

Development of Real time Video/image capturing and displaying architecture on FPGA

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ABSTRACT

Today's Field Programmable Gate Arrays (FPGA's) are in use to implement high performance image processing systems. This paper proposes an implementation of a FPGA based digital camera system for image capturing and real time image processing. For implementation of this image acquisition system another two sub-system are interfaced with FPGA core. One of the sub-modules is CMOS sensor for capturing the views of outside world and other one is digital graphical display for remote viewing of captured image or video. These two sub-modules are bridged with help of FPGA. Main role of this bridge in this implementation is to reframe the incoming data into displaying format. The main goal of this proposed design is to implement and test advanced complex image processing algorithm. Here proposed architecture has been developed on ALTERA'S DE II platform, which has ability to communicate with a Personal Computer (PC) through an interfaced Joint Test Automatic Generation (JTAG) for storing the images on to it and further processing.

Index Terms—CMOS camera, Color filter array (CFA), Field Programmable Gate Array (FPGA), Graphical display, I2C interface, Pixel array scanning mechanism.

INTRODUCTION

Now a day's FPGA technology impressively increases in the area of image acquisition for remote controlling due to its fast response with very lower latency. The biggest advantage of this technology is software programmable processor and hardware computing capability both can be developed within

the same IC (B). For remote viewing and controlling prior need is to capture real time view from outside. To fulfill this requirement solid image sensors are currently used are CCD and CMOS. Apart from these two CMOS sensor technology is in leading stage because of it overcomes all disadvantages of CCD sensor along with it reduces the size, power consumption of electric device(A). Because of its high anti-radiation ability it is widely used in many atomized vision systems (A).

Currently there are many problems of remote visioning especially in real-time because of latency period but by taking advantages of both FPGA technology and CMOS technology remote vision in real time can be achieved at some remarkable level. So I had demonstrated an image and video acquisition system with help of CLCLONE II EP2C35F672 FPGA which is provided by ALTERA DE2 platform. This FPGA provides 33,216 logic elements, 8 MB SDRAM, 512KB SRAM, 4MB Flash etc. The data capturing module used in this system is TRDB-DC2 which is 1.3 MP digital camera and for displaying that TRDB-LCM digital graphical display is interfaced with

help of 40-pin header to the development board. Fig. 1 shows the image acquisition system with its basic sub-systems. Here all the sub systems have been designed in verilog HDL (D).

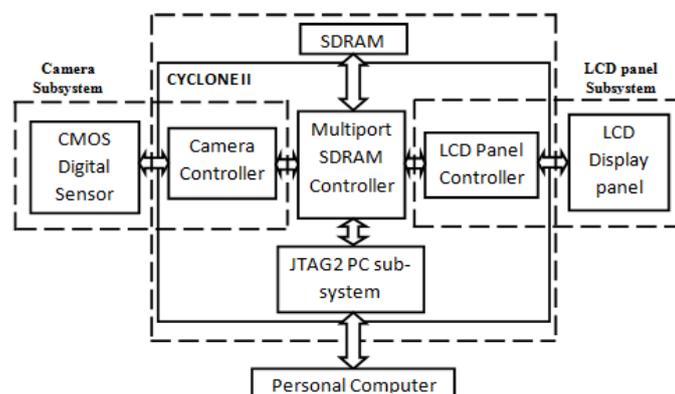


Fig.1 CYCLONE II FPGA based data acquisition system

HARDWARE DESCRIPTION

I CMOS CAMERA SUB-SYSTEM:

Generally the every CMOS camera accommodate following basic parts: the color filters the pixel array, the digital controller, and the analog to digital convertor.

