CDA 4203 Sec 001 Spring 2015
Computer System Design
Mini-project: *Basic Digital Camera Design*
Instructor: Dr. Srinivas Katkoori

You may work with at most two students in the class!
This mini project is worth 25% of the final grade, start early!
Assigned on 23rd February 2015
Design Report due on Canvas 11:59PM, Monday, 30th March 2015

Design Specification: *The camera user should be able to focus on a subject or scene of interest and press a shutter button to take a snapshot. The resulting image should be stored in camera's local memory. The resolution of the image should be at-least 1,024H x 1,024V (~1 million pixels). The user should be able to take several images and store them in the memory. The total budget for the prototype cannot exceed $200. The user should be able to interface the camera with a PC to upload the images. Within the given budget, you need to: (a) maximize the number of pictures that you can store in the camera; and (b) maximize the rate at which snapshots can be taken successively.*

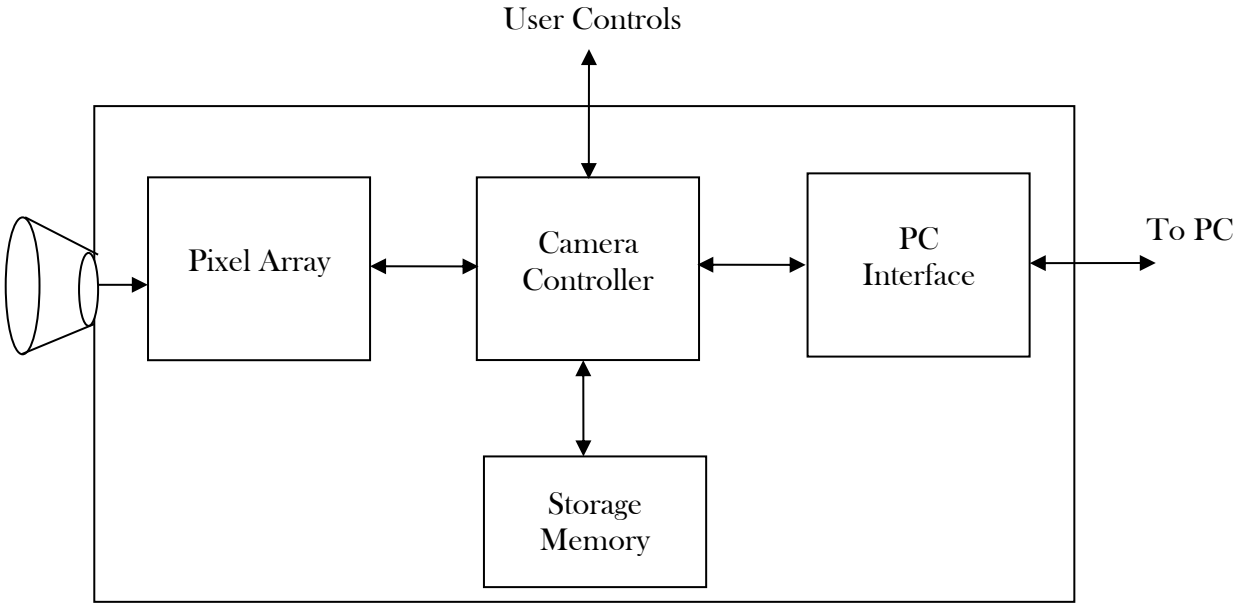

Figure 1: High-level block diagram of the simple digital camera

Figure 1 shows a high-level block diagram of the camera. It has an analog front-end consisting of an array of pixels shown by *Pixel Array* block. Each pixel when exposed to light can register the light intensity which is then digitized into an integer in the (typical) range of 0-255. A value of 0 indicates complete darkness (i.e., minimum intensity), while a value of 255 indicates maximum brightness (i.e., maximum intensity). The pixel array must be exposed for appropriate time to take the snapshot. The brains of the camera are implemented in the *Camera Controller* [1] block. It controls the pixel array block (a) to initialize the block; (b) to initiate the image capture process; (c) read out the pixel data. The raw data so read is stored in the *Storage Memory* block. The *PC Interface* block implements the necessary interface to upload the images from the Storage Memory to a PC.

The mini-project is broken into two parts (a) Part A: Front End Interface; (b) Part B: Storage Memory Interface and PC Interface. You will only do a paper-and-pencil design. No implementation is required for the mini-project.

