Department of Computer Science & Engineering
The University of Texas at Arlington

Architectural Design Specification
CSE 4316: Senior Design I
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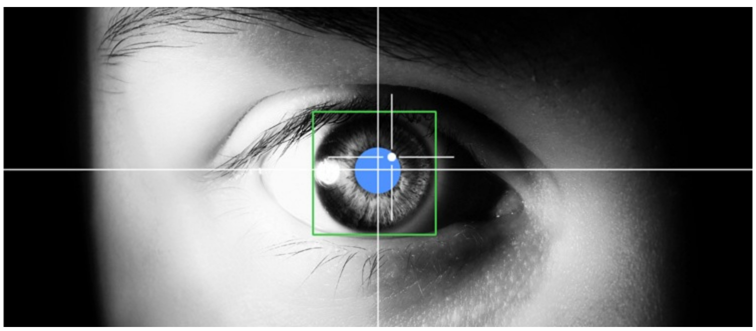

Eyeronic
Eye Tracker

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Revision History

Revision	Date	Author(s)	Description
0.1	11.18.2015	KM , JS , ZA , FN , JT	Created Document

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1 INTRODUCTION

This product shall have three layers that work in unison to track the pupil of the user. The three layers in our system are the Software layer, Daughter Board, and the Cypress CX3. The three layers will be discussed more in the following sections.

2 System Overview

The system consists of three major layers which are: The Daughter Board Layer, The Cypress CX3 Layer, and the Software Layer. The Daughter board is the main interface between the MIPI camera module and the Cypress CX3. It contains the OmniVision 5640 sensor that interfaces to the cypress CX3. The Cypress CX3 layer provides the interface between the MIPI camera and the USB. This layer is what communicates with the computer and the Daughter board. It uses USB to power the device and transfer the data to a computer. The Software layer takes input from the Cypress Interface, processes that data, and tracks the pupil movement in real time. Various Computer Vision algorithms such as the Canny Edge Detector, Gaussian Smoothing, and the Random Sampling Consensus are implemented by the software layer to accurately track the pupil movement.

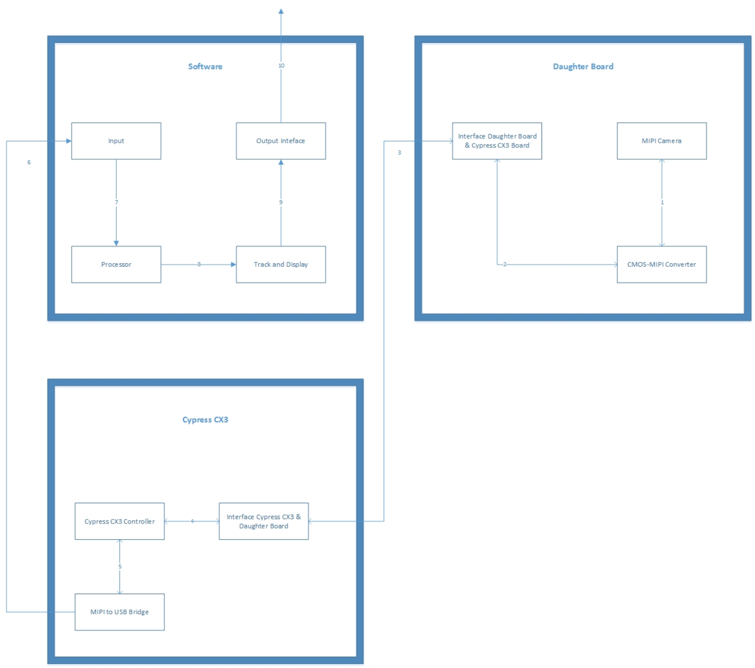

Figure 1: A simple architectural layer diagram

2.1 Software Layer Description

The software layer makes use of the OpenCV library and implements the entire program in C++ language. It consists of three major subsystems. The first subsystem is the Input subsystem. It gets input from the interface provided by the Cypress CX3. A video stream from a device (or a disk for test purposes) is read and stored into a CV::Mat structure. This structure will later be passed onto the processing subsystem. The goal of the processing subsystem is to filter out all the noise (anything but the pupil) and it does so utilizing readily available OpenCV algorithms which shall be discussed in detail later in the document. The final layer is the display layer which gathers information from the processor and displays the final result (fitted elipse) into the original video stream.

2.2 Daughter Board Description

The daughter board is a board that is used to interface between the camera module and the Cypress CX3. This board uses a high-speed rugged ground plane socket (Base BRD Connector) to transfer the data that the camera captures to the CX3. In order for the camera module (pcDuino Camera Module) to function properly the daughter board needed a new camera connector, since the original connector is not compatible. We replaced the old connector with the Panasonic connector (AXK824145WG). The purpose of the new camera connector is to interface the camera with the Base BRD Connector. The daughter board contains the OmniVision 5640 that is interfaced through the 2-lane MIPI interface.

