Design Examples and Case Studies of Program Modeling and Programming with RTOS-1:

Lesson-2

CASE STUDY OF DIGITAL CAMERA HARDWARE AND SOFWARE ARCHITECTURE

1. Specifications

CCD Array

- Camera records the pictures using a charge-coupled devices (CCD) array.
- The array consisting of large number of horizontal rows and vertical columns of CCD cells for the picture
- In each row of cells, a number of CCD cell unexposed to the picture but used for off-set corrections in the each-row output from the picture cells.

Camera Picture resolution

- 2592×1944 pixels, there are $2592 \times 1944 = 5038848$ set of cells.
- Each set of pixel has three cells, for the red, green and blue components in a pixel.
- Each cell gets exposed to a picture when shutter of camera opens on a user command.

Controllers, LCD display, Switches and buttons

- A set of controllers─ to control shutter, flash, auto focus and eye-ball image control.
- LCD display for graphics and GUI
- Switches and buttons for inputs at camera.
- User gives commands for switching on the camera, flash, shutter, adjust brightness, contrast, color, save and transfer.
- When a button for opening the shutter is pressed, a flash lamp glows and a self-timer circuit switches off the lamp automatically

Picture transfer Ports

- JPEG file for a picture can be copied or transferred to a memory stick using a controller
- Sony memory stick Micro (M2) size 15×12.5×1.2 mm, flash memory of 2 GB and 160 Mbps data transfer rate.
- A picture jpg can be copied to a computer connected through USB port controller.

2. Requirements

Purpose

- Digital recording and display of pictures
- Processing to get the pictures of required brightness, contrast and color.
- Permanent saving of picture in file in a standard format at a flash-memory stick or card
- Transfer files to a computer and printer through a USB port

Inputs

- Intensity and color values for each picture horizontal and vertical rows and columns of pixels in a picture frame.
- Intensity and color values for unexposed (dark) area in each horizontal rows and columns of pixels.
- User control inputs

Signals, Events and Notifications

- User commands given as signals from switches/buttons

Outputs

- Encoded file for a picture
- Permanent store of the picture at a file on flash memory stick
- Screen display of picture from the file after decoding
- File output to an interfaced computer and printer.

Functions of the system

- A color LCD dot matrix displays the picture before shooting— enables manual adjustment of view of the picture.
- For shooting a shutter button pressed— a charge-coupled device (CCD) array placed at the focus generates a byte stream in output after operations by ADC on analog output of each CCD cell.

Functions of the system

- A file creates after encoding (compression) and pixel co-processing.
- The byte stream is preprocessed and then encoded in a standard format using a CODEC.

Functions of the system…

- The encoded picture file saved for permanent record. A memory stick saves the file.
- The file is used for display of recorded picture using a display processor and can be copied or transferred to a memory stick and to computer or printer connected through USB port.

Functions of the system…

- The LCD displays picture file after it is decoded (decompressed) using the CODEC. Text such as picture-title, shooting date and time and serial number are also displayed.
- USB port is used for transferring and storing pictures on a computer. Alternatively, Bluetooth or IR port can be used for interfacing the computer

Design metrics

- *Power Dissipation*: Battery operation. Battery recharging after 400 pictures (assumed)
- 2. *Resolution*: High-resolution pictures with options of 2592 × 1944 pixels = 5038848 pixels, 2592 × 1728 = 3.2 M, 2048 × 1536 = 3 M and 1280 x 960 = 1M.
- 3. *Performance*: Shooting a 4M pixels still picture in 0.5 s. 25 pictures per m [Assumed]

Design metrics…

- 3. *Process Deadlines*: Exposing camera process maximum 0.1 s. Flash synchronous with shutter opening and closing. Picture display latency maximum 0.5 s.
- 4. *User Interfaces*: Graphic at LCD or touch screen display on LCD and commands by camera user through fingers on touch screen and switches and buttons
- 5. *Engineering Cost*: US$ 50000 (assumed)
- 6. *Manufacturing Cost*: US$ 50 (assumed)