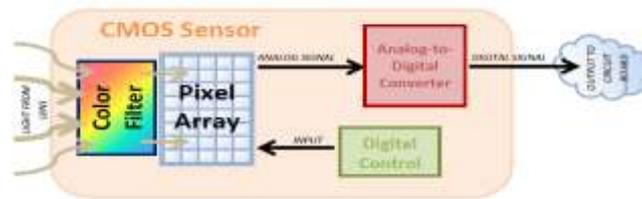


Fig.2 Basic component of CMOS camera system

As shown in diagram firstly the lens is used to configure all light rays to the sensor. In between of lens and sensor array color filter array is used to capture color information. After the color filtering process the light will be exposed on the each photo site of the sensor array and because of that some voltage value has been generated from each photo site according to the exposure of light on it. That output voltage is in analog format which has been multiplexed on single line and given to the ADC for any kind of further data process, it may be on board or to other circuit board; so analog format has been converted into digital format. So output of ADC is row digital data.

1. Color filter

Color filter is used to get the color information from the white light in every color camera system. Now a day's Bayer color filter array is a popular format for digital acquisition of color images [1]. Bayer filter pattern is an array or a mosaic of tiny color filters is placed over the pixel sensor array. In this single particular color filter is placed on each pixel, One tiny filter corresponds to one pixel from array. Due to this type of formation finally a color pattern array has been developed as shown in figure in front of pixel sensor array.

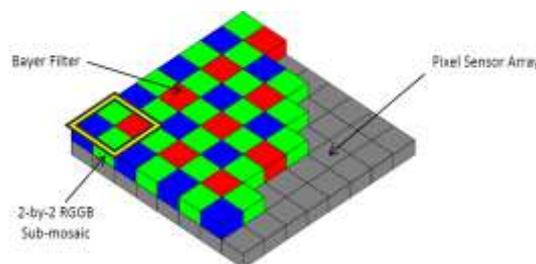


FIG.3 BAYER FILTER ARRAY

As shown in figure half of total no of pixels covered by green (g) filter, while another half part of pixel array quarter part will be covered with blue (b) filter and another quarter part will be covered with red(r) filters .this proposition is designed bases on human eyes dominancy to color component.

Human eyes are more sensitive towards green color rather than other two so green element used twice as shown in sub-mosaic pattern. Sensor Scanning Mechanism: The CMOS camera sub-system shown in Fig 2. Here CMOS sensor is MT9M011 consist pixel array of 1280*1024. Each pixel is a photo site that will generate output voltage that is multiplexed on single channel. For proper scanning of each pixel from an array, the scanning mechanism should be needed to develop on FPGA. For this data capture controller has been designed in FPGA core. This controller provides a master clock (MCLK) to sensor. Here whole system working on the clock mechanism and each operation has been started with positive edge of clock. When sensor gets the master clock, it generates another three scanning clocks that are pixel clock (PCLK), line valid clock (LVAL), and frame valid clock (FVAL). According to this clocking mechanism capture controller will fetch the data of each frame containing 1280 pixel in each row from the data line. Here data of each pixel is coded with 10 bits because of 10-bit inbuilt ADC. This ADC provides digital row data. This digital row data is in Bayer format because of using Bayer color filter array (CFA) before the sensor pixel array. This row data is also called as sequential RGB. So to display this fetched data, sequential RGB or Bayer data will be separated as 30-bit RGB on each channel. To reformat the Bayer row data into RGB the data of full frame will be stored in linear buffer which is one kind of circular buffer so that real time processing can be achieved. The I2C controller shown in fig 3. is used for serial communication which consist two lines one for data transfer that is SDATA and another is serial clock SCLK for synchronization. With help of this data can be read or write into internal register of the CMOS camera.