2.3 Cypress CX3 Description

The Cypress CX3 is a MIPI to USB interface. This controller is fully functional with any image sensor that is compliant with a MIPI Camera Serial Interface (OmniVision 5640). The Cypress CX3 is used to control the communication between a computer and the device, since it uses a USB connection to power the device and transfer the data that it collected. Also in order for the device to store the data read from the camera module, it uses EEPROMS in order to prevent loosing data in cases the device looses power. Then the device will transfer its data to the computer via USB. The Cypress CX3 is also connected to the MIPI camera.

3 SUBSYSTEM DEFINITIONS & DATA FLOW

The following section shows a high level diagram of all layers of our system.

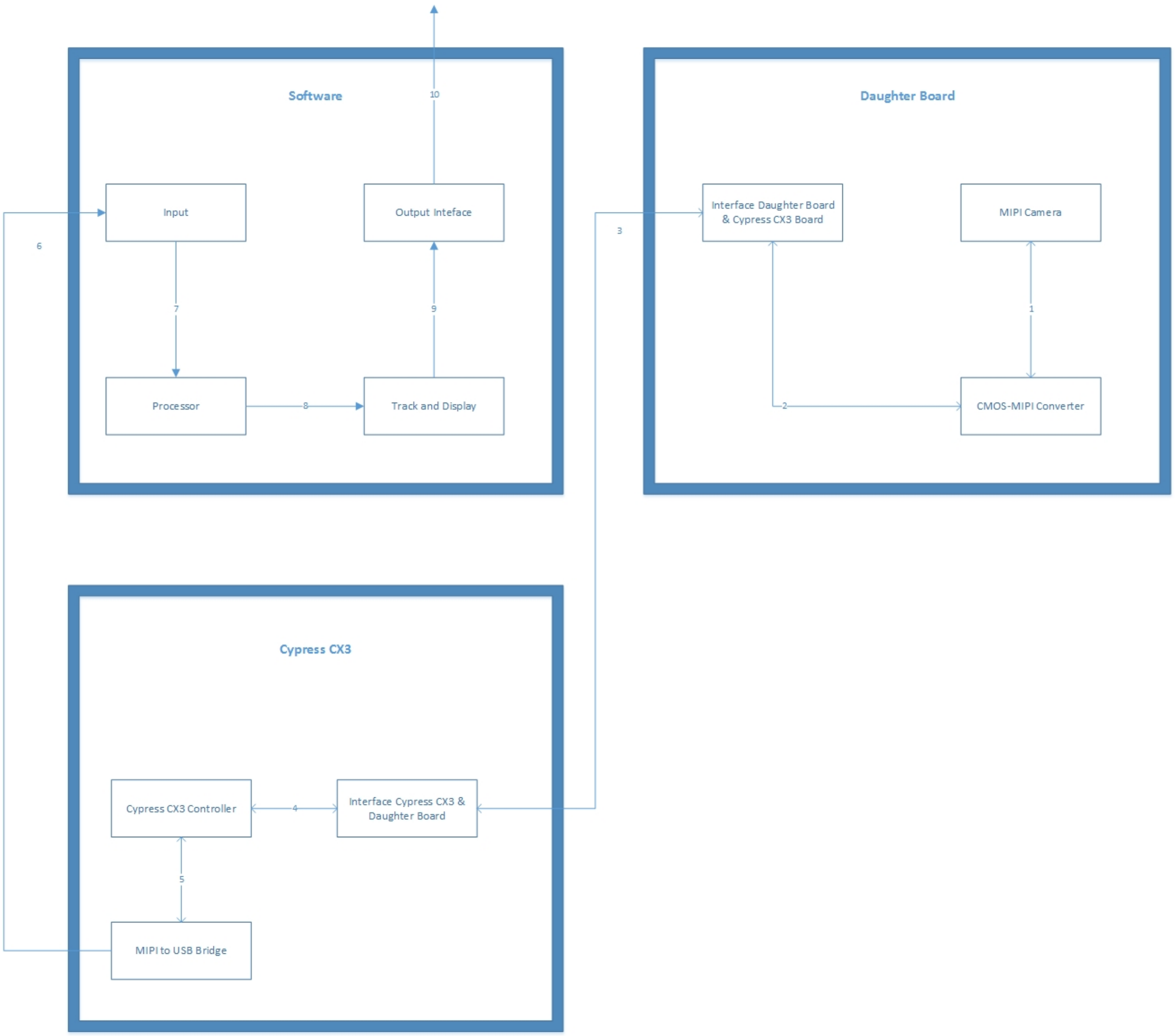

Figure 2: A simple data flow diagram

4 Software Subsystems

This section discusses the software layer which consists of three major subsystems.

