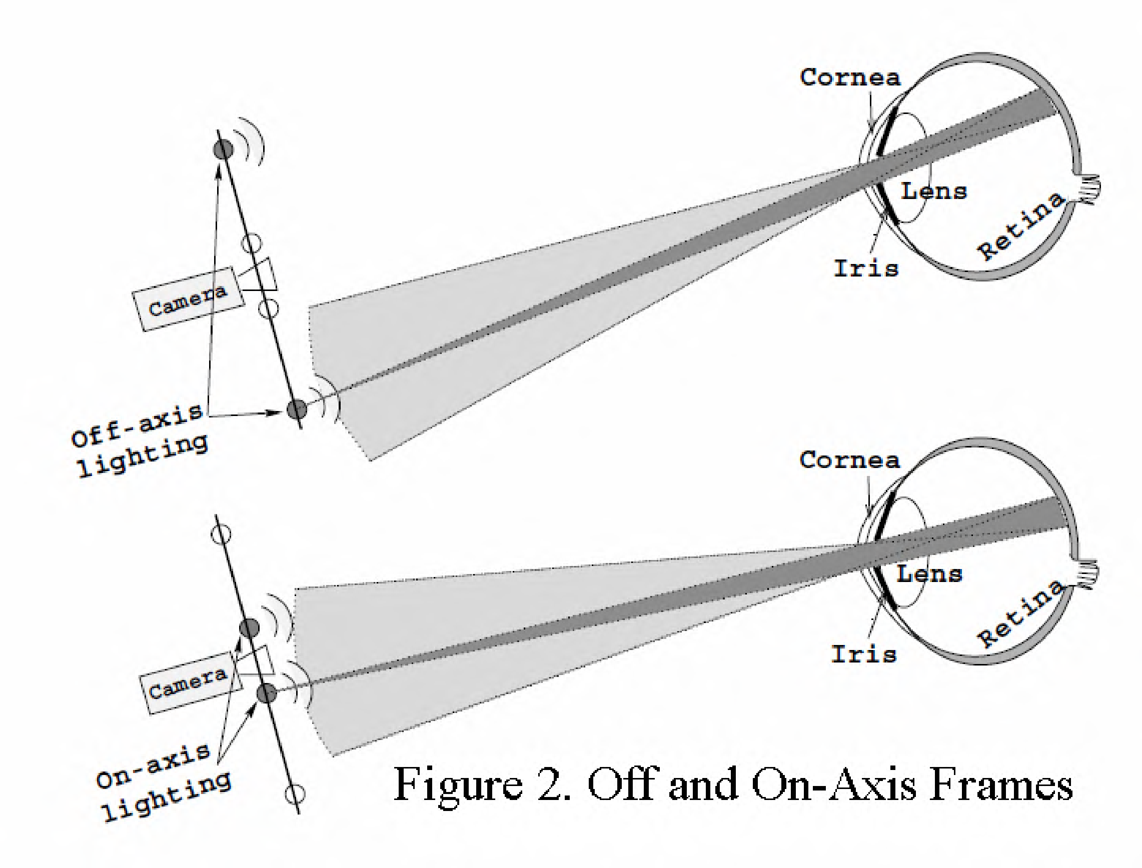


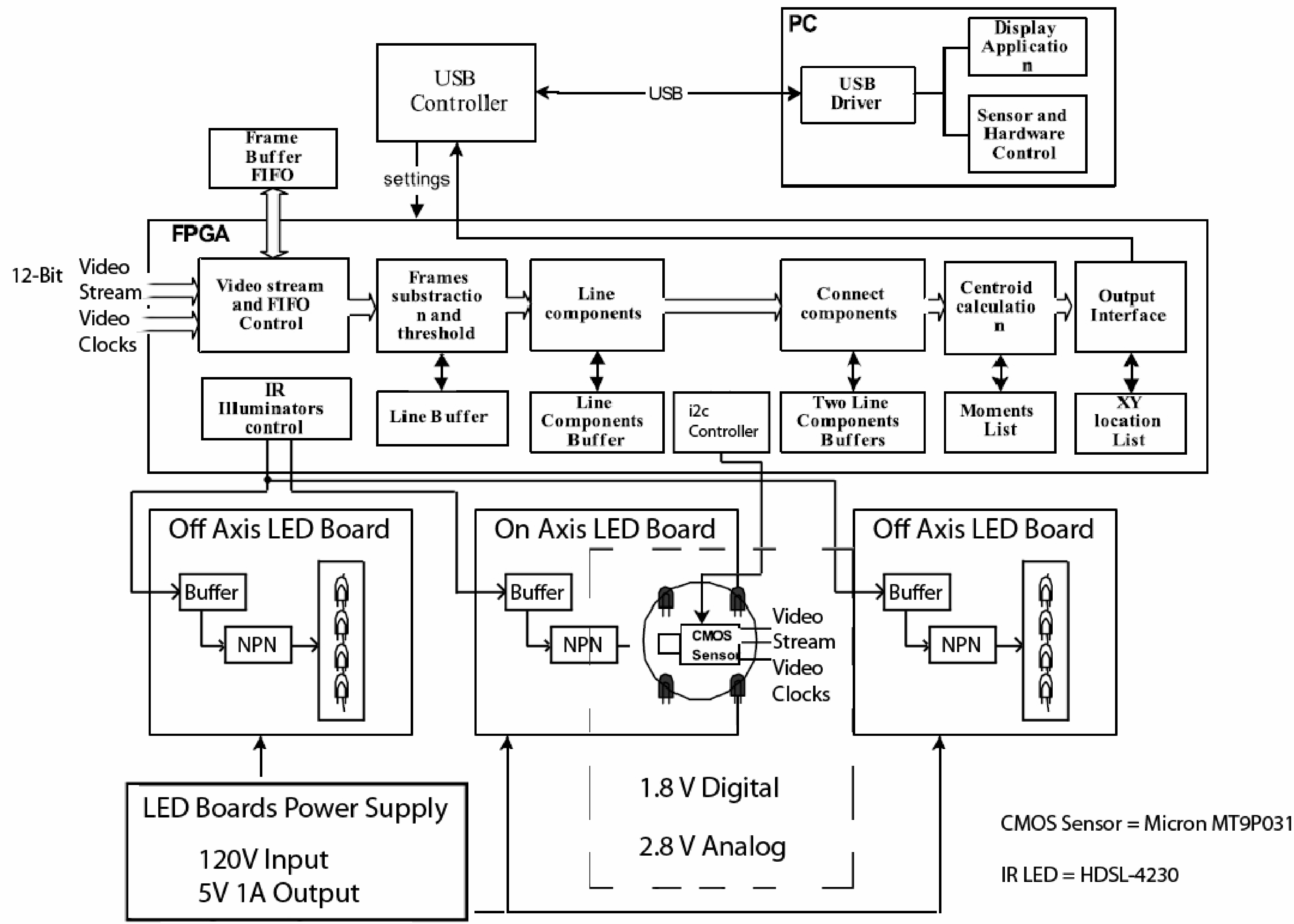
Figure 2. Off and On-Axis Frames

<u>Applications</u>

This system can be applied to many situations where knowing the location and geometry of a pupil is needed. Some examples include facial recognition (by analyzing the shape of the pupil and the distance between them), people counting (counting the number of eye pairs seen), driver alertness (detecting an absence of eyes where they should be), and head tracking as a mode if input (tracking pupil movements as a mode of input). This systems low latency and hardware implementation allows it to work in some situations where other high latency CPU hungry software based eye detection systems cannot.

<u>Functional Block Diagram</u>

Functional Block Diagram



Functionality Requirements

The minimum functionality requirement for our system is to prototype the LED and camera PCBs, and successfully detect stationary eyes with a minimum accuracy of 60%. The system should output the captured camera images as well as the X and Y coordinates of pupils to USB. Medium functionality detects pupils with at least 70% accuracy, and maximum at 80% accuracy.

Analysis

To analyze our system we must perform some calculations analyzing our logic, critical path, maximum clock frequency, etc. Figures 3 and 4 show our current work on designing the LED driver. Some empirical analysis we hope to perform is to use stored images as the input to the logic pipeline so we can do controlled experiments with our logic. We hope to use synthetic eye targets and moving people to experimentally test our algorithms.