[1] Do not confuse the word *Controller* in *Camera Controller* with controller in an RTL design (Datapath and Controller).

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Mini-project: *Part A – Front End Interface (12.5% of Final Grade)*

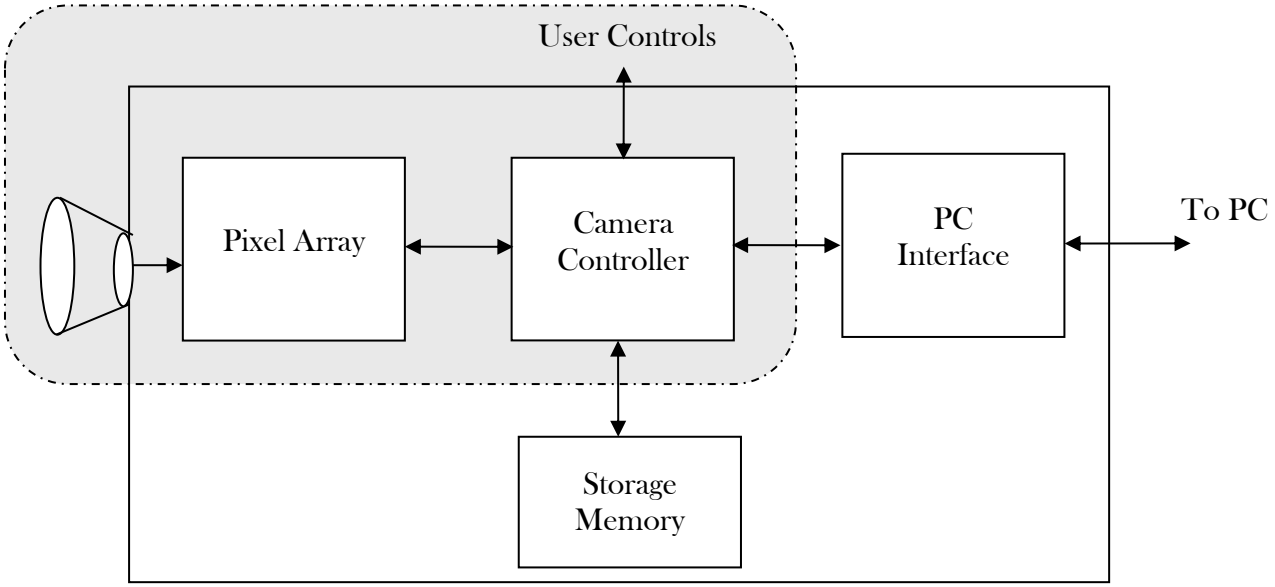

Figure 2: Scope of Part A is shown by the dashed box

Figure 2 shows the scope of Part A which involves the front end design. The Pixel Array must be implemented by the following IC component from Micron Inc.

MT9T031: 1/2-Inch 3-Mp Digital Image Sensor

The datasheet of this component is available on Blackboard. Alternatively, go to www.micron.com and search for this component. The general description (from the datasheet) is: "*The Aptina® MT9T031 is a QXGA-format 1/2-inch CMOS active-pixel digital image sensor with an active imaging pixel array of 2,048H x 1,536V. It incorporates sophisticated camera functions on-chip such as windowing, column and row skip mode, and snapshot mode. It is programmable through a simple two-wire serial interface.*"

Tasks:

(1) **(1 pt.)** Specification Analysis: Analyze the design specification and identify all requirements. What additional features would you like to see in the camera?

(2) **(1 pt.)** Read the datasheet and analyze the sensor array features. Summarize the **features of the sensor array relevant to your design.**

(3) **(1 pt.)** Define the port interface of the Camera controller block. Briefly describe the purpose of each port.

(4) **(2.5 pts.)** Analyze and define the timing interface required between the Pixel Array and Camera Controller blocks.

(5) **(2.5 pts.)** Implement an RTL design satisfying the port and timing interfaces determined in Questions (2) and (3). For the RTL controller, you can stop at the state diagram.

(6) **(1 pt.)** Draw a detailed schematic of the partial design of the front-end as well as user interfaces. Identify any other components that are required (for example, crystal-controlled oscillator). Show these components as well in the schematic.