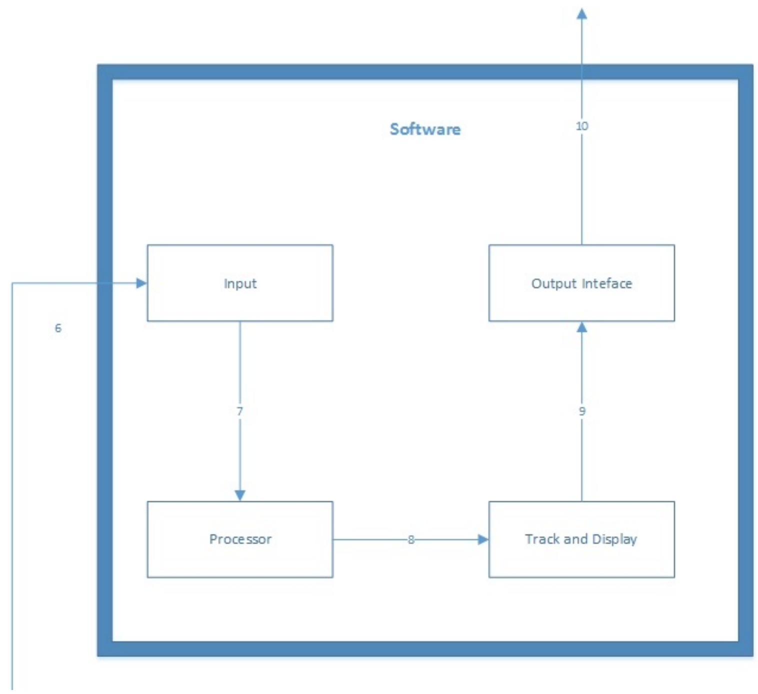

Figure 3: Software Subsystem

4.1 Input Subsystem

The input subsystem is responsbile for receiving video input and sending it to the processing subsystem.

4.1.1 Assumptions

We are assuming that we are getting the required video data from the Cypress CX3 or any other USB device. The software is flexible enough to be able to read the data from a file or directly from the hardware.

4.1.2 Responsibilities

This subsystem is responsible for properly receiving the video data and sending it to the processor subsystem.

4.1.3 Subsystem Interfaces

The input could either from a file (for test purposes) or a live stream from the cypress camera. The details are shown in the table.

Table 2: Input Subsystem interface

ID	Description	Inputs	Outputs
#06	Receive video data	From Camera	Video data

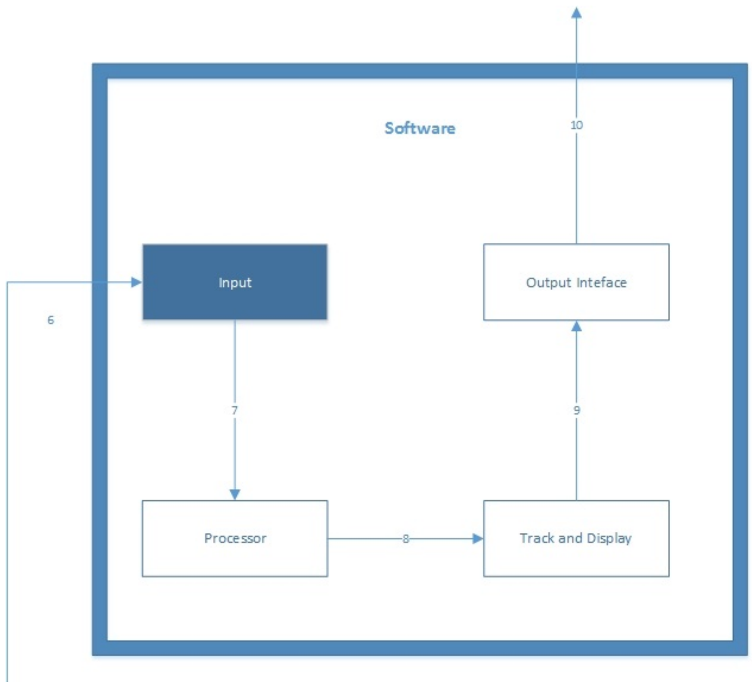

Figure 4: Input Subsystem

4.2 Processor Subsystem

The processor subsystem takes in the video input, processes it sends the processed data to the Track and Display subsystem.