Test and validation conditions

- All user commands must function correctly
- All graphic displays and menus should appear as per the program.
- Each task should be tested with test inputs
- Tested for 30 pictures per m

3. Class diagrams

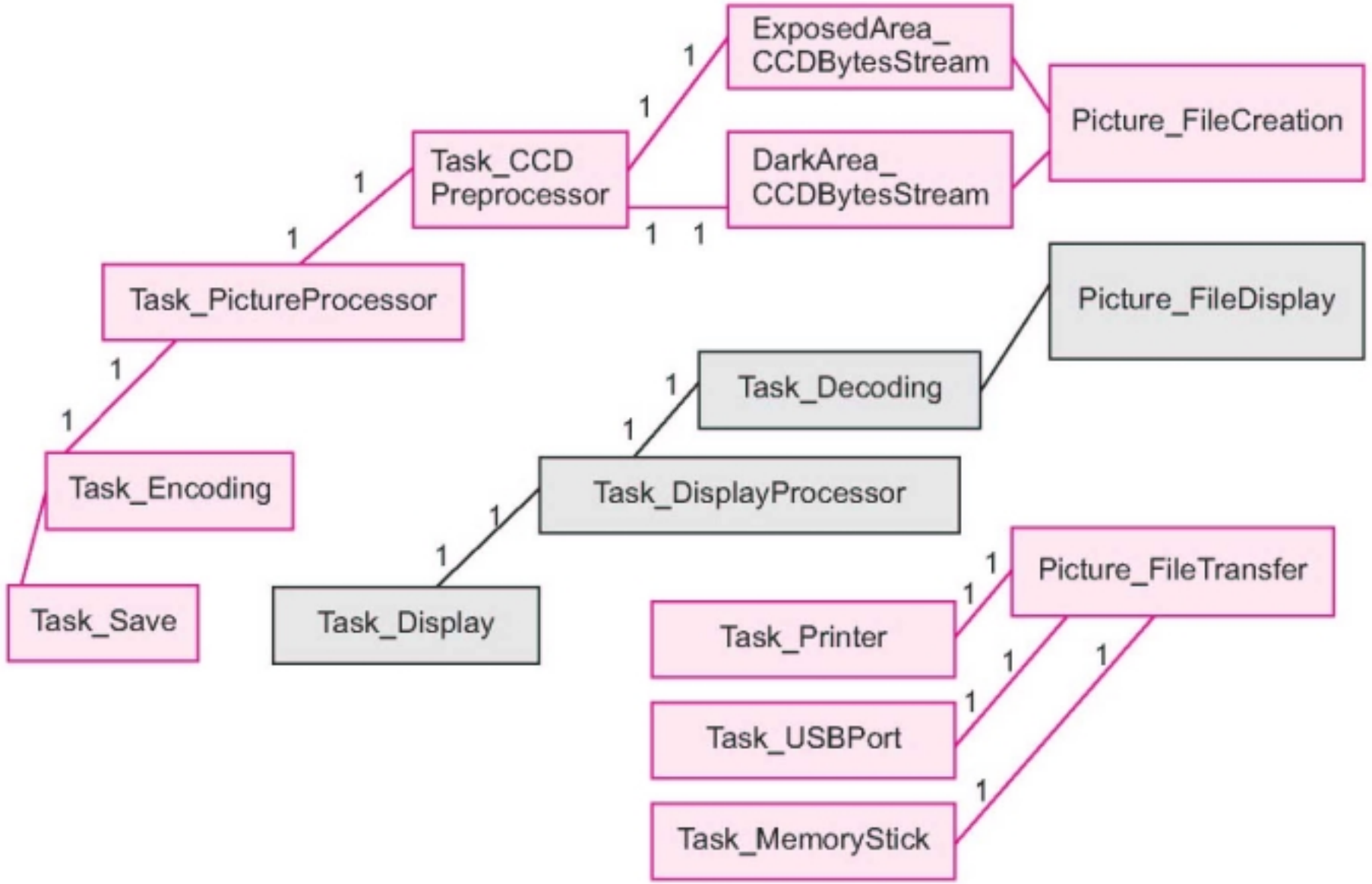
Camera tasks

- Camera tasks are modeled by four class diagrams are divided Picture_FileCreation, Picture_FileDisplay, Picture_FileTransfer and Controller_tasks