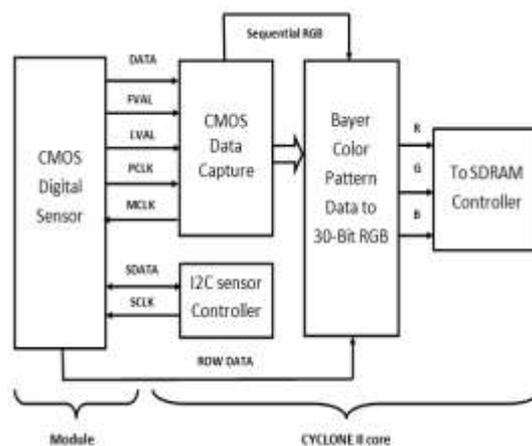


FIG.4 SENSOR SCANNING MECHANISM

2. Code Flow of Pixel array scanning

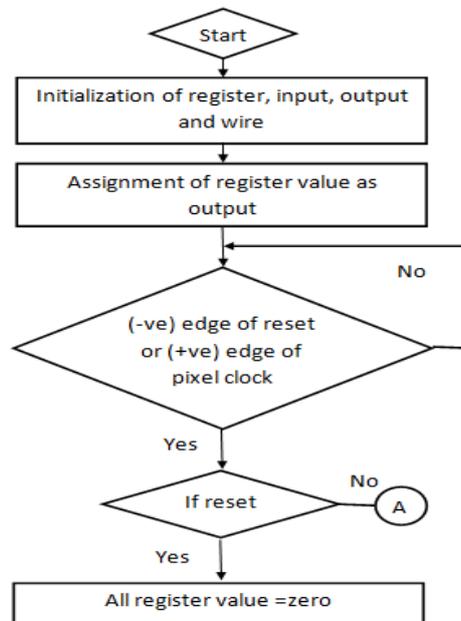


Fig.5 (a) code flow of scanning mechanism

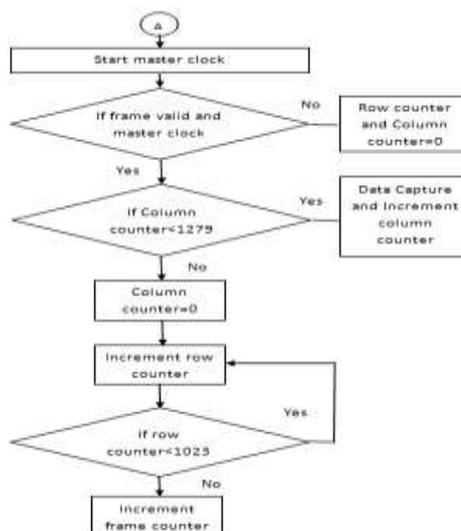


Fig.5 (b) code flow of scanning mechanism

II Graphical display sub-system:

For remote viewing of the captured data from the CMOS camera, a display unit is needed. To fulfill this requirement 3.6 inch TD036THEA1 compact TFT LCD module is interfaced using IDE cable to 40 pin header of the ALTERA board. To grab the reformatted data from the FPGA LCD controller (VGA controller) has to design in the FPGA core. This controller will provide proper display synchronization signals to the display module. As shown in fig. 6 controller takes the RGB data from SDRAM as shown in fig.1.along with this when pixel clock is arrived, controller generates horizontal sync pulse clock (HSYNC), vertical sync pulse clock (VSYNC),data latch clock (DCLK), Global reset (GRESTB), Shutdown control (SHDB) as shown.

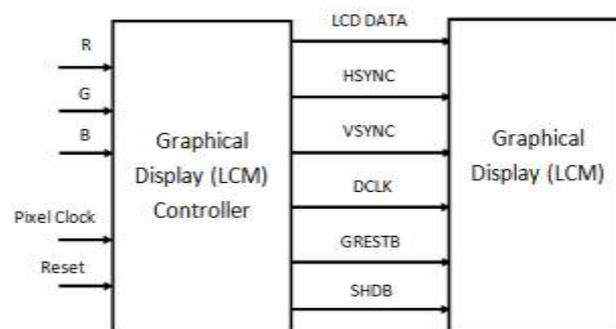


Fig.6 TFT display sub-system

Here HSYNC and VSYNC are generated for Proper fostering of incoming row and column data onto active area of raster in display module. Data clock is used to setup logic whether the incoming data has to display on module or not, while global reset is used to reset all display register value to zero.

1. Code flow of Data displaying mechanism:

As said to display data in an active region of raster the HSYNC and VSYNC are needed. To generate these two signals from controller two counters has been developed that are H_Count and V_Count as shown in fig.7 because here whole mechanism works on the pixel clock tick. According to the specification of the display module data latching on active area logic has been developed.After

that color data latching mechanism has been develop with help of data clock enable /disable. Here color mode 3 is used because in TFT display data will be display in the manner of RGB strips.