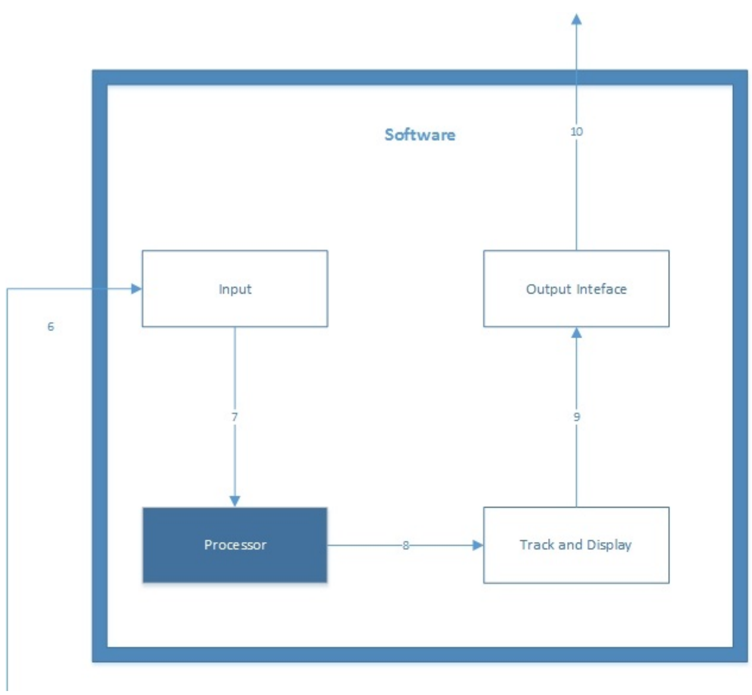

Figure 5: Processor Subsystem

4.2.1 Assumptions

We assume that we are getting video data from the Input Subsystem at 30 frames per second.

4.2.2 Responsibilities

The processor is responsible for utilizing various computer vision algorithms to properly track the pupil. First, the processor needs to smooth each frame in the video. Next, it needs to apply the canny edge detector to detect all the edges. Finally, this processor sends all the detected edges to the Track and Display subsystem.

4.2.3 Subsystem Interfaces

This subsystem gets input of video data and output of a somewhat refined video data.

Table 3: Processor Subsystem interface

ID	Description	Inputs	Outputs
#07	Process Video Frames	Video Data	Detected Edges

4.3 Track and Display Subsystem

This subsystem receives some video data whose edges have been detected by the processor subsytem and it tracks and displays the results.

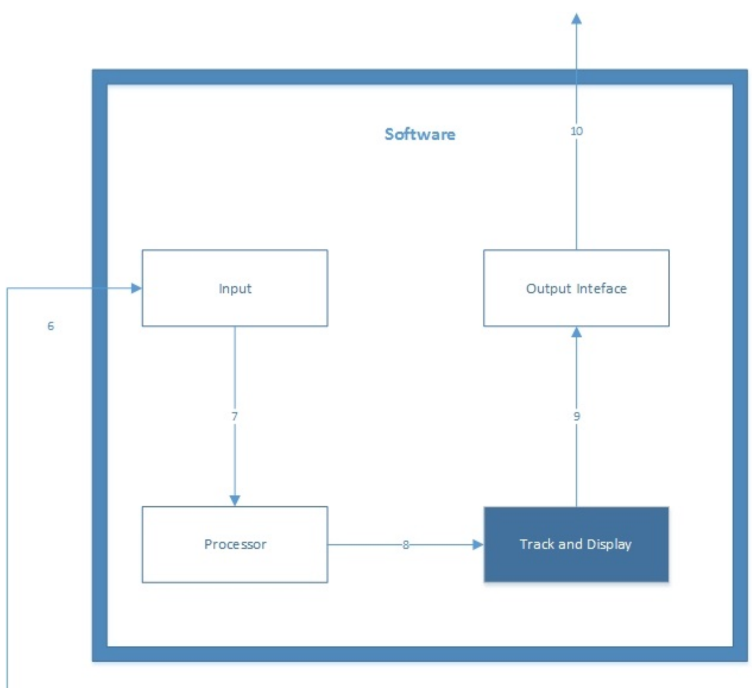

Figure 6: Tracker Subsystem

4.3.1 Assumptions

We assume that this subsystem recieves frames whos edges have been detected.

4.3.2 Responsibilities

This subsystem is responsible for applying the pupil tracking algorithm to the input it receives. It then applies the RANSAC algorithm to fit an ellipse to the pupil. Finally, it displays the video with tracked pupil.

4.3.3 Subsystem Interfaces

This subsystem receives edges that were detected by the processing subsystem and outputs the final results in a video stream.

Table 4: Track and Display Subsystem interface

ID	Description	Inputs	Outputs
#08	Receive data and display	Detected Edges	Tracked Eye

4.4 Output Subsystem

This subsystem simply provides an interface to send a video stream to some external device or module via ethernet or USB. The exeternal device or module shall be either a computer monitor or a cell phone or a webpage.