Class Diagrams for file creation, display and transfer

- Digital camera file creation, display and transferring to printer, memory stick and USB port can be modeled by the class diagrams of abstract class Picture_FileCreation, Picture_FileDisplay, and Picture_FileTransfer

Class diagrams



task objects

- Instances of the classes (i) ExposedArea_CCDBytesStream, DarkArea_CCDBytesStream, Task_CCD Preprocessor, Task_PictureProcessor and Task_Encoding

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Controller_Tasks

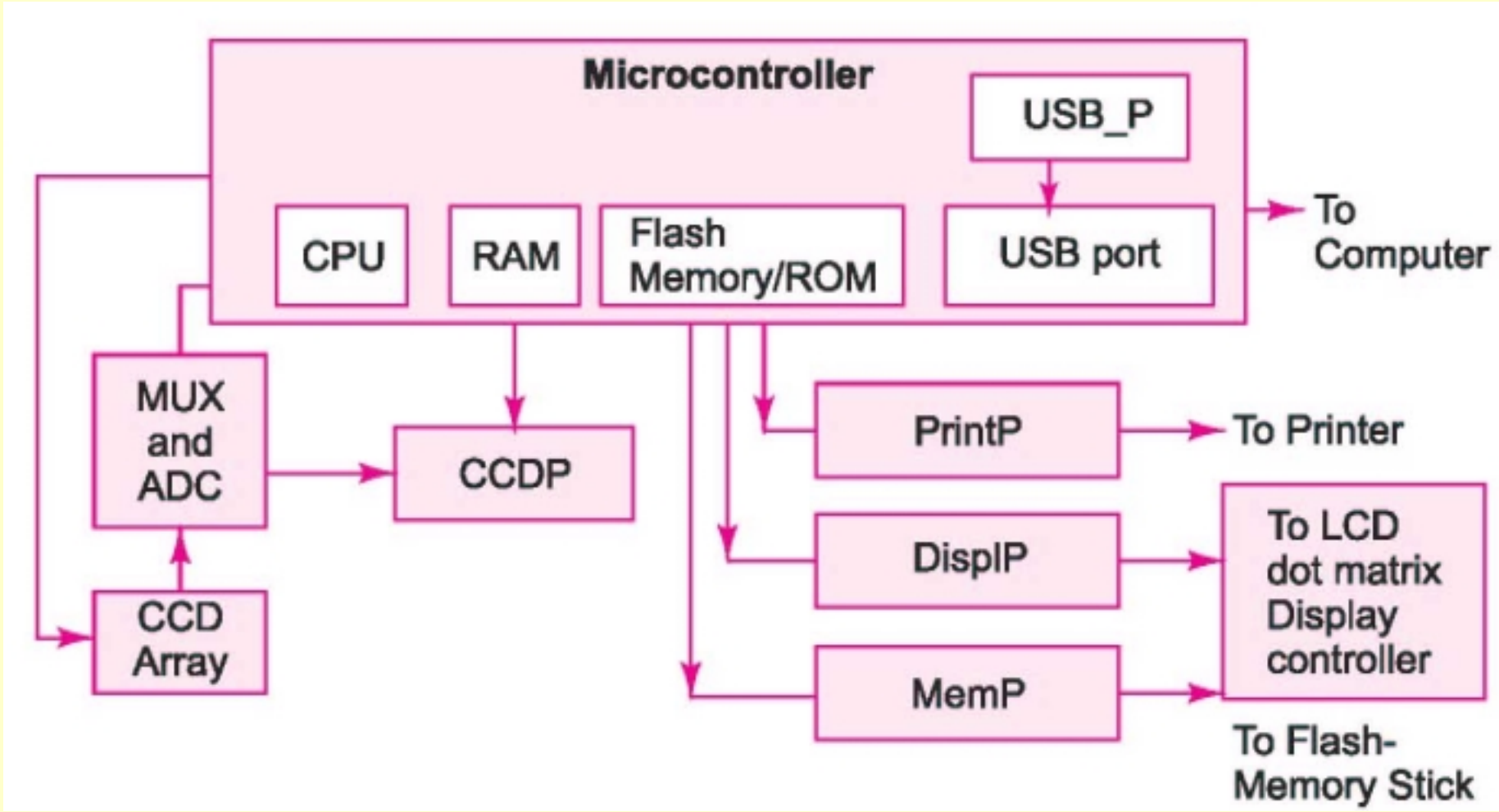
- Tasks_Initialization for initialization of tasks
- Tasks_Shoot for shooting task
- Initiates CCD processor (CCDP) to Initialize_Picture_FileCreation