Figure 3. LED driver circuit analysis

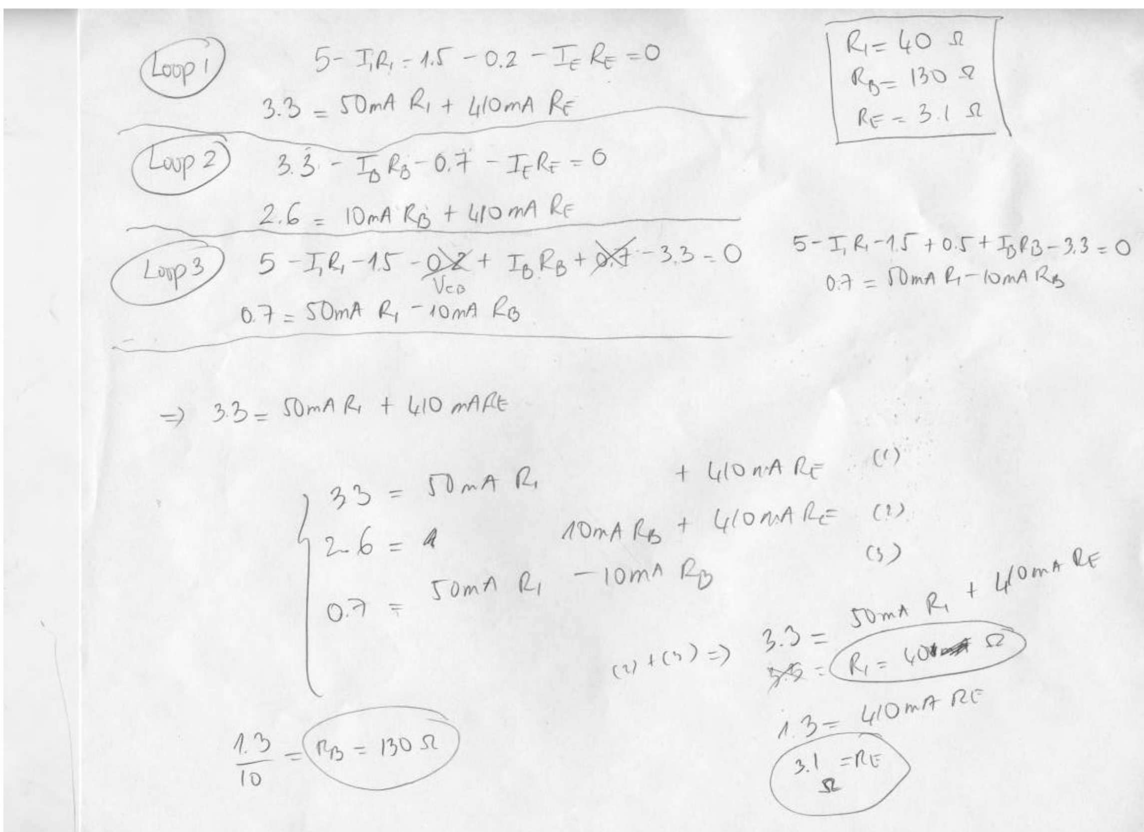
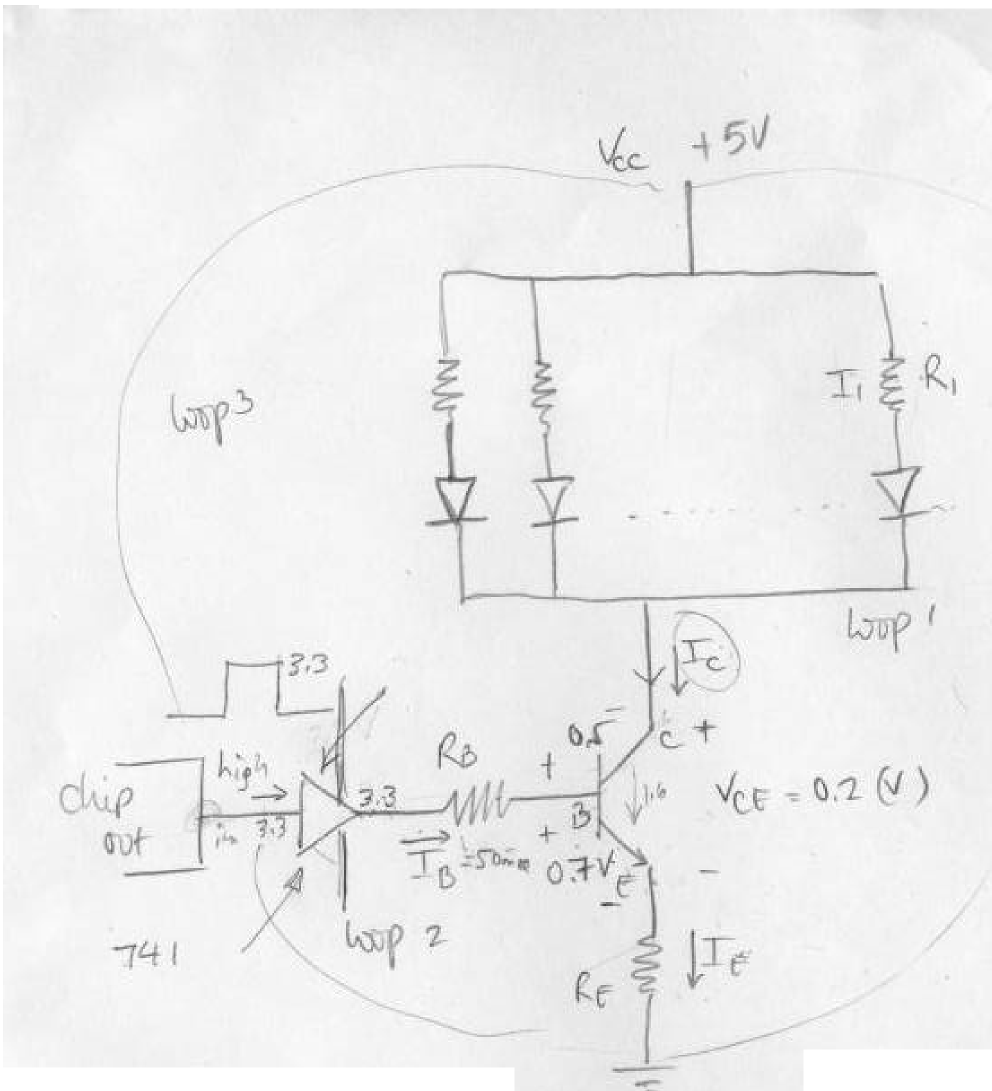