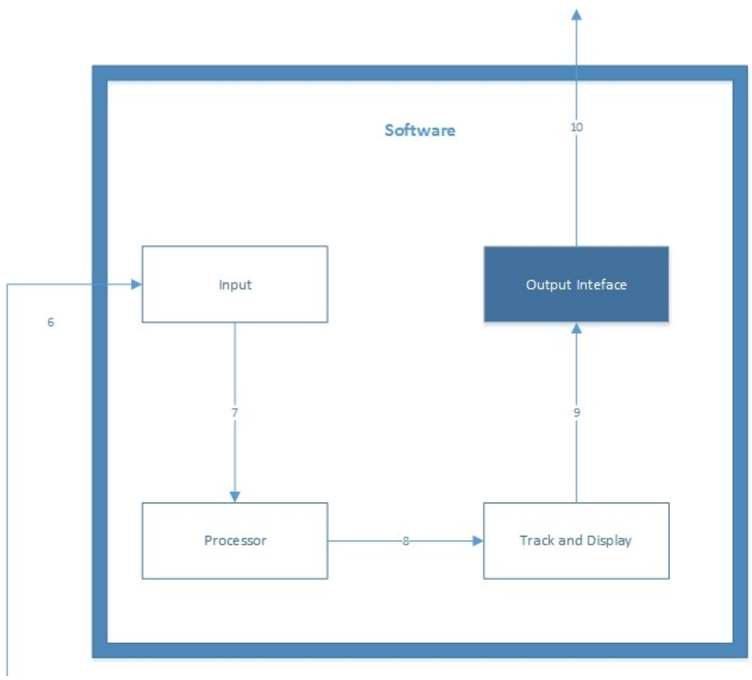

Figure 7: Output Subsystem

4.4.1 Assumptions

We assume that this subsystem recieves video frames that show the tracked pupil.

4.4.2 Responsibilities

This subsystem is responsible for properly sending the final result (video) of the entire system to an output device such a computer monitor.

4.4.3 Subsystem Interfaces

This subsystem receives videos and provides an interface for an output device such as a monitor.

Table 5: Output Subsystem interface

ID	Description	Inputs	Outputs
#09	Send video data to external device	Tracked Eye	Tracked Eye

5 Daughterboard Subsystems

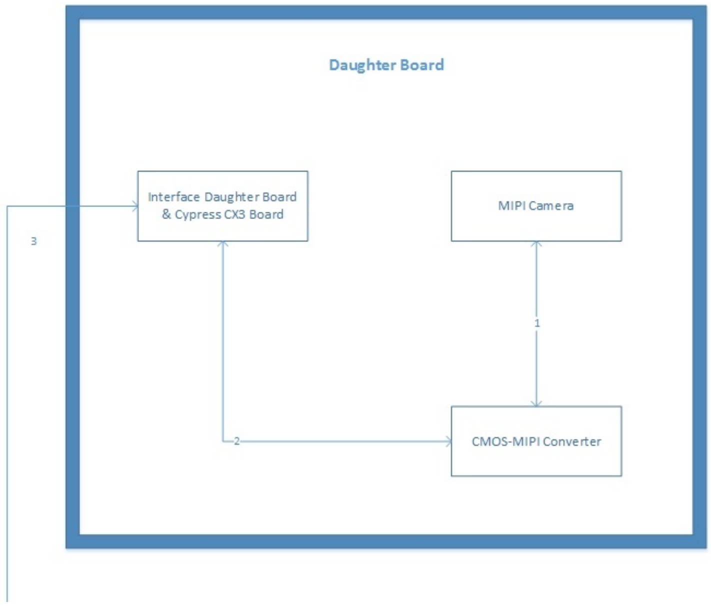

Figure 8: Daughter Board Subsystem

5.1 BRD Connector

The BRD is the interface between the Daughter board and Motherboard.

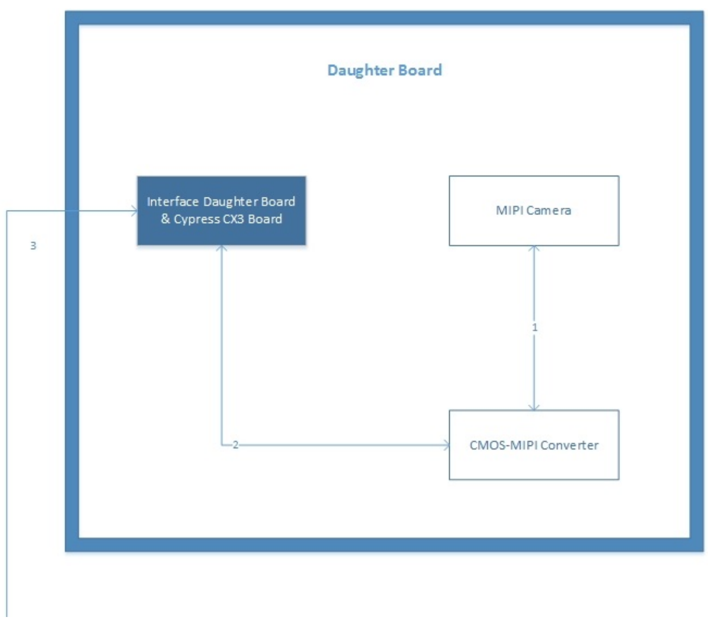

Figure 9: Daughter Board Interface

5.1.1 Assumptions

The BRD should communicate without any issues (like a BUS connection).