Controller_Tasks…

- Initiate Picture_FileDisplay tasks, which run on initiation of display processor (DisplP),
- Initiates ASIP memory save MemP,
- Initiates ASIP for printer PrintP
- Initiates ASIP for USB port (USB_P),
- Task_LightLevel for control level control
- Task_flash

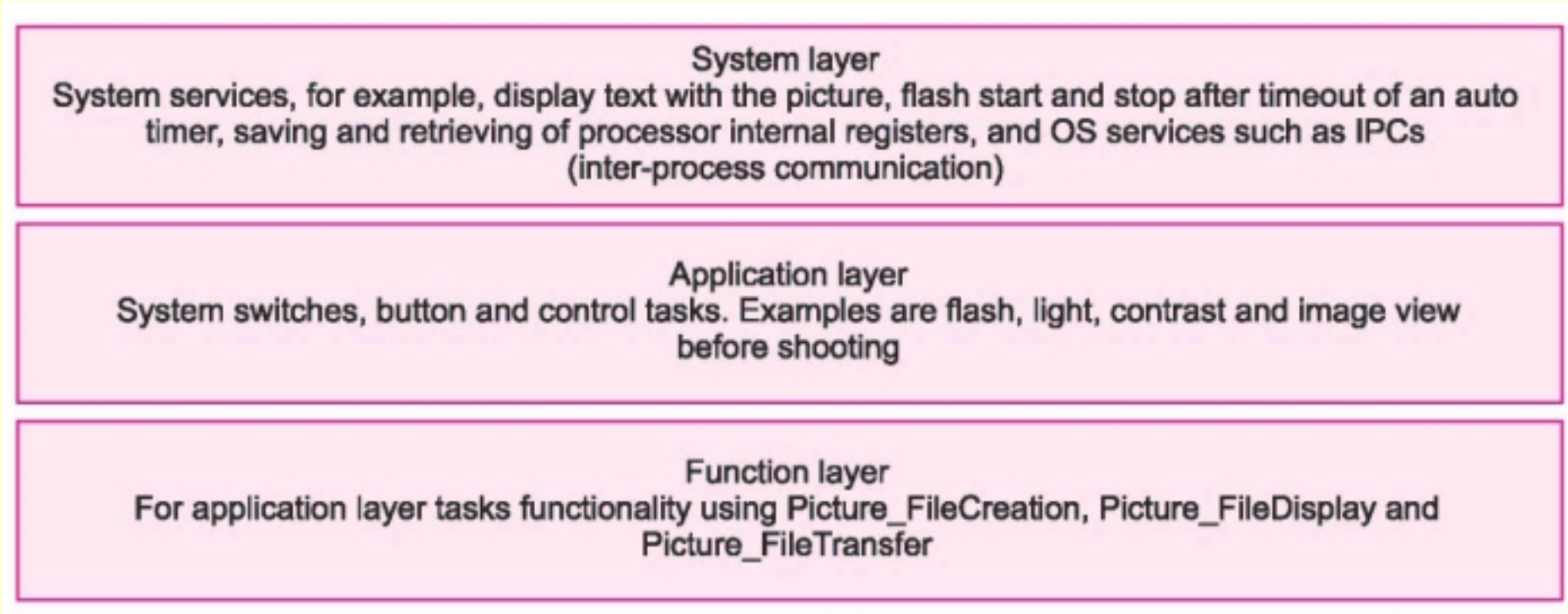
4. Hardware architecture

Digital camera hardware architecture

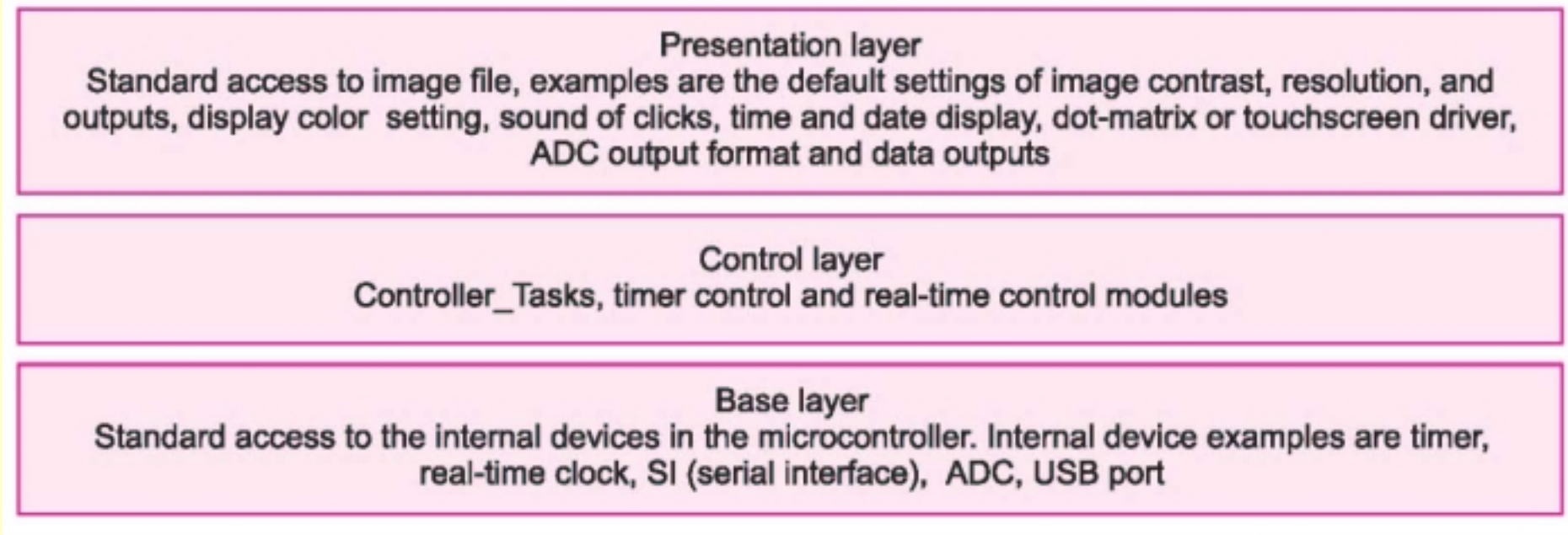


5. Software architecture

Software architecture upper layers

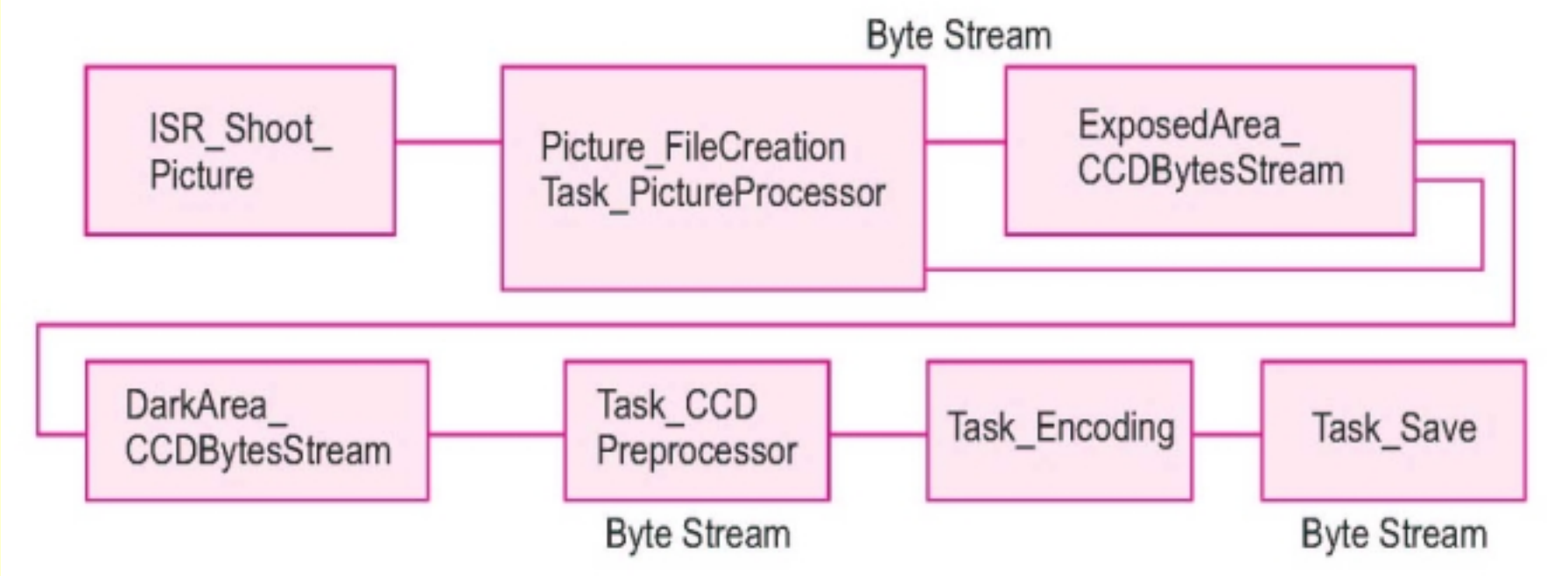


Software architecture lower layers