Figure 4. LED driver circuit



<u>Test Benches, Benchmarks</u>

In the course of developing our system we believe we will find it necessary to develop a software implementation of our algorithms. This will allow us to clearly formulate the architecture of each logic module, as well as offer us a benchmark against which to test our system. Some dimensions that we should test our systems performance in are frame rate, latency, accuracy, resolution. It is also useful for us to test the power consumption of our system to see if it can be deployed in environments where power is a concern.

<u>Division of Labor</u>

Our group has only 2 people, so we are able to work together for each part. John has PCB design and fabrication experience and has studied logic design with Verilog, which lends him the ability to lead the logic design & PCB design. Roy's electrical engineering background offers him the skills needed to be the lead designer of the LED driver circuit and the power supply designs. The project is very modular so we can work together or independently throughout the project. We hope to teach and assist each other throughout the course of the quarter.

Bill of Materials

- CMOS Image sensor = $25
- Fixed focal length lens = $30
- ~10 Infrared LEDs = $10
- PCB board runs = $50
- Discrete Components = $10
- FPGA board + Software = $0 (Provided by Prof. Pak Chan)
- Santa Cruz Camera Development Module = $125

We estimated our total project cost to be around $300. John is from College 8 and Roy is from Crown College, so we are both able to secure substantial funding from our colleges.

References

Figure-1
C.H. Morimoto, D. Koons, A. Amir, M. Flickner, Frame-Rate Pupil Detector and Gaze Tracker

Figure-2
C.H. Morimoto, D. Koons, A. Amir, M. Flickner, Real-Time Detection of Eyes and Faces