5.1.2 Responsibilities

The Base BRD Connector is used to interface between the daughter board and the MIPI Camera BRD Connector on the Cypress CX3 Board and vice versa.

5.1.3 Subsystem Interfaces

This connector contains 52 pins, but not all of the pins will be used. This connector is directly connected to the camera module connector in order to transfer the data back and forth at a faster rate. Throughout this connector, multiple pins receive different types of voltages in order to perform different tasks. For complexity issues, the Base BRD Connector will be connected to the bottom layer of the Daughter Board.

Table 6: BRD Connector interface

ID	Description	Inputs	Outputs
#03	MIPI Controls	Input 1 - MIPI Data Input 2 - MIPI Clock Input 3 - MIPI Power	Output 1 - MIPI Data Output 2 - MIPI Clock Output 3 - MIPI Power

5.2 Camera Module

The camera module used for the Eye Tracker system is a 5MP pcDuino camera that will be used to capture data for processing. The pcDuino camera uses the OV5640 image sensor.

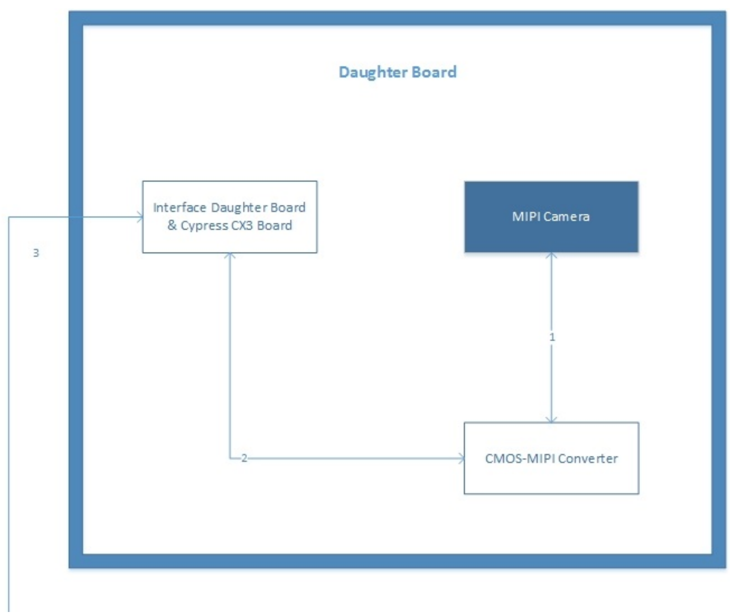

Figure 10: Camera Module diagram

5.2.1 Assumptions

The camera module will capture image and video at least 30FPS at 5MP.

5.2.2 Responsibilities

This image sensor is capable of capturing 2592x1944 active array of image and video at a minimum of 30 FPS. Since this new camera uses the OV5640, it is compatible with the Cypress CX3.

5.2.3 Subsystem Interfaces

The camera uses the OV5640 image sensor, which is a high quality CMOS image sensor.

Table 7: Camera Module interface

ID	Description	Inputs	Outputs
#01	2592 x 1944 Active Array Video (MIPI)	Input 1 - Clock Input 2 - Data	Output 1 - RAW8/10/12/14. YUV422, RGB888/666/565

5.3 Camera Connector

The camera connector is new, and will be replacing the camera connector that was on the CX3 development board. The new connector allows for the use of the pcDuino camera module.

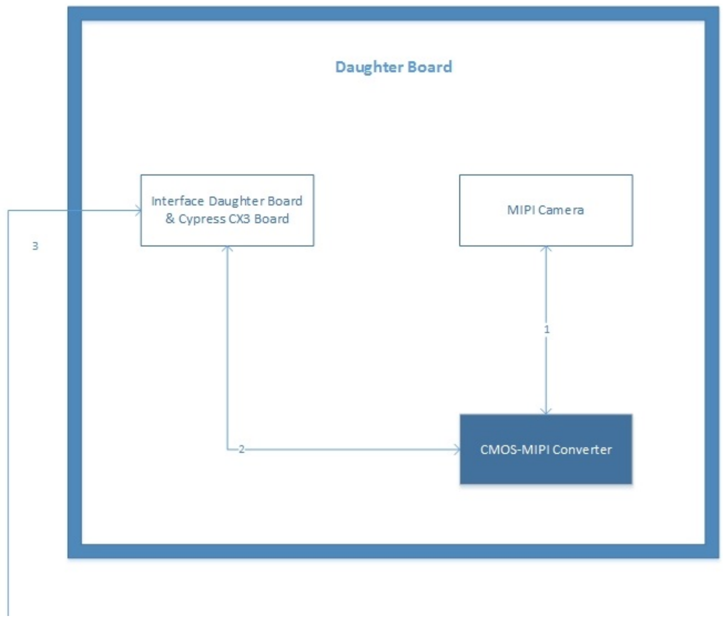

Figure 11: Camera Connector diagram

5.3.1 Assumptions

The camera connector is compatible with the new module and the BRD.