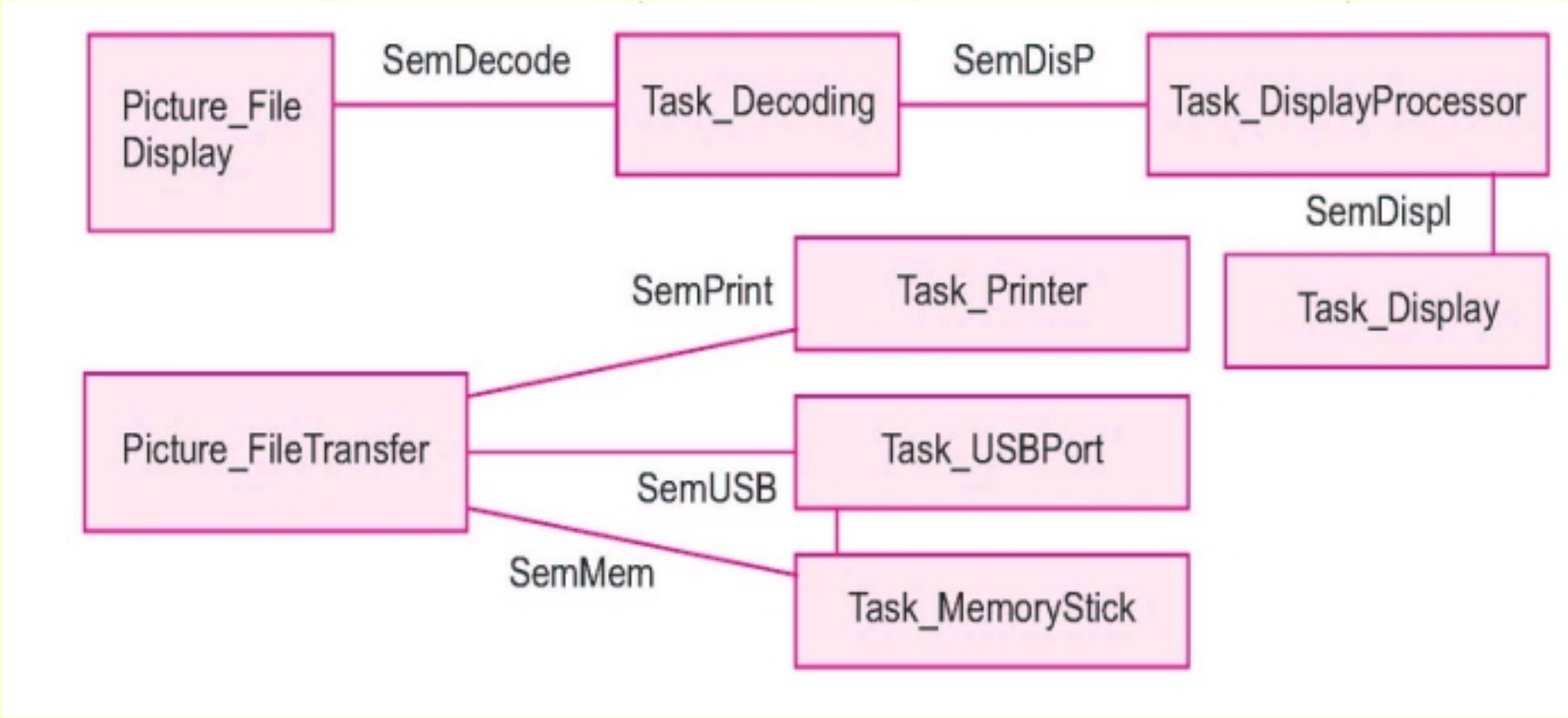


6. Modeling of Synchronization of tasks

Modeling of Synchronization of tasks Part-1



Modeling of Synchronization of tasks Part-2



Summary

We learnt

- Camera tasks are modeled by four class diagrams are divided Picture_FileCreation, Picture_FileDisplay, Picture_FileTransfer and Controller_tasks

We learnt

- Microcontroller and the several ASIPs are required for expected camera performance.
- A microcontroller executes the Controller_Tasks. The controller tasks are the following: (i) Task_LightLevel control (ii) Task_flash (ii) initialization of tasks, (iii) shooting task,

We learnt

- Single purpose CCD processor does Picture_FileCreation tasks, which execute on a for the dark current corrections,
- Single purpose ASIP does the DCT compression, Huffman encoding, DCT decompression, Huffman decoding and file save,
- Single purpose display processor (DisplP) initiates Picture_FileDisplay tasks, which execute on decoded and compressed file image display after the required file byte stream processing for shift or rotate or stretching or zooming or contrast or color and resolution,

We learnt

- Single purpose ASIP initiates memory stick save on notification from Picture_FileTransfer file system object using a single purpose transfer processor (MemP),
- Single purpose ASIP initiates printing on a notification from Picture_FileTransfer using a single purpose print processor (PrintP),
- Single purpose ASIP initiates USB port controller on notification from Picture_FileTransfer using a single purpose USB processor (USB_P).

End of Lesson-2 of chapter 11 on
CASE STUDY OF DIGITAL CAMERA HARDWARE AND SOFWARE ARCHITECTURE