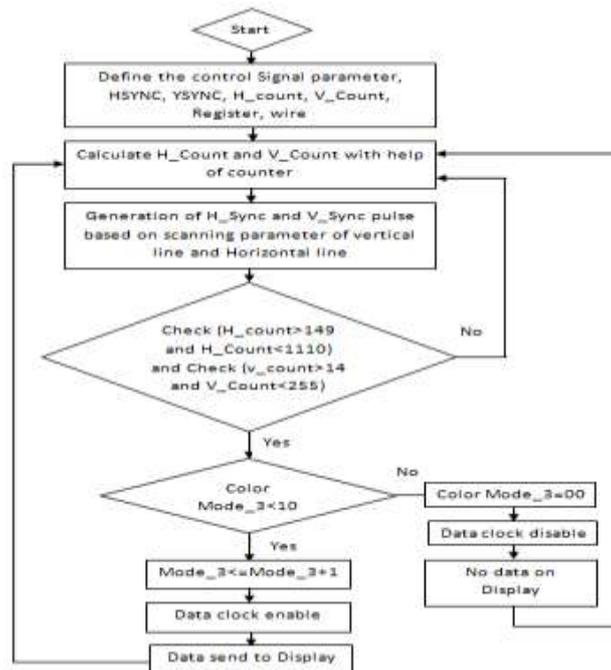


Fig.7 Code flow of Data displaying mechanism

III Results

In this paper, the domain under observation is incessantly supervised by capturing the video of the area. With the help of the CMOS sensor, the capturing of video under observation is successfully completed. This CMOS sensor will produce direct digital output because its associated circuit is incorporated with 10-bit ADC. The mode register of the CMOS sensor is programmed with I2C protocol, so that CMOS settings like resolution, exposure are configured with this protocol. The serial data is assigned to the CMOS sensor which is obtained from the available parallel data. The data is ceaselessly captured by the programmed sensor. CMOS sensor's I2C interface and Pixel Data interface are connected to the FPGA through GPIO interface of the DE2 Board. FPGA will have I2C Slave controller module that will write the CMOS sensor configurable register values. In order to restrain the stream of data coming from the sensor which is programmed to the memory, the IDFC (Image Data Flow Controller) is used. This IDFC influences the stream of data to the memory. Whenever the START signal is triggered then only the data is stored in the memory. It happens

continuously until STOP signal is found. This system consists of the black and white converter module so that the data is laid in the pattern of black and white images only. ALTERA DE2 board consists of SDRAM, which can store the captured image frames. Two frames can lay in the memory at a time. Therefore, it is split into two and the data is read from or written into the memory. SDRAM controller is used to supervising these performances. The read & write signals are rendered by SDRAM controller and it can also track which frame is being read or written. The video can be monitored on a visual display unit such as an LCD monitor. For this purpose, the VGA controller is used. VGA Controller module in the FPGA always reads the pixel data from one of the ports of DDR SDRAM and it generates the required signals to display the video on the screen. Figure 8 shows real-time video capturing and displaying on the graphical display through CMOS camera connected with ALTERA DE2 board.

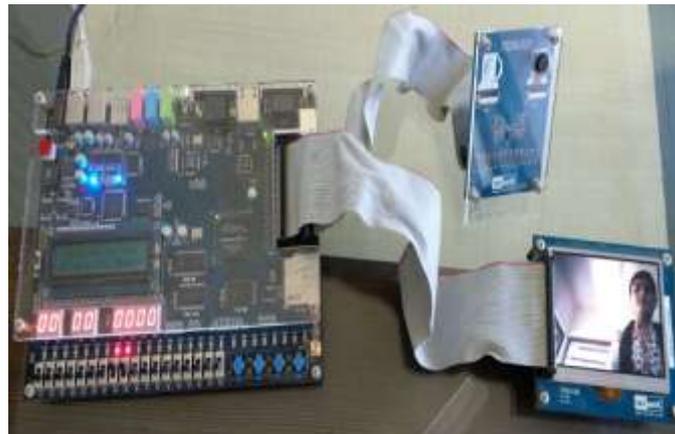


Fig.8 proposed outcomes

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