5.3.2 Responsibilities

The camera connector is used to connect the camera module to the daughter board and transfer the data that the camera captures to the Base BRD Connector.

5.3.3 Subsystem Interfaces

In order for the camera module to function properly with the Cypress CX3, it received different voltage inputs in different pins. The datasheet of the OV5640 (Image Sensor) in order to determine which pins will be used on the camera connector and where to connect each pin at the Base BRD Connector. Since this camera will only be used for eye tracking purposes only, the user will not be able to reset the camera since we disabled the reset pin on the camera connector.

Table 8: Camera Connector interface

ID	Description	Inputs	Outputs
#02	Camera Connector	Input 1 - MIPI Data Input 2 - MIPI Clock	Output 1 - MIPI Control (CCI/I2C

6 Cypress CX3 Subsystems

The Cypress CX3 is a MIPI to USB interface. This controller is fully functional with any image sensor that is compliant with a MIPI Camera Serial Interface (OmniVision 5640). The Cypress CX3 is used to control the communication between a computer and the device, since it uses a USB connection to power the device and transfer the data that it collected. Also in order for the device to store the data read from the camera module, it uses EEPROMS in order to prevent loosing data in cases the device looses power. Then the device will transfer its data to the computer via USB. The Cypress CX3 is also connected to the MIPI camera.

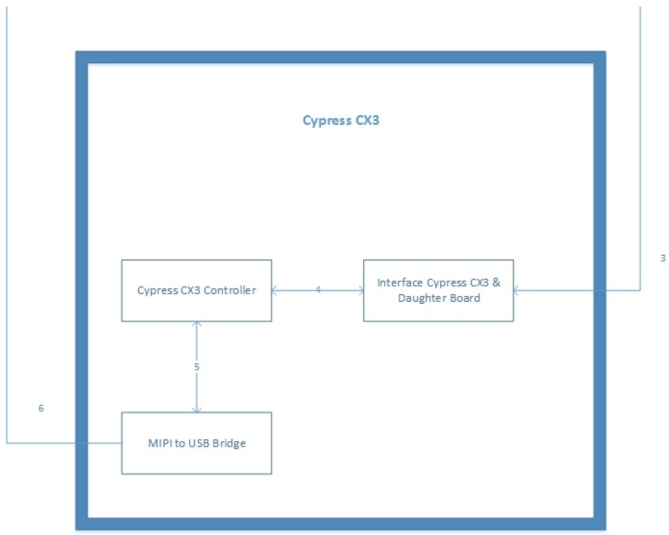

Figure 12: Cypress Subsystem Overview

6.1 Interface Cypress CX3 Daughter Board

This connector is used to interface between the daughter board and the CX3 Controller. The connector is also connected to the EEPROM of the device, since it will transfer the data collected and store it at the EEPROM. Other pins of the MIPI Camera BRD Connector are connected to CX3 Controller and the Base BRD Connector.

6.1.1 Assumptions

TBD

6.1.2 Responsibilities

TBD

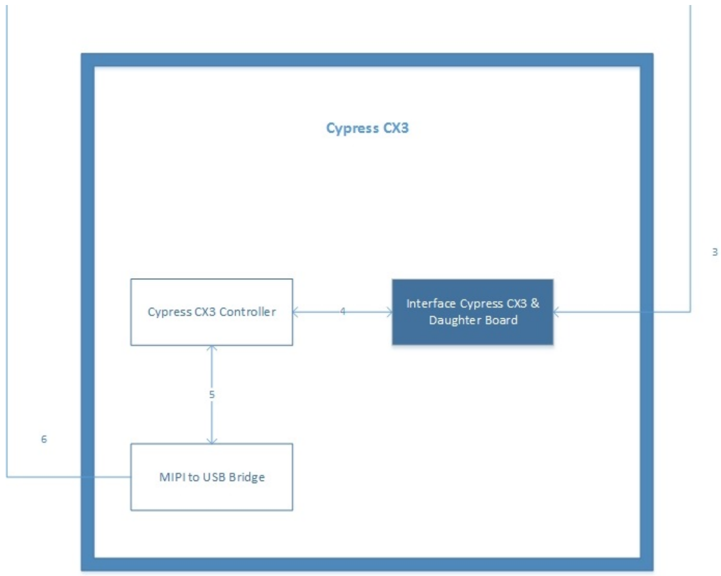

Figure 13: Interface Subsystem

6.1.3 Subsystem Interfaces

Table 9: Cypress CX3 and Daughter Board interface

ID	Description	Inputs	Outputs
#04	Communication with Daughter Board	Input 1 - MIPI Data Input 2 - MIPI Clock Input 3 - MIPI Power Input 4 - SDA	Output 1 - SCL Output 2 - SDA

6.2 Cypress CX3 Controller

The main purpose of the CX3 Controller is to interface with the MIPI camera and then transfer the data collected to the CX3 USB interface. The CX3 Controller its also connected to multiple components of the Cypress CX3, but at the moment we have not determined which components will be needed for the Eye Tracker System. For example, we believe that the Eye Tracker System will not need to be connected to JTAG, so those pins on the controller will not be used.