(7) **(1 pt.)** Estimate: (a) how long it will take for one image capture; and (b) the approximate dollar cost to implement the front-end interface.

Deliverables: A design report using the template provided on the Blackboard.

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Mini-project: *Part B –Memory & PC Interface (12.5% of Final Grade)*

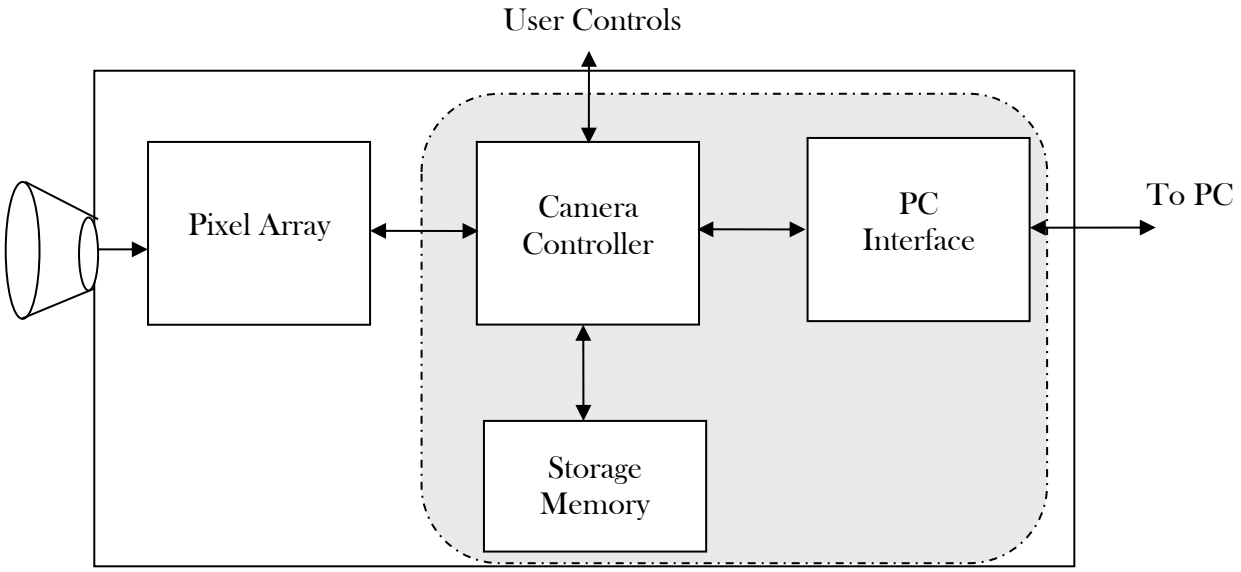

Figure 3: Scope of Part B is shown by the dashed box

Tasks:

(1) **(1 pt.)** Memory Component: Choose an off-the-shelf memory component that can be used as internal memory for the camera. List the memory components that you have researched and provide arguments supporting your memory choice.
(2) **(1 pt.)** Read the datasheet of the selected memory component and briefly summarize its features.
(3) **(1 pt.)** Define the port interface of the memory with the camera controller. Briefly describe the purpose of each port.
(4) **(1 pt.)** Analyze and define the timing interface required between the memory and the rest of the system.
(5) **(2 pts.)** Extend your design (developed in Part A) to implement the port and timing interfaces determined in Questions (3) and (4). For the controller, you can stop at the state diagram.
(6) **(1 pt.)** Extend the detailed schematic of your partial design (developed in Part A) to include the memory. Identify any other components that are required. Show these components as well in the schematic.
(7) **(1.5 pts.)** Choose a suitable interface (serial/parallel/wireless) between the camera and PC such as USB, firewire, Bluetooth, etc. Suggest an off-the-shelf solution to implement this interface. You can "drop in" an existing design provided by the interface vendor. **You need not extend the camera controller for this interface. However, you should include the interface cost in your final cost estimation.**
(8) **(1.5 pts.)** Estimate: (a) the maximum number of images we can store in the memory; (b) the time required to store/retrieve one image; and (c) the approximate dollar cost to prototype the camera (excluding costs for PCB design and manufacturing, component soldering, and testing).

Deliverables: A design report using the template provided on the Blackboard. Datasheets of (a) the memory and other components (if any); and (b) PC interface.