6.2.1 Assumptions

TBD

6.2.2 Responsibilities

TBD

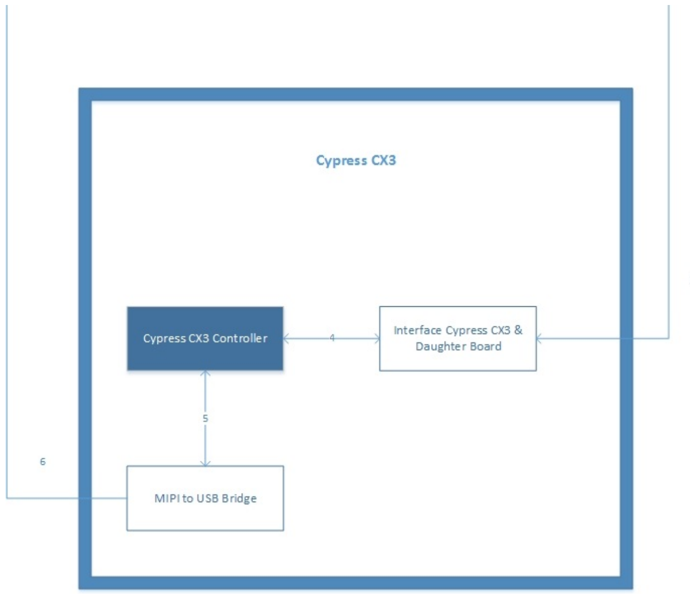

Figure 14: Cypress Controller Subsystem

6.2.3 Subsystem Interfaces

TBD

Table 10: Cx3 Controller interface

ID	Description	Inputs	Outputs
#04	Communication between CX3 Controller and MIPI	Input 1 - MIPI Data Input 2 - MIPI Clock Input 3 - MIPI Power Input 4 - SDA	Output 1 - SCL Output 2 - SDA
#05	Communication between CX3 Controller and USB Interface	Input 1 - SCL Input 2 - SDA	Output 1 - MIPI Clock Output 2 - MIPI Data

6.3 MIPI to USB Bridge

The main purpose of the CX3 USB Interface is to serve as a bridge connection of MIPI camera to USB. The entire system will be powered using the USB connection. This part of the CX3 is also connected to the CX3 Controller and transfers the data collected from the MIPI Camera to a computer via USB. Since this device transfers numerous amounts of data between the CX3 and the MIPI camera, it contains multiple internal clocks.

6.3.1 Assumptions

TBD

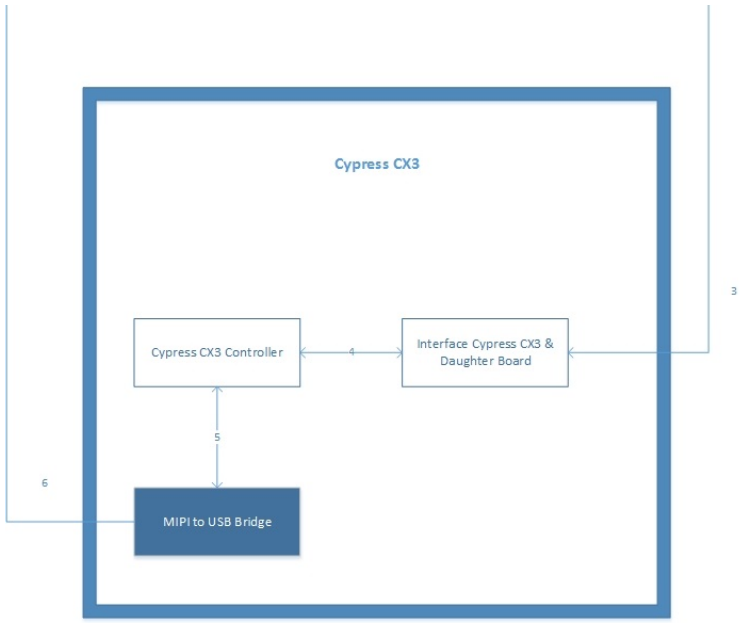

Figure 15: MIPI to USB Subsystem

6.3.2 Responsibilities

TBD

6.3.3 Subsystem Interfaces

TBD

Table 11: MIPI to USB interface

ID	Description	Inputs	Outputs
#05	Communication between USB Interface and CX3 Controller	Input 1 - MIPI Clock Input 2 - MIPI Data Input 3 - CX3$_GPIO$	Output 1 - SDA Output 2 - SCL
#06	Communication between USB Interface and Computer	N/A	Output 1 - USB Data